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Size selection of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) in the Northeast Atlantic bottom trawl fishery with a newly developed double steel grid system

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ABSTRACT

In recent years, Norwegian fishermen have reported problems with fish accumulation in front of the mandatory sorting grids (Sort-X, Sort-V, and Flexigrid). These problems are associated with high fish entry rates and low water flow through the grid sections. In this study, we replaced the lifting panel in the original design of a sorting grid section (Sort-V) by another steel grid ("lower grid") in order to improve water flow and increase sorting area. Two different inclination angles of this new additional "lower grid" were tested. The results demonstrated that both the lower grid and the main grid contributed to the release of cod and haddock. However, the release efficiency of the lower grid was low compared to that of the main grid. A larger proportion of fish contacted at least one of the grids with the lower grid set at 40° compared to at 35°. The new double grid was found to release significantly more haddock between 38 and 50 cm long than the mandatory Flexigrid. For cod, the sorting system was at least as good as the Flexigrid at releasing undersized fish. Thus, the new double grid system represents a potential alternative to the Flexigrid. Although the Sort-V single grid releases significantly more undersized cod and haddock than the new double grid system, it also releases a significantly higher proportion of the targeted commercial sizes.

1. Introduction

Rigid sorting grids in combination with diamond mesh codends have been mandatory in the Barents Sea demersal cod (*Gadus morhua*) and haddock (*Melanogramus aeglefinus*) fishery since 1997. In 2011, the minimum mesh size of the diamond mesh codend was changed from 135 to 130 mm and this remains the minimum mesh size for the fleet today. Fishermen are allowed to use three different grid systems in the fishery, all of them with a minimum bar spacing of 55 mm: the Sort-X, which is a three-section system that is composed of two steel grids and a canvas section (Larsen and Isaksen, 1993); the Flexigrid, which is a double flexible grid section composed of two grids made of plastic (i.e., bars made from fibre-glass) and rubber (Sistiaga et al., 2016;); and the Sort-V, which is a single steel grid section (Jørgensen et al., 2006; Herrmann et al., 2013a). The Sort-X system is considered outdated by fishermen and only the Sort-V system and the Flexigrid are actively used in the fishery today (Fig. 1).

The current stock size of Northeast Arctic cod is estimated to be around 3,200,000 tons (www.imr.no), which is at the top of the levels registered in recent decades. A direct consequence of this stock size is that the trawlers fishing in the Barents Sea often encounter densities of fish that make ordinary fishing operations challenging. Specifically, the grid systems applied in the Barents Sea today experience capacity problems that render more acute when the densities of fish entering the section are high (i.e., > 10 t/h). The causing mechanism is that fish often seem to stop just in front of the grid and keep a somewhat stationary position up to several minutes before being size sorted in the section and pass it in the direction of the codend. This phenomena leads to fish accumulation at the entrance of the grid section, which combined with high entrance rates can result in that the grid section gets blocked (or clogged) by fish, loses its sorting ability and finally breaks in some cases (Grimaldo et al., 2015; Sistiaga et al., 2016). Therefore, a key to eliminate or at least significantly reduce this risk for grid clogging is to ensure that the fish does not stop and accumulate in front of the grid section before being size sorted by it. Reduction in water flow both in front of and inside grid sections is assumed to be one of the key

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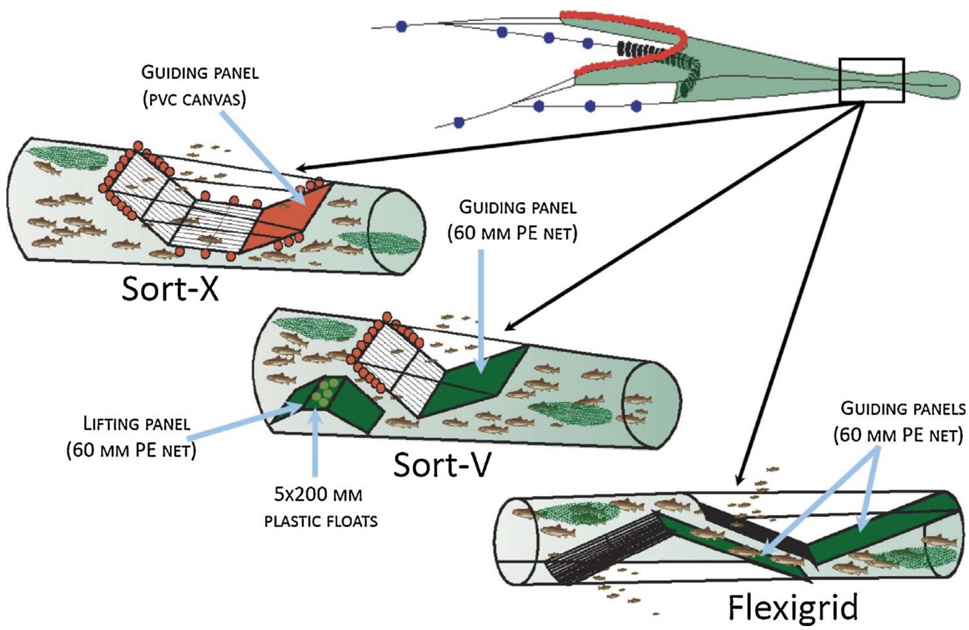

Fig. 1. Sorting grids that are mandatory in the Norwegian Sea (North of 62°N) and the Barents Sea trawl fisheries: (a) Sort-X, (b) Sort-V, and (c) Flexigrid. The figure illustrates how cod and haddock often are observed to swim in the towing direction in the aft of the trawl.

factors that encourages and makes it possible for fish to halt and keep a stationary position in front of the grid section. Therefore, in an attempt to solve this issue, the Norwegian authorities, research institutes, and fishermen are testing alternative gear and grid designs that increase the water flow through the grid sections and facilitate the continuous flow of fish into the grid section and towards the codend. One of the measures proposed by the Norwegian authorities was the removal of the lifting panel from the grid section, which is believed to substantially reduce water flow through the section. Grimaldo et al. (2015) evaluated the importance of the lifting panel in a Sort-V section to see if its removal affected the selective performance of the section. The results showed that the lifting panel has a significant effect on the sorting ability of the Sort-V grid section and therefore it should not be removed. Therefore, the present study examines an alternative design where the lifting panel was not eliminated but substituted by an additional grid that would potentially increase water flow through the section, provide an additional sorting process and at the same time lift the fish towards the main grid. The study aims at first instance at answering the following research questions:

- Do fish stop in front of the grids in the new section, and if not, how fast do they pass through the section?
- To what extent is the water flow maintained through the new section?

In addition to carrying fish through the section and towards the codend effectively, a potential alternative grid section should perform at least as good as the existing grid sections at releasing undersized fish and retaining commercial size fish. However, for a sorting grid to be effective regarding size selection, fish need to have enough time in the grid zone to orientate itself correctly towards the grid for an exposure to a size selection process. Therefore, as increasing the water flow may have negative effect on the size selection, it is essential to examine the size selectivity performance of the new grid section with respect to the main target species in the fishery. Thus, the next research questions to be answered would be:

- Do fish have enough time in the grid section to orientate itself correctly towards the two grids for an effective size selection process?
- To what extent do cod and haddock escape through the new additional grid and through the main grid in the double grid design?
- Does this new grid design provide size selection for cod and haddock comparable to the grid designs used in the fishery today?

2. Materials and methods

2.1. Vessel, area, time, and fishing gear

The experimental fishing was carried out on board the research vessel (R/V) "Helmer Hanssen" (63.8 m LOA and 4080 HP) from 27th February to 7th March, 2015. The fishing grounds chosen for the tests were located off the coast of Finnmark and Troms (Northern Norway) at 71°30′N–27°30′E and 70°30′N–17°20′E. At this time of the year the area is suitable for size selectivity studies under rather high fish entry rates.

We used an Alfredo No. 3 Euronet trawl built entirely of 155 mm polyethylene (PE) netting. This trawl design is commonly used in commercial Norwegian fisheries. The trawl had a headline of 36.5 m, a fishing line of 19.2 m, and 454 meshes in circumference and was constructed entirely in 155 mm nominal mesh size (nms). The trawl was rigged with a set of Injector Scorpion bottom trawl doors (7.5 m^2 and 2800 kg each), 60 m sweeps, and 111.2 m ground gear. The ground gear had a conventional 19.2 m long rock-hopper in the center that was built with Ø 53 cm rubber discs attached to the fishing line of the trawl and five Ø 53 cm steel bobbins distributed on a 46 m × 19 mm chain along each side of the trawl. The headline was equipped with 170 × Ø 20 cm plastic floats. The trawl gear was monitored using Scanmar (Scanmar AS, Åsgårdstrand, Norway) acoustic sensors placed at the trawl doors, headline, and codend. With the given rig details, we achieved ca. 130 m door spread, ca. 14.5 m fishing line spread, and a ca. 5 m headline height at towing speeds of 3.5–4.0 knots, and a depth that ranged between 250 and 320 m.

We built a 4-panel netting section with two steel grids inserted into it. This grid section was made of 138 mm nms Euroline Premium PE netting (single Ø 8.0 mm twine), was 26 meshes long (the section was 18.5 meshes shorter than the mandatory Sort-V steel grid section), and had 104 meshes in circumference. All four selvedges in the grid section were strengthened with Ø 36 mm Danline PE rope. The original Sort-V system is equipped with a 60 mm PE lifting panel and its main function is to guide fish closer to the grid face (Fig. 1). The lifting panel was

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