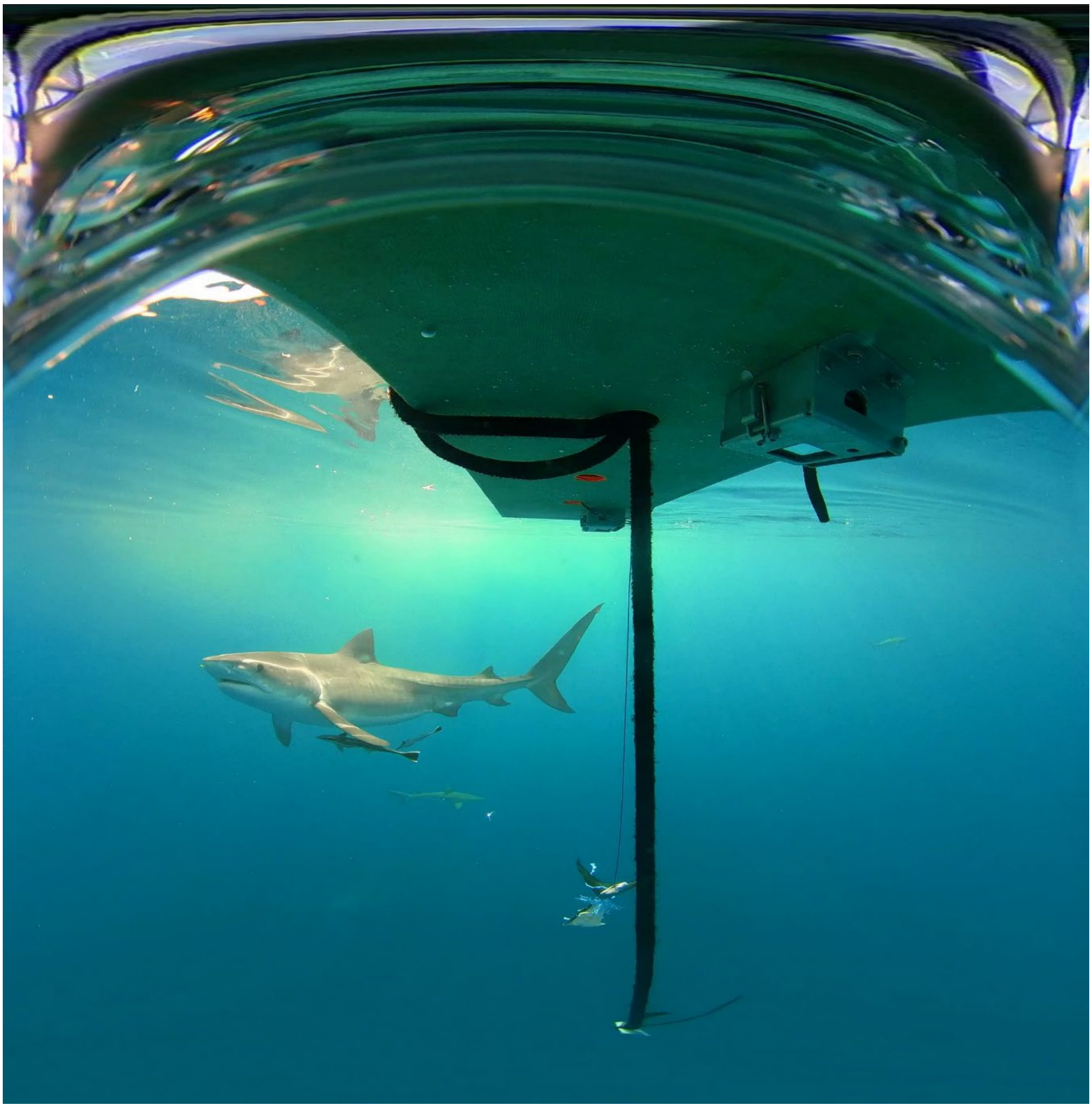
Effectiveness of commercially available personal electric shark deterrents on tiger sharks *Galeocerdo cuvier*



Thomas Clarke[1], Adam Barnett[2,3], Richard Fitzpatrick[3], Laura Ryan[4], Nathan S. Hart[4], Charlie Huveneers[1]

This Publication may be cited as: Clarke, TM, Barnett, A, Fitzpatrick, R, Ryan, L, Hart, NS, Huveneers C. 2022. Effectiveness of commercially available personal electric shark deterrents on tiger sharks *Galeocerdo cuvier*. Final Report to Queensland Department of Agriculture and Fisheries. 53 pages.

1. Southern Shark Ecology Group, College of Science and Engineering, Flinders University, Adelaide, SA 5042, Australia
2. Marine Data Technology Hub, James Cook University, Townsville, QLD, Australia
3. Biopixel Oceans Foundation, Cairns, QLD, Australia.
4. School of Natural Sciences, Macquarie University, North Ryde, NSW 2109, Australia

Southern Shark Ecology Group
College of Science and Engineering
Biology road
Bedford Park SA 5042

CONTENTS

LIST OF TABLES

size; ΔAIC_C: difference in AIC_C between the current and top-ranked model; $wAIC_C$: model probability; Rm: marginal (fixed effects) R^2; Rc, conditional (fixed and random effects) R2.

Table 9. Summary of outcomes from Ocean Guardian Freedom+ Surf and Freedom7 modules on tiger sharks in this study during control (T) and Treatment (T) trials.

LIST OF FIGURES

1. EXECUTIVE SUMMARY

The frequency of unprovoked shark bites in Australia has been steadily increasing over the last 40 years (McPhee 2014, Riley et al. 2022). As a result, there is growing pressure to develop and implement mitigation measures to reduce shark bite risk but maintain conservation objectives. Personal deterrents are a promising, socially acceptable, and non-lethal strategy that can protect swimmers, divers, and surfers (Adams et al. 2020, Simmons et al. 2021). While multiple deterrents are commercially available, few have been tested empirically and independently to assess their ability to deter sharks and reduce shark bite risk. In Australia, tiger sharks *Galeocerdo cuvier* are responsible for the highest proportion of bites that result in fatality, with 38% of bites resulting in casualties (compared to 62% injured or unharmed; Riley et al. 2022). Along with bull sharks *Carcharhinus leucas* and white sharks *Carcharodon carcharias*, these three species deliver the most unprovoked bites, cumulatively responsible for 66% of all bites. Although electric deterrents have been shown to reduce bites by white sharks (Kempster et al. 2016, Huveneers et al. 2018) and bull sharks (Gauthier et al. 2020), these products have not been tested on tiger sharks. The Queensland Department of Agriculture and Fisheries commissioned a study to assess the effectiveness of personal electric deterrents on tiger sharks. This study aimed to test the effects of two electric deterrents (Ocean Guardian's Freedom+ Surf [surf product] and Freedom7 [diving]) on the behaviour of tiger sharks and compare it to findings from previous studies on white sharks and bull sharks. Results of this study showed that both Freedom+ Surf and Freedom7 products reduced the proportion of bites occurring during trials by 69 and 70%, respectively compared to control trials. Electric deterrents used in this study also increased the time for bites to occur, number of passes, and reactions from tiger sharks. The number of failed bites and board nudges decreased when deterrents were active. The effects of electric deterrent were compared to previous studies on white and bull sharks testing the same products. The largest reduction in the number of bites between species occurred with tiger sharks, with additional effects on time for bites, passes, and reactions. Although both products tested can reduce shark bite risk for surfers and swimmers/divers, neither completely eliminated bites from tiger sharks. These results will allow private and government agencies to make informed decisions about the use of these devices for occupational activities and enable the public to make appropriate decisions about the suitability of these two products for personal use.

2. INTRODUCTION

2.1 Human-shark interactions

Interactions between humans and sharks have been steadily increasing globally over the past ~40 years (McPhee 2014, Chapman & McPhee 2016, Midway et al. 2019). Possible causes of the continued rise in shark incidents remain a debated and contentious topic, and are often associated with human population growth in coastal areas and increases in water-based activities such as surfing and diving (Cliff 1991, West 2011). However, environmental and habitat variation, such as changing ocean temperature (Cliff 1991), decreased water clarity (Caldicott et al. 2001), and climate change (Chapman & McPhee 2016) may also contribute to the rising number of shark bites on humans (Ryan et al. 2019).

Australia is the country with the second-highest number of shark bites, which is increasing at a rate of 0.35 incidents year^{-1} (from nine bites year^{-1} from 1990 – 2000 to 22 bites year^{-1} 2010 – 2020; (Chapman & McPhee 2016, Bradshaw et al. 2021). Mitigation strategies and responses to shark bites in Australia have varied temporally and regionally, and include culling programs, enclosures, beach nets, drumlines, land- and aerial-based shark spotting, education (e.g. SharkSmart), and acoustic tracking (Martin 2007, Curtis et al. 2012, Gray & Gray 2017). Whilst these efforts are generally thought to improve safety of water users (McPhee 2012), they often have associated conservation concerns and implications for populations of threatened and non-targeted species (McPhee 2012), or are only suitable for bathers and not desirable for other water sports such as surfing or diving (McPhee 2012).

Of eleven shark species that have been responsible for fatal bites on humans in Australia, three are accountable for 66% of unprovoked bites: white (*Carcharodon carcharias*; 30%), tiger (*Galeocerdo cuvier*; 19%), and bull sharks (*Carcharhinus leucas*; 17%). Of these species, tiger sharks are responsible for the highest proportion of bites that results in fatality (38% of bites; (Riley et al. 2022), followed by bull (32%) and white sharks (25%). As the three species considered to be most dangerous to humans, white, tiger and bull sharks are the primary focus and target of shark bite mitigation strategies.

2.2 Personal electric deterrents

More recently, there has been declining public support for traditional, lethal methods of shark bite mitigation (Adams et al. 2020, McPhee et al. 2021, Rosciszewski-Dodgson & Cirella 2021, Simmons et al. 2021). Instead, there has been a rise in use and support for alternative and non-lethal methods to reduce shark bite risk, e.g., early-warning systems and deterrents (McPhee et al. 2021, Rosciszewski-

Dodgson & Cirella 2021, Simmons et al. 2021). Personal deterrents aim to dissuade sharks from biting by disrupting one or more of their senses (i.e., vision, smell, taste, or electroreception) and has gained traction as a potentially effective mitigation measure (Huveneers et al. 2012, Hart & Collin 2015, Bradshaw et al. 2021). While several personal deterrents are commercially available, electric deterrents were the only type of deterrents reducing probability of shark bites from those that have been tested (Huveneers et al. 2013b, Kempster et al. 2016, Huveneers et al. 2018, Gauthier et al. 2020). However, electric deterrents were not all equal in their ability to affect shark behaviour and demonstrated to reduce shark bite risk (Huveneers et al. 2018, Gauthier et al. 2020).

Ocean Guardian products (formerly named Shark Shield; ocean-guardian.com) is the most tested and effective electric deterrent (Huveneers et al. 2013b, Kempster et al. 2016, Huveneers et al. 2018, Gauthier et al. 2020, Thiele et al. 2020). Their products consist of two electrodes that emit a strong electric pulse that potentially overstimulates the shark's electroreceptive system, the ampullae of Lorenzini, when sharks are in close proximity. Ocean Guardian has developed a series of products based on this technology, with modifications designed for diving, surfing, and protecting larger areas (i.e., boats, beaches). Ocean Guardian surf (Huveneers et al. 2018, Gauthier et al. 2020) and dive (Huveneers et al. 2013b, Kempster et al. 2016) products have previously been tested, and shown to reduce the probability of white and bull sharks biting a baited target. Findings from previous studies led the Western Australian government to introduce a shark deterrent rebate where Western Australian residents are eligible for a $200 rebate when purchasing a product that has been scientifically tested with findings published in the peer-reviewed literature (sharksmart.com.au/staying-safe/rebate-faqs). However, despite being responsible for the highest proportion of fatal bites as a function of total bites, the responses of tiger sharks to these electric deterrent products have not been assessed.

2.3 Objectives

The objective of this study was to assess the effects of the Ocean Guardian Freedom+ Surf and Freedom7 models on the behaviour of tiger sharks and compare the findings to the behavioural responses of white and bull sharks.

Specifically, we aimed to:

1. Assess the efficacy of the Ocean Guardian Freedom+ Surf and Freedom7 to reduce or prevent tiger sharks from biting a baited target (simulated prey item);
2. Characterise the behavioural responses of tiger sharks exposed to Ocean Guardian Freedom+ Surf and Freedom7; and

3. Compare the responses of tiger sharks to two other species responsible for the highest number of unprovoked bites on humans in Australia (i.e., white and bull sharks).

3. METHODS

3.1 Experimental protocol

Trials followed the same methods as previous testing of Ocean Guardian deterrents on white (Huveneers et al. 2013b, Huveneers et al. 2018) and bull sharks (Gauthier et al. 2020). One buoyant fibreglass-coated wooden board was deployed 5–10 m away from the stern of the research vessel and left for 15 minutes (Fig. 1), or until the bait was taken or the board was bitten. Tiger sharks were attracted by dispersing a mix of chum (minced sardines *Sardinops* spp.), and tethered baits (locally caught fish) into the water column behind the vessel. Trials would commence once a tiger shark was sighted at least twice within 3 minutes, or showed consistent interest in a tethered bait. Trial baits (head/frame of a fish, ~50 cm length) were suspended ~0.5 m below the board and centred between deterrent electrodes, with an active deterrent (*Treatment*) or decoy (*Control*) positioned in the middle of the board, so the bait would sit ~0.5 m away in the centre of the electrodes (Fig. 1). Control boards used dummy deterrents (i.e., Freedom7: segments of black garden hose, Freedom+ Surf: replica electrodes made from duct tape) to mimic the appearance of deterrent products. The position of the bait was designed to replicate the distance that the lower leg and foot of a surfer would be while sitting down and waiting for waves (Freedom+ Surf) or lower leg in relation to the antenna cable for divers and snorkellers (Freedom7). Interactions between tiger sharks and deterrent boards were recorded via a 360-camera (Insta360 ONE X2, insta360.com). Surface observations (estimates of distances, behavioural reactions, whether baits were taken) were also recorded by observers on board the research vessel. A set of trials consisted of testing one control and one treatment deterrent in a randomised sequence. Trials during which no sharks were observed in close vicinity to the board during the 15-minute period were repeated.

Norfolk Island trials (Freedom+ Surf)

Norfolk Island is a small island in the Pacific Ocean, ~1,400 km east of Australia (29°02'48.3"S 167°55'07.9"E; Fig. 1). This site has an aggregation of large tiger sharks (>3.5 m in length), with 34 individuals caught and released in the Headstone Bay area in 8 days of fishing in 2020 (C Huveneers pers. obs.). Satellite tracking of 10 sharks revealed a seasonal persistence at Norfolk Island at predictable times, making Norfolk Island an ideal site to test electric deterrents on large individuals. Testing of the Freedom+ Surf product; ocean-guardian.com.au/collections/surf) was carried out at Headstone Bay, Norfolk Island between the 17th and 25th of February 2022. A total of 69 trials (34 with deterrent turned on, 35 with control board) were undertaken during daylight hours across 9 days. Six trials (1 control, 5 treatment) were removed from behavioural analyses due to errors with the video recordings but were used for comparisons of efficacy to reduce bites (i.e., proportion of trials with bites, time for bait to be taken).

Saunders Reef trials (Freedom7)

Saunders Reef is a remote tropical reef located in the far north region of the Great Barrier Reef, Australia (11°30'14.6"S 144°04'21.5"E, Fig. 1). This reef is near Raine Island and is a known tiger shark 'hot spot' (Fitzpatrick et al. 2012, Hammerschlag et al. 2016). The Freedom7 product (ocean-guardian.com/products/freedom7) was tested around Saunders Reef between the 3rd and 15th of December 2021. A total of 93 trials (46 with deterrent turned on, 47 with control board) were undertaken during daylight hours across five days. Nine trials (7 control, 2 treatment) were removed from behavioural analyses due to errors with the video recordings but were included in the bite reduction analysis.

All testing was undertaken according to relevant permits:

- Great Barrier Reef Marine Park permit to undertake research within the Great Barrier Reef Marine Park: permit number G19/42007.1
- Flinders University Animal Use Ethics Approval to test the efficacy of shark deterrents: project number BIOL4985-2

3.2 Video analyses

Video footage collected from the 360-cameras was analysed in Behavioural Observation Research Interactive Software (BORIS, version 7.12.2; Friard & Gamba 2016). A behavioural ethogram of pre-defined behaviours was imported into BORIS based on previous descriptions of pelagic shark swimming behaviour (Table 1; Myrberg Jr & Gruber 1974, Martin 2007, Thompson 2014, Turner 2016, Andrzejaczek et al. 2019) and interactions with deterrent equipment (Huveneers et al. 2018, Gauthier et al. 2020). Behaviours from the ethogram were then classified in two categories; 'event behaviours' which are points that do not have a duration, and 'state behaviours' where duration was counted occurring over a time period (Table 1). Behavioural reactions of sharks towards the experimental setup were coded as 'reactions' (indicated as ^{R} in Table 1; Huveneers et al. 2018). Number of reactions per pass (i.e., concurrent occurrences of a behaviour during one pass; indicated as ^{M} in Table 1) were recorded for nictitating and jaw gaping events. Shark identity (ID) was recorded for each individual where possible using unique markings and colouration (Clua et al. 2013). Behaviour events (sum of occurrences per shark) and states (total duration in seconds) were summarised for identified individuals during each trial. Sharks that could not be confidently identified were assigned as “Unknown”. A trial was deemed a ‘fail’ in the case that a bite occurred on the bait or board (Table 1). For trials missing footage from 360-cameras, surface observations were referred to confirm incidence of bites.

Table 1. Ethogram for labelling of tiger shark behaviour during deterrent trials coded using Behavioural Observation Research Interactive Software (BORIS). Behaviours considered to be reactions to the experimental setup are indicated as ^{R}.

Behaviour type	Behaviour code	Description
State	Approach	Approach towards the deterrent board within 2 – 3 body length with an intent to make contact.
	Patrolling	Straight-line swimming pattern away from the deterrent board, with no apparent interest in the board (Myrberg Jr & Gruber 1974, Turner 2016).
	Glide	Slow, horizontal swimming with no tail beat (Andrzejaczek et al. 2019).
	Out	Shark out of the field of view.
	Swimming away	Shark swimming directly away from the deterrent board.
Events	Enter	First time the shark is visible in 360 camera’s fields of view
	Exit	Last point when the shark is visible in 360 camera’s fields of view
	Bite	Closure of jaw on bait or board, and contact with teeth (Thompson 2014)
	Nictitating^{R}	Closing of the nictitating membrane >30% of the eye (Thompson 2014, Turner 2016).
	Nudge	Contact with the bait or board with snout or head (Martin 2007, Turner 2016)
	Head shake^{R}	Rhythmic, exaggerated lateral shaking of the head, usually rapid (>2 Hz) and through an arc of >30° (Martin 2007)
	Hunch^{R}	Arching of the back with the tail slightly lowered and head slightly raised, so that the body forms a reversed arch shape (Myrberg Jr & Gruber 1974, Turner 2016)
	Jaw gape^{R}	Slow, exaggerated opening of the jaw (approximately 30 – 90°, estimated as the angle formed at the mouth commissure), conspicuously wider than during ram ventilation (Martin 2007, Thompson 2014)
	Rapid withdrawal^{R}	Rapid movement of the shark away from the deterrent board at 2 – 3 body length per second, initiated by several strong tail beats followed by a long glide and covering 1 – 5 m (Martin 2007)
	Attempted bite	Attempts to bite bait or board, but without contact with teeth
	Pass	A directed swim towards the experimental setup (each time a shark veered away from the board and swam back is classified as a new pass; Huveneers et al. 2018)

3.3 Comparison to white and bull sharks

The response of tiger sharks to electric deterrents was compared to that of white and bull sharks by sourcing data from previous studies (Table 2). White shark data was sourced from Huveneers et al. (2018; Freedom+ Surf) and Huveneers et al. (2013b; Freedom7). Bull shark data was only available for the Freedom+ Surf from Gauthier et al. (2020). Behavioural states were not coded for white and bull sharks.

Table 2. Summary of studies testing the effectiveness of Ocean Guardian Freedom+ Surf and Freedom7 models on tiger, white, and bull sharks, including number of trials, sharks, and passes.

Species	Product	Citation	Trials (control/treatment)	Sharks	Passes
Tiger shark *Galeocerdo cuvier*	Freedom+ Surf	Current study	35 / 34	22	373
	Freedom7	Current study	47 / 46	26	789
White shark *Carcharodon carcharias*	Freedom+ Surf	(Huveneers et al. 2018)	71 / 83	44	640
	Freedom7	(Huveneers et al. 2013b)	57 / 75	18	527
Bull shark *Carcharhinus leucas*	Freedom+ Surf	(Gauthier et al. 2020)	75 / 75	29	455

3.4 Data analyses

Effects of the deterrents on all response variables of tiger sharks were tested using a combination of generalised linear effects models (GLMs; no random effects), generalised linear mixed effects models (GLMMs; random effects) using the glm and lmer functions in the `lme4` package (version 1.1.23; Bates et al. 2014) in the R statistical environment (version 4.0.2). Generalised Additive Mixed Models (GAMMs) were used when non-linear responses were tested using the gam function in the `mgcv` package (version 1.8.33). Potential temporal effects were accounted for by including trial set (trial) as a fixed-integer effect, and nesting trial sets within corresponding trips for treatments that occurred over multiple field trips. Shark identity (ID) was included as a random effect to account for pseudo-replication when the same shark interacted with the deterrent set-ups several times within and across trials, and variations in individual behaviour. The most appropriate statistical family for each analysis was determined by examining the distribution of the response variable and visually inspecting model residuals. All models of possible combinations of factors were run and compared for their probability using Akaike's information criterion corrected for small sample size (AIC_c) using the dredge function from the `MuMIn` package (version 1.43.17). Models with Shark ID were run both with and without Unknown sharks to test effects of removing response variables from these individuals from the data. All models removed behaviours from unknown sharks, with the exception of number of passes, which was included as there was no change in $wAIC_c$ or variance explained when these sharks were included or removed from the data. Variance explained from all factors (conditional R^2; R_c) and only fixed-factors (marginal; R_m) were estimated using the *r.squaredGLMM* function (package `MuMIn` version 1.43.17). Estimated marginal means (predicted values) for fixed effects in top ranked models were calculated using the *ggpredict* function (package `ggeffects` version 1.0.1). Deterrent-coefficient estimates were calculated using the *summary* function (package `base` version 3.6.2), to examine the effect of change from modelled data because of deterrents during treatment trials. Individual models were run for each deterrent product to test the effects of deterrents on 1) number of bites, 2) time for bites to occur, 3) number of passes, 4) failed bites (missed bites and board nudges), 5) reactions per pass, and 6) duration in different behaviour states (tiger sharks only). Throughout the report, findings from Freedom+ Surf trials are indicated by circles (●) and Freedom7 by triangles (▲). Filled symbols indicate treatment (active) trials, and empty symbols indicate control deterrent types.

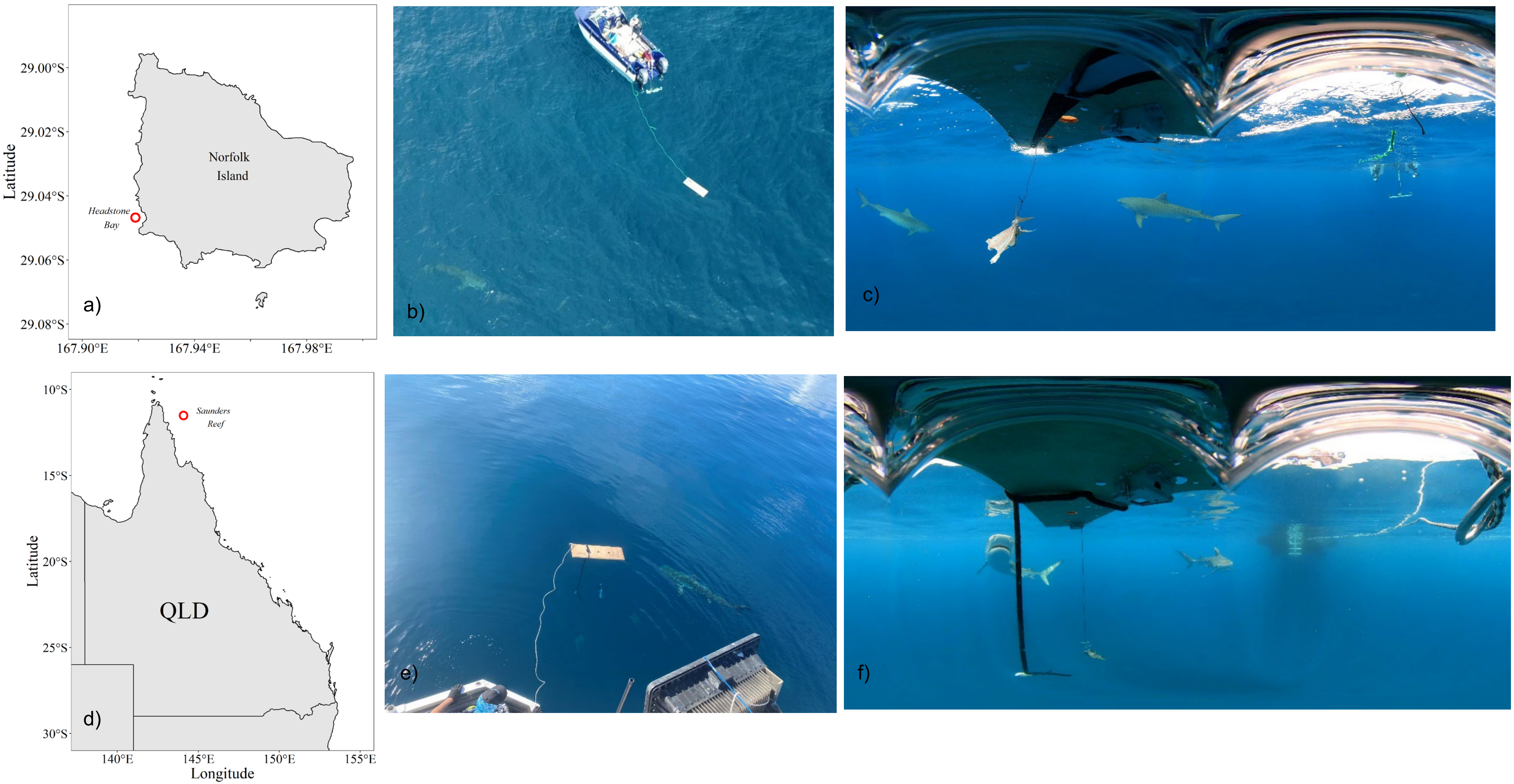


Figure 1. Location (a, d), aerial views (b, e), and sub-surface views (c, f) of trial locations at Norfolk Island [Freedom+ Surf] (top) and Far north Great Barrier Reef [Freedom7] (bottom).

4. RESULTS

4.1 Summary of results

We conducted 70 Freedom+ Surf trials on tiger sharks at Norfolk Island over nine days of sampling (35 control, 35 treatment), with at least 22 sharks interacting with deterrent boards (Table 3), and between 1 to 5 sharks present during each trial. Sharks ranged from 2 – 4 m total length (TL), with most individuals being 3.2 – 3.5 m TL based on visual observations. Most sharks were female (13 individuals, 59%), with only two males (9%) and 7 of unidentified sex (32%). One treatment trial was removed from analyses due to lack of approach to the board during the trial, resulting in a sample size of 35 control, 34 treatment trials. A total of 237 approaches and 373 passes were observed (142 and 196 during control trials and 95 and 177 during treatment trials respectively). Passes included 20 (6%) from individuals that were unidentified. Two hundred and one reactions (i.e., head shake, jaw gape, nictitating) were observed (66 during control trials, 135 treatment).

We conducted 94 Freedom7 trials over five days of sampling (47 control, 47 treatment) at Saunders Reef, with 26 tiger sharks identified (Table 3). Sharks at Saunders Reef were generally smaller than those at Norfolk Island, with individuals estimated between 1.8 – 3.3 m TL, and most commonly ~3 m. Similarly to Norfolk Island, female sharks were dominant (22 vs. 1 individuals, 85%), while 3 individuals could not be sexed (12%). Between 1 and 8 sharks were present during trials. One control trial ended prematurely due to the bait being taken by grey reef sharks *Carcharhinus amblyrhynchos,* and one treatment was removed due to equipment malfunctioning, leaving a sample size of 46 control and 46 treatment trials (92 trials total). During Freedom7 trials, 540 approaches were identified (150 during control, 390 during treatment), along with 789 passes (218 control, 571 treatment). There were 42 passes (5%) from individuals that were unable to be identified. There were 454 reactions observed during Freedom7 trials (27 during control trials, 427 treatment).

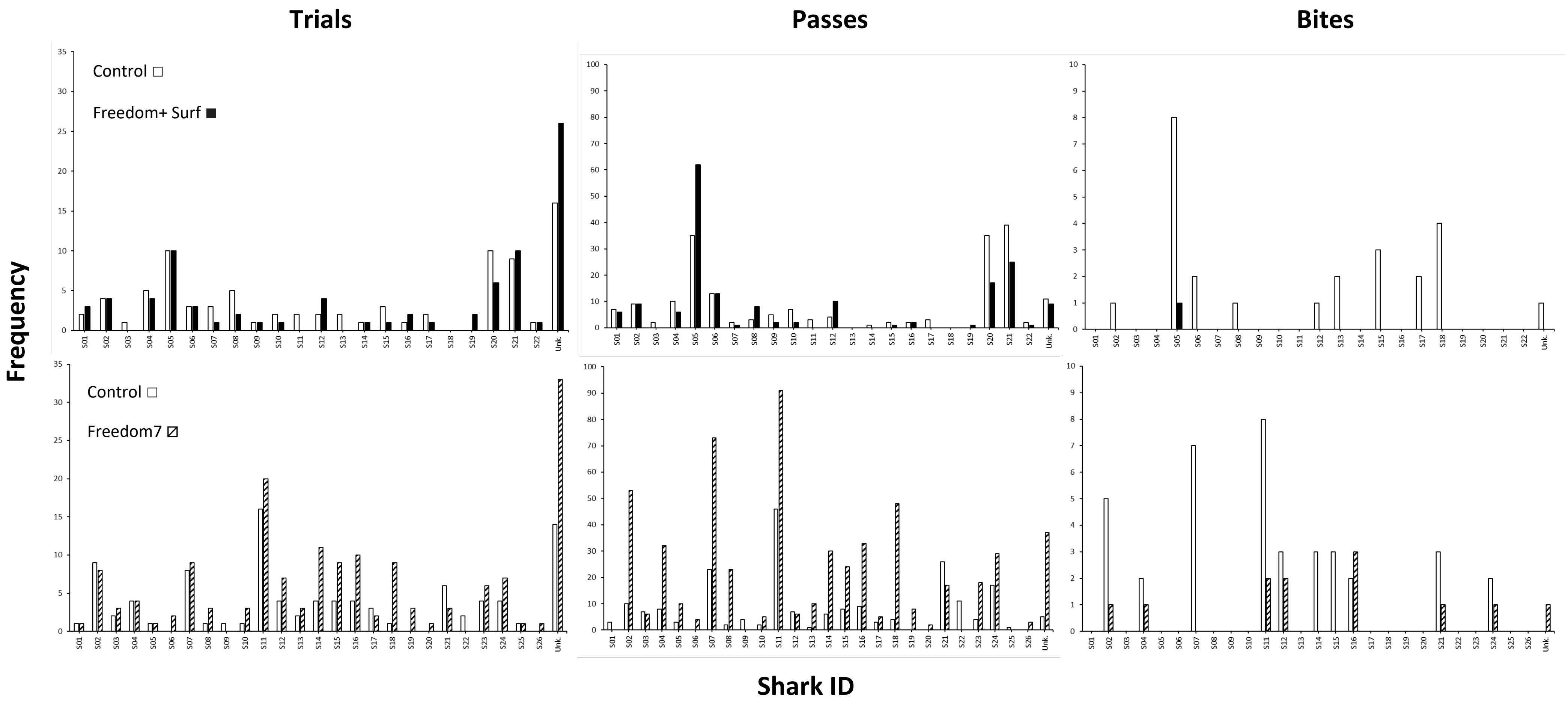


Figure 2. Summary of interactions with tiger sharks during Freedom+ Surf (top) and Freedom7 (bottom) trials

4.2 Number of bites

Freedom+ Surf

Bites by tiger sharks were observed on 25 out of 35 (71%) control trials, and 1 of 34 (3%) treatment trials (Fig. 3). Bites were made by 10 individuals, with each shark being responsible for 1 to 9 bites (Table 3). The top-ranked model ($w\text{AIC}_c$ = 0.69) included deterrent type (i.e., whether the deterrent was control or active) and species, along with the interaction between these factors, highlighting a difference in the responses of tiger sharks, bull sharks, and white sharks to the presence of the Freedom+ Surf. The top-ranked model also included the interaction between species and trial set, revealing an increase in bite frequency throughout the study, which was similar for control and treatment deterrents. Deterrent type had the largest effect on the likelihood of a bite occurring (24% of model variance), with bites from all species reducing between 38 and 68% when the Freedom+ Surf was active (Table 3a, Fig. 4a). Species also influenced the likelihood of a bite (18% of model variation), with tiger sharks being more affected by the Freedom+ Surf than both other species (Fig. 4a, Fig. 4d). The proportion of baits taken by tiger sharks declined by 68%, compared to a 38% and 43% decline in bull and white sharks, respectively. Likelihood of a bite increased with trial number, with sharks of all species more likely to bite as trials went on (Fig. 4b). However, there was no difference in the effect of trial set between control and treatment deterrents (Table 3a, Fig. 4b).

Freedom7

Tiger shark bites were recorded on 42 out of 46 control trials (91%), and 10 out of 46 (22%) treatment trials (Fig. 3). Eleven sharks took the bait, with individuals sharks taking up to 10 baits (Table 3). The top-ranked model ($w\text{AIC}_c$ = 0.89) included the effect of deterrent type (i.e., whether the Freedom7 trial was a control or active, explaining 9% of data variation), and species (2% of data variation), along with the interaction between these factors (Table 2b). There was no temporal effect of sampling on the likelihood of a bite to occur for either tiger or white sharks (Table 2b). When active, the Freedom7 reduced the number of bites from tiger sharks by 70% (Fig. 4c). Comparatively, there was no reduction in bites from white sharks, which instead increased by 6% when the Freedom7 was active (Fig. 4c, Fig. 4d).

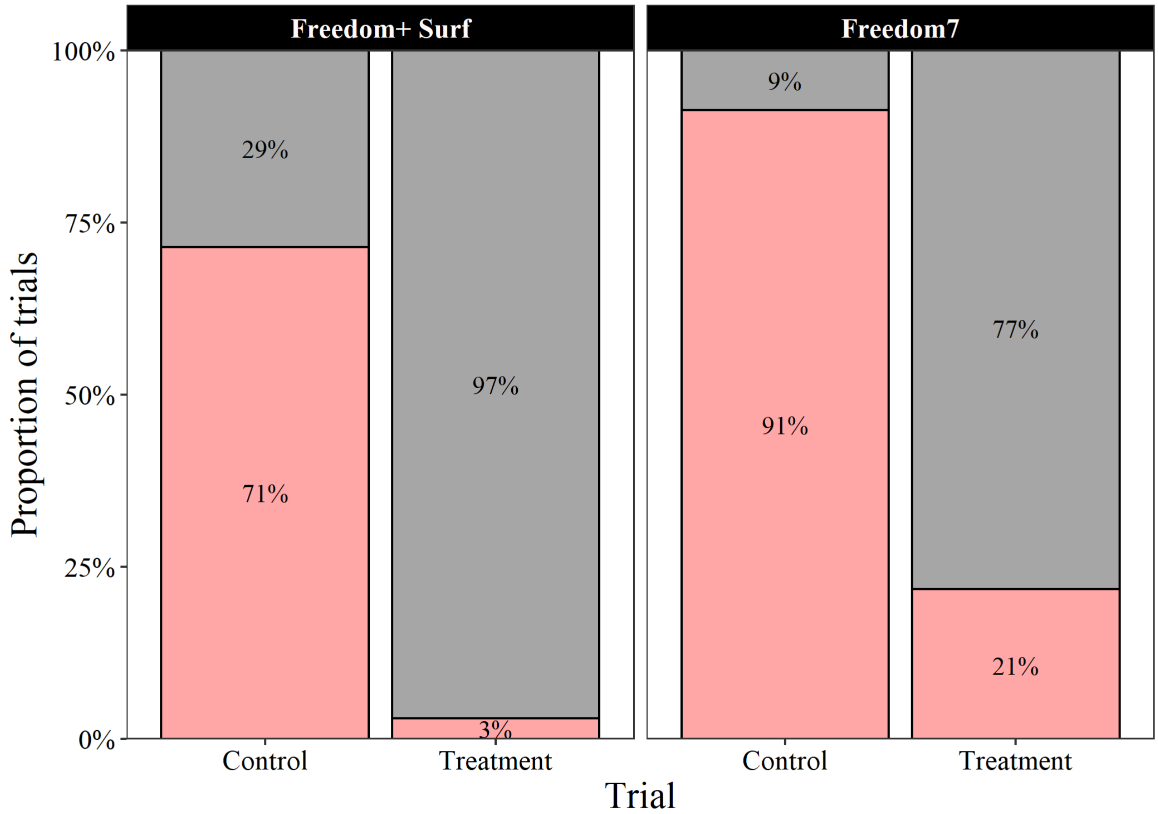


Figure 3. Proportion of trials that resulted in bites (red) vs. non-bites (black) during Ocean Guardian deterrent trials on tiger sharks *Galeocerdo cuvier.*

Table 3. Model summaries of the top four models estimating effects of a) Freedom+ Surf, and b) Freedom7 on the likelihood of a bite from bull, tiger, and white sharks. AIC_c: Akaike's information criterion corrected for small sample size; ΔAIC_c: difference in AIC_c between the current and top-ranked model; $wAIC_c$: model probability; R_m: marginal (fixed effects) R^2. All models include shark ID as a random factor (1|ID).

Model	df	logLik	AIC_c	ΔAIC_c	$wAIC_c$	R_m
a) Freedom+ Surf						
Bite ~ deterrent + species + trial + deterrent*species + species*trialset	**9**	**-157.262**	**333.0**	**0**	**0.685**	**0.68**
Bite ~ deterrent + species + trial + deterrent*species + species*trialset + deterrent*trialset	10	-157.232	335.1	2.05	0.246	0.69
Bite ~ deterrent + species + trial + species*trialset	7	-162.731	339.8	6.75	0.023	0.59
Bite ~ deterrent + species + trial + deterrent*species + species*trialset	8	-161.929	340.3	7.23	0.018	0.59

b) Freedom7

Bite ~ deterrent + species + deterrent*species	**4**	**-119.994**	**248.2**	**0**	**0.882**	**0.3**
Bite ~ deterrent + species + deterrent*species + trial:trip	7	-119.164	252.8	4.68	0.085	0.3
Bite ~ deterrent + species + deterrent*species + trial:trip + Species*trial:trip	8	-119.041	254.8	6.58	0.033	0.3
Bite ~ deterrent + species	3	-137.443	281.0	32.83	0	0.11

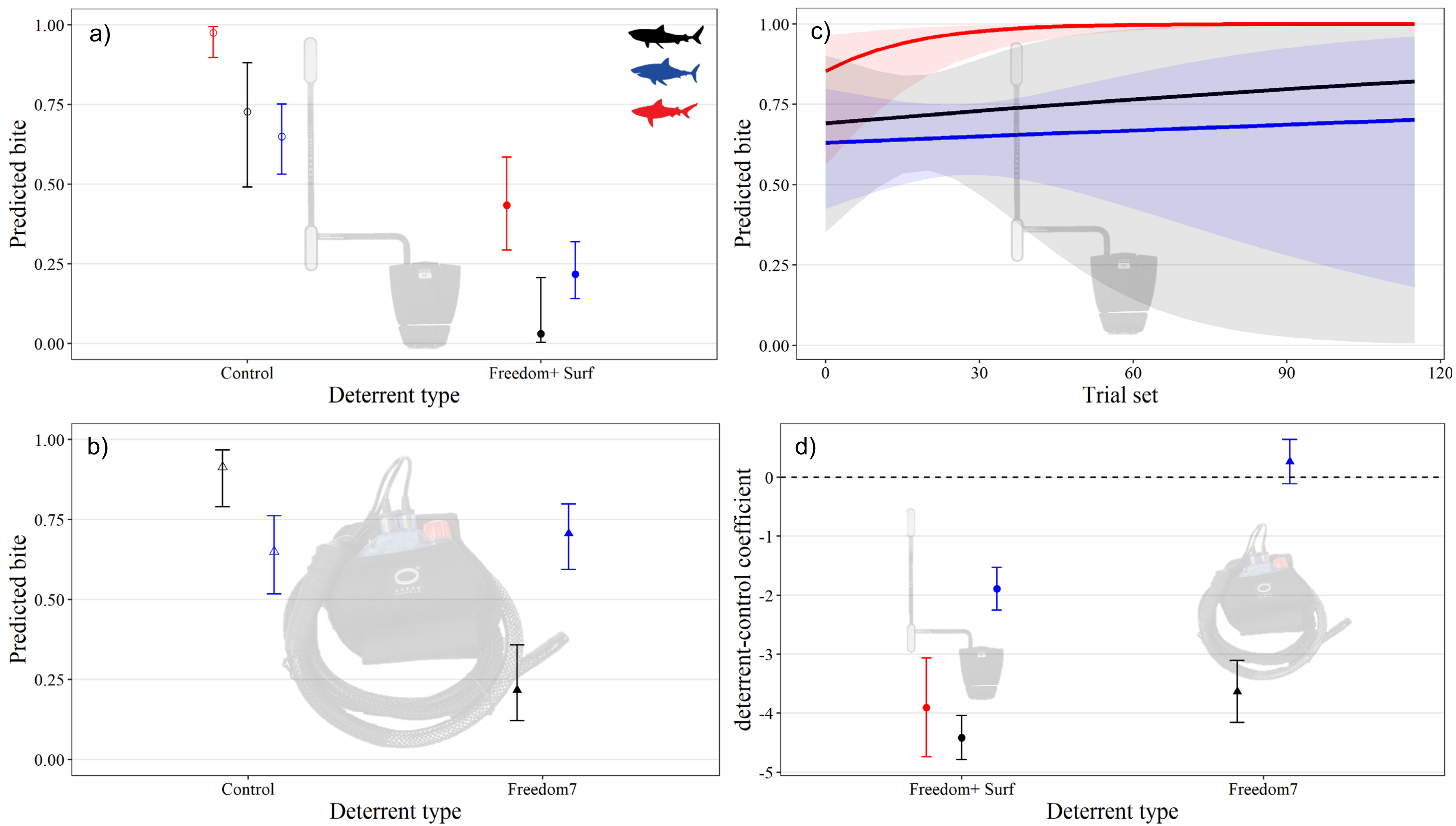


Figure 4. Predicted likelihood (marginal means) of a bite from bull (red), tiger (black), and white sharks (blue) during a) Freedom+ Surf, and b) Freedom7 trials; c) interaction between trial set and species; and d) deterrent-control coefficient values from linear mixed models. Circle symbols indicate Freedom+ Surf and triangles are Freedom7 products. Filled symbols represent active trials, empty symbols are control trials.

4.3 Time for bites to occur

Freedom+ Surf

The time it took for tiger sharks to take the bait ranged from 0.66 – 15 minutes (mean = 5.86 ± 0.8, n = 26). One tiger shark bite was by an unidentified individual during a control trial and was removed from the analysis to enable mixed models to be used. Three white shark bites (5% of bites) and 44 bull shark bites (37%) were from unidentified individuals and were also removed from analysis. Time for a bite to occur was influenced by deterrent (R_m = 1%), species (R_m = 14%), and trial set (R_m = 16%), but not the interaction between these factors ($wAIC_c$ = 0.37, Table 4a). Predicted time for a bite to occur increased by 47% when the deterrent was active (Fig. 5a). Bull sharks were fastest to bite, followed by white sharks, and tiger sharks being the slowest (Fig. 5b). Time for a bite to occur decreased throughout the studies (Fig. 5c). Individual shark also affected the time for a bite to occur, with 16% of the model variance explained by shark ID.

Freedom7

The time for bites to occur ranged from 0.1 – 14.49 minutes (mean = 5.86 ± 0.8, n = 49). The Freedom7 deterrent type (i.e., control *vs*. treatment; R_m = 10%) and species (tiger *vs*. white shark; R_m = 1%) influenced the time for a bite to occur ($wAIC_c$ = 0.31). Fifteen white shark bites (16%) and one tiger shark bite (2%) occurred from unidentified individuals, and were removed from analyses. There was also variation in time for bite to occur between individual sharks, with 2% of the variation explained by shark ID. There was no effect of trial (nested within trip number) on the time taken for a bite to occur. The Freedom7 product increased the time for a bite to occur by 76% (Fig. 5d), however, white sharks were faster to bite when compared to tiger sharks (Fig. 5e).

Table 4. Model summaries of the top four models estimating effects of a) Freedom+ Surf, and b) Freedom7 on time for a bite to occur from bull, tiger, and white sharks. AIC_c: Akaike's information criterion corrected for small sample size; ΔAIC_c: difference in AIC_c between the current and top-ranked model; $wAIC_c$: model probability; R_m: marginal (fixed effects) R^2. All models include shark ID as a random factor (1|ID).

Model	df	logLik	AIC_c	ΔAIC_c	$wAIC_c$	Rm	Rc
a) Freedom+ Surf							
$_{log}$Timebite ~ deterrent + species + trialset	24	-177.12	411.6	0.00	0.37	0.15	0.31
$_{log}$Timebite ~ deterrent + species + trialset + species*trialset	27	-172.82	412.4	0.78	0.25	0.17	0.33
$_{log}$Timebite ~ deterrent + trialset	25	-175.79	414.0	2.41	0.11	0.15	0.31
$_{log}$Timebite ~ deterrent + species + trialset + deterrent*species	26	-175.82	415.2	3.63	0.06	0.15	0.31
b) Freedom7							
$_{log}$Timebite ~ deterrent + species	10	-161.09	344.6	0.00	0.31	0.1	0.12
$_{log}$Timebite ~ deterrent + trialset:trip	10	-161.57	346.0	1.46	0.15	0.11	0.13
$_{log}$Timebite ~ deterrent	10	-161.07	346.2	1.62	0.14	0.08	0.1
$_{log}$Timebite ~ deterrent + species + deterrent*species	11	-161.03	346.8	2.26	0.10	0.1	0.12

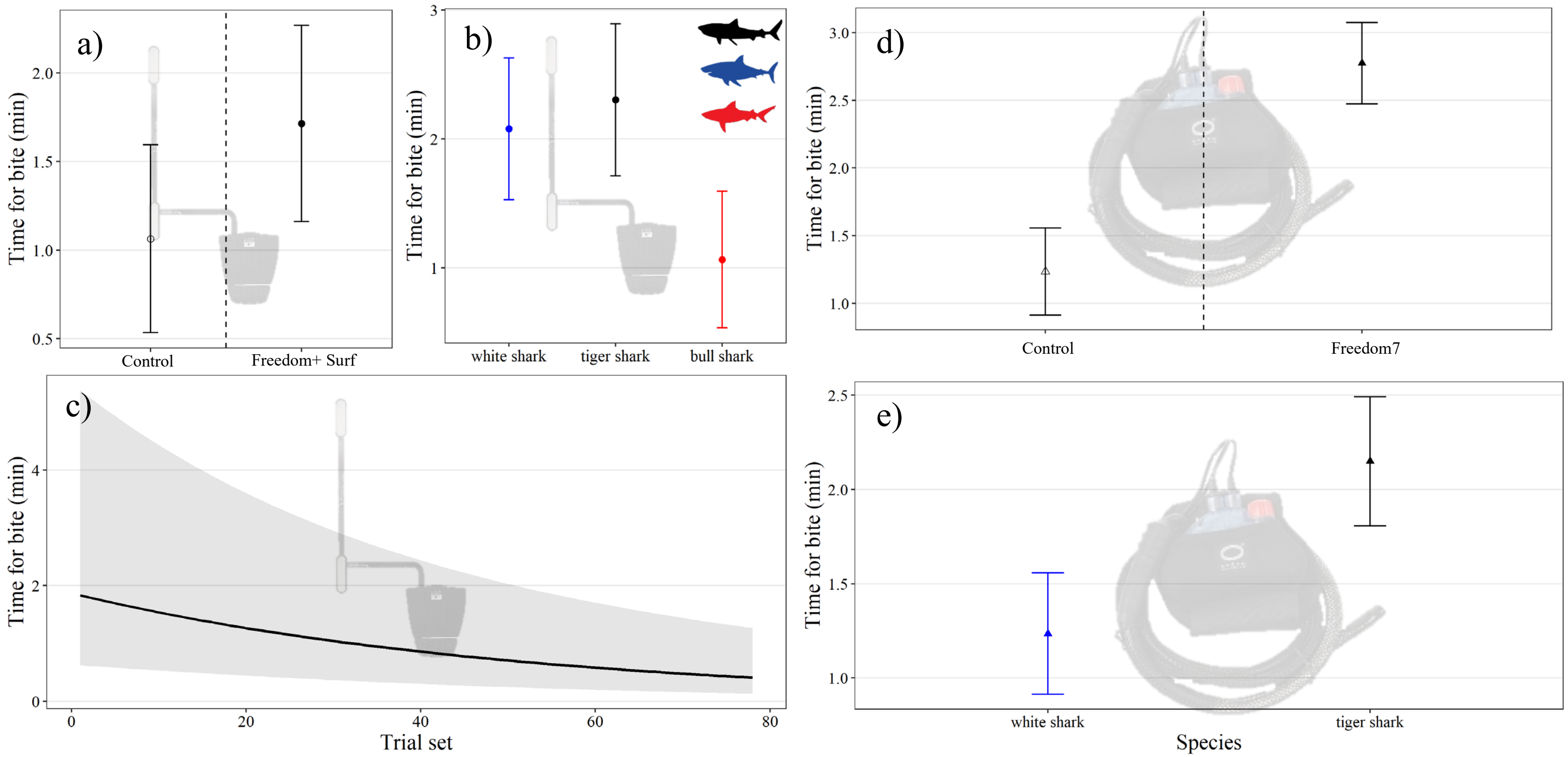


Figure 5. Predicted time (marginal means, log transformation) of bite on bait or board during a – c) Freedom+ Surf and d – e) Freedom 7 trials. Black symbols represent tiger sharks, red represents bull sharks, and black is white sharks.

4.4 Number of passes

Freedom+ Surf

There were 373 passes during tiger sharks Freedom+ Surf trials, with similar number of passes during control and treatment trials (196 vs. 177 passes respectively). This contradicts previous studies showing an increase in the number of passes when the Freedom+ Surf was active in bull and white sharks. The number of passes per shark ranged between 1–17 per trial. Twenty passes were from unidentified tiger sharks. By comparison, 59 white shark passes (581 passes remaining) and 248 bull shark passes were from unidentified individuals (207 passes remaining). The top-ranked model included deterrent type, species, and the interaction between these factors. Marginal mean predictions were therefore calculated including passes from identified sharks to maximise sample size. Species had the largest effect on number of passes per trial (R_m = 7%), followed by the deterrent (R_m = 5%). However, individual sharks also influenced the number of passes, with shark ID explaining 13% of variation. Trial set did not affect pass frequency (Table 5a). Bull sharks (2.3 ± 0.9 vs. 3.6 ± 0.9 passes per trial control and treatment respectively) and white sharks (3.3 ± 0.8 vs. 5.8 ± 0.8) showed significant increases in pass frequency when the Freedom+ Surf was active, with no changes observed for tiger sharks (3.3 ± 0.9 vs. 3.7 ± 0.9; Fig. 6a).

Freedom7

Tiger sharks passed deterrent boards 789 times during Freedom7 trials and this increased during treatment trials (571 passes) compared to control trials (218 passes). Individual sharks passed the deterrent board 1–15 times per trial. Of these passes, 42 (5%) were by unidentified individuals. By comparison, 234 out of 764 passes from white sharks were by unidentified sharks. As for the Freedom+ Surf model, excluding unidentified sharks did not affect which factors were included in the top-ranked model nor the AIC_c (*w*AICc = 0.53), with deterrent the only fixed factor influencing number of passes (5% variation). There was no effect of species or trial set on number of passes during Freedom7 trials (Table 5b). Individual sharks, however, affected the number of passes, with this factor explaining 3% of the model variation. Predicted passes per trial increased when the deterrent was active, from 1.8 ± 0.1 to 3.42 ± 0.7 (Fig. 6b), and there was no difference between white and tiger sharks.

Table 5. Model summaries of the top four models estimating effects of a) Freedom+ Surf, and b) Freedom7 on number of passes from bull, tiger, and white sharks. AIC_c: Akaike's information criterion corrected for small sample size; ΔAIC_c: difference in AIC_c between the current and top-ranked model; $wAIC_c$: model probability; R_m: marginal (fixed effects) R^2. All models include shark ID as a random factor (1|ID).

Model	df	logLik	AIC_c	ΔAIC_c	$wAIC_c$	R_m	R_c
a) Freedom+ Surf							
passes ~ deterrent + species + deterrent*species	42	-1158.8	2411.6	0.00	0.95	0.1	0.23
passes ~ deterrent + species	39	-1166.0	2417.9	6.29	0.04	0.07	0.20
passes ~ deterrent	41	-1164.1	2420.1	8.47	0.01	0.07	0.20
passes ~ species	35	-1186.5	2449.6	37.96	0.00	0.02	0.15
b) Freedom7							
passes ~ deterrent	20	-1100.9	2243.9	0.00	0.53	0.06	0.09
passes ~ deterrent + species	21	-1100.7	2245.6	1.74	0.22	0.06	0.09
passes ~ deterrent +trial:trip	23	-1099.0	2247.2	3.28	0.10	0.06	0.09
passes ~ deterrent + species + deterrent*species	22	-1100.5	2247.7	3.82	0.08	0.06	0.09

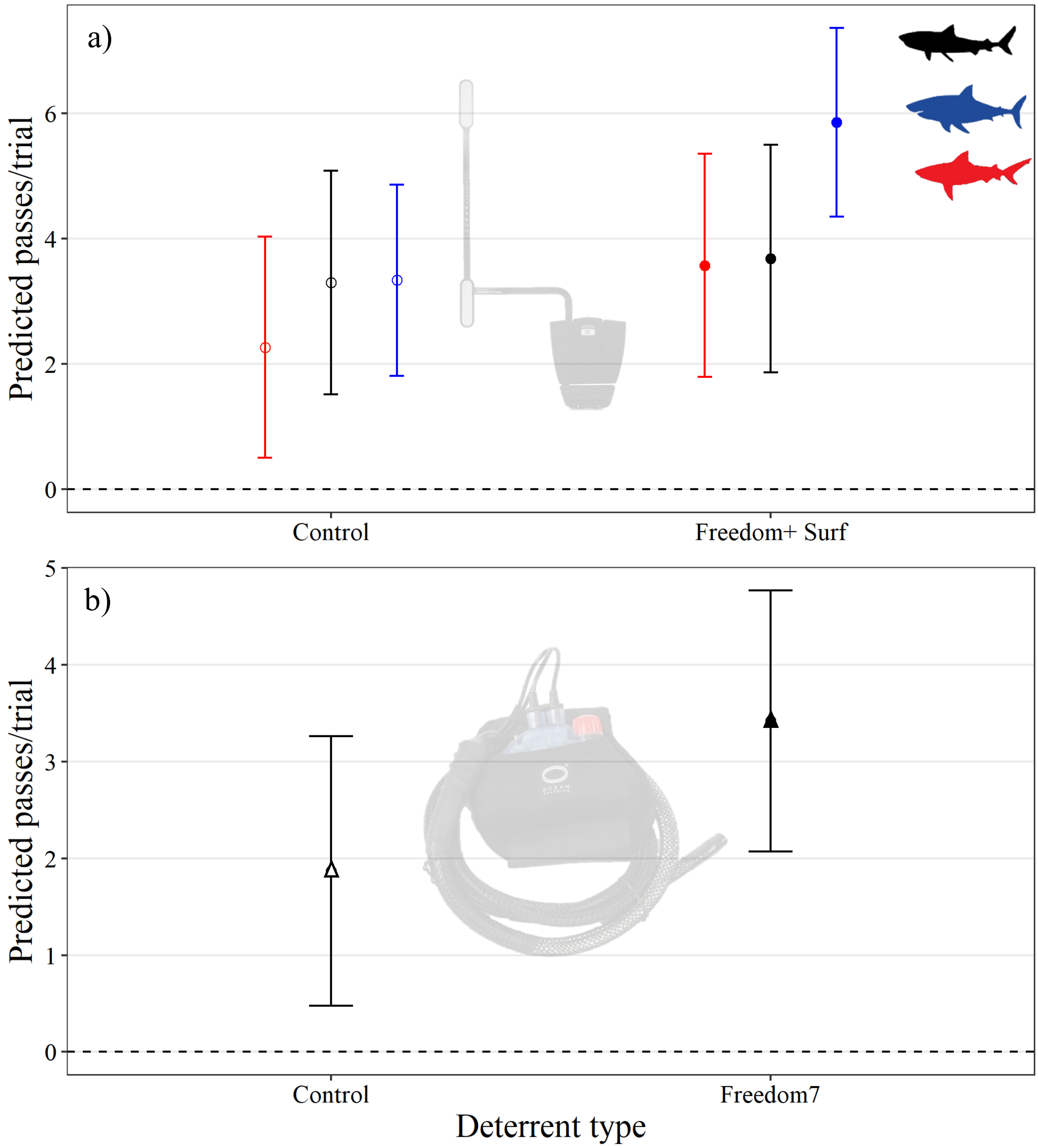


Figure 6. Predicted number of passes (marginal means) from individuals during a) Freedom+ Surf and b) Freedom 7 trials. Black symbols represent tiger sharks, red represents bull sharks, and blue is white sharks.

4.5 Failed bites and board nudges

Freedom+ Surf

During tiger shark Freedom+ Surf trials, 33 failed bites and 64 nudges were observed. No failed bites or board nudges occurred from sharks that were unable to be identified. from Deterrent type (i.e., treatment or control) had no influence on the number of failed bites from tiger sharks ($wAIC_c$ = 0.88, Table 6a). However, the number of nudges on the bait or board decreased when the deterrent was active ($wAIC_c$ = 0.44; 0.87 ± 0.2 – 0.0 3 ± 0.2; Table Fig. 7a). There was a high amount of individual variation in the frequency of failed bites and nudges, with 17% and 10% of the data variation attributed to shark ID respectively (Table 6a). There was no effect of trial number on either failed bites or nudges on boards.

Freedom7

Freedom7 tiger shark trials had 161 failed bites, and 363 board nudges. No failed bites or board nudges occurred from sharks that were unable to be identified. Deterrent type had an effect on both the number of failed bites and board nudges during Freedom7 Trials ($wAIC_c$ = 0.99 and 0.85 respectively; Table 6b). Both behaviours decreased in frequency when the Freedom7 was active (Fig. 7), which had a slightly larger effect on nudges compared to failed bites (Fig. 7). Shark ID largely influenced failed bites and board nudges, explaining 27% and 15% of the data variation respectfully. There was no effect of trial number on the frequency of failed bites or nudges during tiger shark trials (Table 6b).

Table 6. Model summaries of the top four models estimating effects of a) Freedom+ Surf, and b) Freedom7 on failed bites and nudges from bull, tiger, and white sharks. AIC_c: Akaike's information criterion corrected for small sample size; ΔAIC_c: difference in AIC_c between the current and top-ranked model; $wAIC_c$: model probability; R_m: marginal (fixed effects) R^2. All models include shark ID as a random factor (1|ID).

Model			df	logLik	AIC_c	ΔAIC_c	$wAIC_c$	R_m	R_c
a)	Freedom+ Surf	failedbites ~ 1 (Intercept)	3	-112.4	231.1	0.0	0.88	0.0	0.17
		failedbites ~ deterrent type	4	-113.5	235.3	4.2	0.11	>0.01	0.13
		failedbites ~ trialset	4	-115.4	239.2	8.1	0.02	0.03	0.17
		failedbites ~ deterrent type + trialset	5	-116.4	243.5	12.4	0.00	0.03	0.17
		nudges ~ deterrent type	4	-169.5	347.3	0.0	0.44	0.1.0	0.21
		nudges ~ deterrent type + trialset	5	-168.7	348	0.6	0.32	0.22	0.22
		nudges ~ deterrent type + trialset + deterrent type*trialset	6	-167.8	348.6	1.3	0.23	0.27	0.27
		nudges ~ trialset	4	-173.6	355.6	8.3	0.01	0.13	0.13
b)	Freedom7	failedbites ~ deterrent type	4	-435.1	878.2	0.0	0.99	0.05	0.31
		failedbites ~ deterrent type + trialset	5	-438.8	887.6	9.4	0.01	0.06	0.34
		failedbites ~ deterrent type + trialset + deterrent type*trialset	6	-442.2	896.6	18.3	0.00	0.07	0.34
		failedbites ~ 1 (Intercept)	3	-453.7	913.5	35.2	0.00	0.00	0.25
		nudges ~ deterrent type	4	-1074.4	2156.8	0.0	0.85	0.06	0.23
		nudges ~ deterrent type + trialset + deterrent type*trialset	6	-1074.4	2161	4.2	0.10	0.11	0.32
		nudges ~ deterrent type + trialset	5	-1076.3	2162.7	5.9	0.04	0.09	0.30
		nudges ~ 1 (Intercept)	3	-1097.2	2200.5	43.7	0.00	0.00	0.17

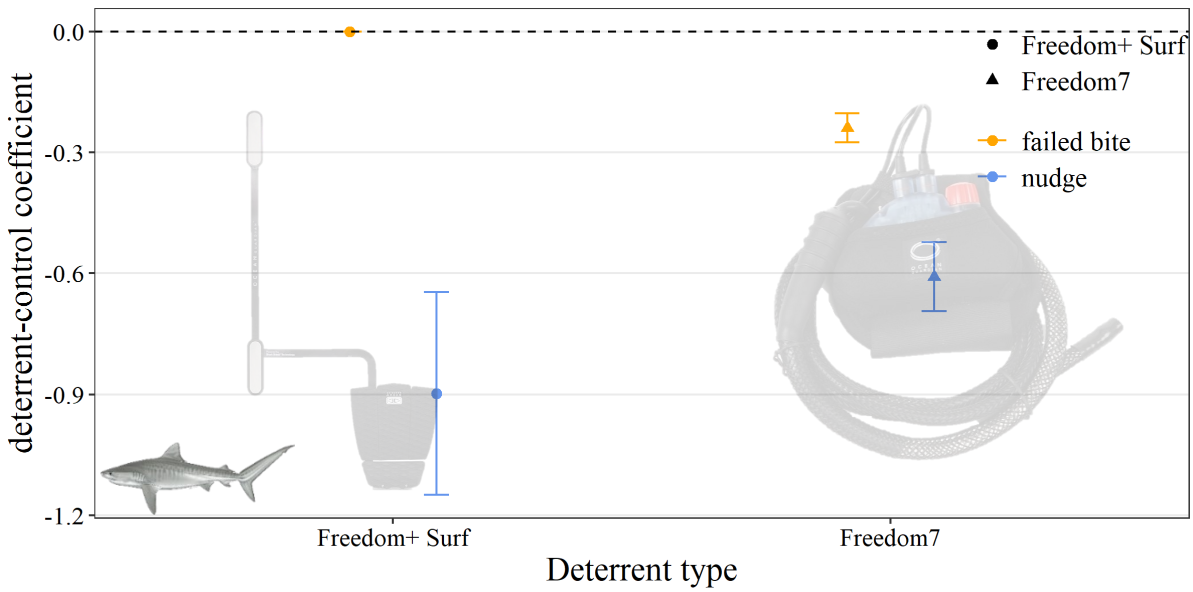


Figure 7. Deterrent-control coefficient values from linear mixed models indicating effect of Ocean Guardian Products on failed bites and board nudges. Circles indicate Freedom+ Surf and triangles are Freedom7 products. Filled symbols represent active trials, empty symbols are control trials.

4.6 Reactions

Freedom+ Surf

Tiger sharks displayed reactions 178 times during Freedom+ Surf trials. The frequency of reactions during passes was affected by deterrent and species, and the interaction between these factors ($wAIC_c$ = 0.970, Table 7a). There was no change in reaction frequency over trial sets. However, there was a large effect of individual shark ID on the frequency of reactions, with 20% of the variance explained by the random effect (Table 4). Despite tiger sharks passing less frequently during trials when the Freedom+ Surf was active (treatment), reactions significantly increased when the deterrent was active (37% increase in frequency, Fig. 8a). However, tiger sharks still displayed reactions when the deterrent was inactive, with 30% of passes displaying reactions during control trials (Fig. 8a). Bull and white sharks also increased reaction frequency with an active deterrent by 63% and 17% respectfully (Fig. 8a).

The number of eye twitches ($wAIC_c$ = nictitating, 0.98) or jaw gapes ($wAIC_c$ = 0.60) per pass increased when the Freedom+ Surf was active (Table 7c, d; Fig. 8c) and was strongly influenced by shark ID (nictitating = 26%, jaw gape = 47% of the data variation).

Freedom7

During Freedom7 tiger shark trials, 291 reactions were recorded during passes. As was observed with the Freedom+ Surf model, deterrent type (i.e., whether the deterrent was active or inactive) during Freedom7 trials strongly influenced the occurrence of reactions of tiger sharks during passes ($wAIC_c$ = 0.98, Table 7a), with no temporal effect of trial number. No reaction data was available for white sharks during Freedom7 trials. There was a 28% increase in the frequency of reactions during passes when the Freedom7 was active, from 10 – 29% of passes resulting in reactions during control and treatment trials, respectively (Fig. 9b). There was also variation in reaction frequency between individual sharks, with ID explaining 9% of the data variation (Table 7b).

Deterrent type and trial set influenced the number of eye twitches (nictitating) per pass ($w\text{AIC}_c$ = 0.532; Table 7b). Nictitating increased 27% when the Freedom7 was active (1.8 ± 0.2 vs 2.3 ± 0.1 per pass; Fig. 8c), but it also decreased over time. Jaw gaping was only influenced by deterrent ($w\text{AIC}_c$ = 0.7), increasing when the Freedom7 was active (Fig. 8c). There was no effect of trial set on jaw gaping during Freedom7 trials. Time into trial did not influence nictitating or jaw gaping, indicating that the temporal effect was over the sampling period rather than within trials.

Table 7. Models estimating effects of deterrents a) Freedom+ Surf, and b) Freedom7 on the frequency of reactions from tiger sharks, bull sharks, and white sharks. AIC_C: Akaike's information criterion corrected for small sample size; ΔAIC_C: difference in AIC_C between the current and top-ranked model; $wAIC_C$: model probability; Rm: marginal (fixed effects) R^2; Rc, conditional (fixed and random effects) R2. All models include shark ID as a random factor (1|ID).

Model	df	logLik	AIC_c	ΔAIC_c	$wAIC_c$	R_m	R_c
Reactions (Binomial)							
a) Freedom+ Surf							
reactions ~ deterrent type + species + deterrent type*species	8	-558.2	1132.6	0.00	0.99	0.30	0.33
reactions ~ deterrent + trialset + species + deterrent type*species	9	-564.4	1146.9	14.34	>0.01	0.30	0.33
reactions ~ deterrent type + species + deterrent type*species + deterrent type*trialset	10	-569.8	1159.7	27.17	0.00	0.30	0.33
reactions ~ deterrent type + species	6	-577.2	1166.5	33.99	0.00	0.26	0.3
b) Freedom7							
Reactions ~ deterrent type	4	-478.6	965.2	0.0	0.99	0.07	0.14
Reactions ~ deterrent type + trialset	5	-483.4	977	11.7	>0.01	0.07	0.15
Reactions ~ 1 (Intercept)	3	-503.7	1013.4	48.2	0.00	0.00	0.90
Reactions ~ trialset	4	-508.9	1025.8	60.6	0.00	>0.01	0.10
Reactions per pass							
c) Freedom+ Surf - Nictitating							
Nictitating ~ deterrent type	4	-210.0	428.3	0.0	0.98	0.11	0.27
Nictitating ~ deterrent type + trialset	5	-212.7	436.0	7.7	0.02	0.12	0.27
Nictitating ~ 1 (Intercept)	3	-216.8	439.8	11.4	0.00	0.00	0.2
Nictitating ~ deterrent type + time	5	-216.0	442.6	14.3	0.00	0.12	0.27
d) Freedom+ Surf – Jaw Gape							
Jaw gape ~ deterrent	4	-44.7	98.8	0.00	0.60	0.07	0.54
Jaw gape ~ 1 (Intercept)	3	-46.5	99.7	0.93	0.38	0.00	0.54
Jaw gape ~ deterrent + trialset	5	-47.2	106.4	7.61	0.01	0.10	0.55
Jaw gape ~ trialset	4	-48.7	106.6	7.88	0.01	0.05	0.53
e) Freedom7 - Nictitating							
Nictitating ~ deterrent type + trialset	5	-335.8	681.9	0.00	0.53	0.14	0.19
Nictitating ~ trialset	4	-337.4	683.1	1.20	0.29	0.11	0.16
Nictitating ~ deterrent type	4	-338.3	684.8	2.94	0.12	0.02	0.13
Nictitating ~ 1 (Intercept)	3	-340.2	686.6	4.72	0.05	0.00	0.12
f) Freedom7 – Jaw Gape							
Jaw gape ~ deterrent	4	-212.1	432.6	0.00	0.70	0.02	0.06
Jaw gape ~ 1 (Intercept)	3	-214.1	434.4	1.8	0.28	0.00	0.05
Jaw gape ~ deterrent + trialset	5	-215.2	440.9	8.3	0.01	0.04	0.08
Jaw gape ~ trialset	4	-216.9	442.1	9.5	0.01	0.02	0.07

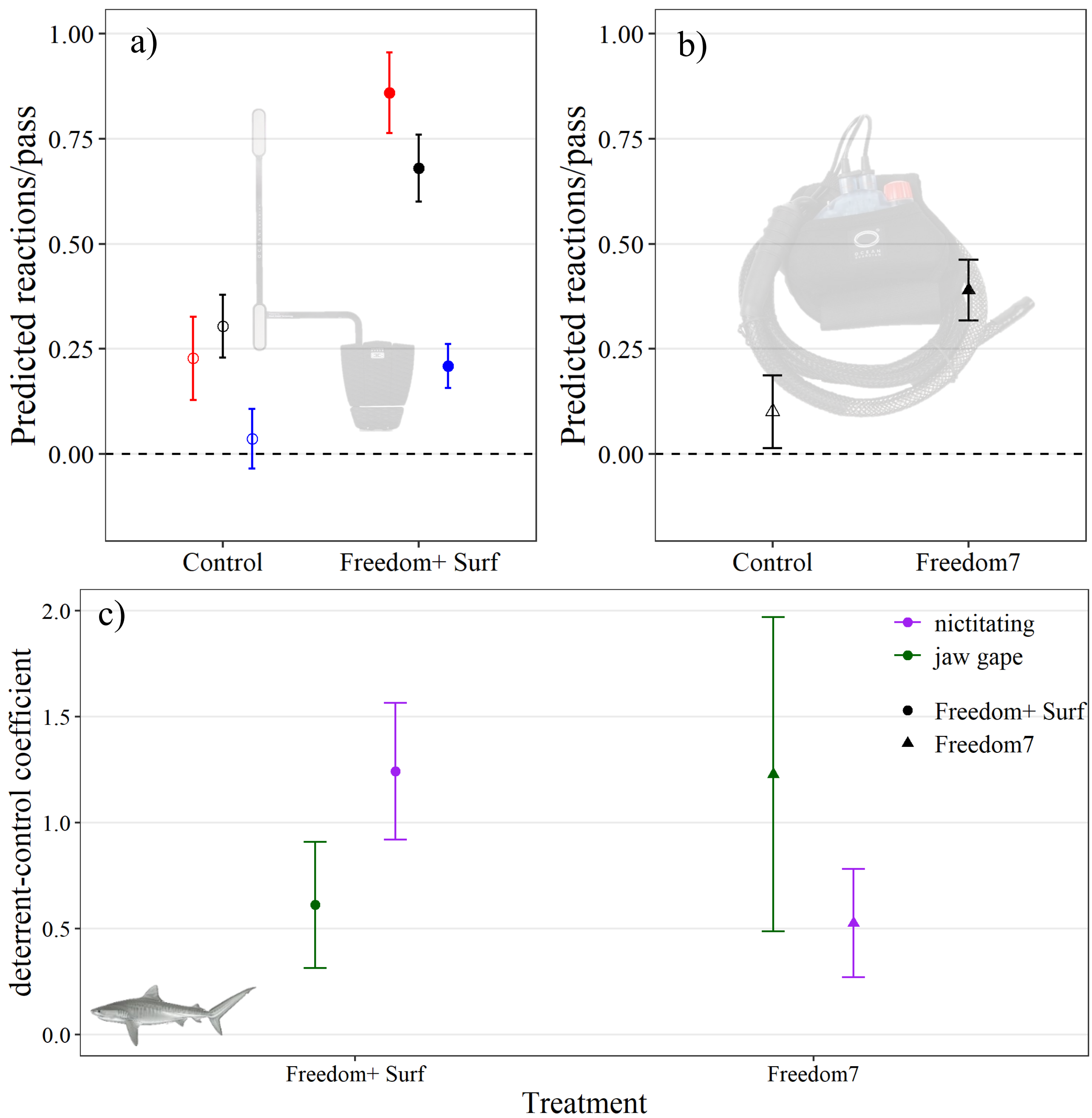


Figure 8. Predicted frequency of reactions (marginal means) during passes from bull (red), tiger (black) and white sharks (blue) during a) Freedom+ Surf, b) Freedom7 trials; and c) deterrent-control coefficient values for reaction types during tiger shark trials. Circles indicate Freedom+ Surf and triangles are Freedom7 products. Filled symbols represent active trials, empty symbols are control trials.

4.7 Behaviour states

Freedom+ Surf

Behaviour states of tiger sharks during Freedom+ Surf trials were coded from 82,507 s (1,375 minutes) of observed footage. This included 21,658 s where the individual shark could not be identified and was subsequently removed from analyses, leaving 60,849 s of coded behaviours. Sharks were most often outside of the field of view (62,850 s, n = 249 events), followed by patrolling (12,408 s; 388 events), approaching (4,725 s; 249 events), swimming away (2,261 s; 138 events) and gliding (261 s; 15 events). The Freedom+ Surf product (deterrent type) increased the duration that sharks spent gliding, outside field of view, and patrolling (Table 8a, Fig. 9). Trial set influenced time spent approaching (Table 8a), decreasing over time (Fig. 9). Duration that sharks were swimming away was influenced by the interaction between deterrent and trial set (Table 8a), increasing during control trials but decreasing during treatment (Fig. 9).

Freedom7

During Freedom7 trials, 99,642 s (1,660 minutes) of vision was coded into behavioural states. From this, 22,314 seconds was from unidentified sharks and consequently were removed, with 77,328 s of behavioural data remaining. Sharks were also most often out of the field of view (60,632 s, n = 569 events), followed by approach (6,891 s; 528 events), patrolling (5,792 s; 298 events), swimming away (3,964 s; 364 events), and gliding (46 s; 4 events). Duration that sharks spent outside the field of view ($w\text{AIC}_c$ = 0.2), and swimming away ($w\text{AIC}_c$ = 0.45) was influenced by deterrent type, increasing when the Freedom7 was active (Fig. 9). Approaching ($w\text{AIC}_c$ = 0.77) and patrolling ($w\text{AIC}_c$ = 0.64) were both influenced by the interaction between deterrent and trial set, increasing in duration during control trials, but decreasing during treatment (Fig. 10).

Table 8. Models estimating effects of deterrents a) Freedom+ Surf, and b) Freedom7 on time spent in behaviour states by tiger sharks. AIC_C: Akaike's information criterion corrected for small sample size; ΔAIC_C: difference in AIC_C between the current and top-ranked model; $wAIC_C$: model probability; Rm: marginal (fixed effects) R^2; Rc, conditional (fixed and random effects) R^2.

Product	Model	df	logLik	AIC_c	ΔAIC_c	$wAIC_c$	R_m	R_c
a) **Freedom+ Surf**	approach ~ trialset + (1|ID)	8	-653.4	1325.9	0.00	0.32	0.02	0.06
	approach ~ (1|ID)	7	-655.3	1326	0.06	0.31	0.00	0.04
	approach ~ trialset + deterrent*trialset + (1|ID)	10	-651.8	1327.4	1.45	0.16	0.04	0.08
	approach ~ deterrent + (1|ID)	8	-655.3	1328.2	2.28	0.1	>0.01	0.04
	glide ~ deterrent + (1|ID)	4	-409.2	828.4	0.00	0.21	0.02	0.02
	glide ~ (1|ID)	3	-410.5	829	0.55	0.16	0	>0.01
	glide ~ deterrent	3	-411.4	829	0.57	0.15	0.02	0.02
	glide ~ 1 (intercept)	2	-412.8	829.6	1.19	0.11	0.00	0.00
	out ~ deterrent + (1|ID)	11	-862.9	1752	0.00	0.5	0.06	0.11
	out ~ deterrent + trialset + (1|ID)	12	-862.8	1753.6	1.59	0.22	0.06	0.11
	out ~ deterrent + trialset + deterrent*trialset + (1|ID)	13	-862	1754.6	2.63	0.13	0.07	0.12
	out ~ deterrent	3	-875	1756.1	4.03	0.07	0.01	0.06
	patrolling ~ deterrent + (1|ID)	13	-715.9	1461.9	0.00	0.51	0.04	0.18
	patrolling ~ deterrent + trialset + (1|ID)	14	-715.5	1463.1	1.25	0.27	0.04	0.18
	patrolling ~ (1|ID)	12	-718.7	1465.4	3.54	0.09	0.00	0.14
	patrolling ~ deterrent + trialset = deterrent*trialset + (1|ID)	15	-715.5	1465.6	3.76	0.08	0.04	0.18
	swimmingaway ~ deterrent + trialset + det*trialset + (1|ID)	11	-534.8	1094.2	0.00	0.90	0.12	0.14
	swimmingaway ~ deterrent + trialset + deterrent*trialset	4	-544.4	1099.3	5.04	0.07	0.09	0.11
	swimmingaway ~ deterrent + (1|ID)	7	-543.3	1102.5	8.31	0.01	0.03	0.05
	swimmingaway ~ deterrent + trialset + (1|ID)	8	-542.3	1104.1	9.82	>0.01	0.04	0.06
b) **Freedom7**	approach ~ deterrent + trialset + det*trialset + (1|ID)	15	-1001.9	2036.4	0.0	0.77	0.07	0.12
	approach ~ deterrent + (1|ID)	12	-1005.9	2039.7	3.4	0.15	0.03	0.08
	approach ~ deterrent + trialset + (1|ID)	13	-1005.8	2041.4	5.0	0.06	0.04	0.09
	approach ~ (1|ID)	11	-1010.7	2044.8	8.5	0.01	0.00	0.05
	glide ~ 1 (Intercept)	2	-396.0	796	0.0	0.22	0.00	0.00

glide ~ (1|ID)	2	-396.0	796	0.0	0.22	0.00	>0.01
glide ~ deterrent	3	-395.7	797.6	1.6	0.10	>0.01	>0.01
glide ~ deterrent + (1|ID)	3	-395.7	797.6	1.6	0.10	>0.01	>0.01
out ~ deterrent	3	-1443.6	2893.3	0.0	0.20	0.17	0.17
out ~ deterrent + (1|ID)	3	-1443.6	2893.3	0.0	0.20	0.15	0.15
out ~ deterrent + trialset + deterrent*trialset	4	-1441.8	2893.9	0.6	0.15	0.18	0.18
out ~ deterrent + trialset + deterrent*trialset + (1|ID)	5	-1441.8	2893.9	0.6	0.15	0.16	0.16
patrolling ~deterrent + trialset + det*trialset + (1|ID)	12	-1028.8	2084.1	0.0	0.64	0.19	0.19
patrolling ~deterrent + trialset + deterrent*trialset	4	-1038.0	2086.4	2.3	0.20	0.19	0.19
patrolling ~deterrent + trialset + (1|ID)	12	-1030.9	2088.2	4.2	0.08	0.17	0.17
patrolling ~ deterrent + (1|ID)	11	-1032.0	2088.7	4.6	0.06	0.16	0.16
swimmingaway ~ deterrent + (1|ID)	13	-917.1	1862.2	0.0	0.45	0.12	0.12
swimmingaway ~ deterrent + trialset + deterrent*trialset + (1|ID)	14	-915.7	1863	0.8	0.31	0.13	0.13
swimmingaway ~ deterrent + trialset + (1|ID)	13	-917.0	1863.4	1.2	0.25	0.12	0.12
swimmingaway ~ deterrent	3	-934.4	1874.9	12.7	>0.01	0.07	0.07

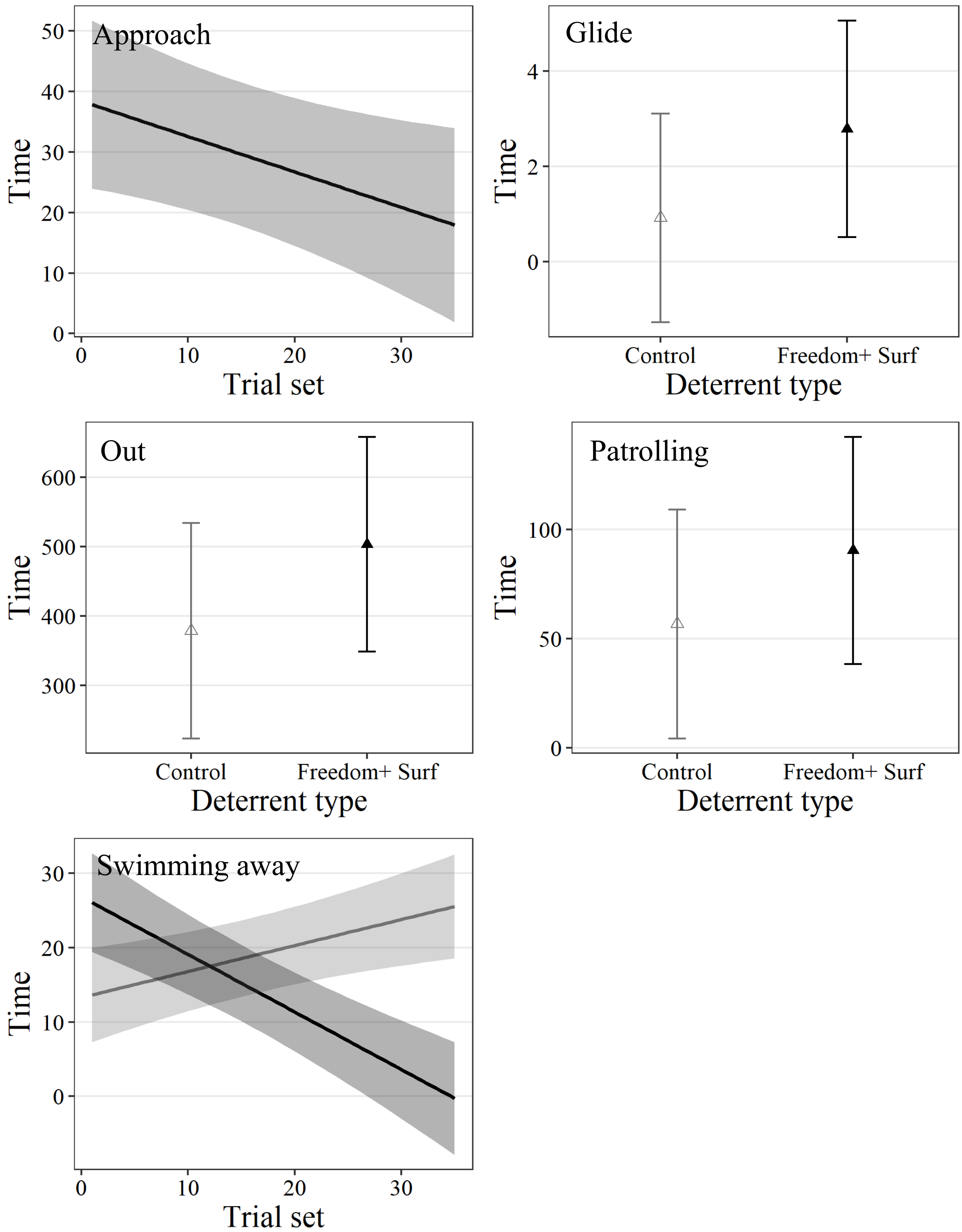


Figure 9. Predicted time in behaviour states (marginal means) from tiger sharks during Freedom+ Surf trials.

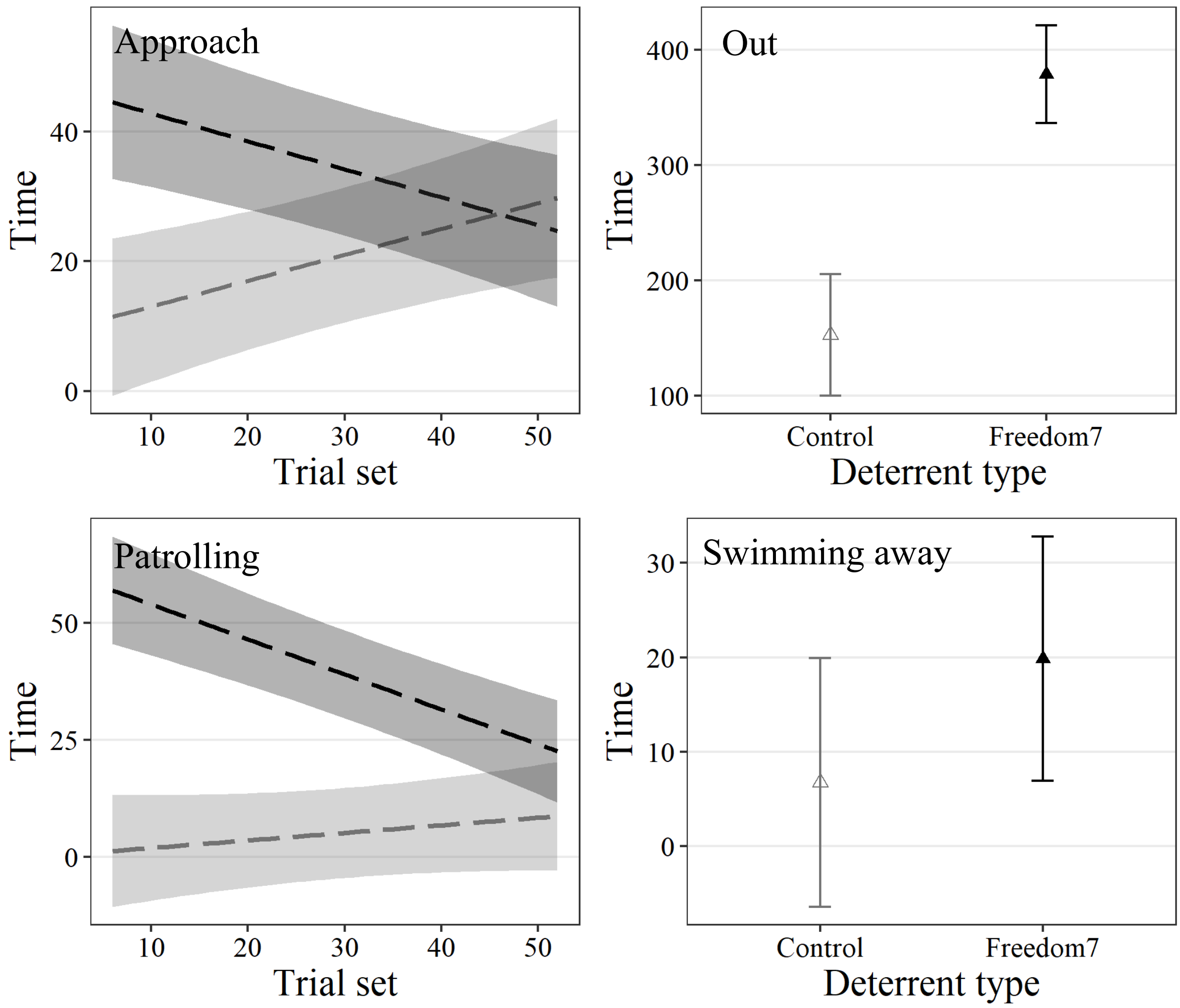


Figure 10. Predicted time in behaviour states (marginal means) from tiger sharks during Freedom7 trials.

5. DISCUSSION

5.1 Summary of findings – Tiger sharks

This is the first study to test the effects of the Ocean Guardian Freedom+ Surf and Freedom7 on the behaviour of tiger sharks *Galeocerdo cuvier*. Both products decreased the proportion of bites on the board or bait by ~70% (Table 9). Additionally, the deterrents increased the time for a bite to occur, number of passes, and frequency of reactions from tiger sharks, most notably for the Freedom7 compared to the Freedom+ Surf (Table 9). For all response variables, there was also a lot of variation among sharks, with some individuals being affected more than others. These findings indicate that both products affect tiger shark behaviour and can likely reduce shark bite risk. However, neither the Freedom+ Surf nor Freedom7 deterred sharks across all trials.

Table 9. Summary of the effects of Ocean Guardian's Freedom+ Surf and Freedom7 products on tiger shark behaviour during control (C) and treatment (T) trials. Colour of cells denotes intensity of the change in value (from yellow-green, pale green, to dark green).

Response variable	 Freedom+ Surf (C/T)	 Freedom7 (C/T)
Bites	↓ 69% (0.72 / 0.03)	↓ 70% (0.91 / 0.21)
Time for bite	↑ 13% (6.6 / 7.6)	↑ 42% (3.1 / 5.4)
Passes	↑ 12% (3.3 / 3.7)	↑ 79% (1.9 / 3.4)
Failed bites	No change	↓ 75% (0.32 / 0.08)
Board nudges	↓ 96% (0.9 / 0.03)	↓ 87% (0.7 / 0.09)
Reactions	↑ 126% (0.3 / 0.68)	↑ 290% (0.1 / 0.39)

5.2 Comparison to other priority species

The current and previous studies show that the Freedom+ Surf and Freedom7 can reduce the likelihood of shark bites across the three species most responsible for shark bites, but with varying degrees of behavioural responses (Huveneers et al. (2013a; 2018; white shark) and Gauthier et al. (2020; bull shark). For example, the reduction in the probability of a bite caused by the Freedom+ Surf varies from 43% in white sharks (Huveneers et al. 2018) to 70% for tiger shark (this study). Despite the effect of the Freedom+ Surf and Freedom7 on tiger shark bite risk being similar (~70%), it is very different for white sharks which were minimally affected by the Freedom7 (6% reduction; Huveneers et al. 2012, Huveneers et al. 2013b). In contrast, a previous study showed that the Freedom7 could lead to an 83% reduction in interactions (i.e. touch or taking of bait) (Kempster at al 2016). This differences between findings is likely due to the position of the baits in relation to the electrodes of the Freedom7. Huveneers et al. (2013b) placed the bait ~2–3 m from the deterrents to reproduce the distance between the deterrent and the head of a user, while Kempster et al. (2016) and this study placed the bait next to or between the electrodes (<0.5 m). The discrepancy between studies therefore shows that while these two products can reduce shark bite risk, it may only do so when the person wearing the device is close to the electrodes and that the position of the electrode is important (Kempster et al. 2016, Gauthier et al. 2020).

The ability of the Freedom7 or Freedom+ Surf to reduce shark bite risk is further supported by the time it took for sharks to take the bait increasing for all species when the deterrent was active. The only situation when this was not the case was with the Freedom+ Surf and tiger sharks. However, tiger sharks only took the bait once when the Freedom+ Surf was active, limiting the ability to estimate how long it would take tiger sharks to take a bait next to this deterrent. Although tiger sharks were on average slower to take baits than white sharks during control and treatment trials, white sharks had a greater increase in bite time when the Freedom7 was active. The number of passes per trial also increased for both deterrents and in all species, although the Freedom+ Surf only had a small effect on tiger sharks despite still increasing the number of passes. The increased amount of time to take the bait and number of passes when the deterrents were active suggests that even though sharks are able to consume baits, the deterrent can cause sharks to hesitate before taking the bait, providing water users more time to leave the water upon seeing a potentially dangerous shark nearby.

The Freedom+ Surf increases the frequency of reactions (i.e., jaw gape, head shake, nictitating, rapid withdrawal) of tiger, bull, and white sharks. Bull sharks showed the largest increase in reaction frequency (68%) when compared to tiger sharks (37%) and white sharks (17%). Reactions to the Freedom7 were only available for tiger sharks but showed a similar increase as during Freedom+ Surf trials (28%). The increased reactions from tiger sharks were attributed to raised frequency of nictitating and jaw gaping behaviours. The presence of a mobile nictitating membrane that can cover the surface of the eye is unique to carcharhiniforms such as tigers and bulls, being the largest order in terms of species among sharks (Hueter et al. 2004). Such flickering of the nictitating membrane of tiger sharks has been described around prey items during feeding (Lea et al. 2018, Tucker et al. 2019), and close encounters with co-specifics (Meyer et al. 2018). The structure of this membrane protects the surface of the eye from injury during quick manoeuvres during hunting (Poscai et al.

2017), but also when opening the jaw (Ritter & Godknecht 2000). The increase in reactions when deterrents were active is likely linked to disruption of the shark's electroreception system by the electric pulse produced by the deterrents but could also be a direct effect of the electric pulse on nerves or muscles that control the membrane. Electroreception coincides with the sharks vision to locate prey items (Kajiura et al. 2010), so the rapid opening and closing of the nictitating membrane to cover the eye may be a mechanical reaction to the pulsing from the electric deterrent. However as lamniformes, white sharks do not possess a nictitating membrane (Eschmeyer & Herald 1999), which might have contributed to white sharks showing the smallest increase in reactions when deterrents were active. Bull sharks showed the largest increase in reactions, which may indicate that their electroreception is more sensitive and prone to disruption than tiger and white sharks. These reactions were also observed during control trials for all species, albeit less frequently. Sharks may naturally perform these reactions during feeding behaviours, or the presence of an unfamiliar object in the water (i.e., deterrent board, boat engines).

5.3 Site comparisons

Tiger sharks at Norfolk Island were less likely to bite a bait or board compared to sharks from the Great Barrier Reef (Saunders Reef), even when deterrents were not active. In spite of this, the reduction in bites during treatment trials was similar across sites (i.e., 70% vs. 69%). This suggests that electric deterrents are similarly effective at reducing the likelihood of a bite even when sharks are frequently biting during control trials. Sharks at Norfolk Island were slightly larger than those from Saunders Reef. Body size may influence the ability of sharks to feed in a social situation (Munroe et al. 2014); however, sharks of larger body size have better feeding opportunities and more likely to bite a free-standing bait (Clua et al. 2013, Juhel et al. 2014). This again contradicts the likelihood that bites were more frequent at Saunders Reef due to shark size, given that tiger sharks were larger at Norfolk Island.

5.4 Habituation/Temporal change

The behavioural response to the Freedom7 was consistent across the trials but changed with the Freedom+ Surf. As individual sharks were repeatedly exposed to the surf product, the time for bites to occur decreased and sharks spent less time approaching the board. Sharks may have tried to minimise exposure to electrodes by either taking baits immediately, or not spending large amounts of time near the board. Additionally, the amount of time that sharks were approaching deterrent boards increased during trials for both products, which may indicate sharks becoming bolder to approach the board after initially being cautious. It is possible that if trials continued, sharks becoming bolder and more accustomed to deterrent boards may have resulted in more bites.

However, the number of trials and passes during which individual sharks were exposed to the deterrents in the current study is likely far greater and within a much shorter period than they would experience in a normal situation, even if a large proportion of ocean-goers used these deterrents. Therefore, any conditioning/habituation observed during the current study in unlikely to reflect what might occur during normal use of these deterrents with no baiting and berleying occurring. It is therefore likely not a major concern for realistic use as a personal deterrent during water activities (i.e., surfing, diving), although may be more of an issue for permanent installations of the technology such as barriers around swimming areas. Potential habitatuation to these deterrents has been observed previously (Kempster et al. 2016, Huveneers et al. 2018, Gauthier et al. 2020), but should be addressed directly in future research to reveal changes in shark behaviour over long periods exposed to deterrents.

5.5 Behaviour shifts

Both deterrent products led to an increase in the amount of time that tiger sharks spent patrolling and outside the field of view after first being sighted. This change in behaviour may be indicative of sharks maintaining a larger distance from the boards to avoid exposure to the active deterrents. While no distance data was collected, previous studies have found the Freedom+ Surf and Freedom7 to increase the mean distance that bull and white sharks pass the deterrent board (Kempster et al. 2016, Huveneers et al. 2018, Gauthier et al. 2020). In addition to increasing distance of passes, these findings suggest that sharks may also be completely avoiding the deterrents by patrolling at a greater distance away from the board or remaining outside of the field of view. Tiger sharks additionally spent more time approaching the rig during the Freedom+ Surf trials, although this was not observed in the Freedom7 trials. More time spent approaching the rig may indicate that sharks were more cautious in their approaches towards the boards, further highlighted by sharks being slower to bite when the deterrent was active. By contrast, during control trials, sharks were less hesitant in their approaches, often biting during their first approach and thus resulting in shorter duration in this behaviour state. Gliding behaviour, while occurring infrequently, increased in frequency when the Freedom+ Surf was active. Passive swimming, such as gliding on descent, and patrolling is associated with up to 50% in energy saving in fishes compared to swimming at a constant depth (Andrzejaczek et al. 2019). Most predatory epipelagic sharks and fish commonly glide to regulate efficient prey searching and energy saving through oscillatory movements, indicating that this behaviour can be an effective strategy during foraging and searching for prey (Gleiss et al. 2011, Meekan et al. 2015, Andrzejaczek et al. 2019). Raised frequency in this behaviour when deterrents are active may therefore be indicative of an energetic-saving strategy by sharks.

5.6 Limitations

Experiments at Norfolk Island and Saunders Reef used berley and bait to attract tiger sharks towards the research vessel, which may have modified the behaviour of the sharks on which the deterrents were tested. The need for sufficient experimental replicates necessitates choosing a place where many sharks aggregate and using berley to attract them (Huveneers et al. 2012, Huveneers et al. 2018). However, the deterrents tested are intended to repel sharks and decrease risks of a bite from a motivated shark and thus testing on highly motivated individuals is needed to represent a worst-case scenario. Ascendancy between individuals at feeding sites has been described for tiger sharks at feeding aggregations (Clua et al. 2013), whereby size and aggressiveness contribute to changing individuals feeding behaviour on a blue whale carcass. This study revealed large influences of shark ID on time for sharks to bite and frequency of passes. This variation between individuals may be reflective of bold individuals more likely to approach and bite a bait or board during a trial.

No distance data were collected during this study. An initial attempt to measure distance between approaching sharks and electrodes via downward-facing stereo-cameras was trialled based on the Remote Monitoring Research Apparatus (ReMoRA; Kempster et al. 2016). However, tiger shark interactions during this study were most frequently occurring on the surface around deterrent boards, outside of the field-of-view of downward-facing stereo cameras. After a lack of interactions from board stereo-cameras were recorded during Saunders Reef trials, handheld stereo-cameras were incorporated during trials at Norfolk Island to measure distance. Previous research of electric fields emitted from these devices, however, suggest emitted electric fields are only effective within a ~0.5 m area (Kempster et al. 2016, Gauthier et al. 2020). While distance wasn't quantified, this study revealed that tiger shark behaviours shifted from initially approaching baits and boards, to patrolling the perimeter at a greater distance from the electric field.

6. CONCLUSIONS

As a proportion of total bites, tiger sharks are responsible for the most fatal bites in Australia, with 38% of all tiger shark bites resulting in death (compared to 32% bull sharks, 25% white sharks; Riley et al. 2022). Public sentiment is also increasingly supporting a shift from traditional lethal mitigation measures (e.g., drumlines, beach netting) towards non-lethal alternatives (Adams et al. 2020). For example, 65% of water users from New South Wales slightly, moderately, or strongly agree with personal deterrents as a management option to mitigate shark risk (Adams et al. 2020, Gibbs et al. 2020, McPhee et al. 2021, Rosciszewski-Dodgson & Cirella 2021, Simmons et al. 2021). These findings show that Ocean Guardian's Freedom7 and Freedom+ Surf are effective, non-lethal devices that reduce the risk of tiger shark bites by ~70%. Behavioural response was, however, variable with differences among individuals and between locations, suggesting that the extent of the deterrent efficacy is likely dependent on shark motivational state or personalities, and location. Our results will allow private and government agencies to make informed decisions about the use of these devices for occupational activities and enable the public to make appropriate decisions about the suitability of these two products.

7. FUTURE RESEARCH

With findings from this study, personal electric deterrents have now been tested on the three species responsible for the most unprovoked bites on humans in Australia, tiger, white, and bull sharks. The study showed that tiger shark bite risk differed between locations regardless of whether electric deterrents were being used. This is likely influenced by individual behaviour or motivational state or site-specific behaviours. Testing these devices at locations where shark bites have historically occurred, might ensure that deterrents are tested at locations where they might be needed. However, this also assumes that future shark bite locations can be predicted, which might not necessarily be the case.

Although both electric deterrents are promising to reduce bite risk for surfers and swimmers/divers, neither product eliminated bites from tiger sharks. It is possible that changes to the nature of the electric pulse emitted from such electric shark deterrents may influence their effectiveness, and further work to optimise both the effective range and efficiency of these devices is likely to be of value. Future research should focus on additional methods to reduce injuries from shark bites when they occur.

8. LITERATURE CITED

Adams KR, Gibbs L, Knott NA, Broad A, Hing M, Taylor MD, Davis ARJSr (2020) Coexisting with sharks: a novel, socially acceptable and non-lethal shark mitigation approach. 10:1-12

Andrzejaczek S, Gleiss AC, Lear KO, Pattiaratchi CB, Chapple TK, Meekan MG (2019) Biologging tags reveal links between fine-scale horizontal and vertical movement behaviors in tiger sharks (*Galeocerdo cuvier*). *Frontiers in Marine Science*:229

Bates D, Mächler M, Bolker B, Walker S (2014) Fitting linear mixed-effects models using lme4. *arXiv preprint arXiv:14065823*

Bradshaw CJ, Meagher P, Thiele MJ, Harcourt RG, Huveneers C (2021) Predicting potential future reduction in shark bites on people. *Royal Society open science* 8:201197

Caldicott DG, Mahajani R, Kuhn M (2001) The anatomy of a shark attack: a case report and review of the literature. *Injury* 32:445-453

Chapman BK, McPhee D (2016) Global shark attack hotspots: Identifying underlying factors behind increased unprovoked shark bite incidence. *Ocean & Coastal Management* 133:72-84

Cliff G (1991) Shark attacks on the South African coast between 1960 and 1990. *South African Journal of Science* 87:513-518

Clua E, Chauvet C, Read T, Werry JM, Lee SY (2013) Behavioural patterns of a tiger shark (*Galeocerdo cuvier*) feeding aggregation at a blue whale carcass in Prony Bay, New Caledonia. *Marine and freshwater behaviour and physiology* 46:1-20

Curtis TH, Bruce BD, Cliff G, Dudley S, Klimley AP, Kock A, Lea RN, Lowe CG (2012) Responding to the risk of White Shark attack. *Global Perspectives on the Biology and Life History of the White Shark CRC Press*:477-510

Fitzpatrick R, Thums M, Bell I, Meekan MG, Stevens JD, Barnett A (2012) A comparison of the seasonal movements of tiger sharks and green turtles provides insight into their predator-prey relationship. *PloS one* 7:e51927

Friard O, Gamba M (2016) BORIS: a free, versatile open-source event-logging software for video/audio coding and live observations. *Methods in ecology and evolution* 7:1325-1330

Gauthier A, Chateauminois E, Hoarau M, Gadenne J, Hoarau E, Jaquemet S, Whitmarsh S, Huveneers C (2020) Variable response to electric shark deterrents in bull sharks, *Carcharhinus leucas*. *Scientific reports* 10:1-13

Gibbs L, Fetterplace L, Rees M, Hanich Q (2020) Effects and effectiveness of lethal shark hazard management: the Shark Meshing (Bather Protection) Program, NSW, Australia. *People and Nature* 2:189-203

Gleiss AC, Jorgensen SJ, Liebsch N, Sala JE, Norman B, Hays GC, Quintana F, Grundy E, Campagna C, Trites AW (2011) Convergent evolution in locomotory patterns of flying and swimming animals. *Nature communications* 2:1-7

Gray GM, Gray CA (2017) Beach-user attitudes to shark bite mitigation strategies on coastal beaches; Sydney, Australia. *Human Dimensions of Wildlife* 22:282-290

Hammerschlag N, Bell I, Fitzpatrick R, Gallagher AJ, Hawkes LA, Meekan MG, Stevens JD, Thums M, Witt MJ, Barnett A (2016) Behavioral evidence suggests facultative scavenging by a marine apex predator during a food pulse. *Behavioral Ecology and Sociobiology* 70:1777-1788

Hart NS, Collin SP (2015) Sharks senses and shark repellents. *Integrative zoology* 10:38-64

Hueter RE, Mann DA, Maruska KP, Sisneros JA, Demski LS (2004) Sensory biology of elasmobranchs. *Biology of sharks and their relatives*:325-368

Huveneers C, Rogers P, Semmens J, Beckmann C, Kock A, Page B, Goldsworthy S (2012) Effects of the Shark Shield™ electric deterrent on the behaviour of white sharks (*Carcharodon carcharias*). inal Report to SafeWork South Australia. SARDI Publication No. F2012/000123–1. SARDI Research Report Series No. 632. Adelaide: SARDI - Aquatic Sciences.

Huveneers C, Rogers PJ, Beckmann C, Semmens JM, Bruce BD, Seuront L (2013a) The effects of cage-diving activities on the fine-scale swimming behaviour and space use of white sharks. *Marine Biology* 160:2863-2875

Huveneers C, Rogers PJ, Semmens JM, Beckmann C, Kock AA, Page B, Goldsworthy SD (2013b) Effects of an electric field on white sharks: in situ testing of an electric deterrent. *PloS one* 8:e62730

Huveneers C, Whitmarsh S, Thiele M, Meyer L, Fox A, Bradshaw CJ (2018) Effectiveness of five personal shark-bite deterrents for surfers. *PeerJ* 6:e5554

Juhel JB, Wantiez L, Mouillot D, Mailau S, Vigliola L (2014) Occurrence of sub-adult tiger sharks (*Galeocerdo cuvier*) in a small and very remote atoll lagoon. *Marine Biodiversity* 45:151-152

Kempster RM, Egeberg CA, Hart NS, Ryan L, Chapuis L, Kerr CC, Schmidt C, Huveneers C, Gennari E, Yopak KE (2016) How close is too close? The effect of a non-lethal electric shark deterrent on white shark behaviour. *PLoS One* 11:e0157717

Lea J, Daly R, Leon C, Daly C, Clarke C (2018) Life after death: behaviour of multiple shark species scavenging a whale carcass. *Marine and Freshwater Research* 70:302-306

Martin RA (2007) A review of shark agonistic displays: comparison of display features and implications for shark–human interactions. *Marine and Freshwater Behaviour and Physiology* 40:3-34

McPhee D (2012) Likely effectiveness of netting or other capture programs as a shark hazard mitigation strategy in Western Australia. *Department of Fisheries, Western Australia*

McPhee D (2014) Unprovoked shark bites: are they becoming more prevalent? *Coastal Management* 42:478-492

McPhee DP, Blount C, Smith MPL, Peddemors VM (2021) A comparison of alternative systems to catch and kill for mitigating unprovoked shark bite on bathers or surfers at ocean beaches. *Ocean & Coastal Management* 201:105492

Meekan MG, Fuiman LA, Davis R, Berger Y, Thums M (2015) Swimming strategy and body plan of the world's largest fish: implications for foraging efficiency and thermoregulation. *Frontiers in Marine Science* 2:64

Meyer CG, Anderson JM, Coffey DM, Hutchinson MR, Royer MA, Holland KN (2018) Habitat geography around Hawaii's oceanic islands influences tiger shark (*Galeocerdo cuvier*) spatial behaviour and shark bite risk at ocean recreation sites. *Scientific reports* 8:1-18

Midway SR, Wagner T, Burgess GHJPo (2019) Trends in global shark attacks. 14:e0211049

Munroe S, Simpfendorfer C, Heupel M (2014) Defining shark ecological specialisation: concepts, context, and examples. *Reviews in Fish Biology and Fisheries* 24:317-331

Myrberg Jr AA, Gruber SH (1974) The behavior of the bonnethead shark, *Sphyrna tiburo*. *Copeia*:358-374

Poscai AN, de Sousa Rangel B, da Silva Casas AL, Wosnick N, Rodrigues A, Rici REG, Kfoury Junior JR (2017) Microscopic aspects of the nictitating membrane in Carcharhinidae and Sphyrnidae sharks: a preliminary study. *Zoomorphology* 136:359-364

Riley M, Meagher P, Huveneers C, Leto J, Peddemors VM, Slip D, West J, Bradshaw CJ (2022) The Australian Shark-Incident Database for quantifying temporal and spatial patterns of shark-human conflict. *Scientific data* 9:1-9

Ritter EK, Godknecht AJ (2000) Agonistic displays in the blacktip shark (*Carcharhinus limbatus*). *Copeia* 2000:282-284

Rosciszewski-Dodgson MJ, Cirella GT (2021) Shark bite survivors advocate for non-lethal shark mitigation measures in Australia. *AIMS Environmental Science* 8:567-579

Ryan LA, Lynch SK, Harcourt R, Slip DJ, Peddemors V, Everett JD, Harrison L-M, Hart NS (2019) Environmental predictive models for shark attacks in Australian waters. *Marine Ecology Progress Series* 631:165-179

Simmons P, Mehmet M, Curley B, Ivory N, Callaghan K, Wolfenden K, Xie G (2021) A scenario study of the acceptability to ocean users of more and less invasive management after shark-human interactions. *Marine Policy* 129:104558

Thiele M, Mourier J, Papastamatiou Y, Ballesta L, Chateauminois E, Huveneers C (2020) Response of blacktip reef sharks *Carcharhinus melanopterus* to shark bite mitigation products. *Scientific reports* 10:1-12

Thompson C (2014) Predicting shark beahviour: the infleunce of species, size and brain organisation. The University of Western Australia, Perth, Australia

Tucker JP, Vercoe B, Santos IR, Dujmovic M, Butcher PA (2019) Whale carcass scavenging by sharks. *Global Ecology and Conservation* 19:e00655

Turner J (2016) Insights into shark behaviour in the pelagic environment by means of a non-invasive sampling. School of Animal Biology, The University of Western Australia,

West JG (2011) Changing patterns of shark attacks in Australian waters. *Marine and Freshwater Research* 62:744-754

9 APPENDIX

Table S1. Estimated deterrent type, species, and interaction coefficients (β) and their standard errors (SE), t-values of factors included in the top-ranked model (indicated for each variable). Significant values are shown in bold.

Level		β	SE	z/t value	Pr(>|z|)
Outcome of a bite (Binomial GLM)					
Freedom+ Surf	**Intercept**	**1.77**	**0.77**	**2.28**	**0.02**
	Freedom+ Surf	**-3.90**	**0.84**	**-4.67**	**>0.01**
	tiger shark	-0.96	1.06	-0.91	0.36
	white shark	-1.23	0.89	-1.39	0.17
	Trial set	**0.07**	**0.02**	**4.39**	**>0.01**
	Freedom+ Surf*tiger shark	-0.51	1.37	-0.37	0.71
	Freedom+ Surf*white shark	**2.01**	**0.91**	**2.20**	**0.03**
	tiger shark*Trial_set	-0.06	0.04	-1.60	0.11
	white shark*Trial_set	**-0.06**	**0.02**	**-3.17**	**>0.01**
Freedom7	**Intercept**	**0.62**	**0.28**	**2.22**	**0.03**
	Freedom7	0.26	0.38	0.70	0.48
Time for bite to occur					
Freedom+ Surf	(Intercept)	0.19	0.24	0.78	0.44
	Freedom+ Surf	**0.42**	**0.16**	**2.57**	**0.01**
	tiger shark	**0.68**	**0.33**	**2.05**	**0.04**
	white shark	**0.59**	**0.27**	**2.16**	**0.03**
	Trial_set	**-0.02**	**0.00**	**-4.08**	**>0.01**
Freedom7	(Intercept)	-0.03	0.17	-0.16	0.88
	Freedom7	**0.68**	**0.18**	**3.80**	**>0.01**
	white shark	**-0.47**	**0.23**	**-2.03**	**0.04**
Number of passes					
Freedom+ Surf	**Intercept**	**1.2513**	**0.5307**	**2.358**	**0.02**
	Freedom+ Surf	0.8001	0.5447	1.469	0.14
	tiger shark	**1.4858**	**0.7388**	**2.011**	**0.04**
	white shark	1.207	0.7138	1.691	0.09
	Freedom+ Surf*tiger shark	-0.2491	0.8017	- 0.311	0.8
	Freedom+ Surf*white shark	**1.9807**	**0.7577**	**2.614**	**0.01**
Frequency of reactions					
Freedom+ Surf	Intercept	0.23	0.05	4.53	
	Freedom+ Surf	0.63	0.06	11.20	
	Tiger shark	0.08	0.06	1.21	

	White shark	-0.19	0.06	-3.08
	Freedom+ Surf*tiger shark	-0.25	0.07	-3.62
	Freedom+ Surf*white shark	-0.46	0.07	-6.73
Freedom7	Intercept	0.1	0.44	2.28
	Freedom7	0.29	0.04	7.55