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Size selection of redfish (*Sebastes* spp.) in a double grid system: Estimating escapement through individual grids and comparison to former grid trials

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ABSTRACT

We inserted a new double steel grid system consisting of a lower and an upper grid in a four-panel section to increase the cross-sectional area and improve the size selectivity in the Norwegian bottom trawl fishery. We tested its ability to size select and release typical bycatch species in the cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinnus*) directed fishery, i.e. two species of redfish (*Sebastes* spp.). The redfish selectivity data were analysed using a new model that included direct quantification of the probability that fish will make contact with the grids. The results showed that the proportion of redfish escaping through the two grids did not differ significantly. The release efficiency of the first (lower) grid was, however predicted to be significantly lower than that of the second grid when accounting for the actual fraction of redfish reaching the zones of the individual grids. An estimated 80% of the redfish made contact with at least one of the two grids. However, the release efficiency and overall size selection for redfish of the new double grid system was not significantly better than obtained in former selectivity trials testing the grid systems used in the fishery today. Moreover, this comparison of results showed that the existing Sort-V single grid system releases significantly more redfish than the new double grid system.

1. Introduction

Two species of redfish, i.e. the golden redfish (*Sebastes norvegicus,* until 2015 known as *S. marinus*) and the beaked redfish (*Sebastes mentella*), are commercially important and exploited throughout the North Atlantic, from Canada and the US to Norway and Russia. Both species are slow growing, they reach maturity at late ages (11–12 years) and can grow very old (>60 years) (ICES, 2014b; Planque and Nedreaas, 2015). These biological characteristics make redfish species vulnerable to the exploitation patterns of the traditional fisheries for cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinnus*), as those species inhabit the same fishing grounds and have shorter life cycles. The current situation for different redfish species is variable. Of the two main species harvested in Norway, the beaked redfish (*Sebastes mentella*) is viewed as an exploitable resource (ICES, 2014a), whereas the golden redfish (*Sebastes norvegicus*) is considered to be overfished and ICES has recommended restricted fishery of this species since 2008 and no harvest of it since 2013 (ICES, 2014b,c). Direct trawl fishery for *S. norvegicus* is not permitted and it is therefore caught only as bycatch. Thus, the 480 t of redfish that each commercial trawler currently is allowed to harvest annually consist almost entirely of *S. mentella* (Planque and Nedreaas, 2015). The minimum landing size for both *S. norvegicus* and *S. mentella* in the Barents Sea is 30 cm (Ministry of Trade, Industry and Fisheries, 2014). As both species are also very similar in morphology and shape (Herrmann et al., 2012), the selective properties of the grid tested in this study are expected to be the same for both species.

In the northern gadoid fisheries, rigid sorting grids in combination with a 130 mm (135 mm until 2011) diamond mesh codend have been mandatory since 1997. Fishermen are allowed to use three different grid systems, all with 55 mm bar spacing:

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a three-section system called Sort-X that consists of two steel grids and a canvas section (Larsen and Isaksen, 1993); a double grid section composed of two grids made of plastic (i.e., bars made from fibreglass) and rubber called Flexigrid (http://www.fiskeridir.no/Yrkesfiske/Regelverk-og-reguleringer/J-meldinger/Gjeldende-J-meldinger/J-55-2015); and a single steel grid section called Sort-V (Jørgensen et al., 2006; Herrmann et al., 2013a). Currently the stock of Northeast Arctic cod is in a healthy state with a peak stock biomass in 2013 and still high (Bakketeig et al., 2015). A direct consequence of this situation is that the trawlers fishing in the Barents Sea encounter such high densities of fish that they pose a challenge to the operation and gear (i.e., effective size selectivity and control of catch sizes are compromised). Over the last 5 years, extreme catch rates in excess of 50 t have occurred, mainly during October–December in the North-eastern Barents Sea; these densities represent at least 400 relatively large fish passing through the grid section each minute. Beaked and golden redfish can be a relevant bycatch species in areas with high densities of cod, i.e. in the North East Atlantic. At these high densities, the grids experience capacity problems and often lose their selective properties because they become saturated, blocked, and sometimes broken. It is assumed that this problem is related mainly to reduction of water flow inside the grid section caused by the various combinations of grid, lifting panels, and guiding panels. At high densities, the fish accumulate in front and behind the sorting grid instead of falling back to the codend very late in the haul-back operation.

In an attempt to solve this issue, the Norwegian authorities, research institutes, and fishermen are testing alternative gear and grid designs that increase the sorting capacity of the grids as well as the water flow through the grid sections to facilitate the flow of fish towards the codend. The increase in flow seems necessary to at least partially solve the saturation problems of the grid. However, little is known about how increased water flow affects the selective performance of the grids for various species (i.e., how increased flow affects grid contact rate).

Solutions applied to the trawl gear to solve the diverse challenges existing in today's cod and haddock fisheries will have direct consequences for the selectivity of redfish species in the Barents Sea. Herrmann et al. (2013b) studied the selectivity of the Sort-X and Sort-V grid systems for redfish and it is the only study in the literature that has documented the performance of sorting grids for *Sebastes* spp. Furthermore, the potential selective role of a grid located on the lower panel of a grid system section has never been evaluated for redfish.

The goal of this study was to evaluate the performance of a four panel double steel grid section in terms of release efficiency and overall size selection for redfish. Relative to the standard two-panel Sort-V grid, its cross-sectional area is approximately 45% larger, and a lower grid replaces the lifting panel. The idea of inserting an additional grid was to provide additional sorting area by simultaneously guiding fish to contact the upper grid. We assessed whether this new double steel grid section is advantageous for redfish selection compared to the existing designs. Specifically, our goal was to answer the following questions:

- To what extent do redfish escape through the first grid (lower grid) of the section?
- Does the angle of the first grid play a role on its selectivity and the selectivity of the grid section overall?
- Does this new grid design provide any improvement for redfish selection compared to that have previously been obtained for existing grid designs?

2. Materials and methods

2.1. Vessel, area, time, and gear set-up

Full scale tests were performed on board the research trawler (R/V) "Helmer Hanssen" (63.8 m LOA and 4080 HP) between 27 February and 07 March 2015. The fishing grounds chosen for the tests were located off the coast of Finnmark and Troms counties (Northern Norway) at 71°30′N–27°30′E and 70°30′N–17°20′E.

We used an Alfredo No. 3 two-panel Euronete trawl built entirely of 155 mm nominal mesh size (nms) polyethylene (PE) netting. The trawl had a headline of 36.5 m, a fishing line of 19.2 m, and 454 meshes of circumference. The trawl was rigged with a set of Injector bottom trawl doors (8.0 m^2 and 3100 kg each), 60 m sweeps, and a 111 m ground gear. Each of the sides of the ground gear had five 53 cm steel bobbins on a 46 m × 19 mm chain. Both sides of the ground gear were joined by a conventional 19.2 m long rock-hopper built with 53 cm rubber discs, which were attached to the fishing line of the trawl. The headline was equipped with 170 × 20 cm plastic floats. The trawl system was monitored using various Scanmar sensors. With the given rig details, we achieved a door spread of 125–135 m, a fishing line spread of ~14.5 m, and a headline height of ~5 m at towing speeds of 3.5–4.0 knots at 250–320 m of depth.

We built a four-panel section with two steel grids inserted into it. This grid section was made from 138 mm 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 was 4 × 26 meshes wide. All four selvedges in the grid section were strengthened with 32 mm Danline PE rope. The 80 mm PE lifting panel of the mandatory steel grid section was replaced by a steel grid with 55 mm bar spacing, hereafter called the lower grid ($grid_1$) with outer dimensions: length 825 mm x width 1234 mm. The effect of the inclination angle of the lower grid ($grid_1$) on selectivity was assessed by testing two different inclinations (35° and 40°). We used a Scanmar grid sensor to measure the inclination angle of the upper grid ($grid_2$) and to test whether the covers affected the water flow through the grid section. The aft section of the lower grid ($grid_1$) was made from square mesh 80 mm nms Euroline Premium PE netting (single Ø 3.0 mm twine). The upper grid ($grid_2$) was a standard steel grid (Sort-V type) with 55 mm bar spacing (outer dimensions: length 1650 mm x width 1234 mm). The square mesh guiding panel behind the upper grid was made of 80 mm Euroline Premium PE netting (single Ø 3.0 mm twine). The length of the guiding panel was approximately one-half of that used in mandatory sorting grids, and it was attached with a steeper angle (Fig. 1).

We built a transition diamond mesh section to connect the two-panel trawl belly to the four-panel grid section. It was made from 138 mm nms Euroline Premium PE netting (single Ø 8.0 mm twine) and was 33.5 meshes long (Fig. 2).

We used two small-mesh grid covers (GCs) to separately collect fish escaping through the lower and upper sorting grids. The upper grid was covered with a GC made of 52 mm nms Euroline Premium PE netting (single Ø 2.4 mm twine) that had a total length of approximately 25 m (Larsen and Isaksen, 1993). The entire GC was reinforced with double 155 mm nms Euroline Premium PE netting (single Ø 4.0 mm twine), and 7 × 20 cm plastic floats were added along the mid-seam to ensure its expansion. The lower grid was covered with a GC made of 42 mm nms polyamide netting (Ø 1.0 mm) in the front sections and 52 mm nms PE netting (single Ø 2.2 mm twine) in the aft sections, and it had a total length of approximately 15 m. Total chain weights of ca. 15 kg were added along the mid-seam to ensure its expansion. The GCs were installed following standard procedures described by Larsen and Isaksen (1993) and Wileman et al. (1996) (Fig. 2).