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Bycatch reduction in the Norwegian Deep-water Shrimp (*Pandalus borealis*) fishery with a double grid selection system

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ABSTRACT

Trawlers targeting Deep-water Shrimp (*Pandalus borealis*) in the North Atlantic use a Nordmøre sorting grid ahead of a small-meshed codend. Based on experimental fishing, the effect of adding a 9 mm spaced release grid behind the mandatory 19 mm spaced Nordmøre sorting grid, was determined. The performance in terms of size selection of the release grid and the two grids combined were assessed for target Deep-water Shrimp and for juvenile Redfish (*Sebastes* spp.) and American Plaice (*Hippoglossoides platessoides*), two of the most common bycatch species in the fishery. The aim of using the release grid was to improve the escape of undersized shrimp and the bycatch of juvenile fish from the gear. The results demonstrated that the release grid improved the escape of the smallest Deep-water Shrimp significantly. The fraction of small shrimp released through this grid was estimated to be 45%. However, the results also revealed the need for further improvements in the design of the release grid to increase the reduction of small shrimp and juvenile fish bycatch. For Redfish and American Plaice the fractions of juveniles escaping through the release grid were estimated to be 16% and 32%, respectively. In addition, the release grid only led to the escape of the smallest juvenile individuals, in particular for Redfish.

1. Introduction

Deep-water Shrimp (*Pandalus borealis*) is a commercially important species which has been fished in the North Atlantic since the 1970s. Peak landings of 105.000–128.000 metric tons were recorded from ICES areas I and II of the Northeast Atlantic during the mid-1980s (ICES, 2017). In Norway and many other countries in the area, shrimp fisheries are often associated with a serious bycatch problem (Howell and Langan, 1992; Isaksen et al., 1992; Grimaldo and Larsen, 2005). The bycatch issues are usually related to catching non-target fish species, however in some areas the excessive catch of small and undersized shrimp also represents a serious problem (He and Balzano, 2013; Larsen et al., 2018a). The bycatch problem in shrimp trawl fisheries is linked to the small mesh size used in the trawl (minimum diamond mesh size of 35 mm), which leaves little or no chance of escape for fish or shrimp once they have entered the fishing gear (Grimaldo and Larsen, 2005). The Nordmøre grid was introduced to the Norwegian and Russian shrimp fisheries in the early 1990s, eliminating the problem of bycatch of fish larger than 25–30 cm total length (Isaksen et al., 1992; Fonseca et al., 2005; Grimaldo, 2006). Today, the Nordmøre grid is used in several shrimp fisheries around the world including Iceland, USA, Canada and Australia (Gabriel et al., 2005; Eayrs, 2007). The maximum bar spacing for the Nordmøre grid in Norway is currently 19 mm, which does not allow bigger fish to pass through it. These fish escape by swimming out or simply sliding along the grid, before being released through the escape opening in the upper panel of the grid section. Although most fish are released through the escape opening, small-sized fish and juveniles of various species are still able to pass through the grid and risk being retained in the codend together with the targeted shrimp (Larsen et al., 2017).

More than 25 years after the introduction of the Nordmøre grid in the Norwegian shrimp fishery, there are still serious concerns regarding the bycatch of juvenile fish in all Norwegian shrimp fishery areas (Gullestad et al., 2015). In the Northeast Atlantic, the regulations in this fishery allow the retention of low numbers of juvenile fish from regulated species. Areas are closed if samples from 10 kg of shrimp catch exceed eight Cod (*Gadus morhua*), 20 Haddock *(Melanogrammus aeglefinus*), three Redfish (*Sebastes* spp.) or three Greenland Halibut (*Reinhardtius hippoglossoides*) (Norwegian Directorate of Fisheries, 2018a). Bycatch of Deep-water Shrimp below the minimum landing size (15 mm

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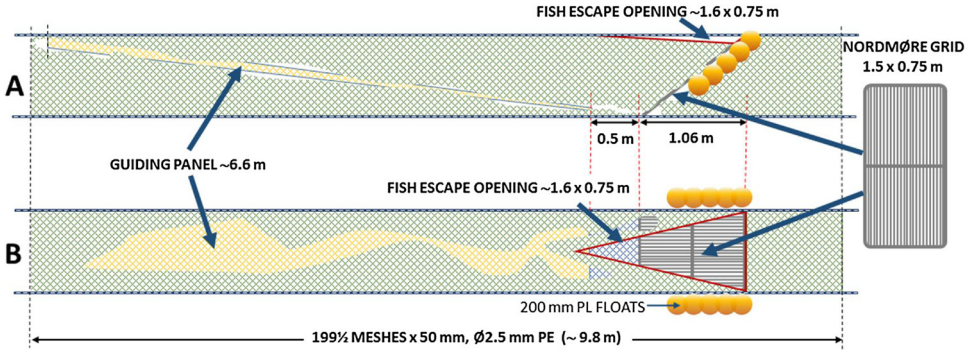

Fig. 1. The four-panel Nordmøre grid section seen from the side (A) and from above (B), with some of the construction details illustrated.

carapace length) cannot exceed 10% by weight. The bycatch rules have frequently led to the temporary closures of several large shrimp fishing grounds in the Northeast Atlantic during the last 30 years (Gullestad et al., 2015; Norwegian Directorate of Fisheries, 2018b). Because these closures can last for weeks, they can have substantial economic impacts for the fishing fleet as they may lose access to the areas with high densities of shrimp, and distances between potential fishing grounds are increased.

In recent years, efforts to reduce juvenile fish bycatch in shrimp trawls in the Northeast Atlantic have increased. This applies to the deep-sea fleet with vessels > 50 m length overall (e.g. Larsen et al., 2017, 2018a,b), as well as inshore fisheries with smaller vessels. There are often small variations in the technical and gear related regulations for these vessel groups, but the selective gear is always comprised of a Nordmøre sorting grid and a size selective codend built from diamond mesh, square mesh, T-90 mesh or other mesh configurations. Both deep-sea and inshore fisheries face the same challenge in terms of fish bycatch and have a common aim of finding solutions to reduce the bycatch of juvenile fish without increasing the loss of marketable shrimp. Bycatch of undersized shrimp and area closures are more common in the inshore and coastal shrimp trawl fisheries (Norwegian Directorate of Fisheries, 2018b), therefore solutions that could reduce the catch of the smallest sizes of shrimp in addition to reducing the bycatch of juvenile fish are sought.

Excluding juvenile fish and shrimp from the gear has many advantages. Apart from the obvious environmental advantages and increased compliance with regulations, removing any kind of unwanted catch reduces the amount of labor onboard. Sorting bycatch from the target shrimp is time consuming and can also have repercussions on the quality of the target species.

To solve the aforementioned challenges, the effects of a 9 mm grid spaced release grid installed behind the 19 mm spaced Nordmøre grid was tested. The aim was to investigate the sorting performance of this release grid and to determine whether it could improve the gear selectivity in comparison with the Nordmøre grid alone. This study investigated the following research questions:

- Does the release grid installed behind the Nordmøre grid improve overall selectivity of juvenile fish and small shrimp compared to the Nordmøre grid alone?
- What is the contribution of each of the grids to the overall selectivity in the combined system using both grids?
- What fraction of small shrimp and juvenile fish bycatch that passes through the Nordmøre grid is then size selected by the release grid?

2. Materials and methods

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

Fishing trials were performed on board the research trawler (R/V) "Helmer Hanssen" (63.8 m length overall and 4080 HP engine) from the 22nd–24th of February 2016. The fishing ground chosen for the experiments was located in the North of the Barents Sea (N 76°06′–E 35°12′ to 76°04′–E 35°40′) at depths of 268–278 m. Fishing trials were carried out using a Campelen 1800# trawl built entirely from 80 mm (wings) to 40 mm (aft belly section) diamond meshes (Ø4 to Ø2 mm polyethylene twines). We used a set of Thyborön T2 otter boards (6.5 m^2 and 2200 kg) with a 20 m long restrictor rope linked between the warps 80 m in front of the doors. The function of the restrictor rope was to keep the distance between the doors at 48–52 m independent on variations in towing speed and depth. A pair of Scanmar distance (door) sensors and a Scanmar height sensor were used to monitor the door spread and height of the trawl. The height of the trawl was between 4.5 m and 4.8 m at a towing speed of 3.0–3.2 knots (1.54–1.65 m^{-s}). The design used 40 m sweeps and a 19.2 m long fishing line with a rockhopper gear comprised by three sections with Ø46 cm rubber discs.

A four-panel standard sorting grid section, consisting of a guiding panel and a Nordmøre grid, was inserted between the trawl belly and the codend, with a fish escape opening in the upper panel just in front of the grid (Fig. 1).

Fishing trials were carried out with a combined selection system comprised of the Nordmøre grid followed by a release grid installed in the lower panel of the section. The codend was blinded with small meshed (6 mm) netting. The 19 mm Nordmøre grid was made of stainless steel. It was 1.5 m high, 0.75 m wide, built with Ø10 mm bars and an outer Ø20 mm steel bar frame. It was mounted so that it would maintain an angle of 45° while fishing. The mean ± SD bar spacing in the Nordmøre grid, measured with a caliper, was 18.8 ± 0.4 mm (based on 40 measurements). The fish escape opening on the top panel just in front of the Nordmøre grid was cut as a 70 bar long and 70 mesh wide triangle, equivalent to 1.6 m long by 0.75 m wide (Fig. 1).

The 9 mm release grid installed behind the Nordmøre grid was 0.6 m wide and 1.2 m long. It was mounted in the section with an operating angle of ca. 20° and covered ~40% of the section's height (Fig. 2). A small-meshed leader panel led the escaping shrimp and fish out from the opening in the lower panel. The bar spacing in the release grid was measured to be 9.0 ± 0.7 mm (based on 40 measurements). The working principle of this release grid is the opposite to that of the Nordmøre grid, as fish and shrimp that pass through the Nordmøre grid and manage to contact and pass through the release grid, escape the gear.

Fish and shrimp escaping from Nordmøre grid and the release grid, were collected using two separate covers (mesh size 18.9 ± 1.2 mm) mounted over each of the grids (Fig. 2). To inflate the covers, seven Ø200 mm plastic floats on cover 1 and ca. 8 kg of chain weights on cover 2 were used. The fish and shrimp that passed through the Nordmøre grid and did not pass though the release grid, ended up in the blinded codend.

All hauls were conducted in the same fishing area, during the same cruise. The catch in the compartments (blinded codend and grid