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Development and observations of a spiny dogfish *Squalus acanthias* reduction device in a raised footrope silver hake *Merluccius bilinearis* trawl

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ABSTRACT

A spiny dogfish *Squalus acanthias* excluder grate (grid) within the extension of a silver hake (whiting) *Merluccius bilinearis* trawl net was designed and tested in Massachusetts Bay, USA between October 2008 and August 2009 using a live-fed underwater video camera. Grates with 50 mm spacing were investigated for effects from color (white or black), angle, and direction (leading to a top or bottom escape vent). Spiny dogfish numbers were greatly reduced for all gear configurations based on video observations and data collected from the codend, while target species were caught in commercial quantities. Four tows (of various gear configurations) resulted in spiny dogfish blockages in front of the grate. The reduction of spiny dogfish led to increases in the quality of marketable catches, likely reductions in non-target species mortality, and decreases in the codend catch handling times.

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1. Introduction

Spiny dogfish *Squalus acanthias* are the most abundant shark species in the western North Atlantic Ocean, including the Gulf of Maine; their abundance has increased markedly in recent years (Sosebee and Rago, 2006). They are considered a nuisance by most fishermen and scientists (La Valley, 2007) and often a hindrance to rebuilding of groundfish stocks and to fishing in general (Bowman et al., 1984; Rago et al., 1998; Hilborn, 2011). Spiny dogfish school by size and sex (Colette and Klein-MacPhee, 2002; Sosebee and Rago, 2006), sometimes in quantities large enough to fill commercial and survey trawl nets to overflowing (pers. obs.; Massachusetts Division of Marine Fisheries, unpublished data). Specifically, spiny dogfish are a primary impediment to exploiting the healthy silver hake (whiting) *Merluccius bilinearis* stock (pers. obs.).

The northern silver hake stock in the Gulf of Maine has generally exceeded its biomass targets in recent years and landings are at a historic low (Col and Traver, 2006). This fishery has traditionally been a source of income for small trawlers in ports from Maine to Massachusetts, USA and has potential to increase in importance as landings of other fish have declined in recent years (New England Fishery Management Council, 2003).

Currently, silver hake are targeted mainly using a small mesh (≤76 mm), mandatory raised footrope trawl. A raised footrope trawl is a trawl with its fishing line (footrope) raised above the groundgear using a number of connecting toggle (drop) chains (He, 2007). For this study, this rigging raises the footrope approximately 0.5 m off-bottom and allows some non-target species to pass under the net (Carr and Caruso, 1993; McKiernan et al., 1998; He and Winger, 2010). However, spiny dogfish, generally unwanted, are still susceptible to this trawl net and are easily retained in the small mesh codend.

Excluding spiny dogfish from trawl nets has multiple benefits, primarily the reduction of dogfish mortality (Harrington et al., 2005). High discards of dogfish could potentially close fisheries if catch allowances are exceeded. Additionally, the abrasive skin and spines of dogfish can damage other catch, reducing quality and market value. Very large catches of spiny dogfish can also clog and damage trawl nets, and may be hazardous to bring on board due to their bulk. Finally, the discarding of spiny dogfish consumes fishing time, which can result in lost income and higher expenses.

Preferably, mixed stocks of silver hake and spiny dogfish are avoided spatially or temporally in the silver hake fishery. As dogfish populations increase, avoidance becomes more difficult. Fortunately, dogfish are generally larger than silver hake, and therefore could potentially be mechanically removed from or herded out of a net using an excluder grate (grid) (Amaru, 1996; Broadhurst, 2000;

Abbreviations: RFT, raised footrope trawl; pers. obs., personal observation; PE, polyethylene; HDPE, high density polyethylene; RFEA, Raised Footrope Exemption Area; nk, not known; Atl., Atlantic; TYP, typical; SMAST, School for Marine Science and Technology.

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Eigaard and Holst, 2004). Excluder grates in trawl nets act somewhat like a sieve; the spacing between the bars of the grate directly influences the size of excluded, unwanted fish and the target fish that can pass through the grate (Fonseca et al., 2005). Finding the optimal bar spacing is the primary challenge in designing an effective grate: if the bar spacing is too narrow, larger target fish will be lost (He and Balzano, 2007); if the bars are too far apart, more larger, unwanted fish will be captured (Kvalsvik et al., 2006) or become wedged between the bars (pers. obs.).

The grate sorting process is not entirely mechanical; some fish avoid direct, physical contact with grates. Specific visual stimuli can enhance fish escape within fishing gear during the capture process (Glass et al., 1995; He, 2010). Different species may have different reactions to visual stimuli, such as color and contrast, which can then be used to encourage unique behavioral responses (Chosid et al., 2008). Therefore, the color of an excluder grate might enhance the escape of certain species without affecting the capture of others. Black and white grates were easily attainable and provided a broad comparison of dissimilar colors and contrasts for this study.

Grates are typically angled into or away from the tow direction to help direct the escape of unwanted fish out of the net, with the net's escape opening (vent) on top or on bottom, at the aft extreme of the grate. Some species of fish are known to vertically separate in the trawl mouth and extension (Main and Sangster, 1981) and prior experience suggests that vent location might alter the ease of escape of some species. Therefore, two grate angles, top and bottom openings, in combination with black and white-colored grates, were investigated during this study.

Four objectives were identified in developing an excluder grate to eliminate spiny dogfish from a raised footrope trawl net: observe the behavior of spiny dogfish and silver hake around excluder grates using underwater video; investigate and refine the effectiveness of excluder grate properties, gauged by target species catches and spiny dogfish exclusions; produce a prototype grate design to be used in follow-up commercial trials; make recommendations for an expanded silver hake fishery in Cape Cod Bay and Massachusetts Bay.

2. Materials and methods

This project was conducted in two phases. Different nets and grates were used in each phase and testing locations also differed between trials. In Phase 1, grate angles were investigated using a white prototype grate with a bottom escape opening in a used raised footrope trawl (RFT). In Phase 2, we refined the grate design and explored the effects from different colored grates (black or white) and escape vent position (top or bottom) in a new RFT.

2.1. Net and grate

2.1.1. Phase 1

Careful examination of this phase's two-panel RFT at the end of the fieldwork revealed multiple irregular modifications to repair prior damage and to adjust for warped meshes that occurred before our acquisition of the net. Headrope and footrope lengths were 27.4 m and 34.1 m respectively. The sweep and drop chains were 7.9 mm galvanized chain; vertical drop chains were 1.1 m long. Sixteen 20.3 cm diameter floats were on the headrope. Single-twine, green polyethylene (PE) diamond-shaped meshes were used unless specified below; nominal sizes are provided. The lower extreme wingends had been replaced with 76.2 cm long, 1.3 cm chains. The lower wings, lower belly, upper wingends, and square were constructed of 152 mm, 3.0 mm diameter mesh. One portion of each upper wing was 152 mm (forward section) white nylon and 76 mm (back section), 2.5 mm diameter mesh. The bellies were constructed of 76 mm, 2.5 mm diameter mesh except for a roughly triangular center portion of the lower belly (152 mm, 3.0 mm diameter mesh), used to fill in after considerable warping. A 51 mm diamond-shaped codend was used with a 152 mm diamond-shaped double mesh strengthening bag. The extension was 200 meshes around with 51 mm mesh.

A white grate with 15, 13 mm wide vertical bars with 50.8 mm bar spacings constructed of high density polyethylene (HDPE) was attached within the net's extension. The overall dimensions of this phase's grate were 1143.0 mm wide × 1257.3 mm high × 25.4 mm thick with one central horizontal cross bar for extra structural support. Four 20.3 cm floats were placed along the top of the grate to keep it upright while towing (Isaksen et al., 1992). The grate was attached to the webbing by plastic fastening strips on each side of the grate, outside the webbing, so that the grate would be at the desired angle (with the lower portion closer to the aft in Phase 1) when the extension was pulled tight. The grate was nearly neutrally buoyant.

A 2.0 m guiding panel (funnel) with 51 mm meshes was attached inside the extension leading fish up to the top of the grate. The mid-point of the trailing end of the guiding panel was set approximately 20.3 cm away from the grate, and approximately 30.5 cm from the nearest mesh of the extension. The escape opening (vent) was located at the bottom of the extension, just forward of the grate and was approximately 38.1 cm long × 114.3 cm wide. A loose flap of webbing was attached forward of the vent acting as a cover to deter silver hake and other target fish from escaping through the vent before passing through the bars. Larger, excluded fish could still be mechanically guided out or escape.

2.1.2. Phase 2

A new whiting net and a grate design were used in Phase 2. The new, typical 4-panel box RFT was constructed with single-twine, diamond-shaped meshes throughout (Fig. 1). Nominal sizes are provided below. The headrope was 28.7 m; the footrope was 29.5 m. A section of the lower bridle, used to adjust the footrope height (flychain), was composed of 3.4 m 9.5 mm diameter stainless steel wire and 0.3 m of 7.9 mm diameter galvanized chain which allowed adjustment by links. Twenty-five 20.3 cm diameter floats were on the headrope spaced approximately 1.2 m apart. The codend was made from 64 mm mesh. The same extension and guiding panel were used as in Phase 1. Nine galvanized drop-chains (7.9 mm diameter, 1.1 m long) from the footrope to the 7.9 mm diameter galvanized chain sweep were set approximately equally spaced.

Two 1219.2 mm square grates were designed and constructed, both with 50.8 mm bar spacings (Fig. 2). The grates were constructed of 25.4 mm thick HDPE, one black and one white. Two horizontal cross bars were used to add additional support to the vertical bars, based on warping observed during Phase 1. Two 20.3 cm diameter floats were initially placed on the sides (near the top) of the grate to keep it upright while towing. The grates were inserted into the net's extension as in Phase 1 testing. The grates angles' were set at 45° from the top and bottom extension walls for all of Phase 2.

Minor modifications to the gear were made during both phases consistent with normal fishing operations and as recommended by the industry partners. These modifications included changes to buoyancy and weights of the grate and net, and setback to bridle chains.

2.2. Field work

Field work for both phases was conducted on-board the F/V *Barbara L. Peters*, a 16.8 m, 214.8 kW Western-rig commercial trawler with two stern ramps, two net reels, and Thyborøn 1.6 m^2 trawl doors. The net was set by the vessel's crew and tow timing began