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Behavior of different trawl codend concepts

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ABSTRACT

The overall objective of this study was to evaluate the behavior of different codend designs to provide basic information that is relevant for implementing technical management measures, improving selectivity and catch quality, and reducing energy consumption. Six different codend designs were evaluated: a traditional diamond mesh codend; a T90 codend (meshes turned 90°); a Bacoma codend with diamond meshes in the lower panel and square meshes in the upper panel; a Bacoma codend with the square meshes orientated in the T0 direction; a two panel square mesh codend; and a four panel square mesh codend. The codends were tested in a flume tank with flow of 1.8 knots/h. A simulated catch of 500 kg was placed in the tested codend. A motion tracking system was used with four track markers placed on each of three successive cross-sections and a single marker at the end of the codend. This made it possible to assess and compare the movements of the codend and the netting in three dimensions. The drag of the codends also was measured and compared.

1. Introduction

Trawling is a method that involves pulling a fishing net through the water behind one or more vessels. The net that is used for trawling is called a trawl. Trawling is one of the most important marine fishing methods in the world (Watson et al., 2006; Anticamara et al., 2011).

The codend, which most often is cylindrical, is the rearmost part of the trawl, and it is connected to the narrow end of a tapered trawl net. The length of the codend depends on the fishery and can vary from a few meters to more than 50 m. The codend is a very essential part of the trawl, as its function is to store the catch. The meshes of the trawl are selective, retaining large fish and letting small fish escape. In general, most mesh selection takes place in the codend (Wileman et al., 1996). Thus, it is the focus of technical regulations in marine fisheries aimed at improving selectivity.

Regulation of trawl selectivity, particularly to improve selectivity, is a major fisheries management tool aimed at achieving sustainable fisheries (Suuronen et al., 2012). In many fisheries, focus on improving selectivity has increased because of declining stocks influenced by too many discards and bycatches of unwanted species and sizes (Graham, 2010). Therefore, development and innovation of codend designs to improve the selective properties of trawl nets and increase sustainability of marine fisheries has become a hot research topic.

Although substantial changes have been made to improve the selectivity of trawl gear, little is known about how these changes influence the physical performance of the codend. Fishermen often express concern about codend constructions when implementing selective gears, and scientists do not have detailed knowledge about actual performance when constructing selective fishing gears. However, such information is important because the performance of the codend could influence the mesh openings, dimensions, movements, and drag of the gear. For example, variations in mesh openings could influence the selective properties of the netting by impacting the likelihood of escape (Herrmann, 2005; Herrmann et al., 2009). The dimensions of the codend might affect the probability of escape, as swimming performance of fish is species and size dependent (He, 1993; Videler and He, 2010). Movements of the codend and catch build-up in the codend might influence catch quality because they can cause epidermal damage. Finally, the drag of the codend affects energy consumption of the fishing vessel. In recent years, focus on reducing the energy consumption in trawl fisheries has increased in an effort to reduce CO_2 emissions and improve the economical sustainability of the trawl fishery caused by increasing fuel prices (Suuronen et al., 2012).

In this study we evaluated the behavior of six different codends at full-scale in the flume tank of SINTEF (Hirtshals, Denmark), that are of general relevance to many fisheries worldwide, but particularly to the Baltic Sea cod fishery. The Baltic Sea is a locale where many selectivity experiments have been conducted, and it is the first area within the European Union (EU) where selective devices and technical regulations were implemented in order to improve

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selectivity (Madsen, 2007; Feekings et al., 2013). However, discards, technical measures concerning selectivity, and minimum landing size remain problematic (Catchpole et al., 2014; Uhlmann et al., 2014), and new management measures are likely to be developed because reform of the EU common fisheries policy requires gradual elimination of discards by reducing unwanted catches and ensuring that all individuals caught are landed (COM, 2012; Sardà et al., 2015). Fishermen will have an incitement to avoid catches of species and sizes that have a low market value. Although many traditional selectivity experiments have taken place in the Baltic Sea and other areas, information about basic codend behavior, which is important for design and construction of innovative codends, is lacking.

The overall objective of this study was to evaluate the basic behavior of different codend designs to provide information that could be relevant to improving selectivity, reducing energy consumption, developing technical management measures, constructing predictive simulation models and improving catch quality. We also used a motion tracking system as an innovative approach to evaluating codend behavior.

2. Methods

2.1. Choice of codends

Six different codends were constructed in full scale (Table 1). Fig. 1 shows pictures of all codends during the flume tank tests. All codends were constructed with particular attention to the Baltic Sea cod fishery, but mesh sizes differed from present legislation in order to standardize constructions and to use mesh sizes that are likely to be used in the future. The codends tested and the reasons for choosing them are described below:

(1) Standard codend: Until 2004, legislation specified that a standard diamond mesh codend be used in the Baltic Sea (Madsen, 2007). Standard diamond mesh codends are the most used codends for fisheries around the world;

(2) T90 codend: Use of the T90 (netting turned 90°) codend has been specified by legislation since 2006 (Feekings et al., 2013) and tested in the Baltic Sea (Herrmann et al., 2007; Madsen, 2007; Herrmann et al., 2013) and in other areas (Digre et al., 2010; Madsen et al., 2012). T90 codends, have the standard diamond mesh netting turned 90°, to increase the mesh opening and hence improve the selectivity of the codend (Wienbeck et al., 2011; Madsen et al., 2012). In the traditional netting orientation of the standard codend, the mesh resistance to open tends to close the meshes. Turning the netting 90° hampers this mechanism, which provides a more open mesh;

(3) Bacoma codend: The Bacoma codend has traditional diamond meshes in the lower panel and square meshes in the upper panel. Use of this codend is specified in the legislation since 2002 (Madsen, 2007) and is widely used in the Baltic Sea;

(4) Bacoma T0: The Bacoma T0 is a Bacoma codend with the square meshes in the traditional direction (T0). The net is inserted with some slack and a rope in the selvedges keeps the net panel at a fixed length. This codend concept was constructed by a local net maker (Nexø vod) to overcome the problem of mesh distortion (uneven and unstable mesh bars) often experienced by net makers and fishermen in the traditional Bacoma codend;

(5) A two panel codend made of full square meshes (Square 2P): This codend might provide better selectivity for roundfish in the lower panel compared to the diamond meshes in the Bacoma codend (Frandsen et al., 2010);

(6) A four panel codend made of full square meshes (Square 4P): The two panel square mesh codend has been criticized for being difficult to handle when bringing the catch onboard the fishing vessel. To reduce this problem, the four panel codend was constructed. Four panel codends have been tested in other fisheries (Frandsen et al., 2011; Madsen et al., 2012) and are widely used commercially in the Kattegat and Skagerrak area.

2.2. Codend construction

Our aim was to standardize the codends as much as possible. Codend specifications are provided in Table 1. The four codends with standard diamond meshes were constructed with the same overall length of 49.5 meshes and with 92 open meshes and 4 meshes enclosed in each of the two selvedges. This is one of the most common ways to produce commercial codends for the Baltic Sea cod fishery. They were made of 4 mm green polyethylene (PE) double twine netting with an inside nominal mesh size of 130 mm. This is the material most used by the Baltic cod trawler fleet. Three rows of diamond meshes similar to what is used elsewhere were inserted into the end of the codends to replace square meshes, ensuring a uniform and strong opening of the codend where the codline is attached. This construction is allowed by legislation and is used by most of the trawlers. The stretched lengths of the codends were around 6.6 m. Rings were attached to carry the lifting rope. However, we did not use the lifting rope that is used on commercial codends to lift the catch out of the water because the rope might have influenced codend performance in an unpredictable way, making it difficult to ensure that the codends were subjected to the same treatments.

For the square mesh netting panels (Bacoma, Bacoma T0, Square 2P, and Square 4P), black PET single braided twine netting of 4.9 mm thickness (Ultra cross) was used. In this netting the twine threads are continuous in all bars directions, making it a very strong and stable mesh configuration when used as square mesh netting. This twine is used to construct the major part of square mesh windows in the Baltic Sea because legislation specifies use of single knotless twine with a minimum thickness of 4.9 mm. It is thought that traditional double twine netting

Table 1
Codend specifications. Netting is described by twine thickness, twine type (DB or SB), meshes in circumference and nominal mesh size. Mesh size indicates measured mesh size with standard deviation in brackets. Meshes are measured with an OMEGA gauge (Fonteyne et al., 2007).

Codend	Top panel			Bottom panel		
	Netting	Meshes (no.)	Mesh size (mm)	Netting	Meshes (no.)	Mesh size (mm)
Standard	4 mmDB–D130 mm	46	129.9 (1.79)	4 mmDB–D130 mm	46	129.8 (2.47)
T90	4 mmDB–D130 mm	46	130.4 (1.16)	4 mmDB–D130 mm	46	130.4 (1.10)
Bacoma	4.9 mmSB–SQ120mm	23	119.6 (1.25)	4 mmDB–D130 mm	46	130.3 (1.31)
Bacoma T0	4.9 mmSB–SQ120 mm	23	119.6 (1.06)	4 mmDB–D130 mm	46	131.0 (1.41)
Square 2P	4.9 mmSB–SQ120 mm	23	120.5 (1.20)	4.9 mmSB–SQ120 mm	23	121.2 (1.63)
Square 4P	[a]4.9 mmSB–SQ120 mm	12	[a]120.6 (1.42)	4.9 mmSB–SQ120 mm	12	121.0 (1.25)

[a] Including side panels. D: diamond meshes; DB: double twine; SQ: square meshes; SB: single braided twine.