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The influence of twine tenacity, thickness and bending stiffness on codend selectivity

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ABSTRACT

We report on trials which measured the selectivity of haddock (*Melanogrammus aeglefinus*) and plaice (*Pleuronectes platessa*) in codends made from netting materials classified by the manufacturers as low, medium and high tenacity. We measured the twine bending stiffness, thickness and tenacity (as defined by Klust, 1982) of the netting materials and investigated which of these most influenced codend selection. For haddock, only twine bending stiffness affected selection, with l50 decreasing as bending stiffness increased. For plaice, none of the twine variables affected l50, but they all influenced selection range. Increasing mesh size increased the l50 of both species, whilst increasing catch size increased haddock l50 but decreased plaice l50. As bending stiffness is difficult to measure, a proxy is required that quantifies the resistance of meshes to opening and that can be reported in future selectivity studies.

1. Introduction

The netting materials used to make fishing gears are typically described in terms of their mesh size and shape and the thickness, number, tenacity and material type of the twines from which they are made. For instance, we speak of 120 mm, 5 mm double, high tenacity polyethylene (PE) diamond mesh netting. These variables are important because they help determine the mechanical, engineering and fishing performance of the fishing gears they make up. They can affect the longevity of the gear, the ease of handling on deck, the fuel efficiency of the fishing operation, fish behavioral reactions and the selective performance of the fishing gear (Klust, 1982; Sala et al., 2008a; Glass et al., 1993; Fryer et al., 2015). Given its relevance to stock status and future yields (Vasilakopoulos et al., 2015), fisheries managers and fishing gear technologists have paid particular attention to how these netting and twine variables affect the selective performance of the gear.

There have been many studies relating an increase of codend mesh size to improved selectivity, examples of which are summarized in the meta analyses of Perez Comas and Pikitch (1994), Madsen (2007) and Fryer et al. (2015). The influence of mesh shape (diamond, square and hexagonal) has been investigated by Tosunoğlu et al. (2009), Broadhurst and Millar (2009), Sala et al. (2008b), Suuronen et al. (1991) and mesh orientation (T90) by Herrmann et al. (2009, 2013).

The material type and the twine number and thickness have all been related to the resistance of meshes to opening and accordingly to changes of codend selectivity. From a mechanical perspective, each of these variables can influence twine bending stiffness. Twine bending stiffness (or flexural rigidity) is a mechanical property of a twine that quantifies the resistance of the twine to bending (O'Neill, 2002). It is dependent on the material type and the cross-sectional geometry of the twine. Twines made from less elastic materials will have a higher bending stiffness, as will mesh bars made from thicker twines or multiple twines (Fryer et al., 2015). As twine bending stiffness increases, the mesh resistance to opening also increases, leading to a decrease of the lateral opening of the meshes of a diamond mesh codend (O'Neill and Priour, 2009; de la Prada and González, 2014). Further, Herrmann and O'Neill (2006) suggest that an increase of twine bending stiffness reduces the ability of fish to deform meshes when attempting to escape (especially during the initial stages of a tow).

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The effect of material type has been examined by Tokaç et al. (2004) who found that codends made from polyamide (PA) are more selective than those made from polyethylene (PE). Lowry and Robertson (1996) and Kynoch et al. (1999) found that the selection of haddock (*Melanogrammus aeglefinus*) reduced with increasing twine thickness and Sala et al. (2007a) obtained a similar reduction in a Mediterranean bottom trawl fishery. Herrmann et al. (2013) found that increasing twine number reduced the selectivity of Baltic Sea cod (*Gadus morhua*) but did not affect the selectivity of plaice (*Pleuronectes platessa*).

Fish behavior may also help to explain some of these relationships. Netting made from thicker and multiple twines will present a greater visual barrier to fish, which can inhibit their penetration of meshes (Glass et al., 1993). Indeed, the simulation study of Herrmann and O'Neill (2006) suggests that both mechanical and behavioral mechanisms play an important role, as their model predictions best reflect the experimental data in the literature only when their model includes contributions from both.

Twine tenacity is the one variable for which there does not appear to be any selectivity studies. This is perhaps not surprising as there is some confusion surrounding the usage of the term. Klust (1982) defines tenacity as the breaking tensile force per unit linear density of a twine, yarn or fibre. While twine and netting manufacturers will calculate this quantity for their products, their subsequent categorization of twines as being low, medium or high tenacity appears to be arbitrary (Bates, 2004) and reflects the broader fishing industry's more holistic use of the term to encompass a range of qualities. In general, less hard wearing and more flexible twines are classified as being low tenacity, whereas more hard wearing and stiffer ones are classified as being of higher tenacity. Often such 'higher tenacity' twines have undergone several treatments (chemical, heat, pressure etc.) or have been made differently leading to an increase of physical properties such as abrasive resistance, stable elongation and stretch recovery.

Here we explore these issues further and investigate the selectivity of codends made from netting materials that their manufacturers classify as low, medium and high tenacity. We measure the twine bending stiffness and twine thickness and calculate the twine tenacity (as defined by Klust, (1982)) from the breaking strength and linear density measurements provided by the manufacturers. We report on trials which measure the selective performance of haddock and plaice in these codends and investigate which of the twine variables is the best predictor of selection.

2. Materials and methods

2.1. Fishing vessel, gear and area

The Carina BF 803, a 745 kW commercial trawler with an overall length of 25.9 m, was chartered for selectivity trials during October 2003. Trials were conducted on commercial fishing grounds in ICES subarea IV, approximately 16 miles east of Aberdeen, Scotland. The vessel's own single whitefish rockhopper trawl was used, with 600 × 160 mm meshes round the fishing circle. This design is typical of those used by the Scottish whitefish fleet. The ground gear was 40 m in length and consisted of 450 mm diameter rockhopper discs all round. The trawl was towed with a two warp system and fished with 4 m double backstrops, 90 m single sweeps, 27 m double bridles and spread with 1900 kg Polyice otterboards.

Scanmar acoustic instrumentation was used to monitor the net geometry. Headline height above the sea bed, wing-end spread and door spread were measured for most hauls. A GPS unit measured the speed over the ground and depth was recorded from the vessels own sonar system.

2.2. Codends and netting materials

Four codends were used during the trials. They were all of a two panel construction with 100 open meshes around the circumference and 50.5 meshes long. Three had a nominal diamond mesh size of 120 mm and were made from 5 mm double PE twine of low, medium and high tenacity (as categorised by the netting manufacturers). The fourth was made of 130 mm diamond mesh with 5 mm double PE medium tenacity twine. They were all fished with 5 mm single PE twine diamond mesh extensions that were 150 meshes long and of the same mesh size as the corresponding codend.

The netting twines had internal cores made of individual yarns around which there was a braid made of a number of strands each of which consisted of a number of yarns. The number of strands in the braid, the number of yarns per strand and the number of yarns per core were counted for each twine.

Twine thickness measurements were made using an optical measurement technique similar to the one described by Ferro (1989), where the light source had been replaced by a laser. Mesh size was measured with an ICES spring loaded gauge (Westhoff et al., 1962) set at 4 kg spring tension and also with a standard EU wedge gauge, midway during the trials, whilst the netting was wet.

The tenacity as defined by Klust (1982) was calculated from the breaking strength and linear density measurements provided by the twine manufacturers and expressed in N/tex.

Twine bending stiffness was measured following the procedure set out in Sala et al. (2007b) using the prototype instrument named the ROD-m. Small panels of netting (3 × 3 meshes) can be mounted on the ROD-m in such a way that they can deform in response to forces that are applied perpendicular to the panel edges via four load cells. The load cells can be positioned using an endless screw driven by a stepping motor and the forces acting on the netting panel and the resulting netting deformation can be recorded. By making assumptions about the netting construction and the mechanical properties of the netting twine, these data can be used to estimate the twine bending stiffness (Sala et al., 2007b).

2.3. Experimental technique and catch handling

The covered codend technique (Wileman et al., 1996) was used to assess the selective properties of each codend. The small mesh codend cover was approximately 16.65 m stretched length and made of 50 mm mesh netting of 2 mm single twisted PE twine. The cover was held away from the codend by attaching two supporting hoops around its circumference on the outside of the cover (Wileman et al., 1996). The hoops were 1.8 m and 3.1 m in diameter (forward and rear) and were removed after each haul and the cover was hauled round to the bag hatch. The codend was always emptied first into the fish hopper through the zips in the side of the cover. This ensured that wash-out did not occur.

The codend and cover catches were sorted by species (haddock, plaice and mixed) into baskets and weighed. The lengths of haddock and plaice were then measured to the nearest cm below. When catches were large a subsample was measured: for haddock, these subsamples always contained more than 375 fish from the codends (and in most instances it was >500) and more than 775 from the cover; for plaice, all codend fish were measured and the subsamples from the cover always contained more than 200 fish.

2.4. Statistical analysis

The selection of the different gears was investigated by modeling the numbers of fish at length in the codend and cover in each haul using generalized nonlinear mixed models assuming a binomial distribution and a logistic link and with the log ratio of the subsampling fractions in the codend and the cover as an offset