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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.

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 contribute >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 (Brazner 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 electroreceptors or ampullary organs can detect low frequency bioelectric fields (5–10 nV/cm) produced by prey at short range (Murray, 1960; Kalmijn, 1971; Tricas, 2001). The ampullae of Lorenzini are restricted to the head in sharks and consist 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 (Kajiura, 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.,

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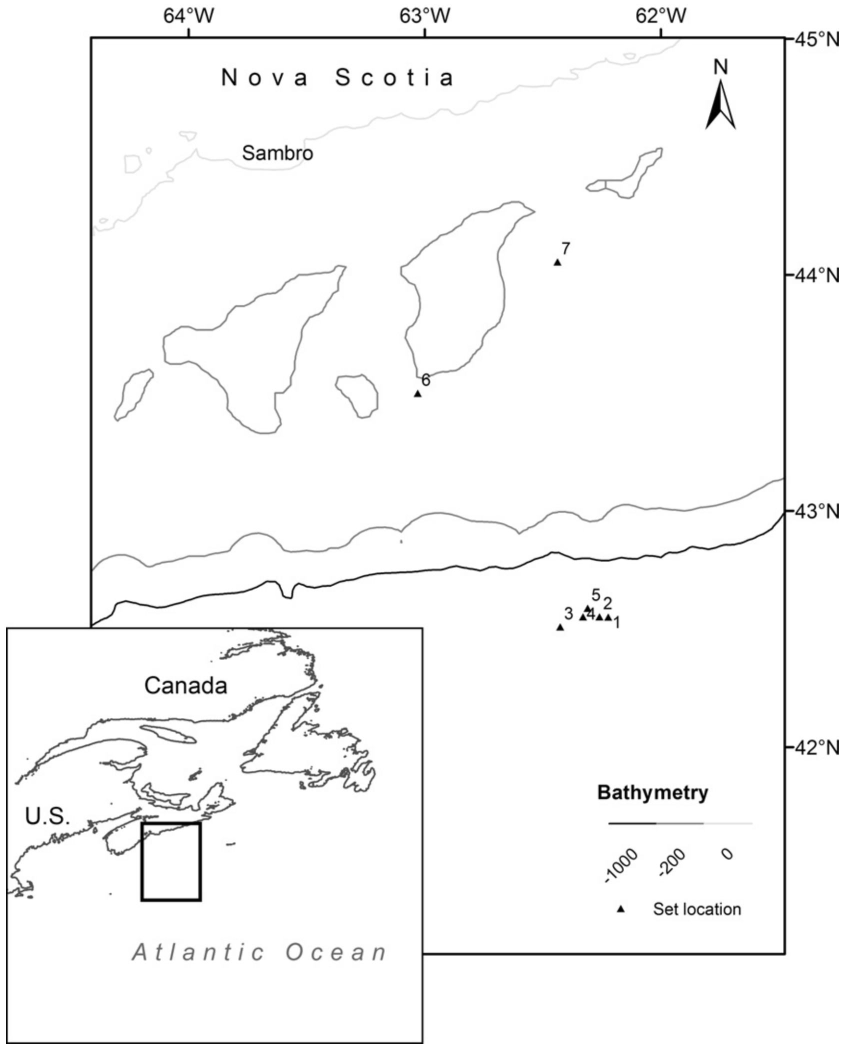

Fig. 1. Map showing locations of experimental fishing on Scotian Shelf off Nova Scotia Canada.

2009; O'Connell et al., 2010; Stoner and Kaimmer, 2008; Wang et al., 2008). The mechanism of deterrence is not fully understood, but it is believed that these metals perturb the electrosensory system in sharks and cause the animals to exhibit avoidance behaviors (Rice, 2008). Because tunas and swordfish do not have electroreceptors, this method has the potential to reduce shark bycatch rates without affecting target catch rates. However, data from controlled trials under commercial pelagic longline fishing conditions are not yet available. In collaboration with the World Wildlife Fund (WWF)-Canada and the Canadian swordfish industry, we tested the null hypothesis that electropositive metals do not reduce shark bycatch or target (swordfish) catch in a commercial pelagic longline fishery.

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

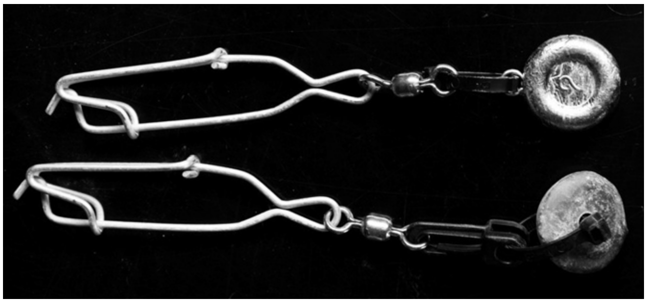

Fig. 2. Nd/Pr alloy and lead attached to a small tuna clip using a cable tie (total length, approximately 17.5 cm). The diameters of the Nd/Pr and lead weights were approximately 3 cm.

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., 2010,

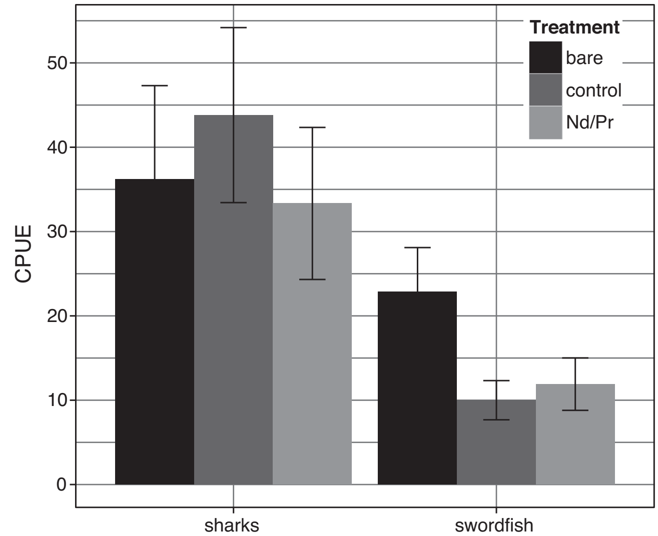

Fig. 3. Mean catch-per-unit effort (CPUE; individuals per 1000 hooks) in the experimental longline trial (7 sets) for swordfish and all shark species combined. Error bars represent the 95% confidence intervals.

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 (Kajiura 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

Table 1
Species caught in the experiment. Catch composition, mean catch-per-unit effort (CPUE, number per 1000 hooks), total catch (*N*), and percent composition for all species captured (total of 6300 hooks) with 3 different treatments (2100 hooks per treatment).

Species	Treatment			*N* *n*(CPUE)	Percent composition
	Standard *n*(CPUE)	Lead *n*(CPUE)	Nd/Pr *n*(CPUE)		
Swordfish *Xiphias gladius*	48(22.86)	21(10.00)	25(11.90)	94(14.92)	27.9
Blue shark *Prionace glauca*	69(32.86)	84(40.00)	65(30.95)	218(34.60)	64.7
Shortfin mako *Isurus oxyrinchus*	6(2.86)	8(3.81)	2(0.95)	16(2.54)	4.7
Porbeagle *Lamna nasus*	1(0.48)	0	3(1.43)	4(0.63)	1.2
Bluefin tuna *Thunnus thynnus*	1(0.48)	1(0.48)	0	2(0.32)	0.6
Albacore *Thunnus alalunga*	0	0	1(0.48)	1(0.16)	0.3
Anglerfish *Lophiiformes* spp.	0	0	1(0.48)	1(0.16)	0.3
Unidentified	1(0.48)	0	0	1(0.16)	0.3
Total	126	114	97	337	100

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 tests 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.

Table 2
Estimated parameter values, standard error, degrees of freedom, t-values, and p-values from the generalized linear mixed models.

	Value	Std. error	DF	*t*-Value	*p*-Value
Blue sharks					
(Intercept)	1.787	0.487	12	3.668	0.003
Lead	0.197	0.183	12	1.077	0.303
Nd/Pr	−0.059	0.194	12	−0.307	0.764
All sharks combined					
(Intercept)	2.076	0.385	12	5.392	0.0002
Lead	0.191	0.183	12	1.043	0.318
Nd/Pr	−0.082	0.196	12	−0.420	0.682
Swordfish					
(Intercept)	1.755	0.309	12	5.688	0.0001
Lead	−0.827	0.246	12	−3.367	0.0056
Nd/Pr	−0.652	0.231	12	−2.818	0.0155

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References

Brazner, J., Mcmillan, J., 2008. Loggerhead turtle (*Caretta caretta*) bycatch in Canadian pelagic longline fisheries: relative importance in the western North Atlantic and opportunities for mitigation. Fish. Res. 91, 310–324.

Brill, R., Bushnell, P., Smith, L., Speaks, C., Sundaram, R., Stroud, E., Wang, J., 2009. The repulsive and feeding-deterrent effects of electropositive metals on juvenile sandbar sharks (*Carcharhinus plumbeus*). Fish. B-NOAA 107, 298–307.

Camhi, M.D., Valenti, S.V., Fordham, V.F., Fowler, S.L., Gibson, C., 2009. The Conservation Status of Pelagic Sharks and Rays: Report of the IUCN Shark Specialist Group Pelagic Shark Red List Workshop. Biological Conservation, vol. 4 , Newbury, UK, April 2009.

Campana, S.E., Joyce, W., Manning, M.J., 2009. Bycatch and discard mortality in commercially caught blue sharks *Prionace glauca* assessed using archival satellite pop-up tags. Mar. Ecol. -Prog. 387, 241–253.

Campana, S.E., Marks, L., Joyce, W., Kohler, N.E., 2006. Effects of recreational and commercial fishing on blue sharks (*Prionace glauca*) in Atlantic Canada, with inferences on the North Atlantic population. Can. J. Fish. Aquat. Sci. 63, 670–682.

Carruthers, E.H., Schneider, D.C., Neilson, J.D., 2009. Estimating the odds of survival and identifying mitigation opportunities for common bycatch in pelagic longline fisheries. Biol. Conserv. 142, 2620–2630.

Carruthers, E.H., Neilson, J.D., Smith, S.C., 2011. Overlooked bycatch mitigation opportunities in pelagic longline fisheries: soak time and temperature effects on swordfish (*Xiphias gladius*) and blue shark (*Prionace glauca*) catch. Fish. Res. 108, 112–120.

Carruthers, E.H., Neis, B., 2011. Bycatch mitigation in context: using qualitative interview data to improve assessment and mitigation in a data-rich fishery. Biol. Conserv. 144, 2289–2299.

Collin, S.P., Whitehead, D., 2004. The functional roles of passive electroreception in non-electric fishes. Anim. Biol. 54, 1–25.

Dulvy, N.K., Baum, J.K., Clarke, S., Compagno, L., Cortes, E., Domingo, A., Fordham, S., et al., 2008. You can swim but you can't hide: the global status and conservation of oceanic pelagic sharks and rays. Aquat. Conserv.: Mar. Freshw. Ecosyst. 482, 459–482.

Gilman, E., Clarke, S., Brothers, N., Alfaro-Shigueto, J., Mandelman, J., Mangel, J., Petersen, S., Piovano, S., Thomson, N., Dalzell, P., 2008. Shark interactions in pelagic longline fisheries. Mar. Pol. 32, 1–18.

Gilman, E.L, Clarke, S., Brothers, N., Alfaro-Shigueto, J., Mandelman, J., Mangel, J., Petersen, S., et al., 2007. Shark Depredation and Unwanted Bycatch in Pelagic Longline Fisheries: Industry Practices and Attitudes, and Shark Avoidance Strategies. Honolulu, USA.

He, X., Bigelow, K.A., Boggs, C.H., 1997. Cluster analysis of longline sets and fishing strategies within the Hawaii-based fishery. Fish. Res. 31, 147–158.

Hutchinson, M., Wang, J.H., Swimmer, S., Holland, K., Kohin, S., Dewar, H., Wraith, J., Vetter, R., Heberer, C., Martinez, J., 2012. The effects of a lanthanide metal alloy on shark catch rates. Fish. Res. 131–133, 45–51.

Kaimmer, S., Stoner, A., 2008. Field investigation of rare-earth metal as a deterrent to spiny dogfish in the Pacific halibut fishery. Fish. Res. 94, 43–47.

Kajiura, S.M. 2008. Sensory systems in elasmobranchs and electric field measurements of E+ metals. In: Swimmer, Y., Wang, J.H., McNaughton, L. (Eds.), Shark Deterrent and Incidental Capture Workshop, 10–11 April 2008. US Department of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-16, pp. 36–40 (72 pp.).

Kajiura, S.M., Cornett, A.D., Yopak, K.E., 2010. Sensory adaptations to the environment: electroreceptors as a case study. In: Carrier, J.C., Musick, J.A., Heithau, M.R. (Eds.), Sharks and their Relatives. II. Biodiversity, Adaptive Physiology, and Conservation. Taylor & Francis Group, LLC, pp. 393–429.

Kalmijn, A.J., 1971. The electric sense of sharks and rays. J. Exp. Biol. 55, 371–383.

Lewison, R.L., Crowder, L.B., Read, A.J., Freeman, S.A., 2004. Understanding impacts of fisheries bycatch on marine megafauna. Trends Ecol. Evol. 19, 598–604.

Mandelman, J.W., Cooper, P.W., Werner, T., Lagueux, K.M., 2008. Shark bycatch and depredation in the US Atlantic pelagic longline fishery. Rev. Fish. Biol. Fisher. 18, 427–442.

Murray, R.W., 1960. Electrical sensitivity of the ampullae of Lorenzini. Nature 187, 957.

O'Connell, C.P., et al., 2012. Effects of the SMARTT (Selective Magnetic and Repellent-Treated) hook on spiny dogfish catch in a longline experiment in the Gulf of Maine. Ocean. Coast. Manage., http://dx.doi.org/10.1016/j.ocecoaman.2012.08.002.

O'Connell, C.P., Abel, D.C., Gruber, S.H., Stroud, E.M., Rice, P.H., 2011. Response of juvenile lemon sharks, *Negaprion brevirostris*, to a magnetic barrier simulating a beach net. Ocean. Coast. Manage. 54, 225–230.

O'Connell, C., Abel, D., Rice, P., Stroud, E., Simuro, N., 2010. Responses of the southern stingray (*Dasyatis americana*) and the nurse shark (*Ginglymostoma cirratum*) to permanent magnets. Mar. Freshw. Behav. Phys. 43, 63–73.

Paul, S.D., Neilson, J.D., 2009. An exploration of targeting variables in the Canadian swordfish longline CPUE. Coll. Vol. Sci. Pap. 65, 124–134.

R Development Core Team, 2008. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, www.R-project.org

Rice, P., 2008. A shocking discovery: how electropositive metals (EPMs) work and their effects on elasmobranchs. In: Swimmer, Y., Wang, J.H., McNaughton, L. (Eds.), Shark Deterrent and Incidental Capture Workshop, 10–11 April 2008. US Department of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-16, pp. 21–25 (72 pp.).

Rigg, D., Peverell, B., Hearndon, M., Seymour, J., 2009. Do elasmobranch reactions to magnetic fields in water show promise for bycatch mitigation? Mar. Freshw. Res. 60, 942–948.

Robbins, W.D., Peddemors, V.M., Kennelly, S.J., 2011. Assessment of permanent magnets and electropositive metals to reduce the line-based capture of Galapagos sharks, *Carcharhinus galapagensis*. Fish. Res. 109, 100–106.

Stone, H.H., Dixon, L.K., 2001. A comparison of catches of swordfish. *Xiphias gladius*, and other pelagic species from Canadian longline gear configured with alternating monofilament and multifilament nylon gangions. Oceans 216, 210–216.

Stoner, A.W., Kaimmer, S.M., 2008. Reducing elasmobranch bycatch: laboratory investigation of rare earth metal and magnetic deterrents with spiny dogfish and Pacific halibut. Fish. Res. 92, 162–168.

Swimmer, Y., Wang, J.H., Mcnaughton, L., 2008. Shark Deterrent and Incidental Capture Workshop, April 10–11, 2008.

Tallack, S.M.L., Mandelman, J.W., 2008. Do rare-earth metals deter spiny dogfish? A feasibility study on the use of electropositive 'mischmetal' to reduce the bycatch of *Squalus acanthias* by hook gear in the Gulf of Maine. ICES J. Mar. Sci. 66, 315–322.

Tricas, T.C., 2001. The neuroscience of the elasmobranch electrosensory world: why peripheral morphology shapes behavior. Environ. Biol. Fish. 60, 77–92.

Wang, J.H., McNaughton, L., Swimmer, Y., 2008. Galapagos and sandbar shark aversion to electropositive metal (Pr–Nd alloy). In: Swimmer, Y., Wang, J.H., McNaughton, L. (Eds.), Shark Deterrent and Incidental Capture Workshop, 10–11 April 2008. US Department of Commerce, NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-16, pp. 31–35 (72 pp.).