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Assessment of permanent magnets and electropositive metals to reduce the line-based capture of Galapagos sharks, *Carcharhinus galapagensis*

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ABSTRACT

Sharks possess anterior electrosensory pores (ampullae of Lorenzini), which allow them to detect very weak electromagnetic fields. Powerful magnetic fields may overwhelm this sense, and repel sharks, even in the presence of an attractant. Using underwater video, we tested seven rare earth magnet configurations, two ferrite magnet configurations and two rare earth electropositive metals as means to reduce the rate at which Galapagos sharks (*Carcharhinus galapagensis*) depredated baited lines. Configurations of three 50 mm diameter rare earth magnet discs showed the most potential, with a vertical configuration of magnets alongside the bait reducing depredation by 50%, and a stacked configuration of the same magnets above the bait also producing significantly more aborted investigations of the bait prior to depredation. No other magnetic or electropositive metal configuration produced significant reductions in depredation rates, time taken to strike, or number of prior investigations. Our study showed that the overriding factor determining Galapagos shark behaviours towards baits was conspecific density. The number of sharks present increased as trials progressed, with a corresponding decrease in their time to depredate baits. This effect was particularly apparent when three or more animals were present. These higher shark densities diminished the effectiveness of our experiments as individuals engaged in non-selective “mob” rushes towards the closest bait. Although our results showed that social interactions between sharks outweighed individual responses to depredation-mitigation devices, magnetic deterrents have high potential for reducing shark bycatch for species that occur in lower densities, or which interact less vigorously with conspecifics than Galapagos sharks.

1. Introduction

Incidental bycatch of sharks is an ongoing concern in recreational and commercial fisheries around the world. Even when not targeted, sharks often comprise a high proportion of landings in line-based fisheries (Francis et al., 2001; Megalofonou et al., 2005). Reducing the unintentional bycatch of sharks is desirable from both an economic and ecological perspective, such as when sharks are commercially less valuable than target species, or where their levels of exploitation are unsustainable.

Numerous methods exist to reduce line-based shark capture. The use of monofilament leaders rather than wire trace may allow captured sharks to bite through the line and break free (Ward et al., 2008). Different hook types can also affect shark retention rates; although J-hooks deep hook more often than circle hooks, they can provide the opportunity for sharks to bite through the monofilament line as it passes out their mouth (Ward et al., 2008; Watson et al., 2005). Modifying fishing practices, such as setting lines at depths or in areas of lower shark abundance, or changing fishing location once sharks start being hooked, can also reduce the number of sharks landed.

Unfortunately, even when successful, the above methodologies still result in sharks being hooked and damaged. The extent and results of this damage are difficult to quantify, due to the wide variety of gear configurations involved, but can include reduced prey-capture capacity, infection, necrosis and ultimately death (Borucinska et al., 2002). A more desirable solution is one in which sharks actively avoid taking baits. Substituting baits for types which are less attractive to sharks may reduce shark capture, although this may also affect capture rates of target species (Watson et al., 2005). A preferred method would be one which deters sharks from baits without influencing the attraction of baits to the target species.

A limited number of studies have investigated the applicability of deterrents to reduce incidental shark bycatch. Recent studies have focussed on the ability of sharks to detect weak electromagnetic fields using their ampullae of Lorenzini. Found only in the anterior of elasmobranch heads, this unique sense allows sharks to detect the faint bioelectric fields around prey (Haine et al., 2001), and to navigate using the electric potentials induced as they pass through the earth’s geomagnetic field (Kalmijn, 1988; Klimley,

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1993). By applying much stronger localised electric or magnetic fields, studies have attempted to overwhelm this sense to deter sharks from taking baits (Kaimmer and Stoner, 2008; Tallack and Mandelman, 2009), or to keep sharks away from objects or areas (Rigg et al., 2009).

Two materials which generate detectable electromagnetic fields in seawater are electropositive metals and permanent magnets. Electropositive metals (known as "rare earth" metals or "mischmetals") are made from highly reactive lanthanide elements such as neodymium, cerium or praseodymium. They spontaneously hydrolyse when immersed in seawater, producing positively charged cations. A galvanic cell reaction is generated by the more negatively charged bodies of animals when they pass close by, resulting in electric potentials of a magnitude detectable by sharks (Rice, 2008).

Laboratory trials have shown that proximally placed electropositive metals can significantly reduce bait depredation by spiny dogfish (*Squalus acanthias*) (Stoner and Kaimmer, 2008). These findings have been supported by subsequent trials with longline gear in the Alaskan halibut fishery, with a significant reduction in dogfish catch found on hooks equipped with an electropositive metal (Kaimmer and Stoner, 2008). Studies on open ocean requiem sharks have similarly reported the reduction of bait depredation by Galapagos sharks (*Carcharhinus galapagensis*) and sandbar sharks (*Carcharhinus plumbeus*) in the presence of electropositive metals (Brill et al., 2009; Wang et al., 2008). However a more recent study determining the efficacy of electropositive metals to reduce spiny dogfish catches in longline and rod-and-reel fisheries in the Gulf of Maine found no such decrease in catches in either fishery (Tallack and Mandelman, 2009). Additional laboratory trials also failed to find significant reductions in bait depredation following food deprivation (Tallack and Mandelman, 2009). The inconsistencies in results when using electropositive metals supports calls for further investigation into their efficacy (Brill et al., 2009; Kaimmer and Stoner, 2008), and highlight the difficulties in trying to develop a panacea for reducing depredation of baits by sharks.

Permanent magnets project detectable magnetic fields underwater without dissolution of their base metal. Strong ferrite magnets have recently been shown to produce sufficient magnetic fields to elicit avoidance responses in individual sharks (Rigg et al., 2009). However, their practical application in items such as commercial fishing nets is limited by the number and weight of magnets required (Rigg et al., 2009). A more powerful alternative to ferrite magnets is the neodymium-iron-born ("rare earth") magnet. This is the strongest permanent magnet currently available, with surface field strengths much higher than the avoidance response thresholds identified for sharks (Rigg et al., 2009). Although laboratory experiments are yet to demonstrate the effectiveness of rare earth magnets in decreasing bait depredation (Stoner and Kaimmer, 2008), their greater strength gives them greater potential as line-based shark repellents as smaller magnets can be used.

There are presently very few peer-reviewed studies investigating the application of electropositive metal (Kaimmer and Stoner, 2008; Stoner and Kaimmer, 2008; Tallack and Mandelman, 2009), rare earth (Stoner and Kaimmer, 2008) and ferrite (Rigg et al., 2009) magnetic shark deterrents. Moreover, no study has tested the responses of sharks to all three compounds using the same experimental procedure. This study investigated the usefulness of rare earth magnets, electropositive metals and ferrite magnets as means to reduce the incidental bycatch of sharks in recreational line fishing. Only experimental configurations that were considered feasible to deploy during typical recreational fishing were tested. Trials were conducted on wild Galapagos sharks (fam. Carcharhinidae), which are a large, oceanic species known to interact with baited lines.

2. Methods

Fieldwork was conducted across a number of locations around Lord Howe Island (31.545°S, 159.085°E), approximately 330 nm east of the Australian mainland. This area was chosen because high densities of Galapagos sharks occur in this region (Hobbs et al., 2008), where they commonly interact with local anglers targeting yellowtail kingfish (*Seriola lalandi*). Trials took place over 12 days during March and April 2009.

Sampling was undertaken during daylight hours on the reef slope. Shark interactions with baits were filmed with a *Seaviewer*™ underwater trolling video camera. The camera provided live video feedback to a monitor and digital recorder on the boat, allowing both real-time observations, and recording for later review and analysis. To ensure the electronic field generated around the underwater camera did not influence shark behaviours, we first investigated the activities of the Galapagos sharks in response to the camera's power status. The camera was suspended at 3 m, with a burley canister consisting of a 30 cm perforated PVC pipe filled with a mixture of Australian sardines (*Sardinops sagax*) and tuna oil suspended a further 3 m underneath. The camera was powered on and off remotely from the boat in a series of 5 min replicates. The number of sharks present, and their interactions with the burley canister were recorded by an observer on snorkel, who remained approximately 15 m from the camera on the surface throughout the trial.

Bait deterrents constructed as eight separate magnetic and electropositive metal configurations were tested separately by simultaneously dropping two monofilament lines, each of 50-lb wt breaking-strain with 120 lb wt plastic-coated wire leaders 1.5 m apart over the side of a small vessel. Each of the two lines – test line and control line – had a single whole Australian sardine as bait and was attached to an overhead fishing reel to prevent the line breaking if pulled by a shark. The test line had a magnet or an electropositive metal associated with the bait, whereas the control line had lead weights in a similar configuration (Fig. 1). Additional lead sinkers were added to both lines to ensure a rapid descent to the test depth (5.5 m) when necessary. Hooks were attached to both baits, with their tips removed to avoid catching sharks. The burley canister was used when necessary to attract sharks to the area. The trolling camera was suspended vertically 0.4 m from the surface midway between the fishing lines, and recorded all 30 replicates for each magnet or electropositive metal configuration tested. Four rare earth (neodymium–iron–boron) magnet configurations, two ferrite magnet configurations and two electropositive metal configurations (neodymium and neodymium–praseodymium alloy) were tested in this fashion. The field strength of each magnet configuration was measured using a handheld gauss meter in the laboratory. Because the electric potential generated around the electropositive metals was a direct result of interactions with the more negatively charged body of a shark, we could not determine the electric potential in the laboratory.

The bait taken (test or control), time to strike the bait, the number of prior encounters (bumps and bites) that successful sharks had with the depredated baits, and the maximum number of sharks onscreen before the bait was taken were determined for each replicate during later review of the footage. The time to strike the bait was calculated from the time the baits first appeared on video, a delay of approximately 2 s from when they were deployed. A successful bait strike was recorded when a shark engulfed a bait in its mouth.

To examine whether our magnets were too powerful (and so potentially overwhelming the sharks' electromagnetic senses), we conducted three additional trials of much smaller, weaker cylindrical rare earth magnets. Each trial used a single fishing line only (i.e. no paired control bait), with the magnets mounted above the

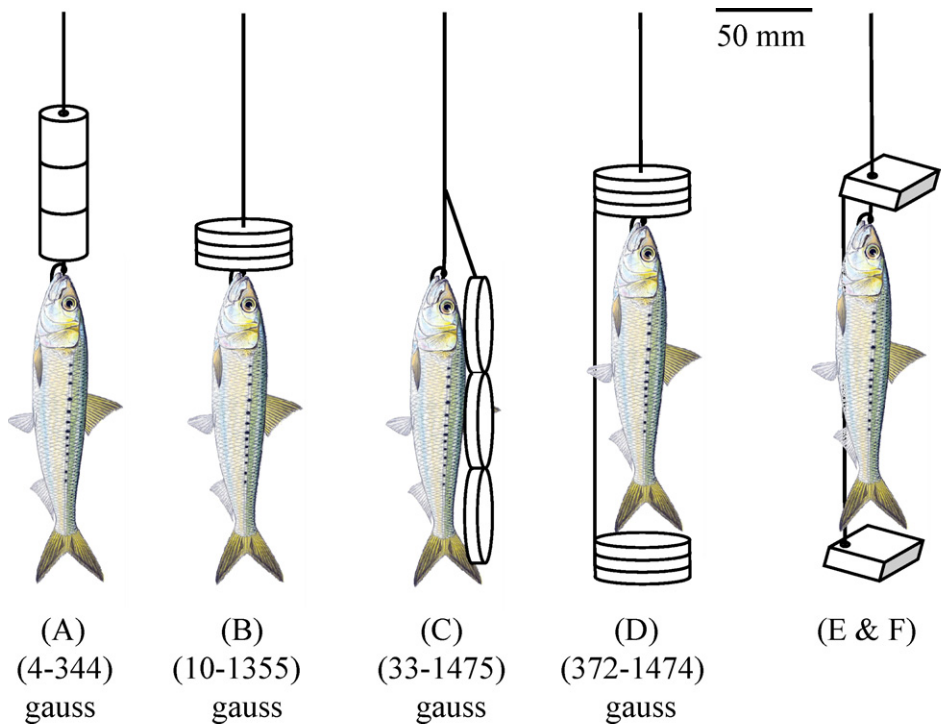

Fig. 1. Bait configurations used during the paired experiments. (A–D) The neodymium–iron–boron (rare earth) magnet configurations; the neodymium (E) and neodymium-praseodymium alloy (F) electropositive metal configurations. Numbers indicate the range of magnetic strength (gauss) along the bait. The electric field induced by the electropositive metals could not be measured in the laboratory. The two ferrite magnets tested included a single hollow disc situated above the bait as per (B) (1–84 gauss along bait) and a small block magnet above the bait as per (B) (5–595 gauss along bait). Scale bar applies to all diagrams.

bait as per Fig. 1(A). A half-sardine was used as bait. The time to strike, the number of prior encounters and the number of sharks were determined by later review of the video footage.

Statistical analyses of the paired trials were carried out using "R" 2.9.1 (R Development Core Team, 2004). A logistic regression model examined the effectiveness of the deterrent configurations on bait depredation. Covariates of the time to strike, the number of prior interactions and the number of sharks present were also modelled to examine their influence on the sharks' bait preferences. The complete model used was:

$$\text{logit}(Y_i) = a + b \times \text{configuration}_i + c \times \text{time to strike}_i + d \times \text{prior interactions}_i + e \times \text{number of sharks}_i + \epsilon_i$$

where a to e are constants, and Y is a binary outcome (test or control bait taken). A total of 240 binary responses were considered, comprising 30 replicates for each of the eight treatments. The significant difference of each variable from zero was examined using partial z-tests. After running the full model, any non-significant covariates were removed, and the model re-ran with significant variable(s) only. Further examination of individual variables was carried out by hand using t-tests and χ^2 tests as necessary. Yates correction was applied to χ^2 tests having only one degree of freedom (Zar, 1996).

3. Results

The behaviour of Galapagos sharks was unchanged towards the burley canister when power was applied to the video camera. The time to first bump or bite the canister, the number of interactions per replicate and the number of sharks around the canister were all indistinguishable with respect to power status (Table 1). These results and the apparent disregard for the physical presence of the camera observed in the sharks indicated that the camera did not influence the sharks' behaviour. This result confirmed it was valid to use the camera for monitoring the experimental trials.

The magnet and electropositive metal devices tested elicited only a weak effect on shark feeding behaviour. Although the deterrent-protected baits were generally depredated less (Fig. 2A), logistic regressions showed that the test configurations had no significant effect in reducing bait depredation (Table 2). Similarly, the covariates of the time to strike and the number of sharks present did not influence the rates at which the test and control baits were depredated (Table 2).

Table 1
Influence of power status of *Seaviewer*™ trolling camera on Galapagos shark behaviours. Interactions were assessed on a burley canister suspended 3 m below the camera. Times in min and s. Number in parenthesis show standard errors. All analyses were non-significant at $\alpha = 0.05$ level.

Factor	Power off	Power on	t	p
Time to first bite or bump	1:40 (0:33)	1:47 (0:33)	−0.14	0.89
Interactions per replicate	3.0 (0.56)	3.2 (0.84)	−0.20	0.85
Number of sharks present	10.0 (1.51)	10.0 (1.65)	0.00	1.00

Table 2
Logistic regression on the effects of configuration type, the time to strike, the number of prior interactions and the number of sharks in determining the outcome of bait depredation. Significant result in bold.

Variable	Value	SE	z	p
Intercept	0.02	0.37	0.050	0.960
Configuration type	0.05	0.06	0.881	0.378
Time to strike	0.00	0.00	0.467	0.640
Prior interactions	**−0.26**	**0.14**	**−1.986**	**0.047**
Number of sharks	0.00	0.06	0.033	0.974

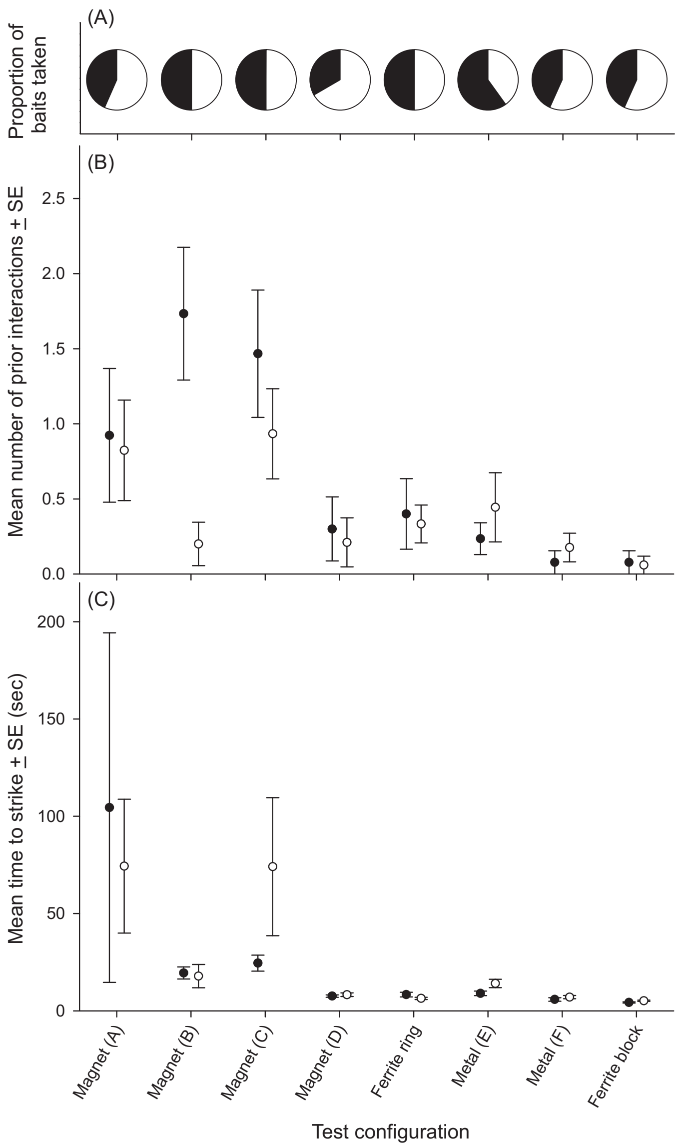

Fig. 2. Results of paired trials with magnet and electropositive metal configurations, in the order in which they were conducted. (A) Percentage of times the test and control baits were taken per trial; (B) the number of investigatory interactions a shark had with the bait prior to depredating it; and (C) the time taken to depredate test and control baits per trial. Closed symbols and black pie segments indicate replicates where the test bait was taken, open symbols indicate control bait depredations. $n = 30$ for each trial. Configurations are listed in Fig. 1.

The number of prior interactions showed a significant effect between control and test bait depredation (Table 2). This effect remained true when the model was refitted with the non-significant covariates removed (regression value = −0.27; $z = -1.991$; $p < 0.05$). However this result was driven solely by a single configuration. The 50 mm magnetic disc (configuration B) showed a highly significant increase in the number of prior investigations of the test bait (t-test; $p < 0.005$; Fig. 2B), although it was depredated at the same frequency as the control (Fig. 2A). The alternative arrangement of 50 mm magnetic discs (configuration D) also elicited strong behavioural responses in Galapagos sharks, with this configuration reducing bait depredation to half the rate of control baits, although this was statistically non-significant (Yates-corrected $\chi^2 = 2.7$, d.f. = 1, $p > 0.05$; Fig. 2A).

The time to strike baits decreased as our trials progressed, with no differences between test and control baits for all but the neodymium metal (configuration E). In this case the test baits were taken significantly quicker than the control baits (t-test; $p < 0.05$; Fig. 2C). Magnet configuration C showed a more variable (although non-significant) increase in the time to strike control baits, however this was due entirely to two replicates in which one and two individual sharks repeatedly investigated both baits before taking the control bait.

A review of all paired trials showed that in 85% of cases the bait taken was the first encountered by the depredating shark. This suggests a very limited overall influence of the magnets and electropositive metals. Our trials of the smaller rare earth magnets showed they similarly had limited efficacy as shark deterrents. Although the baits were smaller, they were depredated at a comparable rate to the paired configurations (Table 3). They also had comparable numbers of prior investigations as the paired trials (Table 3). The weak magnetic fields enveloping the baits suggest that the non-significant findings of our previous experiments could not be attributed to an excess of magnetic gauss overloading the sharks' senses.

To investigate the overall lack of bait selectivity in our paired trials, we closely examined three of our paired trials (magnet configurations B and C, and the ferrite block). These trials were all conducted in the morning, limiting any interactive effects with previous activities. Each trial was separated into three sequential groups of 10 replicates, and the total number of sharks present examined. Shark numbers markedly increased during the course of each trial, as greater numbers of individuals were attracted into the sampling area (Fig. 3A). The time taken for sharks to strike baits decreased as the trials progressed, however the rate at which this reduced was greater than the increase in shark numbers (Fig. 3B). It appeared that the higher shark densities were resulting in more rapid individual strike rates.

The relationship between the time to strike and shark density was examined across all paired trials. The time to strike was longer, and more variable, when only one or two individuals were present, and markedly decreased with shark abundance until it reached an asymptote once three or more individuals were present (Fig. 4). Regression analysis showed the strike rate was unchanged across these higher densities (MS = 355.08, $F = 2.79$, $p > 0.05$). The video footage showed the sharks rushing at the closest bait when at higher densities, apparently in an attempt to reach it before their conspecifics. This appeared to negate the more cautious, investigative behaviours seen on the occasions when only one or two animals were present. Although logistic analysis showed no effect of shark density on depredation rates of test or control bait (Table 2), this can be attributed to the high numbers of sharks present during each of the configuration trials. All trials had at least five sharks present on multiple replicates, with most replicates (71%) having three or more sharks concurrently present.

Table 3
Effects of small rare earth magnets on bait depredation. All experiments used small cylindrical magnets in the same configuration as Fig. 1(A). Numbers in parenthesis indicate standard errors. n indicates number of replicates per trial.

Magnet size (diam × height)	n	Magnetic field around bait (gauss)	Mean time to strike (SE) (s)	Number of prior investigations (SE)
25.0 × 9.0 mm	12	4–61	5.83 (0.49)	0.08 (0.08)
12.5 × 12.5 mm	15	0–19	9.40 (1.10)	0.13 (0.09)
12.5 × 6.3 mm	23	0–11	10.48 (0.96)	0.48 (0.15)

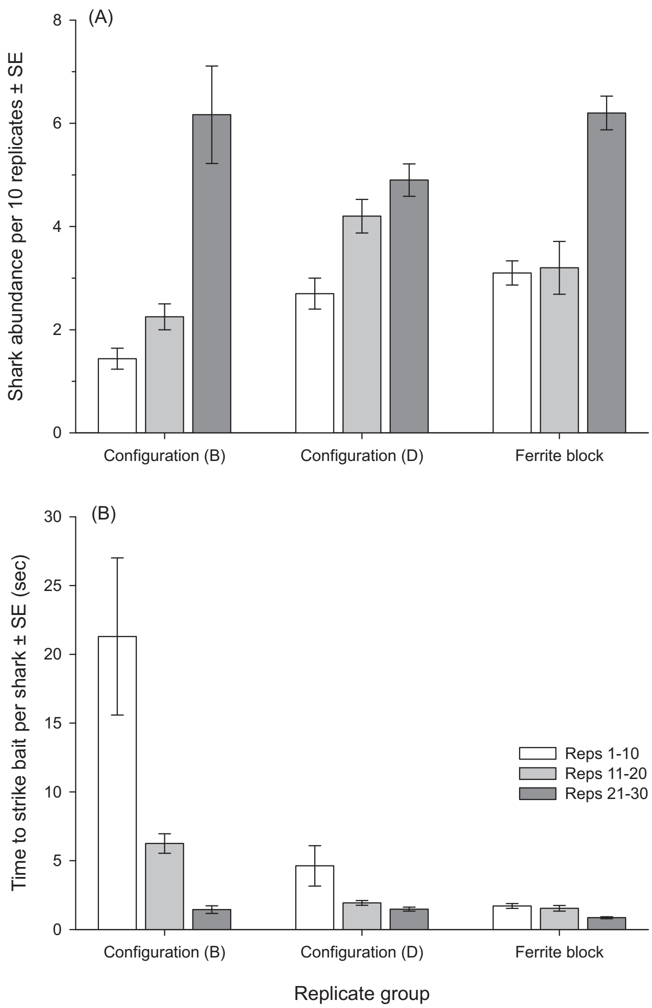

Fig. 3. Effects of shark numbers during individual trials. (A) Increases in shark abundance per group of 10 replicates and (B) time to strike as a function of shark density per group of 10 replicates. Letters in parenthesis relate to the configurations in Fig. 1.

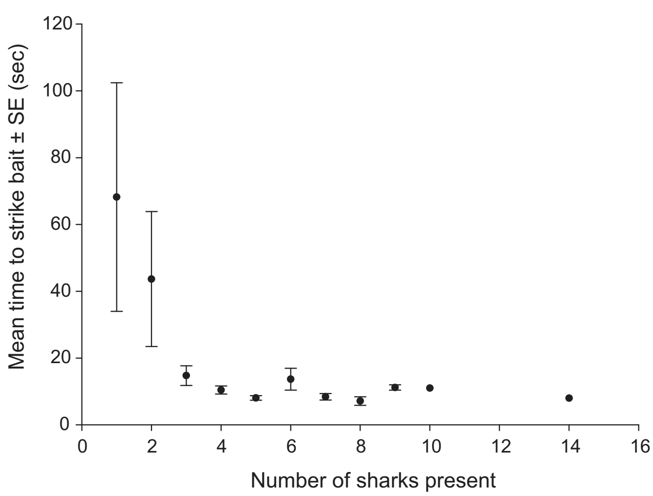

Fig. 4. Shark strike rate as a function of density.

4. Discussion

Permanent magnets and electropositive metals are becoming increasingly investigated as potential shark deterrents (Brill et al., 2009; Kaimmer and Stoner, 2008; Rigg et al., 2009; Tallack and Mandelman, 2009; Wang et al., 2008). The successful application of such materials will provide great benefits in reducing shark bycatch, especially in line-based fisheries. Because the present study tested a variety of compounds (rare earth magnets and metals, plus ferrite magnets) under the same experimental conditions, we could, for the first time directly compare the efficacy of these compounds in reducing wild Carcharhinid bait depredation in a hook-and-line situation.

The lack of influence of the camera on shark predatory behaviour is encouraging for future studies of free-ranging sharks where detailed behavioural analysis may be required. These findings are to be expected considering that the underwater cameras used in this study are remotely powered, thereby reducing battery-emitted electrical signals. Self-powered cameras would be more likely to have potential impacts, yet they too have been successfully used in elasmobranch studies with no apparent effect (Cappo and Meekan, 2004; Heithaus et al., 2001). Our reliance on careful examination of video footage during this study highlights the benefits of recording experimental trials when studying free-ranging animals, and not merely relying on instantaneous behavioural observations, as has previously been used in deterrent experiments with wild sharks (Smit and Peddemors, 2003).

We found no significant difference in the time taken to depredate the experimental and control baits, with both bait types taken more rapidly in later trials. The time to strike and the number of investigations prior to striking were similarly non-significant between bait types for most configurations. These data differ to those previously reported for a range of shark species, including Carcharhinids, where some of the materials examined here elicited movement and avoidance behaviours that may be beneficial for developing bycatch mitigation devices (Rigg et al., 2009; Stoner and Kaimmer, 2008). We conclude that the presence of baits coupled with the presence of conspecifics in a non-captive environment is the factor driving the difference between ours and previous studies. Our more detailed analysis of the shark behaviour around the presented baits concur with the findings of Stoner and Kaimmer (2008), where certain combinations of rare earth magnets affect the abilities of sharks to attack the bait, as indicated by an increase in the number of investigations before bait depredation. Interestingly, our results indicated that configurations with the most powerful magnetic field were not the most effective at producing aborted bait investigations, suggesting that magnet strength alone does not determine the efficacy of such deterrents.

Close analysis of shark behaviour indicated that depredation rates were highly dependent on the total number of sharks present at the time of the experiment. The more exploratory and cautious behaviour exhibited by sharks when alone, or in the presence of one other conspecific, was abandoned once three or more sharks were present. Unfortunately, these higher shark densities were present during the majority of replicates in this study. Our data imply a substantial behavioural component as sharks react to presented baits, and may explain some of the variability found between studies investigating the efficacy of various compounds as bycatch mitigation measures (Brill et al., 2009; Kaimmer and Stoner, 2008; Stoner and Kaimmer, 2008). Density effects have been found to limit the effectiveness of electropositive metals in reducing spiny dogfish (*S. acanthias*) catches in commercial longlines, due to the sheer number of animals caught overshadowing any preferential bait selection process (Kaimmer and Stoner, 2008). Density effects are likely to have operated through a different mechanism in our study, with reduced cautiousness appearing to be a competitive response to increased numbers of conspecifics. Increased feeding motivation through competition has been commonly recognised in wild feeding schools of the tropical grey reef shark (*Carcharhinus amblyrhynchos*) (Nelson and Johnson, 1980), and has been hypothesised to reduce the effectiveness of electropositive metal deterrents for captive sandbar sharks (*C. plumbeus*) (Brill et al., 2009). Clearly such factors should be considered in any future bycatch mitigation trials.

The sharks in our trials may also have been demonstrating learned behaviours, as individuals became increasingly tolerant of the momentary irritation of the magnetic fields in order to obtain food. Although this has not been observed in short (30 min) captive trials (Rigg et al., 2009), repeated exposures have been suggested to initiate such a response in sandbar sharks (*C. plumbeus*) (Brill et al., 2009). Such an effect would be to decrease an individual's bait selectivity, and reduce their individual strike times. In the present study we were unable to examine changes in the behaviours of individual sharks to the baits over time, as we could not uniquely identify most individuals. Nevertheless, it is compelling that the mean time to strike both the test and control baits rapidly decreased throughout the duration of this experiment, and when possible, identifiable individuals were observed to return on multiple occasions.

The return of individual animals might also compromise the independence of the sampling methodology during latter configuration trials. To minimise this possibility, we sampled at multiple random locations over a 7 km range around the lee side of the study site, Lord Howe Island. While the foraging and detection range of Galapagos sharks is unknown, other small reef-associated Carcharhinid sharks have demonstrated site fidelities smaller than this (Garla et al., 2006; Randall, 1977; Robbins, 2006). To further minimise attracting individuals from previously sampled areas, the artificial attractant (burley) was only used until animals were first sighted. From a statistical point of view, non-independence of such sampling is most likely to produce higher levels of significance in the results (D. Collins, Industry; Investment NSW, pers. comm.), when individuals repeatedly focus on a single bait type (test or control). Although we have no formal test for this, our high level of non-significant findings among test configurations, and the finding that sharks took the first bait encountered in over 85% of trials, suggests that potential non-independent influences of returning sharks did not affect the outcomes found here.

We also considered the possibility that the fields to which we were exposing sharks during our paired experiments may be overriding the sharks' electromagnetic senses, thereby reducing the efficacy of magnets in stopping sharks depredating the baits. However, additional trials using smaller magnets emitting less powerful fields showed that baits were depredated at similar rates. Although it is possible that the high magnetic fields had damaged the sharks' electrosensory ampullae (preventing them from detecting fields in subsequent trials), it is highly unlikely that sharks would have voluntarily entered the magnetic fields if this was occurring.

Prior feeding opportunity is another significant factor that may affect the success of shark deterrents. Arousal from a bait stimulus is a key factor in determining shark behaviours and response thresholds (Kajiura, 2003), and experiments have demonstrated that food deprivation can overcome the presence of deterrents as the primary influence on feeding behaviour of both squaloid and triakid sharks (Mandelman, 2008). The sharks observed in our trials all appeared in healthy condition, with reefs in the Lord Howe Island complex having high abundances of potential prey species (Choat et al., 2006). Although we can only speculate on the health and feeding status of these sharks, it remains unlikely that the minimal effectiveness of deterrents seen in this study were due to food deprivation. Nevertheless, prey availability and likely foraging strategies should be considered when experimenting in areas of high shark densities, or low prey availability.

At present we can offer no magnetic or electropositive metal panacea to deter sharks from taking baited lines. Our experiments showed a clear detection of the magnetic fields encompassing our baits, while supporting previous findings that behaviours of sharks can overcome any selectivity initially shown in bait choice (Brill et al., 2009; Mandelman, 2008). We therefore emphasise the need for future research to consider the implications of stock densities and social behaviours when designing and implementing shark deterrent experiments. It is quite possible that an appropriate deterrent configuration can be found for shark species which lack the agonistic behaviours of Galapagos sharks in the presence of food, and occur in sufficiently low densities that food availability and overall numbers will not affect the results. If this is the case, and the use of such materials does not reduce the capture rates of target species, the implementation of such devices in both recreational and commercial line fishing should be strongly encouraged from both an economic and ecological perspective.

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