Short communication

No effect from rare-earth metal deterrent on shark bycatch in a commercial pelagic longline trial

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ABSTRACT

The indiscriminate capture of non-target organisms (bycatch) in commercial fisheries undermines the sustainable development of marine resources. In the Northwest Atlantic, blue sharks (Prionace glauca) account for most of the bycatch in the Canadian pelagic longline swordfish fishery. Minimizing the capture of this species is of interest to conservationists as well as the fishing industry because the high incidence of shark bycatch negatively affects fishing operations through bait loss and increased handling time. Electropositive metals (e.g., lanthanide) oxidize in seawater and create electric fields, which can alter the swimming and feeding behaviors of several species of sharks. Although electropositive metals appear to have the potential to reduce shark bycatch in pelagic longline fisheries, there have not been any controlled trials reported from a commercial fishery. A total of 7 sets (6300 hooks) with 3 hook treatments (standard hooks, hooks with electropositive metals (neodymium/praseodymium), and hooks with lead weights) were deployed in 2011 on the Scotian Shelf in the Northwest Atlantic. The results of this study show that electropositive metals did not reduce the catch of blue sharks or other common shark bycatch species, and hence do not present a practical bycatch mitigation measure for the Canadian longline fishery.

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1. Introduction

The incidental capture of sharks in fisheries worldwide has been implicated as one of the leading causes of observed shark population declines and represents an important challenge for their management and conservation (Lewison et al., 2004; Gilman et al., 2007; Dulvy et al., 2008; Camhi et al., 2009). Pelagic longline fisheries are well known for their significant shark bycatch, which accounts for a large percentage of the total catch (Gilman et al., 2007; Mandelman et al., 2008). In the Northwest Atlantic, sharks often constitute >30% of the Canadian pelagic longline fishery catch by weight (Campana et al., 2009). This fishery primarily targets swordfish (Xiphias gladius) and, more recently, albacore (Thunnus alalunga), bigeye (T. obesus), and yellowfin (T. albacares) tunas (Paul and Neilson, 2009). Fishing practices differ for tuna and swordfish-targeted sets (Brazier and Mcmillan, 2008; He et al., 1997), with the latter accounting for most of the shark bycatch (Campana et al., 2006). Blue sharks (Prionace glauca) account for more than 90% of the shark catch, with shortfin mako (Isurus oxyrinchus) and porbeagle sharks (Lamna nasus) contributing the majority of the remaining catch (Campana et al., 2006).

High numbers of shark bycatch can result in gear damage, bait loss, lower target catch, and handling risks to the fishing crew (Gilman et al., 2008). As such, reducing shark interactions is a priority for fishermen, and interest in the topic has further increased with the fishery assessment for Marine Stewardship Council (MSC) certification (Carruthers and Neis, 2011; Carruthers et al., 2009, 2011). Many fishermen aim to avoid shark catch (Carruthers and Neis, 2011), although convincing solutions are not yet available. One possible option involves mitigation measures that take advantage of the electrosensory system in sharks (Swimmer et al., 2008). Sharks employ a variety of sensory mechanisms to detect and localize prey. Their electrosensory organ, the ampullae of Lorenzini, is restricted to the head in sharks and consists of a network of hundreds of receptor cells located below the surface of the skin (Collin and Whitehead, 2004). Electropositive metals (e.g., lanthanide) oxidize in seawater and create electric fields that can be hundreds of times greater than the threshold of sensitivity for some elasmobranchs (Kajjura, 2008). Experiments have indicated that the presence of these metals can alter the swimming and feeding behaviors of several species of sharks (Rigg et al., 2009; Brill et al., 2008).
2. Methods

Fishing operations were conducted aboard the commercial fishing vessel Addie n’Ainslie using longline gear typical for targeting swordfish. A total of 7 sets (70 trials) made up of 6300 hooks were deployed between September 27 and October 3, 2011. The exact fishing locations were selected based on the local knowledge of the Captain (Fig. 1). The fishing gear included 16/0 10-degree offset circle hooks (Mustad 39966) attached to 8-m branchlines clipped to the mainline. The gear was set to fish in the upper 20 m (4.5-m drop lines) with 3 hooks fished between buoys (a ‘basket’). Each section consisted of approximately 20 baskets (3 km in length). Gear was baited with Atlantic mackerel (Scomber scombrus), set in the evening at approximately 5:00 pm local time (9:00 pm UTM). The soak time averaged 7 h and 05 min and ranged from 6 h and 13 min to 8 h and 18 min.

Three different treatments were tested: standard hooks, hooks with electropositive metals, and hooks with lead weights as inert controls for the shape and weight of the deterrent metals. The electropositive metal pieces were an alloy of 76% neodymium and 23% praseodymium (Nd/Pr) from HEFA Rare Earth Canada Co., Ltd (Richmond, BC, Canada). The experimental design was developed in collaboration with fishermen to minimize interference with standard fishing practices. The lead weights and Nd/Pr alloys were mounted with cable ties on small tuna clips (Fig. 2) to facilitate rapid clipping and unclipping on the gangion. The small tuna clips were attached approximately 20 cm above the hook such that the lead weight and Nd/Pr alloys were positioned just above the hooks. The Nd/Pr alloys were provided as half spherical weights that were approximately 55 g with a 5 mm hole for attachment (Fig. 2). Because the Nd/Pr alloys react electrochemically with and dissolve in seawater, the metals were used for 2 sets and then replaced with new ones. Commercial lead weights (57 g tidal flat sinkers) with a comparable weight and shape served as procedural controls and were attached in a similar manner as the Nd/Pr alloys.

Each longline set had a total of 900 hooks and consisted of 10 trials of the following 3 treatments: a standard hook treatment, Nd/Pr alloys, and a control lead weight. Each treatment was applied over blocks of 30 hooks each. Each trial consisted of an
Nd/Pr treatment, followed by a control lead weight treatment, followed by a standard hook treatment such that a trial consisted of 90 hooks. Two to 4 standard baskets were set in addition to the experimental gear and fished during the experiment. The data from these hooks were excluded from analysis. An experienced scientific observer from Javitech Limited (Bedford, Nova Scotia) contracted by the Department of Fisheries and Oceans Canada monitored the experimental protocols and collected information on the number and estimated weight of all species caught for each 30-hook treatment.

The mean catch-per-unit effort (CPUE, number per 1000 hooks) was calculated to assess the relative catchability between treatments (all sets included). To account for possible dependencies between treatment subsections within sets, the count data were further analyzed by fitting generalized linear mixed models (GLMM) with a random-effect for ‘set’ and a log-link function (Poisson regression). Model adequacy was verified using Pearson residuals plotted against fitted values, and F tests were used to test for treatment differences. For blue sharks, all sharks combined, and swordfish, the GLMM predicts the mean catch as the number of individuals per set as a function of the treatment. All statistical analyses were performed using the function glmmPQL in the MASS package in R version 2.14.0 (R Development Core Team, 2008).

3. Results

Overall, 337 individuals from 7 species were captured, with an overall catch rate of 53 fish per 1000 hooks. Blue sharks, swordfish and shortfin mako sharks accounted for 97.3% of the total catch (Table 1). Shark catch rates (all species combined) varied between 33.3 and 43.8 per 1000 hooks, while swordfish catch rates varied between 10 and 22.9 per 1000 hooks (Fig. 3). Blue shark catch varied greatly from 3 to 80 individuals per set with the last three sets accounting for over 80% of the catch.

For blue sharks and all sharks combined, no significant differences in the CPUE were observed between the treatments (Table 2). However, the swordfish catch was significantly reduced on the hooks treated with the control lead and Nd/Pr weights by 56% and 48%, respectively, compared to the standard hooks (Table 2).

4. Discussion

This study suggests that electropositive metals do not have any significant deterrent effect on the most common shark bycatch species in a pelagic longline fishery. Over the last five years, an increasing number of studies have investigated the effects of electropositive metals as a shark deterrent (Kaimmer and Stoner, 2008; Stoner and Kaimmer, 2008; Tallack and Mandelman, 2008; Wang et al., 2008; Brill et al., 2009; O’Connell et al., 2011; Robbins et al., 2011; Hutchinson et al., 2012). Several controlled experiments (e.g., laboratory trials) have shown that these electrochemically active metals can have a significant deterrent effect on some shark species. Yet, few studies were able to verify these findings in commercial fishing operations. To date, fishing trials on longline gear typical of that used in the Pacific halibut fishery in Alaska showed that electropositive metals reduced spiny dogfish (Squalus acanthias) catch by 19% (Kaimmer and Stoner, 2008). This contrasts with a 70% reduction in dogfish catch that was reported in previous laboratory trials (Stoner and Kaimmer, 2008). In the Gulf of Maine, bottom longline and rod-and-reel trials did not find any effect on spiny dogfish catches (Tallack and Mandelman, 2008) whereas a recent study which tested a combination of magnetic and electropositive metals (known as the SMART hook) reported a 28% reduction (O’Connell et al., 2012). Other coastal bottom longline trials on the east coast of Oahu, Hawaii showed a significant reduction in juvenile scalloped hammerhead (Sphyrna lewini) catch, but did not detect any effect on other coastal shark species (Hutchinson et al., 2012). Similar to our findings, results of pelagic longline trials off the coast of Southern California and Ecuador indicated that there were no differences in the catch rates of blue sharks, shortfin mako sharks, and other pelagic species among electropositive and control hooks (Hutchinson et al., 2012).

Several factors can influence the deterrent effects of electropositive metals in the field, such as shark density, competition and hunger level (Stoner and Kaimmer, 2008; Brill et al., 2009; Robbins et al., 2011), presence of conspecifics (Robbins et al., 2011), and differences in feeding ecology (Rigg et al., 2009; Stoner and Kaimmer, 2008). In the present study, blue shark catch varied greatly among sets, with the majority of sharks (over 80%) captured during the last three fishing sets. Hypothetically, high local densities of blue sharks may have increased competition and aggressiveness, thereby limiting the effects of the electropositive metals in this study. In addition, studies on shark sensory physiology and brain structure have shown that pelagic species have significantly fewer electrosensory pores than coastal ones (Kajura et al., 2010). This could explain why electropositive metals are a more effective deterrent in some coastal regions, but are not as effective in the pelagic environment (see detailed discussion in Hutchinson et al., 2012).

A contributing factor in this experiment might have been the visual differences between the hooks with and without metals.
attached. Large pelagic teleosts, such as marlins, swordfish, and tuna, are predators that rely largely on their vision to catch prey. Increased visibility of the fishing gear (e.g., through multifilament lines) can reduce the catch of pelagic fish, including swordfish (Stone and Dixon, 2001). The swordfish catch was lower using both the Nd/Pr and lead control weights, which suggests that the observed effects may have been the result of the physical structure attached to the branchline rather than the electromagnetic properties of the metal. Although pelagic sharks are also visual predators, the visual cues of the metals did not decrease their catch rates. Previous authors (Kaimmer and Stoner, 2008; O’Connell et al., 2012; Hutchinson et al., 2012) agreed that the use of electropositive metals is currently impractical on a fast–past commercial fishing scale because of the cost and repetitive replacement of the deterrents. Following discussions with fishermen, the small tuna clip method was ultimately the only realistic approach for setting metals in a timely manner without altering fishing methods. This technique increases gear visibility, which may have caused the reduced swordfish catch in these trials. This unwanted side effect further impedes the use of these deterrents in a commercial pelagic longline fishery.

We caution that the sample size in this experiment (total n = 21) limits the power of the statistical tests. Yet we note that differences in the catch rates of sharks were minimal between treatments, indicating that any possible effect of electropositive metals would likely remain small, even if sample size was increased and the results were statistically significant. Electropositive metals may still be an option for reducing shark bycatch in coastal environments for particular shark species (e.g., juvenile scallop hammerheads [Hutchinson et al., 2012]), but additional commercial fishery trials are necessary to test these methods. In our view it is important that experiments be conducted under realistic conditions that reflect typical fishing operations for which these deterrents may be used as bycatch mitigation tools.

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