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The influence of twine thickness, twine number and netting orientation on codend selectivity

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ABSTRACT

Based on an experimental Baltic trawl fishery, we tested diamond mesh codends with different twine thicknesses, twine numbers (single or double), and netting orientation (T0 or T90) to quantify the effects of the twine characteristics on the size selection of cod (*Gadus morhua*) and plaice (*Pleuronectes platessa*). For a given twine thickness: going from T0 to T90 increases selectivity of cod; while going from single to double reduce it. Increasing twine thickness reduces selection but the extent depends on whether the twine is single or double and whether the netting orientation is T0 or T90. In general, the results demonstrate the benefit of using a relatively thin single twine netting to ensure the appropriate size selection with round fish and the best results were obtained using netting with a T90 orientation. For a given twine thickness going from T0 to T90 decreases selectivity of plaice. Increasing twine thickness reduces selection for plaice. Our results demonstrate that very different selectivity results can be obtained using the same mesh size, simply by varying the twine thickness, the twine number, and the netting orientation. In some fisheries, the size selectivity could be improved considerably by adjusting these simple design parameters alternatively to produce more advanced and complex designs.

1. Introduction

Because of its simplicity of construction and ease of operation, diamond mesh codends have traditionally been used to fish for round fish such as cod and haddock (*Melanogrammus aeglefinus*), and flatfish species such a plaice, at the aft end of demersal trawls in northern European fisheries (Graham et al., 2007; O'Neill and Herrmann, 2007; Krag et al., 2008). In recent years, the fishing industry has introduced stronger, stiffer, and thicker twines, which are often used as double twine netting, particularly in the designs of diamond mesh cod-ends used by many European trawl fisheries (Herrmann and O'Neill, 2006). Concerns about their effect on codend size selectivity led to restrictions on the maximum twine thickness and twine number allowed onboard EU fishing vessels. EU regulations, such as 850/1998 and 1967/2006, define the maximum twine thickness permitted in codends used in European waters. The maximum thickness of diamond meshes is 6 mm for double twines and 8 mm for single twine in northern European waters while it is 3 mm in the Mediterranean area. For the size selection of haddock, experimental studies (Lowry and Robertson, 1996; Kynoch et al., 1999) and theoretical studies (Herrmann and O'Neill, 2006; O'Neill and Herrmann, 2007) have demonstrated a significant decrease in the 50% retention length (*L*50) with increasing netting twine thickness for double twine diamond mesh codends. In particular, Herrmann and O'Neill (2006) formulated a set of hypotheses, using the simulation tool PRESEMO (Herrmann, 2005a), to investigate mechanisms that might potentially explain and quantify the effect of twine thickness on haddock size selection using traditional double twine diamond mesh codends (T0 cod-ends). The authors reported that an increase in twine thickness could lead to a reduction in selectivity, because: (i) the internal lateral mesh opening of meshes made of thicker twine would be smaller with the same knot-center to knot-center lateral mesh opening; (ii) the increased twine bending stiffness of thicker twines would increase the mesh resistance to opening; (iii) it would be more difficult for fish to deform and escape via partly open meshes compared with those made from stiffer twine; and (iv) netting made from thicker twine

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would present a greater visual barrier to fish, which may discourage them from making escape attempts. Thus, the effect of twine thickness on haddock size selection using traditional double twine diamond mesh codends have been well described in the scientific literature, based on experimental and theoretical investigations. From a mechanistic perspective, the effect of twine thickness on haddock size selection using double twine diamond mesh codends can probably be extrapolated to predict and understand the size selection of morphologically similar round fish species such as cod. However, this extrapolation is less likely to be applicable to flatfish species such as plaice, which has a very different cross-sectional shape compared with round fish species. In Baltic Sea trawl fisheries that target cod, the codends made solely from traditional diamond mesh netting has been banned in the legislation since 2003, while it is legal to use diamond mesh netting in combination with square meshes in the BACOMA design and codends where the diamond mesh netting direction is turned 90° (T90)(EU Regulation No. 2187/2005). The T90 codend, which for cod, is believed to have better size selectivity properties compared with the traditional T0 cod-end (Dahm, 2004), was introduced as a legal alternative to the BACOMA codend in the Baltic Sea cod trawl fishery during 2005. For a specific type of single twine netting, Wienbeck et al. (2011) have documented improved cod size selective properties when using T90 cod-ends compared with similar T0 cod-ends. However, Wienbeck et al. (2011) cautioned that their results are specific to the type of netting used for the cod-ends in their experiments and they recommended that a systematic study should be conducted to investigate the effects of twine parameters such as thickness and twine number on the size selectivity of T0 and T90 codends. Furthermore, the legislation describing the construction of T90 codends for the Baltic Sea trawl fishery did not define a specific twine thickness, although an upper limit of twine thickness for single and double twine codends was specified (EU Regulation No. 2187/2005 and EU Reg. No. 686/2010). It is unknown to what extent the size selectivity properties of the T90 codend vary within the legal ranges for twine thickness below this maximum thickness and to what extent the twine number in the netting is important.

During trawl fishing, the codend meshes are stretched by hydrodynamic drag forces that act primarily on the accumulated catch in the aft (Herrmann, 2005b; Herrmann et al., 2006). However, difference in mechanical properties of the T0 and T90 codends mean that the shapes of their meshes can be very different during fishing, which can influence their size selectivity properties. According to Herrmann et al. (2007), the bending stiffness of the T0 codends mesh bar, which depends on the twine thickness, tends to keep the meshes closed. By contrast, an increased twine bending stiffness will increase the resistance against mesh closing with the T90 netting. Furthermore, the netting knot size, which increases with twine thickness, may also contribute to the benefit of turning the netting by 90°. These effects seem to favor the use of T90 constructions made of thick twine to achieve high L50 values.

However, some mechanisms that influence the effect of the twine thickness on size selection were described by Herrmann and O'Neill (2006), such as the ability of fish to partly deform the mesh bars during escape attempts and the visual barrier, which favors constructions based on thinner twine netting. These potentially counteracting mechanisms make it difficult to predict the overall effect of changing the twine characteristics (twine thickness and number) on the size selectivity of T0 and T90 cod-ends for round and flatfish species.

Given this lack of knowledge, the main aim of this study was to investigate and quantify the effect of twine thickness, twine number (single or double), and the netting orientation on size selectivity. Therefore, we formulated the following research questions: (i) To what extent does the twine thickness in the codend affect the size selection of round fish (cod) and flatfish (plaice)? (ii) Does it matter whether the codend is made of single or double twine netting? (iii) Do these twine characteristics affect the size selectivity of cod and plaice in different ways with the T0 and T90 codends?

2. Materials and methods

2.1. Experimental design

To investigate the research questions regarding the effect of twine characteristics on codend size selection, we tested a total of 12 different codends made of six different commercial netting types (Fig. 1). All codends were made of polytit COMPACT netting (EuroRed S.L., Callosa de Segura, http://www.eurored.org). A T0 and a T90 codend were made from each netting type, resulting in six pairs of codends. Three pairs of nets were made of double twine netting (nominal twine diameter 3, 4, and 6 mm), and three pairs were made of single twine netting (nominal twine diameter 4, 6, and 8 mm). The actual twine diameter was estimated by scanning sample pieces of the different nets using a high resolution flatbed scanner and the image analysis facilities in the FISHSELECT program (Herrmann et al., 2009).

All codends were constructed with 50 open meshes in the circumference to comply with the current legislation for the Baltic Sea trawl fishery regarding this design parameter for T90 codends. A symmetrical two-panel construction with identical upper and lower panel was used for all codends. All codends had the same number of meshes in the two selvedges (three). We attempted to keep the mesh size identical for all codends (approximately 123 mm), although it differed slightly between the different nettings. The mesh size was measured using an OMEGA-gauge (Fonteyne et al., 2007; Council Regulation (EC) No. 517/2008 of 10 June 2008). Based on their construction and twine characteristics, all of the T90-codends described in Fig. 1 can be used legally in the demersal Baltic Sea trawl fishery.

Each of the 12 codends was fished alternately, one at a time, while attached to the same trawl and the same extension piece. The trawl used was a "Codhopper," which has a circumference of 530 meshes and a 160 mm mesh size in the belly. The trawl was spread using two 3.5 m^2 Bison trawl doors. The extension piece was a T90 construction with 50 open meshes around and 50 meshes in length, made of nominal 120 mm single 5 mm netting using the same polytit COMPACT netting that was used for the codends. The codend was the only change in gear between the individual tows.

The covered codend method (Wileman et al., 1996) was applied. Supporting hoops were applied to keep the cover netting clear of the test codend. The cover was connected to the extension piece two mesh rows before the codend. The cover was 238 meshes long. The 2.6 m diameter of the cover hoops ensured that the diamond shaped cover meshes were almost open like square meshes. The cover was a two panel construction with a total of 264 meshes in circumference. The cover mesh size was 80 mm because previous experience during experimental fisheries in the same region demonstrated that fishing with a smaller cover mesh size was impossible because of the retention of large amounts of herring in the cover (Wienbeck et al., 2011). Compared with the recommendations of Wileman et al. (1996), this cover mesh size was rather large compared with the test codend mesh sizes (Table 1). Therefore, special attention was given in the analysis to remove length classes where the selection of cover and test codend potentially overlapped. The experimental fishing was conducted onboard the German Fishery Research Vessel (FRV) "Solea" (total length = 42 m, 950 kW). To make the conditions as similar as possible for each codend, all hauls were conducted on the same fishing ground.