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Avoidance of Atlantic cod (*Gadus morhua*) with a topless trawl in the New England groundfish fishery

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ABSTRACT

Low quotas of Atlantic cod in the New England groundfish fishery may restrict fishing with trawls for mixed stocks of groundfish. Previous studies using topless trawls (i.e. trawls with a headrope more than 20% longer than the footrope) in this region showed reductions of cod, but also reductions in species of flatfish. In May and June 2011, we tested a topless trawl on a commercial trawler with a much greater headrope to footrope ratio and greater flotation than previous studies in the region. Thirty haul-pairs were successfully conducted and demonstrated a 51% reduction in the catch of cod, with no significant loss of any flatfish species, except for a significant loss of sublegal American plaice. Our results suggest that a topless trawl can be an effective method of cod avoidance for fishermen in the region, without substantial loss of landable flatfish. We infer from the results that: cod rise in response to an approaching trawl footrope and sand cloud; headrope layback may not be a critical value in the effectiveness of topless trawl designs; and, headrope flotation, particularly in the center of the headrope, may be an important factor in retaining flatfish.

1. Introduction

The Atlantic cod (*Gadus morhua*) stock in the Gulf of Maine has been subject to persistent fishing pressure for over 400 years (Murawski et al., 1999). Cod landings reached a peak of approximately 68,000 mt in 1861 (Bolster, 2012), but have since declined significantly despite the introduction of bottom trawling and other technological advances. In 2013, the spawning stock biomass of cod in the Gulf of Maine declined to 4% of the target for maximum sustainable yield (NOAA, 2014), a record low in the fishery, and the commercial quota of cod was reduced to 207 mt (NOAA, 2015). The cod stock on Georges Bank has now suffered a similar fate. Deliberate fishing for cod in the region has now all but ceased, and the quota restrains ('chokes') the ability of fishermen to land relatively abundant species such as yellowtail flounder (*Limanda ferruginea*), American plaice (*Hippoglossoides platessoides*), and witch flounder (*Glyptocephalus cynoglossus*).

Commercial fishermen in the Gulf of Maine and nearby Georges Bank (collectively, "New England") now frequently need to avoid cod to the greatest extent practicable. However, achieving this outcome is a challenge because the imperative to avoid cod has never been strong in the fishery. Many New England fishermen have traditionally used the same trawl design to target a mix of groundfish, including cod, haddock (*Melanogrammus aeglefinus*), yellowtail flounder, and other species (Pol et al., 2003). Many of these species are also caught during the same tow (Rothschild et al., 2014). Consequently, a ready-made trawl design that can avoid cod and land other groundfish does not yet exist in the fishery.

One trawl design that has shown potential to avoid cod is the topless trawl. This revolutionary design, also dubbed the "coverless" (e.g. Eustace et al., 2007; Montgomerie and Briggs, 2012), or "cutaway" trawl (e.g. Catchpole and Revill, 2008), eliminates a significant portion of the upper panel of netting and permits cod an opportunity to rise upwards and escape prior to reaching the codend. Underwater observations of cod have confirmed rising behavior (Pol, personal observation), and several studies have exploited this behavior by fitting large- or square-mesh netting windows to the upper panel of a trawl (e.g. Thomsen, 1993; van Marlen, 1993; Walsh and Hickey, 1993; Pol et al., 2003). However, the circumstances that elicit rising behavior are not well understood, nor is if this behavior is consistent temporally and spatially.

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The topless trawl has been tested previously in the U.S. west coast groundfish fishery to avoid rockfish (*Sebastes* spp.) (King et al., 2004; Hannah et al., 2005), in the Gulf of Maine pink shrimp (*Pandalus borealis*) fishery to avoid herring (*Clupea harengus)* (e.g. He et al., 2007), and in the mid-Atlantic summer flounder (*Paralichthys dentatus*) fishery to avoid sea turtle bycatch (DeAlteris and Parkins, 2012; Gahm et al., 2014).

In the *Nephrops norvegicus* fishery in the northeast Atlantic, the topless design has been considered to avoid cod and other groundfish (Eustace et al., 2007; Catchpole and Revill, 2008). In the North Sea, at Farne Deeps, Revill et al. (2006) reported a reduction of small cod (<35 cm) by 42% with little reduction in large cod (although sample size was low).

Topless trawl designs have also been tested in groundfish-targeting fisheries to avoid cod, although the results have been inconsistent and sometimes inconclusive. Thomsen (1993) used a topless trawl in the coastal waters around the Faroe Islands to reduce cod by 38% with no loss of flatfish. Also at Farne Deeps, Dunlin and Reese (2003) reported reductions in whiting (*Merlangius merlangus*) and haddock using a topless design; reductions in cod were not significant, although fewer numbers of smaller cod were caught. Mieske (2012), using the same topless trawl off the coast of Denmark, reported a 63% reduction in cod and 92% increase in flounder on one boat followed by a 69% reduction in cod and a 23% reduction in flounder on another boat. In the Gulf of Maine, Pol et al. (2003) reduced cod by 87%, and in nearby Georges Bank, Chosid et al. (2008) reduced cod by 56%. Partly in response to Pol et al. (2003), a special gear provision was introduced in 2004 allowing fishermen to use a topless ("flatfish") trawl on Georges Bank, providing the headrope was at least 30% longer than the footrope and footrope length was not greater than 32 m (NOAA, 2004).

Here, we present a comparison of catching performance between a topless trawl and a traditional bottom trawl in the Gulf of Maine, USA. This experiment responded to a request from Captain Carl Bouchard, a local commercial fisherman who considered the topless trawl, if modified based on his ideas, a potential way to avoid cod while retaining catches of yellowtail flounder. This fisherman recognized the limitations of previous topless trawl designs, especially the escape of flounders, but was confident his modifications to the design would overcome these limitations.

2. Methods

We compared the catching performance of the topless trawl against a standard (traditional) bottom trawl over a 10-day period in May and June 2011 in the Gulf of Maine, USA (Fig. 1). Both trawls were newly constructed by Trawlworks Inc. (Narragansett, Rhode Island), and were identical in design and construction except for the longer headline in the topless trawl. Both were a two-seam design constructed from 152.4 mm polyethylene (PE) netting with a twine diameter of 3.5 mm (Fig. 2). The fishing circle of the standard trawl measured 43.59 m, and the lower panel of each trawl was identical. Both trawls were fitted with a cookie footrope (also called a sweep in New England) comprising a 27.0 m steel wire rope threaded through 76.2 mm Ø rubber disks. The headline length of the topless and standard trawls measured 46.27 m and 20.98 m respectively; their respective headline to footrope ratios were 1.71:1 and 0.78:1. Both trawls used identical nominal 165 mm square mesh codends.

A total of 32 plastic floats measuring 203 mm Ø was attached to the headrope of the topless trawl in 8 groups of four floats; 4 groups of floats were located either side of the center of the headrope, 1 group at each wingend, and 1 group at each wing between those at the wingends and those coming from the center of the headrope.

Catch data from each trawl was collected from three pairs of alternating hauls per day (6 hauls total): three 'standard' hauls and three 'topless' hauls in an A-B-A-B-A-B sequence. The trawl from the final haul was then used in the first haul the following day. Individual hauls in a haul-pair were conducted parallel to each other and in the same direction. The F/V Stormy Weather was used in this experiment, a 13.7 m stern trawler equipped with a double net reel so that each trawl could be quickly deployed or stowed clear of the deck when not in use. All hauls were limited to daylight hours, between 5:30 and 15:30; nominal haul duration and speed were 45 min and 1.35 m s^{-1} (2.6 kts) respectively.

For each haul the catch was sampled by species. All regulated groundfish were sorted by species into 'kept' and 'discarded' (undersized) categories before being enumerated or weighed in totes to the nearest kilogram. These fish were then measured (total length) to the nearest centimeter. Non-commercial species were similarly weighed and then discarded overboard. When the catch was excessive, a subsample was collected and the total catch of each species was extrapolated based on the proportion of the subsample to the total catch. All catch rates were standardized to a haul duration of 60 min.

Catch rates of regulated groundfish species and dominant species were compared between trawl types using equal catch plots. A paired two-sample *t*-test was applied to compare the catch weight of cod, American plaice, yellowtail flounder, witch flounder (*Glyptocephalus cynoglossus)*, unclassified skates (Rajidae), and spiny dogfish (*Squalus acanthias)*; a Welch's *t*-test was used where F-tests for unequal variance indicated a significant difference ($p < 0.05$). For all species other than cod, two-sided hypotheses of equal mean catch rates (kg h^{-1}) were tested. Haul-pairs were excluded if a species was absent from both hauls.

Length-based differences were explored using generalized linear mixed models (GLMMs) to fit proportions of catch-at-length in the experimental net with biologically realistic low-order polynomials (Holst and Revill, 2009). Lengths were used as a fixed effect, and haul was a random effect. A binomial link function was used to fit the simplest model, followed by increasing complexity up to a cubic polynomial. Model terms were assessed with Wald tests at a level of $p < 0.05$. Only lengths from fully-sampled hauls were used in this analysis; also, haul-pairs were excluded if a species was absent from both hauls.

3. Results

A total of 60 hauls (30 haul-pairs) were completed using both trawls. Mean recorded towing speed was 1.4 m s^{-1} (min: 1.35; max: 1.45) and fishing depth was 62 m (IQR: 58.5–69.5 m). The median interval between hauls within a haul-pair was 35.5 min, and the median length of towing (warp) wire was 183 m (IQR: 100–229 m). The weather was calm throughout the experiment and wave height was no greater than 1 m.

Approximately 21,300 kg of fish, crabs, and lobsters from 26 taxa were captured over 48.4 h of trawling (Table 1). Six species/species groups (Atlantic cod, yellowtail flounder, American plaice, witch flounder, spiny dogfish, and unclassified skates) comprised 95% of the total catch by weight. Catches from the standard trawl were considered typical of the commercial fishery in composition and volume.

Catch rates of Atlantic cod were significantly reduced using the topless trawl by an average of 192.3 kg h^{-1}, or 51.4% (Welch's $t = 3.02$, df = 29, one-sided $p = 0.003$; Table 2). Catch rates ranged from 0 to 2000 kg h^{-1} and differences in catch rates in haul-pairs were consistently lower in the topless trawl, or nearly equal (Fig. 3). Length of cod (range 35–118 cm) between trawls was not significantly different in GLMM analysis (n = 25 pairs), although there was a decreasing proportion of cod in the topless trawl with size (Fig. 4).