THE SCIENTIFIC FOUNDATION

OF ETHICAL AND EFFECTIVE SHARK REPELLENT TECHNOLOGY

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E L E C T R O N I C   S H A R K   D E T E R R E N T

SharkShield®

PROVEN PROTECTION FROM SHARKS

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SUMMARY

Between 1982 and 2011 unprovoked shark bites were recorded from 56 countries with 27 recording fatalities; however 84.5% occurred in only six countries - United States, Australia, South Africa, Brazil, Bahamas and Reunion Island. While shark attacks directed at humans are, and will continue to be extremely rare, the frequency is increasing, principally along with increasing numbers of humans participating in ocean sports, but also influenced by other factors. Fear of such attacks, partially fuelled by films such as Jaws is psychologically powerful.

Ocean users (casual recreational visitors, scuba divers, surfers, kayak fishermen, etc.) at risk of shark attacks, often cite the possibility of such encounters as a major concern (Eilperin, 2013). Evidence, both anecdotal and survey-based, shows this fear can keep many potential ocean users away from the water .That same fear may also be contributing to a slow decline in the scuba diving industry, as seen over recent years.

No method of mitigating the risk of an unprovoked shark bite is 100% successful in all circumstances, and this is the case for methods of risks to human safety in all contexts, whether it be seatbelts and airbags in cars, or the emergency brace position on planes. The traditional method of reducing the risk of unprovoked shark bite has been through culling, using shark nets and/or drumlines. These practices are unlikely to remain to be acceptable due to their environmental impacts on species of conservation interest. There are alternatives which reduce the risk of unprovoked shark bite for bathers which include enclosure nets and shark spotter programs, but such approaches are impractical for surfers, divers, spearfishers,snorkelers, and kite surfers. The most environmentally-friendly, non- lethal method for preventing unprovoked shark bite on any water user, that leaves other marine life unaffected, is lowpower, electronic shark deterrents. This method utilises the shark's highly sensitive electroreception organs, by creating pulses of low-power electrical current, which are extremely uncomfortable for approaching sharks, without affecting humans wearing such devices, or any other marine animals.

This prospectus explains how electronic shark deterrents function, and why it is a safe, practical, and most importantly an effective method of repelling sharks at distances of 2 metres and greater, thus reducing the risk of unprovoked shark bite. These products are backed by multiple scientific studies and over a decade of field-testing with multiple shark species.

UNPROVOKED SHARK BITE:

RISK AND RISK PERCEPTION

Between 1982 and 2011 unprovoked shark bites were recorded from 56 countries with 27 recording fatalities; however 84.5% occurred in only six countries - United States, Australia, South Africa, Brazil, Bahamas and Reunion Island (McPhee, 2014). As well as unprovoked shark bites, there are numerous instances of provoked shark bite where a person has deliberately bothered a shark which has led to a bite. Of the more than 480 species of sharks, only three are responsible for the majority of fatalities - the white, the tiger and the bull, are responsible for the majority of fatalities from unprovoked shark bites (McPhee, 2014).

The incidence of unprovoked shark bite globally is on the rise. The primary reason for this is an increase in the recreational use of coastal waters, but at a regional or local level it can also be influenced by factors which for a period of time change the habitat use of relevant shark species. In the example of white sharks, for instance, the distribution of prey such as humpback whales and pinnipeds (seals and sea lions) can influence the distribution of this species and the level of spatial overlap between sharks and water users. Despite the increase in incidents, the risk that unprovoked shark bites pose is extremely low. For example, you are several times more likely to be fatalty injured by lightning, riding a bicycle, in a hunting accident or from a dog bite, (Florida Museum of Natural History, 2010). Fortunately as well many unprovoked shark bites result in relatively minor injuries only.

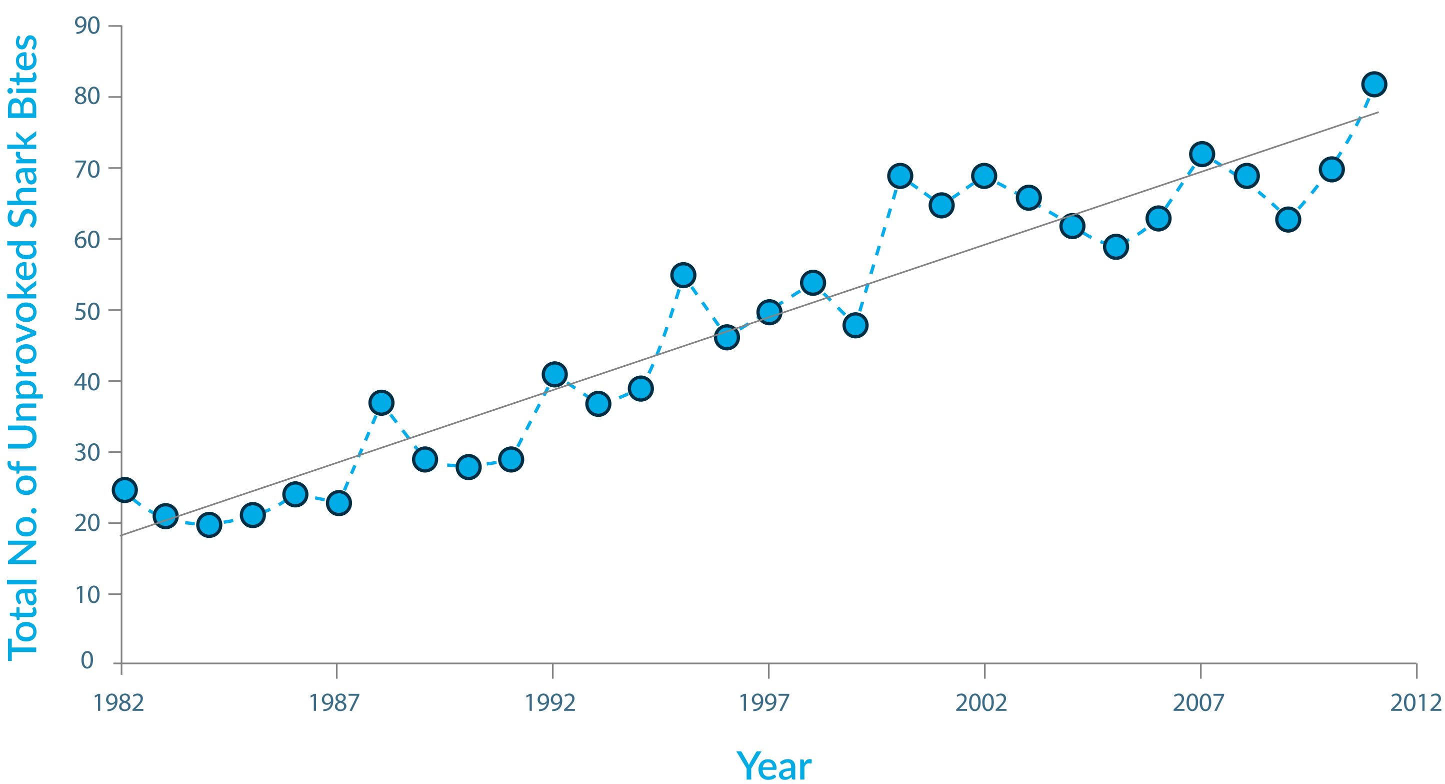


Figure 1. Number of annual unprovoked shark bites globally between the period 1982 and 2011, (From McPhee, 2014).

Ocean users (casual recreational visitors, scuba divers, spearfishers, surfers, kayak fishermen, etc.) at risk of shark attacks, often cite the possibility of such encounters, as a major concern (Eilperin, 2013). Information, both anecdotal and survey-based, shows this fear can keep many potential ocean users away from the water (Marwick, 2014; O'Conner, 2013). That same fear may also be contributing to a slow decline in the scuba diving industry, as seen over recent years (Cline Marketing, 2011). Despite the very low risk of an unprovoked shark bite, many people fear sharks, fear of sharks is even a recognised phobia: galeophobia. Fear can paralyse efforts to think clearly about risks and can specifically lead us to neglect the probability of an event happening (Sunstein and Zechauser, 2011). Solutions to the shark-human "problem" need to address the risk and placate the fear. An unprovoked shark bite is and will continue to be "newsworthy" and the constant reminder of an incident can reinforce the fear over and above less newsworthy sources of harm. The status quo government approach to address the issue o f unprovoked shark bites that result in fatalities is through the use of methods which target and kill large sharks – drumlines and shark nets.

THE ROLE OF SHARKS IN THE ECOSYSTEM

Sharks play a vital ecological role in marine ecosystems. Large predatory sharks sit atop marine food webs and are termed apex predators, and as such play an important role in the overall functioning of the marine environment. Removal of such apex predators can result in significant and varied changes in the food web as a whole. Many species of shark are of conservation concern and are identified globally as threatened or near threatened, largely due to unsustainable fishing for their fins, teeth and jaws. Sharks are less resilient to fishing pressure than finfish due to many of them being long-lived, slow growing, and producing relatively few young. This low resilience to fishing pressure is one of the main reasons that sharks have become a focus of contemporary conservation efforts and these efforts will only increase.

SHARK CULLING:
THE ANTIQUATED METHOD

Shark nets and drumlines have been used in a number of locations to cull large sharks in order to attempt to reduce the risk of an unprovoked bite. Understanding the important role that sharks play in the structure and function of marine ecosystems were largely unknown when the initial traditional methods to reduce the risk of unprovoked shark bite were implemented. Given our current knowledge of the role of sharks in the marine ecosystem, and their conservation focus, the traditional approaches of using methods that deliberately target and kill large sharks are meeting strong public opposition. Not only do these methods kill sharks, but they can also can result in injury and death to sharks and marine creatures that are harmless to humans, such as rays turtles and marine mammals. This is particularly the case with regards to shark nets, and this issue remains, despite the best efforts to manage the impact through such approaches as gear configurations, and spatial and seasonal controls on deployment. Shark culling programs can be expensive for government agencies to run and as government budgets shrink, and conmbined with the strong public opposition; they have a questionable long term future.

Shark nets consist of large size mesh and float about four metres below the surface. They are disconnected from the shoreline to minimize interactions with boats and often entangle sharks and frequently cause death via suffocation. The justification of this method is the popular viewpoint “fewer sharks means fewer attacks”. In New South Wales, Australia, there are more than 50 beaches and 250 kilometres of coastline which are protected by shark nets. Nets have officially been deemed successful, even though 63% of all shark attacks at ocean beaches in New South Wales occurred at netted beaches. With an increased awareness of the importance of sharks to ocean ecology, shark nets have drawn widespread criticism due to their impact on shark populations and other animals. Shark nets don’t discriminate as to species trapped (bycatch) and often kill threatened species, such as sea turtles, dugongs, dolphins and whales, along with other harmless species (Table 1).

Drumlines involve setting a series of very large baited hooks in order to capture large sharks. They can be used in conjunction with shark nets or in isolation. Despite best efforts to reduce it, drumlines can also have high rates of bycatch, in particular of harmless shark species, although marine turtles can also be common bycatch if they are set within the range of marine turtle species (Weatherbee et al.,1994; Sumpton et al., 2010; McPhee, 2012). Drumlines are not particularly effective at catching white sharks which are one of the three main species responsible for unprovoked shark bites.

SPECIES OR SPECIES GROUPS	NUMBER
Hammerheads	1292
Stingrays	1269
Whalers	536
Angel sharks	259
Port Jackson sharks	107
Great white shark	100
Sevengill shark	92
Dolphins	52
Tiger shark	49
Marine turtles	47
Finfish	43
Thresher shark	40
Shortfin mako	31
Grey nurse shark	15
Whales	6
Seal	4
Penguin	1
Dugong	1

Table 1: Bycatch from Drumlines

NON-LETHAL METHODS FOR MITIGATING THE RISK OF UNPROVOKED SHARK BITE

Given the environmental cost of shark culling methods, and the public opposition to their ongoing use, there is continuing interest in environmentally friendly methods that further mitigate the risk of unprovoked shark bite. There are a number of programs that aim to provide the public with information on the presence of a large shark species at a specific location at a specific time. The best known is the Shark Spotters program in False Bay (Cape Town, South Africa). The Shark Spotters warn bathers (using flags and sirens) when a shark is spotted in the area (Kock et al., 2012). Shark spotting has a number of limitations such as, impaired visibility due to choppy seas, glare or cloud cover, day length, skill of the spotter, the ability to achieve an effective observation point, ability to attract the attention of bathers when sharks are spotted, the necessity of bathers to remain vigilant while recreating and the requirement that all bathers understand the shark spotter signals. This method offers no protection for divers, surfers and kayakers, who are likely to be away from the areas being observed by shark spotters. Nonetheless, such programs can make an important contribution to beach safety and providing confidence to the public.

Another method aimed at mitigating the risk of unprovoked shark bite is the use of exclusion nets. Exclusion nets are physical barriers designed to prevent capturing sharks from entering a beach area, and unlike shark nets, they are not designed to kill sharks and thus offer a better environmental alternative to shark nets (McPhee, 2012). However, these can only be used in relatively sheltered waters, and are impractical as protection for a range of key ocean users including surfers, divers, kite surfers and snorkelers.

ELECTRONIC SHARK DETERRENTS

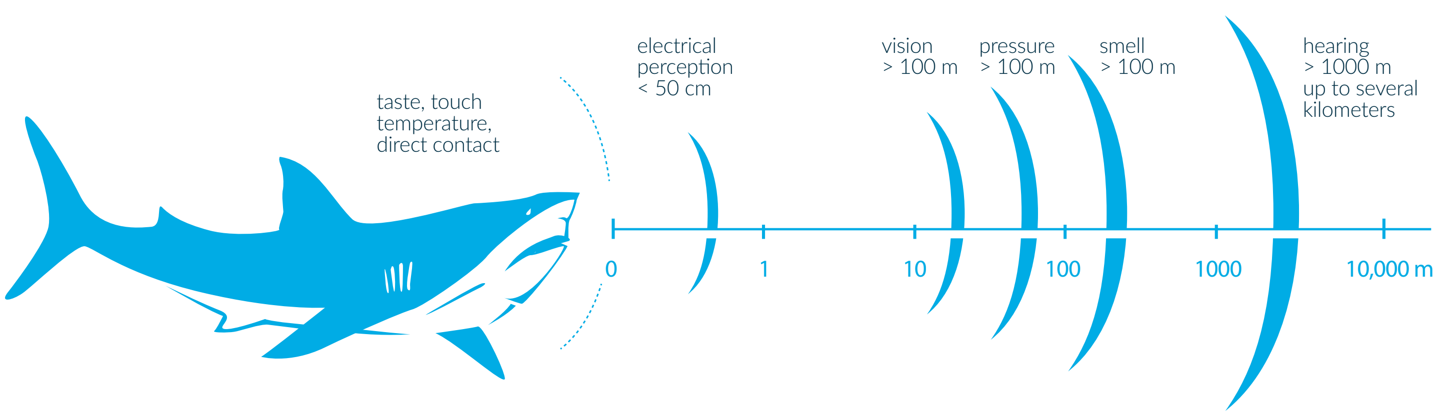
Electronic shark deterrent technologies are a safe, effective and humane solution that provide a number of benefits over the methods discussed. Besides completely negating shark deaths, electronic deterrents can be at locations not protected by stationary devices, and are effective at repelling sharks from any area they are used in. Electronic methods can provide protection for all ocean users whether it be surfing, scuba diving or snorkeling. To understand how they work, it is worthwhile to begin with understanding how sharks sense their world.

Sharks are extremely well adapted to their environment, enabling them to dominate the oceans as apex predators. Part of their success can be attributed to their highly adapted sensory organs which allow them to detect both food and foe. Besides the senses we humans are familiar with – eyesight, smell (which is extremely well-developed in sharks), hearing, touch, and taste — sharks have two additional senses: mechanoreception and electroreception which gives them distinct advantages as predators (Winther-Janson, Wueringer & Seymour, 2012).

An understanding of them offers the opportunity to design deterrents based on these senses. Mechanoreception through pressure detection is via the lateral line system which consists of fluid-filled vessels, called neuormasts, running along the side of the shark's body. These receptors sense water flow over the skin and detect close-range movements of predators or prey moving through the water. The other sense that is vital to our discussion of preventing shark attacks – is electroreception or the ability to sense small changes in electrical fields. A shark's electroreception system, the Ampullae of Lorenzini are clusters of multiple nerve fibres in gelfilled canals opening to the surface by pores. They are generally visible as series of dark pores on a shark's head and the exact arrangement of the canals and pores differ between species. This highly sensitive system can detect electrical fields at voltages as low as 5 nV/ (five one billionths of a volt)/cm. Besides predation, this system is also believed to help sharks navigate using the Earth's electromagnetic fields and assist in communication and mating.

Electroreception allows the shark to detect low-power electrical fields generated by an animal's muscle contractions. It's only effective at distances less than one meter, and is most useful to sharks in situations where the water is dark due to depth or turbid (e.g. murky after rainfall and run-off in the coastal zone) (Winther-Janson et al., 2012).

With a baseline detection level of 5 nV/cm, the shark is an impressive stalker, but that same sensitivity can be used in deterring the animal. To an approaching shark, an electrical impulse, sufficiently powerful can be disorientating or physically painful. Remember the last time you were listening to a speaker using a microphone, and a momentary uncontrolled feedback in the sound system caused everyone to cover their ears as fast as they could? You instantly detect it, strongly wish to avoid it, but short exposure to it does no harm. The same thing happens when an approaching shark crosses the boundary line of an electrical field at the non-lethal, but still disturbingly strong levels generated by electronic shark deterrents.



Several decades ago, scientists began to suspect that electroreception might be a chink in a shark's armour. Soon thereafter, the KwaZulu-Natal Sharks Board – the South African government organization tasked with protecting ocean-goers from shark attacks – began to conduct scientific research on electroreception. The research confirmed the scientist's suspicions; namely, electroreception could be used to deter sharks without causing them any harm. The first generation of technology based on this method was called SharkPOD, and proved to be an effective shark deterrent for personal use by scuba divers and other ocean users (Smit & Peddemors, 2003; Marcotte & Lowe, 2008). The latest generation of this electronic shark deterrent system, known as Shark Shield®, expands on the capabilities of the first generation (Cilliers, 2012; Huveneers et al., 2012; Sprivulis, 2014).

TESTING THE EFFECTIVENESS OF THE SHARK SHIELD®

Smit and Peddemors (2003) examined the effectiveness of the approach in detail. In two series of tests, data was collected measuring the time needed to attack the bait, where the SharkPOD was embedded, under power- off (inactivated) and power-on (activated) conditions. Conclusions were separately drawn after completion of the first experiment in power-off mode, in which there were eight successful "attacks" in 98, five-minute active periods by shark who were allowed access to t h e bait. In the second experime in power-on mode, there were no successful attacks were recorded in 24, ten-minute active periods by sharks who were allowed access to bait. It was concluded that the probability of an attack in sharks allowed access to bait for a 5 minute period was reduced from about 0.70 when the SharkPOD was in power-off mode, to about 0.08 when the SharkPOD was in power-on mode. When sharks were allowed access to bait for a 10 minute period, the probability of an attack was reduced from 0.90 when the SharkPOD was in power-off mode, to 0.16 when the SharkPOD was in power-on mode (Smit & Peddemors, 2003). Additional studies published in 2010 (Marcotte & Lowe, 2008) and 2012 (Cilliers, 2012) confirmed the efficacy of electronic shark deterrents and the SharkPOD device. Thus, there are a number of published independent studies that document a statistically significant probability of an unprovoked shark bite from using a SharkPOD.

The next step in the development of electronic shark deterrents came with the introduction of the Shark Shield®. Extensive scientific testing has been conducted on the Shark Shield® electronic shark deterrent, both by Shark Shield® and by independent organizations. The results are clear and positive: the Shark Shield® is effective at repelling sharks and reducing the probability of a shark bite (Cilliers, 2012; Huveneer 2012; Sprivulis, 2014). Publicly available video also documents the effectiveness of the devices1 In 2006, Shark Shield® conducted extensive field testing off Neptune Island, South Australia, using the FREEEDOM4 and FREEDOM7 models.[1] Ian 'Shark' Gordon, a world famous shark expert and experienced diver, directed these tests and has used the Shark Shield® for nearly two decades, on dozens of shark species. These tests added to the evidence in favour of Shark Shield®'s effectiveness (Gordon, 2006).

In 2010, SafeWork SA, the government agency responsible for administering occupational health, safety and welfare laws in South Australia (South Australia, 2014) commissioned a further study (Huveneers et al. 2012) into the effectiveness of the Shark Shield FREEDOM7 device. This study involved two separate experiments: a static bait test with a large bait suspended at the extremity of the electrical field and a second dynamic test using a seal decoy being towed with a Shark Shield being located under it. A total of 116 trials using static bait were undertaken at the Neptune Islands, South Australia and 189 tows were conducted using a sealdecoy near Seal Island, South Africa.

During the static bait test, the proportion of baits taken were not affected by the deterrent, however, the deterrent doubled the time it took for sharks to take the static bait, as well the number of interactions per approach, indicating that the sharks investigated how to approach the bait with minimal affect by the field. During the dynamic seal decoy, no breaches and only two surface interactions were observed when the deterrent was activated, compared to 16 breaches and 27 surface interactions, when the deterrent was not activated. Although the fine-scale positioning and presence or absence data collected to assess the potential of the device to attract white sharks was limited to one trip, the results did not suggest that sharks were attracted to the deterrent. The results showed that the deterrent had an effect on the behaviour of white sharks, but did not deter or repel them in all situations. that the sharks investigated how to approach the bait with minimal affect by the field.

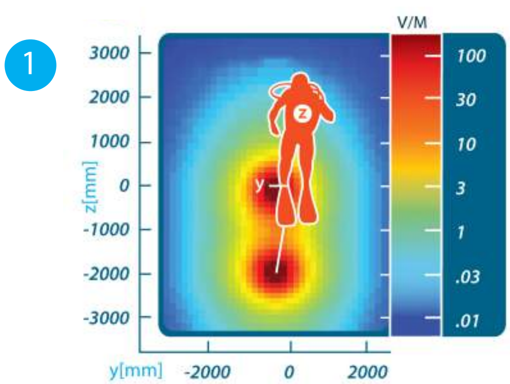
1 Shark Shield Video Action, 2012 (Wilson, A. 2014) and Shark Shield® as used on the Kayak Fishing Show, 2012.

BENEFITS
OF THE USING THE SHARK SHIELD®

The Shark Shield® FREEDOM7 is an electronic device that fits snugly inside a neoprene pouch, and attaches onto the user's ankle with a Velcro strap. This securely fastens the 2.2 meter flexible mesh antenna, designed for minimal drag, which emits the electronic pulses from two electrodes and trails behind the person as they move through the water. The sea water surrounding the electrodes acts as a conductor and forms an electronic field that surrounds the user. Kayakers can also use Shark Shield® by inserting the antenna cable through a scupper in the hull of the kayak, or dangling it off the vessel into the water.

The Shark Shield® devices can be operated for 6-7 hours before needing to be recharged. Once the electrodes are submerged underwater, the device is ready to be activated. It is equipped with both a visual and audible warning system to alert the user when the battery power level is running low, so that they can exit the water to recharge the battery.

When a shark approaches within a few metres of someone wearing a Shark Shield® device, pulses from the electrodes interfere with the shark's electroreceptor system, located in the shark's snout, which results in muscular spasms and levels of discomfort to the shark. Scientific tests of the Shark Shield®, conducted using bait to attract sharks and under strictly controlled variables have shown that the Shark Shield® reduces the chance of the shark moving closer than several feet from the device (Huveneers et al. 2012). Most often, the shark will quickly turn away from the electronic field a few meters distance from the device. In this manner, the Shark Shield® is able to effectively repel sharks and protecting the user.



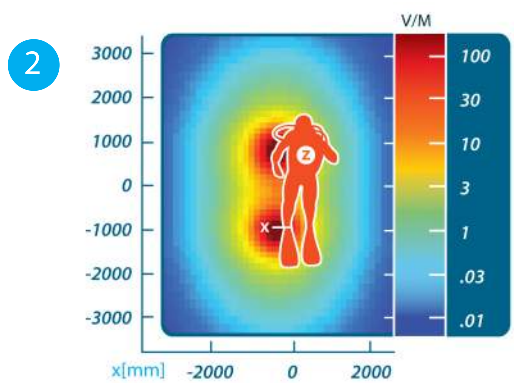


FIGURE 1: Shows the pattern and magnitude of the E-field surrounding the SharkShield® FREEDOM7 unit that attaches to the the leg of swimmers, surfers, divers, etc.

FIGURE 2: Shows the estimated magnitude of the E-field surrounding a model of a diver wearing the Shark Shield® device (Scuba Diving/SCUBA7, 2012).

While it is true that sharks are attracted to the electric fields emitted by their prey at short range, the electric field emitted by the electronic shark deterrent does not encourage sharks to investigate the device or attract them to the user. The reason for this is that the sensory organs of a marine shark are extremely sensitive to voltage gradients (of at least 5 nV/cm) and are adapted to detecting low-frequency signals of between 1-8Hz at close-range, with prey being located and captured with the aid of input from other senses — visual, chemoreception and mechanoreceptor at much longer distances.

Collins (2010) concluded sharks are not attracted to electronic shark deterrents. His measurements found sharks would only be attracted to a deterrent, if the electric field strength of the deterrent device had dropped off enough to represent a prey-like stimulus (approx. 1-100nV/cm). However, at that point, if they continued approaching the device, the field strength would increase rapidly, and the shark would quickly realise that this is not prey, and be deterred by the discomforting effects of the device. Collins (2010) determined from the data collected, that the distance at which the device might momentarily resemble prey to an approaching shark was about three metres. Given how fast the field strength from a very low powered source drops off in seawater, he estimated that beyond a six metre radius the shark would not detect nor react to the device (Collins, 2010).

FURTHER INFORMATION

For further information on the Shark Shield®, FREEDOM7 and related products available for other ocean users, visit our website: www.sharkshield.com

Alternatively, visit our YouTube channel to see interviews with shark attack victims where Shark Shield® has saved lives and also see our independent scientific test results https://www.youtube.com/user/Sharkshield?feature=guide

To review the detailed independent scientific research on Shark Shield® or download the full research, please visit http://www.sharkshield.com/view/SharkShieldResearch To review Frequently Asked Questions on the Shark Shield® site, please visit http://www.sharkshield.com/view/FrequentlyAskedQuestion.

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