Adaptive Camouflage Concept

Why is Sharkview™ is a viable method of avoiding sharks

Most research on sharks is performed by using chum (fish, oil and blood) to attract them but this does not replicate natural behaviour and so cannot be used to predict actions on beaches when sharks are hunting normally. Sharks search for prey by random and sense directed means and once located decide if its eatable, able to captured and then make an attacking run to subdue the prey. Senses are used at different ranges to find that prey; at longer range smell and hearing are used, mid range electrical and lateral line and at close range vision and finally taste. Vision is well understood by marine scientists to be critical to hunting success and the decision making process as only it gives the rapid response to changes in the position of the prey item.

Figure 1 Small shark used a breaking wave to sneak up on fish (a) when close enough it makes it run (b) it misses and the fish scatter (c)

Failed attempts are often the result of the shark losing sight of the object. Current scientific knowledge of shark vision is that it consists of very high contrast with a blue or green hue and has special features to increase it effectiveness in low light or murky water. Many attacks are the result of an error in the assessment by the shark that the surfer is a prey item and the attack is not usually continued beyond the first initial bite. The most commonly used method in nature of avoiding predators is not being identified by using camouflage to blend in to the background and disguise the shape. Fish that live on the bottom match that background, fish in mid water are not blue or other fixed colours as the background water varies throughout the day. Most mid water fish have sliver reflective scales that passively adapt to changing light and water colours to hide at a distance and can confuse predators at close range.

At the air and water interface light passes through at different rates, more light is reflected the further away from directly vertical until it becomes almost mirror like. The reflected image is at the opposite angle to the to the viewer at and the less water movement and the greater the clarity the better that image will be. The concept uses these factors to help an object blend into surface and disguise the shape of that object as it adapts passively to changes in light levels and water colours. Sharkview™ mimics the scales of fish by the use of a specially engineered reflective film on the bottom of the board with a patented specific range of reflective values and pattern of a determined shape and scale to make it blend to the surrounding water. The board will reflect the exact colour and movement of the water around it at a reciprocal angle from the viewer and change as it changes. This will reduce encounters by limiting the distance at which the board can be seen and if the shark is aware that there is an object on the surface it will be a perfect match to the water with

an indeterminate shape giving it no reason to investigate any closer.

Figure 2 Best current estimate of what a shark actually sees (high contrast blue/green) compared to our trichromatic vision (blue green and red). For us the fish are more visible against the blue background and less so the coloured. For a shark its the opposite they are easier to see against the coloured background but harder in mid water due to the silver scales reflecting the colour of the water

Black wetsuits are a poor option not to be seen by sharks as they create a high contrast against the surface or light coloured board. Legs and arms are the most exposed and most vulnerable body part and are the areas bitten in over 90% of attacks. Coloured wetsuits will match the water as some times but not others, soft shapes of an appropriate scale in greys perform better in tests as camouflage to break up the outline. Should the shark come within visual range the base camouflage can be overlaid with patterns of objects that sharks are familiar with or items that are likely to be avoided to lead to a dismissal of the item as potential prey. The combination of the reflective board and wetsuit will hide the surfer giving little reason for the shark to come within the critical striking range or lead to mistaking them for possible prey. The shark can not become accustomed to the effect nor will it imped the surfer or board performance, it will be effective in all geographical locations, water conditions and times of day.

How it works

Water has some special properties that need to be kept in mind when trying not to be seen. Because of the higher density of water molecules to air light passes though and is refracted or bent. There's also reflection of some of the light reducing the overall amount. Colours have different wavelengths and some penetrate better than others. Red is lost first at about 10m, then orange, yellow, green with blue at 70m. This is why a lot of deep-water fish are red because they look a dull grey colour. The other problem in the water is that it constantly changes even in short time frames with the sun angle of the sun and the position the viewer.

In deep water blue dominates due to the loss of red in the water and also in the sky but in shallow water the bottom is reflected and changes as depth increases. The video link shows the surface of the water reflecting the rocks, getting burnt out by the sun, algae and finally the blue of deeper water.

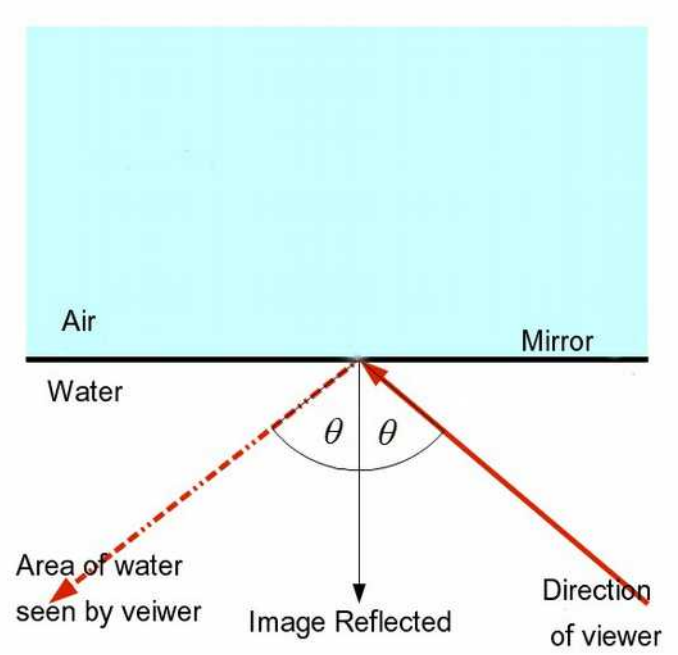

Figure 3 At the water and air interface still water reflects light like a mirror the more acute the angle the better. If very still the image will be at its best but the water cannot be as good as a mirror as some light passes the through, reflected and refracted.

Our main concern is at the surface so all colours are visible but sharks don't see the full range. The best current science says they see only black and white with Blue/green in high contrast. A bright red wetsuit would appear to them as grey. Dose this mean blue and greens are easier for them to differentiate? Yes, they see these colours in the background also. So if the contrast is right between the colours of the suit and that background it can be a way of disguising the shape but its hard to get right, the amount of contrast is critical. The difficulty is the constant changes in the background. Most of the time sharks are looking up against a light background further increasing the importance of balancing the contrast correctly. The other important aspect when looking up at the surface is from directly below you can see through the water but as the angle increases the more light is reflected until the surface almost reflects all the light and become a mirror. The calmer

Figure 4 Shows the surface on the water can be seen through close to the camera then reflecting the sand and blue further away. Our early test board in the replicates the surface by also reflecting the sand with even the ripples from the sunlight copied.

the water the better the mirror but some light is lost so a perfect mirror would out perform the water. A single reflective value cant be used as it highlights the outline or shape. These separate aspects when used in conjugation can create a highly effective surface camouflage.

Our concept uses these factors to help an object blend into surface and disguise the shape of that object as it adapts passively to changes in light levels and water colours. Sharkview™ mimics the scales of fish by the use of a specially engineered reflective film on the bottom of the board with a specific range of reflective values and pattern of a determined shape and scale to make it blend to the surround water. The board will reflect the exact colour and movement of the water at a reciprocal angle from the viewer and change as the water changes. This reduces encounters by limiting the distance at which the board can be seen and if the shark is aware that there is an object on the surface it will be a perfect match to the water with an indeterminate shape giving no reason to investigate any closer.

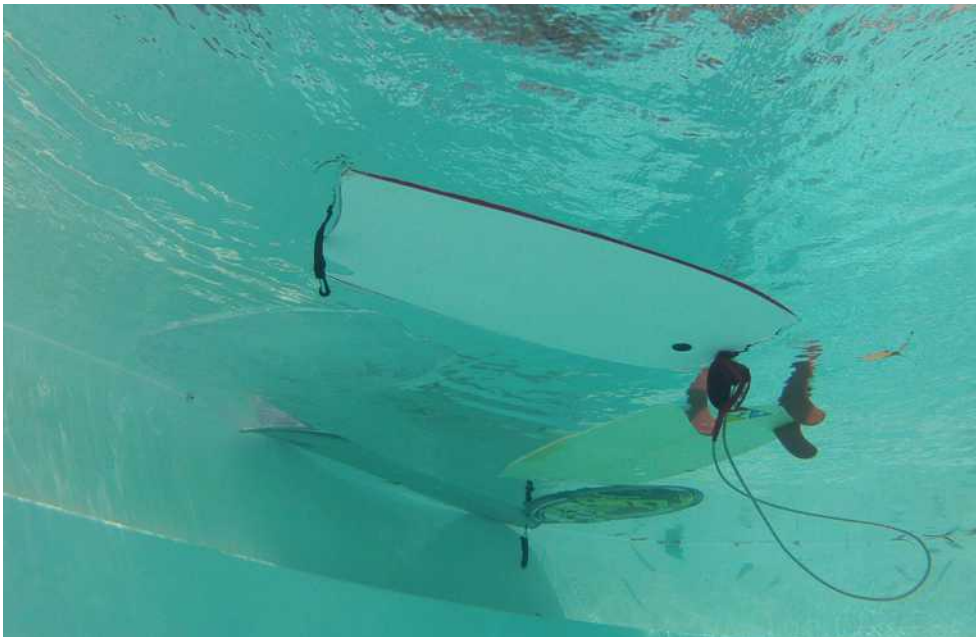

Figure 5 A selection of boards clockwise from top white body board, cream surfboard, back and yellow skim board, blue surfboard and at the 9 o'clock position the a board covered with the Sharkview decal

Our method is to attach a specially developed optical reflective patterned film to the bottom of the surfboard as a self-adhesive film decal that is UV stable, water and immersion proof, with an adhesion method suitable for marine conditions. The film and pattern can also be included as an internal layer during the construction of the surfboards with the resin used as the adhesive base and top protective layer. The area covered will be the complete underside of surfboard. When retrofitting a sticker or decal it can be cut to fit around or between fins. The best results will be achieved by the using a neutral grey edge of the board onto the upper surface to help hide the board when partially submerged.

The film will give the appearance of just more water making the shape of the surfboard indistinct from underneath. At a 45° angle of approach the shark the shark would see a reflection of the water at 90° of its position. The refection will be of the surrounding water and act as highly effective camouflage and the more acute the angle the more acute the area reflected. The surface of the water when viewed from underneath also acts as a mirror with distortions due to the movement of the water is matched by the mirror film. In shallow water the reflection on the surface is that of the bottom, this too is matched by the mirror film. It has long been considered that sharks attack surfers as the silhouette resembles a seal when viewed from underneath. By negating the shadow and giving the appearance of more water the shark will not initiate an attack as the seal shape can no longer be seen.

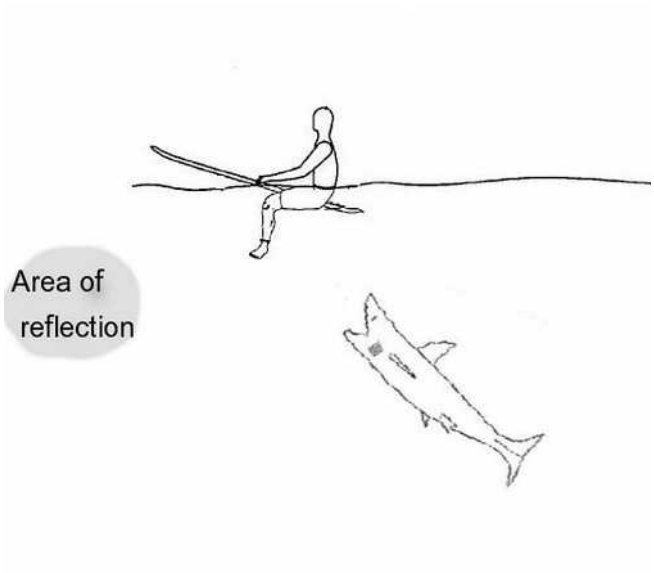

Figure 6 When Sharks approach a surfer the most common direction of attack is from below and behind. At a 45^{o} angle of approach the shark the shark would see a reflection of the water at 90^{o} of its position. If the surfboard is at an angle due to the weight of the surfer and their position on the board the reflected image would be greater than 90^{o} of the shark and still be of the surrounding water.

The product will be in 2 forms a decal to allow for retro fitting to existing boards and a version for internal construction. The lightweight decal will consist of a base layer of adhesive, optical mirror film and cover. The protective cover will be a transparent film with properties that ensure isolation of the internal sections from the water and have no detrimental effect to the function of the surfboard. The adhesive layer will appropriate for marine use. The greater the coverage of the decal and the inlay the more effective the product will be. The main area of protection needed is where the surfer's legs hang 1/3 to ½ from the rear of the board. Provided greater than 80% of the board is covered by the decal sufficient surface for an image will occur however may not be as effective as complete coverage.

The wetsuits designs came from the need to make the vulnerable and visually obvious limbs more camouflaged to match or at least replicate the reflective board. Black wetsuits are a poor choice as the contrast makes them highly visible against the lighter surface. Early vision tests in the 60's with Grey Reef sharks showed when presented with a pair of 3 inch cubed pieces of fish one dyed black the was a distinct preference for the blackened fish. In 172 trails the back piece was taken 72% compared to the natural coloured flesh with 28% taken.

Sharks according to the best current scientific knowledge is that they are are unable to see red or yellow but can see blue to green and in high contrast. As the surface is brighter and many surfboards have white underside any colour that enhances the contrast is detrimental. They show the exact opposite to what fish and land animals exhibit as basic camouflage to hide and disrupt their shape which is counter shading. This is the difference is in shades or colours on the body to better match the background. For land prey animals that are targeted particularly from the air have darker backs to match the ground and lighter underbellies to reduce the shadow. Fish also have counter shading with lighter undersides and darker upper for predators from above. Prey fish in mid-water are vulnerable from attack from all directions above and below. The vast majority of fish have have counter-shading of darker backs and lighter undersides and those that live in shallow bright sunlit habitats many are also ventrally compressed to assist in the effect. A few deep water fish even have light emitting cells on their underside to help match the surface. Fish that live on the bottom will exhibit counter-shading with their backs coloured to match the background and underside often white to reduce the shadow created. Pelagic or mid water fish will also hide from predators using this but as the background is blue or shades of blue/green they need to match the colour.

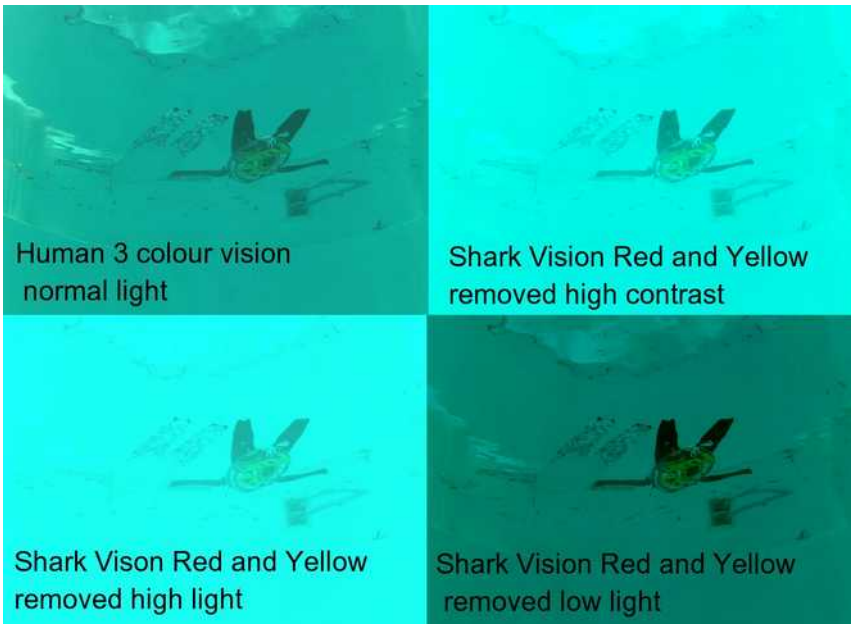

Figure 7 An example of the same board and wetsuit combination under differing light and colour conditions

The other difficulty for mid water prey fish is that blue background is constantly changing with time of day, seasons, weather conditions and light levels. The colour of the background is also greatly affected by the position of the viewer in relation to the sun. A blue that is a perfect match may not be an hour later or if the fish is seen from a different angle. The evolutionary response was to develop silver mirror like scales with high reflectance to show the colour of the surrounding water and most importantly to change as the water or angle of the viewer changes. The scales adapt passively without the fish controlling the effect. Some fish are able to change colour manly to signal or communicate but if used for camouflaging changing colour to hide from a predator approaching in one direction may make it more visible to another.

The combination of the reflective board and wetsuit will hide the surfer giving little reason for the shark to come within striking range or lead to mistaking them for possible prey. The shark can not become accustomed to the effect nor will it imped the surfer or board performance, it will be effective in all geographical locations, water conditions and times of day.

Its an Accumulative Effect

If a shark deterrent device is 60% effective it's better than nothing but if a couple of 60% effective products that used different avoidance measures were combined the effect accumulates. So the 1st method cuts down attacks by 60 out of 100, and the remaining 40 is cut down by the next method by 60% to 24. Now we have something that's 84% effective. Not bad, but not scientifically significant. What if there was a 3rd measure that cuts the 16 by a further 60% giving 93.65% effective. Now were getting somewhere. Still not scientifically significant but a hell of a lot better that 50%. There is a law of diminishing returns as no matter how many layers of protection you have you cant get to 100% and the cost becomes too high and the board now weighs 20 kg. So where is the acceptable level? 50% is a coin toss, heads bitten tails not bitten so is a waste of time, 80% better 90% better again 95% now its scientifically significant. To be effective and to justify the cost it needs to between 95 and 99%.

We are trying to avoid not the inquisitive sharks or little sharks or curious sharks or sharks drawn in by burly or sharks swimming past minding there own businesses. But big predatory hungry sharks on a full blown attack run at 30 km per hour with no warning of their presence hoping to get a fast moving fish or seal. Better not be seen at all than rely on being able to turn that shark away.

In the real World
If you're surfing on a beach in clean water and big hungry shark that could possibly attack a surfer is swimming through foraging for food. The path it takes and its senses cover 10% of the area or about a 50m width with vision of about 30m. So you have 1 in 10 chance of being sensed or spotted but if the board reduces your chance of being seen by 66% so the shark has to come within 10m for you to be spotted. So you have now 3.4 chances out of a 100 of being seen. Without any other factor we have reduced the possible encounter to 3.4 chances out of 100 instead of 10 in 100 a reduction factor of 66%. If the shark dose comes within the 10m, what will it see? A sight distortion of the surface that doesn't look like food. How many will swim on? Lets say 50% swim on; because some may want to look at those black things hanging down our chance is now 1.7 in 100 (reduction at 83% of the 1 in 10). Black wetsuits are not the best option. We have a camouflage wetsuit (designed for shark vision)that also leads to again a 50% swim on. Now it's a 0.85 chance in 100 or 91.5% reduction of the 1 in 10. This is close the scientifically significant 95% level. But we are dealing with people's lives so we have to get it better. On our camo wetsuits we have 2 concepts to add as an overlay to the special colours. The 1st is a pattern that the shark is familiar with and is not eatable and the other is an object the shark is likely to avoid. These are the 2 factors we currently testing on real sharks in the water but if with either we get another 50% swim on then we are at 0.425 chances in 100 or a reduction of 95.75% and it is significant.

At close range several other factors contribute to the accumulative effect, they include loss of position or the object disappearing with angle change, identified but unable to determine position, perceived as too big or in a tight formation will increase the number of times a predatory while actively hunting will dismiss or swim by without making contact. At very close range a number of behavioural responses that also deter contact occurring and will be disclosed at a later time once the research is completed.

Our actual estimate of the vision perception range of sharks to our board is 6-8m in clean water in dirty its even less, the wetsuits will be geographically limited but can be adjusted for other areas. The estimate of the swim on of value of the wetsuit patterns are much higher than 50% but rather than work on the best possible scores we will work on the worst to improve and perfect. 95.75% is not 100% so further improvement of the Wetsuits is continuing.

Assumptions and result of the Accumulative effect
Clean open Beach 10 Km with 1000 Surfers in the water or 100 every 1km
Large Predatory Shark hunting 50m perception range and 30m visual range
Chance of being spotted by random foraging 10% or 100 Surfers

Reduction Estimate Conservative within 10 m Range
Board reduction to 10m visual gives 2/3 reduction or 66% leaving 34 surfers spotted
Swim on value of early dismissal not interesting 50% reduction 83% leaving 17 surfers spotted
Swim on value of wet suits 50% reduction 91.5% leaving 8.5 surfers spotted
Swim on value of just 1 other close range factor 50 % gives 95.5 leaving 4.25 surfers spotted
Or 19 out of 20 attacks avoided

Reduction Estimate High values within 6m Range
Board reduction to 6m visual gives 5/6 reduction or 83.3% leaving 17 surfer spotted
Swim on value of early dismissal not interesting 60% reduction 93% or 7 surfer spotted
Swim on value of wetsuits 60% reduction 97.5% or 3 surfers spotted
Swim on value of just 1 other close range factor at 60 % gives 99% leaving 1 surfer spotted
Or 99 out of 100 attacks avoided

Close range factors
Loss of position disappearing with angle change swim on value 50%
Identified but too big swim on value 50%
Tight formation unable to pick individual swim on value 50%
Depth perception error by over shooting swim on value 50% but may get bumped
Minor Black hole factor only when angle correct swim on value 66% incorrect angle 33%

BB factor only when angle correct swim on value 33%
Sun edge flare, flash of light swim on value 10%

Our Real world estimate is 39 out of 40 attacks avoided

Scientific Methods

What is meant by scientific proof? It is the rigorous testing of an idea or theory or hypothesis to say how likely it is to be true or not. The tests have to set up so that they are not biased one way or the other; with enough trials to be sure the results are not just a fluke and able to be repeatable over and over again with the same result. In biology we use 95% or under 95 times out of 100 the results are just flukes and can't be relied on. So if you score above this it's considered correct or significant and under even if you score 94% its not. Because of the maths (or statistics) involved we try to test our idea by proving it wrong (called falsification). So if we think there are more sharks at location A than location B (why is a different question) we test that:

"There is NO significant difference between the number of sharks at location A and location B"

Its called a Null Hypothesis. So we now work on if it's under 5% its significant 6% is not and 1% is better than 5%. The 1% means there is only 1 chance in 100 that the result was a fluke and 0.001% means there's only 1 chance in a 1000 you were wrong. Then you count your sharks and get numbers for location A and B but is the result just right for that day? So you do it over several days. What if it's just that week? Ok so you do 1 day a week for a month or year or 3 years or 10 years. The more you do adds strength to your result. What about the location? If Location A is Deep Ocean and Location B is Shallow then the result could be biased by depth so now you add another location in-between called a control. Now how are you counting them? By helicopter? Shallow B might score better than A because of the method so you add 2 different methods (electronic tagging and side scan sonar). Your simple idea that there are more sharks at location A than B is now a 3 year study of 4 locations by 3 different methods. Getting complicated isn't it. So why bother?

The more you do the stronger your result and the less chance that it was just a fluke or you are wrong because when you publish your conclusions in scientific journals it will be examined by shark scientists worldwide looking for any possible way to rip your work to shreds as being worthless in an anonymous process called "peer reviewed". Nothing in nature is as vicious, nasty and pedantic as the peer review process where disagreements about the definition a single word can prevent a paper from being published. In an ideal world this is meant to be constructive method to strengthen the research, share and build knowledge. Young researchers soon learn that sharing sadly is often only one way and doing so before publication can led to their concepts being appropriated, their input dismissed and their names excluded.

Once an idea that has been published and peer reviewed and survived the process its considered correct until someone else proves it wrong. Any report, study or technical document that claims to be "scientific proof" that is evaluated in house by the same government department that did the research is not independent. It could be true but is not scientific proof. Research funded by the maker or where the scientists doing the work own, employed by or even associated with the product is biased and cant be relied on. Even ours. One piece of video showing a shark avoiding a device is not scientific testing no matter what the marketing of that product says. 100's of hours of video tests over multiple locations over long time periods with different sharks with proper controls and the numbers tested statistically showing a significant result is.

Once our next round of pilot studies are concluded consent for our product to be tested by reputable Shark Scientists worldwide against any other deterrent method in any location with any shark species will be given without reservation.

By mid 2018 we hope to be able to announce that 2 Australian and 3 overseas universities are testing our concept independent of any involvement by Sharkview. We know what our products do and have nothing to fear by handing it over for others to test.

Experiments and Results
The design, methods and procedures for ocean testing have been approved by NSW DPI Fisheries and a Scientific Permit for 2016 to 2019 to conduct field work off Port Stephens has been granted (Permit No P16/0114-1.0). It will use covered bait canisters deployed in known shark areas and the resulting behaviour recorded for empirical and statistical analysis.

The project will evaluate the effectiveness of adaptive camouflage as a method of shark avoidance to test the 2 main null hypotheses and several other hypotheses within the experimental design in regard to the close range effects.

HO1There is no significant difference in the contact by sharks between the test patterns Base Camouflage, Familiar Object and Avoid Item and the control

HO2 There is no significant difference in the rate of approach of sharks between the camouflaged board A30 and the control

The reflective boards were first tested in the ocean and the pattern, reflective levels and other factors further improved in a pool by using the MOE method were visibility was higher, colours restricted and water movement reduced. Final prototypes match the surface water from underneath and can not be seen from 6m away. Wetsuit patterns were printed on Lycra and evaluated in differing light and water conditions. The resulting photographs were then adjusted for the best understanding of a shark vision with No red or Yellow, High contrast blue/green.

In water field tests have been conducted at Port Stevens using covered bait canisters deployed in known shark areas and the resulting behaviour recorded for analysis. The canisters will contain a uniform mixture of pellets, fish oil and ground fish flesh.

The canisters will be covered in the 3 patterns and a 4th control canister. Boards with varied reflective levels and patterns will be deployed at the same time as the wetsuit tests and evaluated in a similar manner. The behaviour of sharks will be recorded by underwater video cameras and a 4 channel CCTV security system with memory and power for 4-8 hours or on action sport cameras for deployment further from the boat.

Results to Date
Pilot trials and pre testing have been conducted since 2015 and official studies under the methods set out in the scientific permit began in November 2016. Over the 2016-17 summer sharks have shown no interest in reflective board with bait attached in 40 hours of deployment over 10 days. 50 hours of wetsuit testing over 12 days with the 3 patterns and a control has attracted sharks with no unexpected contact being made. Highly promising examples of sharks veering off the Avoided Item pattern have been recorded on video on several occasions however, low shark numbers and poor water conditions had hampered the number of interactions. Testing was not performed over winter as even lower shark numbers are present in the location and will resume as numbers increase with the Avoiding pattern for behavioural responses and the full control and blind trials of the boards.

The testing will attempt to determine and to quantitatively describe the "swim on" values of the effects described previously and investigate the close range behavioural responses to the board and wetsuits. The outcome will be a final set of products that are cost effective, accepted and most importantly successful method of avoid shark attack with no detrimental effects on the surfer or marine life.

While testing off Port Stephens Sharks were present on many occasions and 3 were positively identified as Whites from the surface. Indications from side scan sonar suggested that

most avoided the camera trap area and bait by 4-5m, some passed under or at a distance of 3 m (CH3). One shark LC18 approached from behind the bait canister where the Avoiding pattern was obscured. The shark came to with 1m before sighting the pattern and veered off. The video shows the moment when the shark sees the pattern and when it decides not to take the bait. Importantly and unlike other proposed methods no shark to date has made repeated passes or have any baits been taken unexpectedly. While this is encouraging conformation of the Avoid effect is possible until further evidence is obtain the pattern will not be shown or released.

Current Testing
Following the direction of partnering agencies within Australia and overseas the pilot study of 2016-17 will be extended to a larger comprehensive effort over 2017-18. Highly promising examples of sharks veering off the Avoided Item pattern have been recorded on video however, low shark numbers and poor water conditions limited the number of interactions. The design, methods and procedures were approved by NSW DPI Fisheries (Permit No P16/0114-1.0) from Mungo Beach between Little Gibber and Big Gibber or on Stockton Beach consisting of 25-50 events in 2017-18. The use of burly limited to the minim required to attract sharks to the target area while not generating an over stimulated state.

Landoa Pty Ltd will provide equipment, oversee field work and supply video, sidescans and recorded data in raw form to BlackEarth Environmental for evaluation, statistical testing and preparation of reports. On completion BlackEarth will present the results to the proposed partnering institutes in Australia and overseas with the intention of further studies validating effectiveness conducted concurrently over multiple locations with other species.

Future Research projects
Once commercialised in conjunction with our own research goals a proportion of funds will be allocated to students and other independent researchers for shark and marine studies. This may take the form of finical support, equipment loans, boat time or other means. Projects performed will be at the highest scientific and ethical standard for both students and supervisors with the overarching goal to do no harm.

Projects that will NOT be supported or funded:
That require permanent collection or harming of any marine life
Repetition of past research
As an alternative to University or Government funding
Investigation of known concepts

Future Projects
Easterly Black hole
Safe distances
Day/night movements
Aquaculture MOE
Rope OCM
Hunting stratagems
Dawn and dusk light and shadows
Observation drone and or blimp or Live tracking
Interactions with Salmon, Tuna, Dolphin and Whale
Eagle ray schooling