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Broadening the horizon of size selectivity in trawl gears

Daniel Stepputtis[a,∗,1], Juan Santos[a,1], Bent Herrmann[b,c], Bernd Mieske[a]

[a] Thünen-Institute of Baltic Sea Fisheries, Alter Hafen Süd 2, 18069 Rostock, Germany
[b] SINTEF Fisheries and Aquaculture, Fishing Gear Technology, Willemoesvej 2, 9850 Hirtshals, Denmark
[c] University of Tromsø, Breivika, N-9037 Tromsø, Norway

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ABSTRACT

The discussion of alternative harvest patterns in commercial fisheries has been raised by stock assessment and fishery modelers, especially in the wider context of balanced harvesting. But often, these theoretical approaches propose alternative exploitation patterns that are difficult to achieve within the current limitations in the selectivity characteristics of fishing gears, such as trawl gears. The aim of the present study is to broaden the horizon for size selectivity in trawl gears by demonstrating the feasibility of alternative selectivity patterns for trawls. As a case study, we combined two well-known selection devices to obtain a bell-shaped selectivity curve in trawls with low catch ability of both small and large individuals from the target species. We have successfully tested this gear in the Baltic Sea cod fishery. The results revealed that completely different exploitation patterns for trawl gears can be achieved by means of gear technology.

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1. Introduction

Selectivity can be defined as the dependence of a fishing gear's capture efficiency on factors such as size, age, and species (MacLennan, 1992). Adapting the selectivity of fishing gears is the most important strategy used in many fisheries around the world to achieve the desired exploitation patterns. So far, a widely accepted paradigm is that "Improving selectivity leads to a more efficient exploitation of the stock's growth potential" (Macher et al., 2008), and that good fishery management requires fishing gears to catch large adult fish while allowing small juveniles to escape (Armstrong et al., 1990). According to classical theory, length at first catch is the key parameter to optimizing a stock's yield. (Armstrong et al., 1990; Beverton and Holt, 1957).

The size selection of fishing gears is described by selectivity curves, which quantify the probability that a given length class of a given fish species will be caught, assuming that it is available to the gear. Selectivity curves differ between gear types and configurations of gears (Dickson et al., 1995; Hovgård and Lassen, 2000; Wileman et al., 1996). Passive gears, such as gillnets, have size selection properties usually described as bell-shaped curves (Dickson et al., 1995; Hovgård and Lassen, 2000; Huse, 2000; Millar and Fryer, 1999; Millar and Holst, 1997). They are characterized by low retention probabilities at small length classes, as well as at large length classes, with the result that gillnets catch primarily medium-sized length classes.

Historically, the selective properties of trawls and other active gears were adapted by altering the size selection in the codend (Glass, 2000). This strategy assumes that most fish entering the gear drift toward the codend, where a simple size-selection process occurs: smaller fish with specific morphological characteristics have a greater probability of passing through the meshes and escaping, whereas larger fish have a greater probability of being retained in the codend. In contrast to passive gears, the selection curve in trawl gears is S-shaped. Thus, the retention probability increases with the size of fish (Dickson et al., 1995; Gulland, 1983; Huse, 2000; MacLennan, 1995; Millar and Fryer, 1999; Reeves et al., 1992; Wileman et al., 1996). To reduce unwanted bycatch, the classical codend selection is often supplemented with additional selectivity approaches, such as grids (He and Balzano, 2012; Sistiaga et al., 2010), escape windows (Armstrong et al., 1998; Bullough et al., 2007; Catchpole and Revill, 2008; Madsen, 2007), and other strategies (Herrmann et al., 2015). Currently, the selective properties of these types of devices are optimized by changing the S-shaped selectivity curve, resulting in a change in the position of the curve along the length range of the species (often described as the L50-value, length of 50% rejection/retention) and/or in the steepness of the curve often described as the SR-Value, L25–L75; (Dickson et al., 1995; Wileman et al., 1996). A good example of such a limited approach is the development of gear regulations for cod-

∗ Corresponding author.
E-mail addresses: daniel.stepputtis@ti.bund.de (D. Stepputtis), juan.santos@ti.bund.de (J. Santos), Bent.Herrmann@sintef.no (B. Herrmann), bernd.mieske@ti.bund.de (B. Mieske).
[1] Equal authorship

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directed fisheries in the Baltic Sea (Feekings et al., 2013; Madsen, 2007). Since 1999, fishery management and fishery science have tried repeatedly to adapt the size selectivity of legal codends to accomplish specific management goals. This effort, mostly limited to discard reduction, has been carried out without considering a broader set of fishery management objectives, such as optimal population dynamics and healthy population structure. Nevertheless, owing to a lack of alternative selectivity options, the standard S-shaped trawl selectivity curve was "only" moved left and right (Fig. 1).

The lack of possible alternatives to the S-shaped trawl selectivity curves also narrows the range of potential exploitation patterns to be investigated in fishery models, in the search for optimal harvest strategies. Typically, such studies only considered S-shaped selectivity scenarios (Kronbak et al., 2009; Macher et al., 2008). With the debate about balanced harvesting (Garcia et al., 2012; Jacobsen et al., 2013; Zhou et al., 2010), additional selectivity patterns are being discussed and used for modeling purposes (Jacobsen et al., 2013). However, it often remains unclear how the alternative harvest patterns could be implemented technically in the fisheries.

Apart from the fundamental concept of balanced harvesting and underlying aims, other rationales offer themselves as alternative harvest strategies for trawl fisheries: Although the importance of age structure for recruitment success is still under discussion (Brunel, 2010; Morgan et al., 2011), there are arguments for a healthy age structure, including large and old individuals (Berkeley et al., 2004; Hixon et al., 2014; Law et al., 2015). For several stocks, the positive influence on population dynamics caused by older individuals has been postulated, with varying driving factors, including parental effects (Cardinale and Arrhenius, 2000; Cerviño et al., 2013; Marteinsdottir and Begg, 2002; Trippel et al., 2005) and enhanced resilience against excessive fishing pressure and against climate variation (Ottersen et al., 2006). The extent of such effects is still being debated (Marshall et al., 2010; O'Farrell and Botsford, 2006). In addition, age-structure indices are also important to ecosystem-based fishery management.

In line with the above arguments, we aim in this study to reduce the catchability of trawl gears for both tails of the length distribution (juveniles and older fish) for a given target species. Achieving this through fishing technology would require finding ways to shift

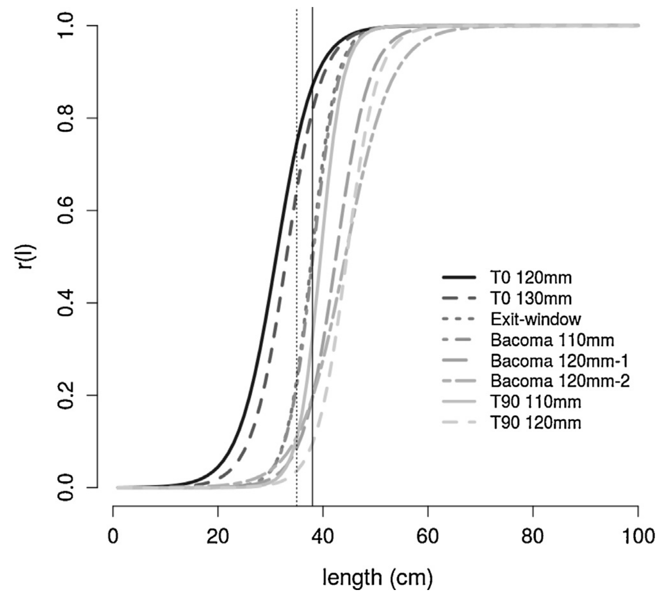

Fig. 1. Selection curves of legalized codends for the Baltic cod trawl fishery, 1999–2015. Vertical lines represent the corresponding minimum landing/reference sizes (MLS; 35 cm, 1999–2002 and 2015; 38 cm, 2003–2014). Codends are (a) T0 120 mm (1999–2001); (b) T0 130 mm (2002–2003); (c) Exit-window (1999–2001); (d) Bacoma 110 mm (2003–2009); Bacoma 120 mm (2001–2003 and 2010–2015); T90 110 mm (2006–2009); T90 120 mm (2010–2015). Selectivity curves were derived from personal, unpublished selectivity experiments conducted between 1999 and 2010. A description of the legislative development can be found in Feekings et al. (2013).

the traditional S-shaped trawl selection curves toward bell-shaped selection curves, commonly associated with passive gears such as gillnets (Dickson et al., 1995). The strategy adopted here emulates gillnet-like bell-shaped selectivity by adding the rejection of larger individuals during the selectivity process in a standard trawl gear. The technological approach is simple and is based on the combination of two well-known and widely used selection devices. The proof of concept was carried out in the Baltic Sea cod-directed fishery.

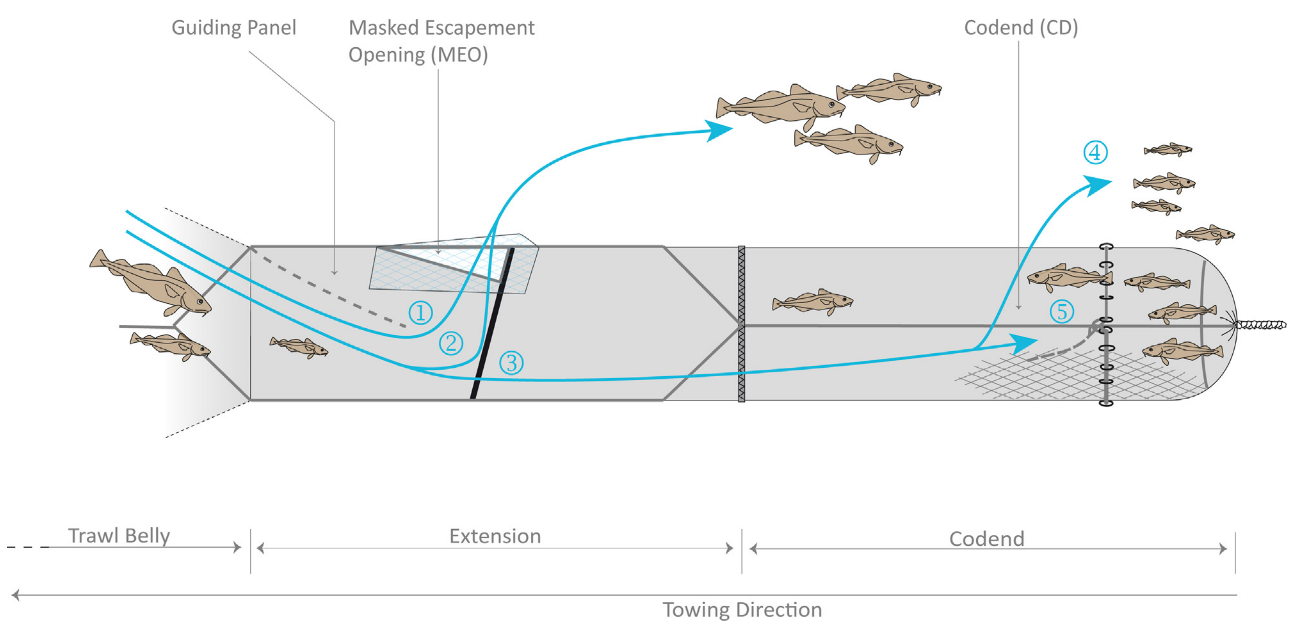

Fig. 2. Illustration of the grid and codend selection system used to obtain bell-shaped trawl selectivity. In addition to technical details, the different traits of fish entering the extension piece are illustrated: (a) fish not contacting the grid and escaping through the MEO; (b) fish contacting the grid, but not able to pass through; (c) fish contacting the grid, passing through, and entering the codend; (d) fish escaping through the codend meshes; (e) fish finally caught within the test codend.

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