Changes in selectivity in the Baltic Cod Trawl Fisheries (1999-2017) – with focus on T90 and Bacoma codends

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Summary

1) The use of current 120mm codends in the Baltic cod fisheries is not optimal, resulting in a significant decrease in commercial catches, an increase in discards and increased fishing pressure on large cod when compared to the previous 110 mm codends. This has likely contributed significantly to the current poor situation of the cod stock in the eastern Baltic. Therefore, extensive further investigations, as well as policy decisions are required to improve the current situation:

2) Short-term actions required:

   a) Since the ultimate identification of an optimal selectivity requires time to conduct thorough experiments, it is advisable to change the current legislation and reintroduce the former 110mm BACOMA and T90-codends as soon as possible. One argument for a re-introduction of 110mm codends is that these codends are well tested and most Baltic fishers may still have them. Nevertheless, these codends are most likely also not optimal.

3) Mid-term actions required:

   i) Over the past two decades, a number of different codend designs were legally implemented in the Baltic Sea. However, many more codend types were invented in recent years and their performance was assessed regarding their selectivity, including for example a gear modification which releases the very large individuals for the protection of megaspawners. Therefore, the necessary next step is not the overhasty introduction of a new gear/codend, but

      (1) the specification of specific management targets (short-term and long-term)
      (2) the identification of optimal selectivity properties to reach the specified management targets (e.g. using specific population models and economic models)
      (3) the identification of available codend/gear designs (quicker) or the development of new codend/gear designs (more time required) with these optimal selectivity properties
      (4) the introduction of one or more optimized codend(s)/gear(s) in the fishery

   These tasks could be addressed in an international and interdisciplinary project.
**Introduction**

In contrast to other areas such as the North Sea, where pulse trawls were introduced recently, the main fishing techniques used in the Baltic Sea fisheries did not change significantly over the last few decades (active gears, like demersal and pelagic trawls; passive gears, such as gill nets, pound nets).

As for many other mixed fisheries around the world, the Baltic fisheries management (and gear technology research) mostly focused on improving the selectivity for a given target species (“single-species approach”) and almost exclusively focused on the selective properties of codends (the final collecting bags in trawls) (Feeings et al., 2013; Madsen, 2007; Stepputtis and Wienbeck, 2010).

When introducing new gear measures to the Baltic cod trawl fishery, the aim of the fisheries management was to reduce the capture of juvenile cod, and subsequently cod discards through trawl selectivity (Feeings et al., 2013).

In recent years, fishery management, science and the fishery experienced some unexpected developments in the Baltic cod stock and Baltic cod fishery. This was also discussed e.g. during ICES WKBALTCOD 2015 (ICES Benchmark Workshop on Baltic Cod Stocks) and can be summarized as follows:

a) Unexpected high discard rates  
b) Low fishing efficiency / underutilisation of the TAC  
c) Decline of abundance of large length classes  

Therefore, this document discusses the gear related technical changes in the Baltic mixed demersal trawl fishery targeting cod, and the effect on catch of cod below MLS/MRCS on commercial catch as well as on large fish. The main focus will be the effect of the increase in mesh size of the BACOMA-window and the T90-codend from 110mm to 120mm in 2010.
Codend selectivity in the Baltic – overview

In the Baltic trawl fishery for cod, several changes in technical measures were applied during the last years (Table 1, Table 2, Figure 1). Two council regulations (and their amendments) set up the framework for technical measures to be applied in the Baltic Sea cod fishery (88/1998 and 2187/2005). Additionally, technical measures including gear regulations were introduced in annual council regulations fixing fishing opportunities (and their amendments). A major step in gear change in the Baltic Sea took place when T0-gears with their poor selectivity were banned. For some years, the BACOMA-codend was the only legal gear (08/2003-01/2006), at which the mesh opening of the BACOMA escape window made of knotless square meshes was reduced in 08/2003 from 120mm to 110mm. The T90-codend as an alternative to the BACOMA-codend was introduced in 01/2006. The T90 (110mm)-codend had comparable selectivity properties compared to the BACOMA 110mm codend but is much cheaper due the usage of normal netting. The next major change occurred in 2010 when the mesh opening of the T90-codend and the BACOMA window was increased from 110mm to 120mm.

During the last 12 years, eight codend types were in use in the Baltic Sea cod trawl fishery (Table 1, Table 2, Figure 1). In this overview, gears were grouped, and listed even if there were some minor changes in regulation for a specific codend type. For example, no twine thickness was defined for T0-codends prior to 2002.

For these eight gear types, selectivity data were derived from sea trials onboard the German fisheries research vessel "Solea" (Table 1, Figure 1). All selectivity data presented here are derived from sea trials using the covered codend method. Logit (formula (1)) curves were fitted to haul data using a maximum likelihood estimation, following the procedures described in Wileman et al. (1996):

\[
r(l) = \frac{\exp\left(\frac{(l-L50)\times \ln(9)}{SR}\right)}{1 + \exp\left(\frac{(l-L50)\times \ln(9)}{SR}\right)}
\]

Where \( r(l) \) models the retention likelihood of a cod at length \( l \) given it enters the codend. \( L50 \) is the 50% retention length and \( SR \) the selection range (= L75 – L25). Hence, \( L50 \) and \( SR \) can be used to quantify the size selection of cod in the codend.

Due to the use of experimental data, the used codend mesh opening might differ slightly from nominal legal mesh size. For example, the investigations of codends with 120mm nominal mesh opening (BACOMA, T90) in spring 2010 were conducted with standard netting delivered by German net makers; hence comparable mesh opening was also used by commercial fishermen. The
Codend selectivity in the Baltic – historical overview

Mesh opening for these trials was significantly larger than the nominal mesh size of 120mm (BACOMA-window: 129.8mm; T90: 127.8mm). We argue that this reflects reality as also fishermen typically order mesh larger than the legal nominal mesh size. Two trial series exist for BACOMA 120mm codends, one series from 2002/2003 and the other from 2010. The selectivity parameters for both series differ slightly. Therefore, results of both series are given separately (BACOMA 120mm (2002); BACOMA 120mm (2010)).

Table 1: Technical regulations and changes related to the codends, used in the Baltic mixed demersal fishery in the Baltic Sea. Technical details can be found for each codend.

<table>
<thead>
<tr>
<th>Year</th>
<th>Regulation</th>
<th>Exit Window Model 1 and 2</th>
<th>BACOMA Window</th>
<th>T90 without Window</th>
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<tr>
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Table 2: Selectivity parameters for cod (Gadus morhua) of different codends, which were in legislation in the mixed demersal fishery over the past two decades. Given are the L50 and the Selection Range (SR) values, which describe the selectivity of a specific gear. L50 is defined as the length where the likelihood that a fish of a given length is retained in the codend is 50% (i.e. the chance to escape is 1:1). The Selection range is defined as the length range between L25 (25% retention probability) and L75 (75% retention probability). The smaller the selection range, the steeper the selection curve and hence ‘sharper’ the selection.
Figure 1: Example for selectivity curves for cod (*Gadus morhua*) of different codends, which were in legislation in the past two decades. Y-axis: Likelihood that a fish of a given length is retained in the codend. Description of codends (including period when legal): a) T0_120=T0 120mm (1999-2001); b) T0_130=T0 130mm (2002-2003); c) Exit1= Exit Window Model 1 (1999-2001); d) BACOMA _120_1= BACOMA Window 120mm (2001-2003); e) BACOMA _110= BACOMA Window 110mm (2003-2009); f) BACOMA _120_2= BACOMA Window 120mm (2010-recent); g) T90_110=T90 110mm (2006-2009); h) T90_120=T90 120mm (2010-recent). Curves obtained from German selectivity trials / German selectivity database. Green vertical lines indicate the minimum landing sizes (MLS, 35cm until 2002, 38 cm 2003 until 2014) and minimum conservation reference size (MCRS, 35cm since 2015), respectively. This figure does not show the large number of other codend designs which were developed and tested over the last years.

Figure 1 shows the selection curves of the eight codend types together with MLS/MCRS. It is obvious that at least the selectivity of the T0-trawls did not fit to the MLS at this time, as it caught fish which then had to be discarded because it could not be landed legally. Additionally, it is important to mention the less steep selection curve of the BACOMA 120mm (trials in 2010), result-
ing in a relatively wide selection range: In contrast to the T90 trawl, the BACOMA codend is made of two types of netting. Since the introduction of the BACOMA codend, the codend is made of T0 105mm-netting, except of the BACOMA-window. Of course, both nettings (T0 105mm and the BACOMA window) have different selectivity properties. The overall selection of the BACOMA-codend is a combination of both selectivities (dual selectivity). With the increase of mesh opening of the BACOMA-window from 110mm to 120mm in 2010, the difference in selectivity between both netting increased, resulting in an increase in the selection range (i.e. the curve is less steep).

Figure 2: Photograph of a BACOMA-codend with T0 105mm-netting (green) and 120mm square-mesh-panel (black)

In addition to changes of gear specification, the amount of discards is also determined by the minimum landing size (MLS). In 01/2003, the MLS was increased from 35cm to 38cm. In 2015, the MLS was replaced by a Minimum Conservation Reference Size (MCRS) and reduced to 35cm for Baltic cod.
Change of mesh size in 2010

The last change in codend legislation was the increase of the mesh size of the Bacoma-square mesh-window and the T90-codend from 110mm to 120mm in 2010 (Table 1, Table 2, Figure 1). In this chapter, the effect of changed selectivity on the catch composition of 120mm codends will be compared against formerly used 110mm codends.

The influence of a given gear selectivity on the catch depends on a variety of parameters, such as

- **gear selectivity**: defines the escapement probability / catch probability of specific length classes for a given gear

- **population structure**: to give an extreme example, if there are no small individuals available, the catch of undersized fish will be zero – independent of gear selectivity. Therefore, catch comparison experiments will only give a snapshot insight of the effect on catch for a very specific population structure

- a number of other parameters, which are difficult to use for a standardized analysis, such as towing speed, catch volume, water temperature, specific rigging of the gear, haul back procedures etc.

Consequently, we investigated the effect of the gear change in 2010 using a simple theoretical simulation: The known selectivity properties of a specific gear (see Figure 1 and Table 2) can be applied to the length distribution within the population to calculate the fraction of the population which would be retained in the trawl (assuming the population entering the trawl has a similar length distribution as the population in the field) (Figure 3).

As good estimate for the population structure, the length distributions for SD24 (western Baltic Sea) and SD25 (eastern Baltic) were extracted from the ICES-DATRAS database (http://datras.ices.dk). Data from the Baltic International Trawl Survey (BITS) 2010 and 2014 in quarter 1 (February-March) were used. Only mean selection curves (Figure 1) were applied and between-haul variation, which is potentially significant, was neglected. Theoretical discard rates were calculated based on the theoretical catches above and below MLS (38cm in 2010 and 2014), given as percent in numbers (Table 3).
**Discard ratio:** It is obvious that the increase in mesh opening did not result in the desired significant reduction of catch ratio of undersized specimen for the BACOMA- and the T90-codend (Table 3). Moreover, the 120mm BACOMA-codend shows higher catch ratios for undersized cod, compared to the 110mm codends. The unbalanced selectivity of both nettings used in the BACOMA-codend (as discussed above) is a likely reason for this poor performance of the BACOMA 120mm codend.

**Commercial catch:** In addition to a lack of desired reduction of catch of undersized cod, Figure 3 demonstrates that the increase in mesh size in 2010 has resulted in a significantly reduced catchability of sized/marketable fish for the BACOMA-codend, as well as for the T90-codend. In some cases, most of the sized fish which enters a trawl will escape through the codend meshes.

Under the current population structure, this will result in

- increase in fishing effort to catch the same amount of fish (i.e. TAC), resulting in
  - increased fuel consumption (higher CO2-emission)
  - increased environmental impact (e.g. bottom contact)
- possible problems to catch TAC within allocated days at sea
- commercial loss for fishermen (which might influence the willingness to comply with existing rules)

**Population structure:** As mentioned before, the theoretical catch profile and hence the discard rates depend on the specific population structure, which is typical e.g. for year, season and location. As seen in Figure 3 and Table 3, the adverse effects of the increased mesh size (higher discard ratio and commercial loss) are even more pronounced in 2014 compared to 2010, due to a change of population structure. Figure 3 also shows a dramatic change in the length distribution found in the population (here SD25). In 2010, quite a number of fish were found to be larger than 50cm - this part of the population was almost absent in 2014. The long-term overview (Figure 4) reveals a reduction of large length classes in recent years, starting around 2010 when the 120mm mesh sizes were introduced.

The reasons for this decline of large cod are not clearly identified and several mechanisms might potentially contribute. Nevertheless, it is also clear that if the catchability for mid-sized fish is significantly reduced – and the catchability for the larger length classes kept relatively stable (see catchability of different gears for lengths larger 50cm in Figure 1), the fishing pressure on large length classes increases – especially when fishing effort is increased to compensate for catch losses. Therefore, it is likely that the changed selectivity contributed to the decline of large cod. Nevertheless, additional analysis and modelling approaches are required to investigate the effect of changed selectivity on discard rates, catch efficiency and the population structure.
Figure 3: Theoretical catch of cod in ICES SD25 for different years (left column 2010, right column 2014) and different gear (top row: BACOMA-codends; bottom row: T90-codends). Selection curves of different codends (see legend) were applied on population structure derived from Baltic International Trawl Survey. The overall curve (white) describes the population structure of cod in ICES SD25 in Q1 2010 (left column) and 2014 (right column) (as extracted from ICES DATRAS-database http://datras.ices.dk). The shaded areas indicate the simulated catches based on the given population structure and specific size selectivity of the different codends. The theoretical catch of a T0 130mm codend (legal 2002-2003) is shown for reference. Red vertical lines show the 38cm minimum landing size (2002-2014) to indicate which part of the catch would be discarded (assuming all undersized fish are discarded and no highgrading occurs). Corresponding discard rates are given in Table 3.

Table 3: Comparison of theoretical discard rates (percent in numbers) of cod in different years (2010 vs. 2014) and different codends, assuming a population structure as derived from the Baltic International Trawl Survey (BITS Q1 2010 and 2014, SD24 and SD25; data extracted from the DATRAS-database, http://datras.ices.dk) and selectivity curves for the different codends.

<table>
<thead>
<tr>
<th>codend</th>
<th>SD24 2010</th>
<th>SD25 2010</th>
<th>SD24 2014</th>
<th>SD25 2014</th>
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<tr>
<td>Bacoma 110mm</td>
<td>29.04%</td>
<td>19.52%</td>
<td>35.70%</td>
<td>46.14%</td>
</tr>
<tr>
<td>Bacoma 120mm</td>
<td>30.77%</td>
<td>20.23%</td>
<td>40.74%</td>
<td>57.62%</td>
</tr>
<tr>
<td>T90 110mm</td>
<td>18.40%</td>
<td>11.60%</td>
<td>23.73%</td>
<td>31.06%</td>
</tr>
<tr>
<td>T90 120mm</td>
<td>13.16%</td>
<td>7.67%</td>
<td>19.11%</td>
<td>29.18%</td>
</tr>
</tbody>
</table>
Figure 4: Length composition of Baltic cod over the years (in SD25, Q1). The length distribution in the population of Baltic cod is derived from the Baltic International Trawl Survey (BITS Q1 SD25; data extracted from DATRAS-database http://datras.ices.dk).
Conclusion and Outlook

The introduction of the present 120mm codends in 2010 were definitely a change for the worse. To avoid another overhasty and premature introduction of another trawl gear modification and to ensure a sound process in this matter, thorough experiments and analyses are required. Therefore, a two-step approach would be suitable:

Short-term: On the short-term, progress can be achieved by changing the current legislation. The 120mm codends should be removed and the 110mm codends should be re-introduced instead, because the selectivity properties of the 110mm codends are superior to the 120mm codends presently used, the 110mm codends are well tested and most Baltic fishers may still have them at hand.

Medium-term: As mentioned above, many different codend designs were legally implemented over the past 20 years (e.g. Figure 1, Table 2) and much more were tested and intensively investigated regarding their selectivity. As shown in Figure 1, the current and past legal codends cover a wide range of various selective properties with current 120mm codends on the far most right position, at which the 120mm BACOMA also shows a reduced steepness (larger Selection range = less sharp selectivity). Additionally, other gear designs are available to obtain specific targets and give more options and flexibility to the fishery and the fishery management, such as some of the recent developments of the Thünen Institute of Baltic Sea Fisheries:

- bell-shaped selectivity curve of the trawl gear to protect small fish and the large mega-spawners simultaneously (Stepputtis et al., 2016)
- devices to significantly reduce the catch of flatfishes in the cod fishery (FRESWIND and FLEX) (Santos et al., submitted; information available on demand, see also presentation at BALTIFIC HLG 01.09.2017)
- device to significantly reduce the catch of cod in flatfish fisheries (iFLEX) (manuscript in preparation, information available on demand, see also presentation at BALTIFIC HLG 01.09.2017)

Some of these devices alter cod-selectivity directly (bell-shaped selectivity curve and iFLEX). Others (FRESWIND and FLEX) primarily aim to alter the selectivity of flatfish species. Since flatfish often block codend meshes (Figure 5) and hence hamper the successful escapement of small cod, it can be assumed that the magnitude of flatfish catch influences the size selectivity of cod indirectly (scientifically valid data are currently not available, relevant experiments are planned for the end of 2017). Consequently, a “multi-species-approach” of gear selectivity could help to significantly improve the selectivity of cod in the Baltic Sea.
Given the large number of different available selectivity options, covering a wide range of fishing strategies, it can be assumed that the lack of suitable alternative codend/gear designs is not the primary cause for the current unfavourable situation. Therefore, the necessary next step for mid-term-improvement is not the invention/introduction of a new gear/codend. Instead, to improve the selectivity in the Baltic trawl fishery targeting cod in the medium-term and long-term, we recommend the following steps:

1. Specification of specific targets (or combinations thereof) for the management. This is necessary to know in which direction the gears need to be optimized and to be able to test the different alternatives against these targets. The management targets could be (preferably including target levels):
   
   a. Short-term: decrease the discard rate, increase the catches of commercial sizes, keep very large individuals ("mega spawners") in the population to improve the recruitment, etc.
   
   b. Long-term: ‘healthy’ population structure, optimal yield in long-term, etc.

2. Identification of optimal selectivity properties to reach the specified management targets. Especially when taking into account the medium-term/long-term targets, but also taking into account the different factors influencing short-term effects of changed selectivity (e.g. changed population structure), specific length-based population models are required. Such an approach was successfully applied for the brown shrimp fishery in the North Sea (Neudecker et al. 2015).

3. Identification of available codend/gear designs (quicker) or the development of new codend/gear designs (more time required) with these optimal selectivity properties

4. Introduction of one or more optimized codend(s) in the fishery

These tasks could be addressed in an international and interdisciplinary project.
Figure 5: Flatfish blocking codend meshes: Top: External view towards the square-mesh escapement window of a BACOMA-codend. Bottom: Internal view into the end of a T90-codend. Flatfish block open codend meshes in both cases. It has to be noted that the magnitude of flatfish catch is low in both pictures. Photos taken by the Thünen Institute of Baltic Sea Fisheries.
References


