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Reducing elasmobranch bycatch: Laboratory investigation of rare earth metal and magnetic deterrents with spiny dogfish and Pacific halibut

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Abstract

Spiny dogfish (*Squalus acanthius*) comprises a significant unwanted bycatch on demersal longlines set for halibut and cod in shelf waters of the east and west coasts of North America. In this laboratory study, attacks on baits were tested in the presence of two different rare earth materials (neodymium–iron–boride magnets and cerium mischmetal) believed to deter elasmobranch catch. Experiments were made with spiny dogfish and with Pacific halibut (*Hippoglossus stenolepis*) in pairwise tests of the rare earth materials and inert metal controls. Dogfish attacked and consumed baits tested with cerium mischmetal at a lower frequency than controls. Times to attack the baits were significantly higher in the presence of mischmetal, as were numbers of approaches before first attack. The time differential between mischmetal and control treatments and the number of baits consumed converged with increasing food deprivation (1 h, 2 d, and 4 d), but treatment differences were always significant. Cerium mischmetal appeared to be irritating to dogfish and may disrupt their bait detection and orientation abilities. Magnets also appeared to irritate dogfish but provided no protection for baits in feeding trials. Pacific halibut showed no reaction whatsoever to the rare earth magnets or cerium mischmetal. Mischmetal, therefore, may be useful in reducing spiny dogfish bycatch in the halibut fishery. Disadvantages in using mischmetal in commercial operations are expense, hazardous nature, and relatively rapid hydrolysis in seawater.
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1. Introduction

Unwanted bycatch of elasmobranchs is a worldwide problem in both commercial and recreational fisheries (Gilman et al., 2007). Sharks, skates and rays compete with target species for baits and can occupy a large proportion of hooks set on longlines, reducing capture efficiency and increasing costs of operation. Also, it is now recognized that declining populations of elasmobranchs might result in unintentional changes in ecological structure in both coastal and offshore waters (Worm et al., 2006; Myers et al., 2007). Thus, methods need to be developed for the reduction of elasmobranch bycatch.

Spiny dogfish (*Squalus acanthius*) are found in temperate and subarctic shelf waters worldwide (Mecklenburg et al., 2002). This small shark (<120 cm) has some economic and cultural significance (e.g., Aasen, 1965; Ketchen, 1986), but its abundance, toxic spines, and low market value make it a frequent nuisance species in both recreational and commercial fishing. Spiny dogfish often occur in large schools (Bigelow and Schroeder, 1953; Mecklenburg et al., 2002) and cause great damage to fishing gear (Ketchen, 1986). The species represents a significant bycatch problem in longline fisheries for cod, haddock and halibut on the east and west coasts of the North America, and can make up more than 90% of the catch in surveys for Pacific halibut conducted by the International Pacific Halibut Commission at some locations off Alaska and British Columbia, where dogfish populations appear to be increasing (IPHC, unpubl. data). During 2006, spiny dogfish was the single most common species caught off British Columbia and the northwest United States, occupying 15 and 5% of the hooks fished in those areas, respectively (Soderlund et al., 2007). The area off Kodiak Island in Alaska also had high dogfish catches (16% of hooks), barely exceeding halibut catch. Over 20 years ago, the IPHC recognized the negative effects of dogfish on longline catchability of halibut; the difference between areas with low and high dogfish abundances was more than fourfold (Kaimmer et al., 1988). Longline

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baits were common in the stomach contents of dogfish caught in trawl samples taken nearby, suggesting that competition by dogfish includes stealing baits as well as occupying hooks.

In 2006, the World Wildlife Fund grand prize for “Smart Gear” was awarded for the discovery that rare earth magnets can be used to repulse certain sharks (WWF, 2006). Although most of the evidence is circumstantial, it is widely accepted that elasmobranches can detect the earth’s geomagnetic field (Klimley, 1993; Klimley et al., 2002; Meyer et al., 2005), and that they respond to electrical and electromagnetic fields using the ampullae of Lorenzini (Murray, 1960; Kalmijn, 1971, 1982; Tricas, 2001). However, recent evidence suggests that stationary permanent magnetic fields generated by strong rare-earth magnets will alter elasmobranch swimming behavior as they enter the magnetic field, and this is the first fishing-related application aimed at reducing shark bycatch. Further communication with the recipients of the prize, Shark Defense LLC, indicated that rare earth metals also produce a shark repulsing effect. For example, alloys in the lanthanoid series are electropositive, giving up electrons in seawater to the more electronegative skin of a shark. While the mechanisms of deterrence are not understood, the potential for reducing dogfish bycatch is promising. However, to date, there has been no peer-reviewed experimentation to assess the efficacy of rare earth materials in deterring sharks.

This study was conducted to test the hypothesis that rare earth magnets and metals placed in close proximity to baits would reduce attacks on and consumption of baits by spiny dogfish. Trials were also conducted with Pacific halibut (*Hippoglossus stenolepis*), an important target of longline fishing. This laboratory-based experimentation was conducted as a test of feasibility, before making a commitment to a more expensive fishing trial.

2. Methods

2.1. Subject species and experimental systems

Spiny dogfish and Pacific halibut were tested for responsiveness to rare earth magnets and cerium mischmetal. Dogfish for this study were acquired on loan from the Oregon Coast Aquarium (Newport, OR). The other subjects for this study were 3-year-old Pacific halibut collected from nursery grounds in Kodiak, Alaska. All of the fish were adapted to frozen foods (fish and squid) and in excellent condition.

Each species was held and tested in two separate indoor pools (4.6 m diameter and 1 m deep) for each species. Each pool was supplied with flow-through, sand-filtered seawater at a rate of 500 ml/s. Temperatures were maintained at 8.2 °C (range: 7.9–8.6 °C) for halibut, and 9.8 °C (range: 9.2–10.2 °C) for spiny dogfish. The pools were subject to a 12:12 h light and dark photoperiod. Dogfish were tested in two groups of six fish matched as closely as possible for size. One pool contained two males and four females ranging 41–53 cm total length (mean = 47, S.D. = 5). The second pool contained four males and two females ranging 56–73 cm (mean = 61, S.D. = 7). Pacific halibut were tested in two groups of eight fish with similar size distributions (mean = 46 cm, range = 39–52 cm total length).

2.2. Baits, deterrents, and controls

Two types of potential deterrent were tested with both spiny dogfish and Pacific halibut. The first was a permanent rare earth magnet (neodymium–iron–boride). The magnetic field associated with this type of magnet corresponds with the detection range of the ampullae of Lorenzini that function to detect weak magnetic and electrical fields at short range in elasmobranchs. The magnets, supplied by Shark Defense LLC, were cylindrical (25 mm diameter, 25 mm high), with a hole through the central axis. The second deterrent was a rare earth metal alloy comprised of cerium (64.02%), lanthanum (34.22%), neodymium (0.55%), praseodymium (0.11%), and minor amounts of other non-rare earth impurities. This alloy is referred to in metallurgy as a cerium mischmetal (mixed metal). The alloy was tested in flat plates (35 mm × 60 mm × 3 mm) with a 3 mm hole drilled in each end for attachment to a line.

Magnets and mischmetal were tested independently for avoidance by both dogfish and halibut in pairwise presentations with controls. Two stainless steel nuts stacked together provided a size, weight and color close to the magnet’s dimensions, and aluminum plate cut to dimension provided a reasonable control for the rare earth metal. Stainless steel and aluminum were assumed to be inert with respect to the behaviors of the test fish. Each of the deterrent materials and the controls were suspended (from the pool lip) on black twine (∼2 mm diameter). A short section of twine, with a small loop on the end, extended 6 cm below each test material for bait attachment. Pieces of squid mantle (*Loligo opalescens*) (∼8–10 g wet weight) were pierced with a small cable tie (3 mm wide) and attached to the loop. The attachment was secure but halibut and dogfish were able to remove the bait with moderate effort. As in earlier bait-related laboratory investigations (Stoner and Ottmar, 2004; Stoner and Sturm, 2004), hooks were not used because this would influence willingness to attack baits in repetitive trials.

2.3. Experimental protocol

Baits were presented in association with deterrents (magnets or mischmetal) and controls in pairwise tests. Lines holding the baits and test materials were attached securely to the pool lip with a 60 cm distance between, and they were long enough to place the bait at least 10–20 cm from the pool wall. The line maintained position of the baits within camera view following multiple attacks and pulls by fish. The two test baits (deterrent and control) were presented simultaneously and fish behavior around the baits was recorded with a digital camcorder mounted on a tripod. Video recording continued until both baits were removed or until 20 min elapsed. The field of view was oblique, spanning a radius of ∼1.5 m around the baits. The positions of deterrent- and control-equipped baits were alternated in repeated trials made over the course of the experiments.

Baits were presented to dogfish and halibut after feeding to satiation followed by 48 h periods of food deprivation. This ensured that the fish were sufficiently hungry to feed aggressively. Since no apparent effect of deterrents occurred with halibut, runs were made 1 h after feeding to increase potential