Please note that the Woods Hole Group is in no way associated with the world renowned Woods Hole Oceanographic Institute.

Dear Interested Parties,

This document has been written in order to bring to light a number of serious problems and errors associated with the recently released “Outer Cape Shark Mitigation Alternative Analysis Report” herein referred to as the Woods Hole Report.

The section of the Woods Hole Report focused on visual observation was thoroughly reviewed along with all primary sources. The problems associated with this section are so severe as to bring into question the validity of the entire report. The Woods Hole Report has severely misrepresented the potential of visual observation as a means of shark detection at Cape Cod beaches.

This document provides a detailed analysis of Section 5.2 (Visual Observation) as well as a bulleted list of some of its most critical problems. It also contains a detailed analysis of the discussions related to Section 5.2 (Visual Observation) that took place at the October 17, 2019 meeting at Nauset High School. Comments related to permitting and costs are also included.

This effort has been for the sole purpose of making these problems clear to any interested parties. This analysis is not meant to endorse any particular approach or suggest any particular course of action.

Thank you,

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This document was revised with minor clarifications and changes on December 15, 2019. The overall analysis and conclusions from the original version published on November 6, 2019 remain the same.

Critical technical errors in the Woods Hole Report (visual observation)

- Report fails to understand the single study, Robbins et al., from which it draws nearly all of its conclusions as demonstrated by numerous indisputable factual errors in the description of the study and its results

- Report fails to recognize that, provided adequate water clarity, the relatively shallow waters found at many Cape Cod beaches would enhance contrast, significantly increasing the ability to detect sharks as compared to the relatively deep waters in which the Robbins et al. study was conducted.

- Report erroneously claims that the performance results of the Robbins et al. study are "likely to carry across all methods of visual detection" while providing no evidence, references or theory for this assertion and in fact ignoring strong evidence to the contrary.

These errors bring into serious doubt the comments, observations and conclusions in regards to visual observation contained in the Woods Hole Report. The technical details of the Woods Hole Report cannot be trusted.

Critical errors of the Woods Hole Report (visual observation) in regards to costs and permitting

- Report provides unrealistically high cost estimates for drone use based on quotes from drone service providers that specialize in geo mapping and use drones with advanced sensing equipment that is not applicable to shark detection

- Report falsely states that permits from the Cape Cod National Seashore (CCNS) are required to fly drones within the CCNS. Report states that information regarding permitting came directly from the government agencies themselves

These errors demonstrate further failures of the Woods Hole Report and raise serious doubts as to whether there is any value in this report at all. It simply cannot be assumed that even basic information in the report is correct.

Technical Analysis of Section 5.2 (Visual Observation, pages 35-37)

- Introduction

The Woods Hole Report devotes a section to the analysis of visual observation methods which include the use of manned aircraft, drones, balloons and elevated towers. This section references a single peer reviewed journal article. This reference is a 2013 paper by Robbins et. al. that details a two part study conducted to test the ability of observers in planes and helicopters to spot sharks. The authors attempt to use this single study to draw broad conclusions across all forms of aerial observation in an area with a very different environmental conditions from those where the study took place.

When we examine the Woods Hole Group's analysis of this study it becomes very clear that they did not give the paper more than a cursory read. The Woods Hole Report misrepresents the findings and nearly all key details of the Robbins et al. study. Six of the nine numbers that the Woods Hole Report claims to take directly from Robbins et al. study are incorrect and in every instance the report uses a number that implies the performance results were below those actually reported in the study. The only numerical detail from the study that the Woods Hole Report gets correct and describes in the same manner in which it is described by Robbins et al. is that the shark analogs used were 2.5m in length. The Woods Hole Report displays a lack of understanding of the study, consistently misrepresents details of the study, fails to recognize the limitations of the study and demonstrates a lack of understanding of the physics of subsurface aerial imaging in a marine environment.

Despite the failure to describe and report the study correctly, the most critical errors of the Woods Hole Report stem from the authors erroneous conclusions that the results of Robbins et al. are directly applicable to the very different environmental conditions found on Cape Cod and that they are likely to carry across all methods of visual detection.

The Woods Hole Report fails to recognize the tremendous influence that the shallower waters present around many Cape Cod beaches can have on the ability to detect sharks. Robbins et al. recognized the importance of this and made a point to explicitly state that their "study was not conducted along coastal beaches" and noted that programs may be "most effective at sloping beaches with extended regions of shallow waters". The Woods Hole Report also claims performance results from the Robbins et al. study are likely to carry across all methods of visual detection. They do so without providing any evidence, explanation or even theory. Robbins et al. do not come to this conclusion and recognize that their work was specific to manned aircraft. Robbins et al. allude to both of these study limitations and state in their discussion section while referring specifically to drones that "The application of such methods to detect inshore sharks has yet to be determined, however they are worth further investigation"

- Failure to understand and explain Robbins et al.

The Robbins et al. paper details the results of two separate studies. In the “depth study” shark analogs (painted plywood shark cutouts) are slowly raised towards the surface and the depths at which the observers circling in either helicopters or fixed-wing aircraft first detect them are recorded. In the “distance study”, the ability of aerial observers to detect shark analogs placed 1.8 to 2.2 meters below the surface is tested as they traverse an area in either a helicopter or fixed-wing aircraft. The Woods Hole Report does not appear to understand that the paper explains what are essentially two separate studies. The Woods Hole Report only explains the test methods of the distance study and it appears as though only the distance study is referenced throughout the analysis and discussion. However, numbers and information from the depth study are consistently mixed in.

The Woods Hole Report describes the Robbins et al. study as follows:

“The study was carried out using 2.5m (~8ft) shark analogs (plywood cutouts traced from the bodies of white, hammerhead, and bull sharks) moored in a test area. The water was clear over a white sand and seagrass bottom. Winds were light and the area was sheltered from waves. Depths varied from 6m to 12m (20ft to 40ft). These are relatively ideal conditions for spotting.”

This is clearly a description of the distance study but the depth information provided is from the depth study. The depths of the distance study are actually 9.3m to 15.3m. (30 - 50 feet). The comment that these are relatively ideal conditions for spotting is simply not true due to the relatively deep water the study was conducted in.

Interestingly, there was no significant performance difference between the experienced and inexperienced observers. The inexperienced observers actually did better in some circumstances.

This description is misleading. There was no direct comparison between experienced and inexperienced observers in the Robbins et al. study. Fixed-wing aircrew had experience in shark spotting while helicopter crew did not. The study suggests that the aircraft category (fixed-wing vs. helicopter) has a greater impact on performance than aircrew experience, but the study does not suggest in any way that experience may not be an important factor in shark spotting.

“While there were exceptions, shark analogs moored deeper than approximately 2.5m were not spotted by the observers in the Robbins study.”

With no description or even mention of the depth study we have to assume that the Woods Hole Report is still referring to the distance study here. This is somewhat puzzling because the distance study did not include any shark analogs below 2.5m. In the depth study the average depths at which the analogs were seen for the two aircraft were 2.5m and 2.7m so if we assume a normal distribution more than half the analogs were seen below 2.5m. We could also look at

Figure 1. (reprinted from Robbins et al.) and count the numerous sharks spotted below 2.5m. The statement makes no sense for either study.

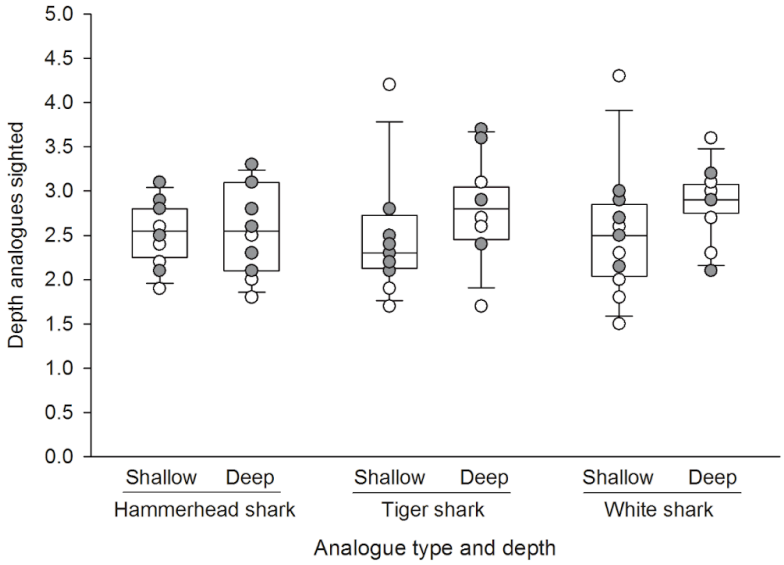

Figure 1. Depths at which shark analogues were sighted by fixed-wing and helicopter observers maintaining their position at 500 ft (~150 m) around a known position. Overlaid are individual data points from each aircraft; open circles represent fixed-wing sightings, closed circles represent helicopter sightings.
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"DMF notes that they have on occasion clearly detected a shark near the bottom in much deeper water, but have also lost sight of a shark in much more shallow water. The take-away here is that visual spotting depends on several dynamically changing variables and gets rapidly less reliable for sharks swimming further from the surface. "

The Woods Hole Report does not properly report the water depths or the shark detection depths of the study it is referencing. As such it is difficult to make sense of the comments from the DMF. That being said, it is not surprising to hear that DMF has spotted sharks "much deeper" than the 2.5m the Woods Hole Report seems to be referring to here. In the Robbins et al. study shark analogs were actually spotted as deep as 4.3m. It is unfortunate that the influence of water depth and the difference in the depths at which DMF often operates and those found in the Robbins et al. study are not discussed. It is also worth noting that aircraft in the Robbins et al. study flew at altitudes of 500ft. The spotter plane used by DMF typically flies above 1000ft. The Woods Hole Report combines information from the Robbins et al. study and conversations with DMF without ever addressing or even mentioning the large difference in techniques used by the two groups.

"We note from discussions with Greg Skomal and others that white sharks typically swim just above the bottom when hunting and attack suddenly on a fast trajectory. Nearshore Cape waters are relatively shallow, typically less than 3m (10 ft.), but that is still sufficiently deep to hide sharks from visual detection"

It is interesting to read this comment from Dr. Skomal. and certainly an important observation. It would be valuable to know who the other researchers were that the Woods Hole Group spoke with and also how this data has been collected. There does not appear to be anything published in regards to swimming depths and distance from the bottom prior to great white attacks in Cape Cod waters. Research suggests that hunting patterns of great white sharks vary considerably between geographic areas and so information specific to Cape Cod is important. That being said sharks swimming at or near the surface still pose a risk to swimmers. A recent study from Watenabe et al. which used accelerometers and video cameras attached to great white sharks was able to detail seven likely predatory events off of the Neptune Islands in Australia. Of these seven, the only confirmed predatory event (captured on video camera), occurred when a shark encountered a seal while the shark was swimming along the surface.

It is true that the relatively shallow waters of the Cape are deep enough to hide sharks from visual detection, in fact any water deep enough to allow a shark to be completely submerged is deep enough to hide sharks from visual detection. However, the shallow nearshore waters of the Cape which the Woods Hole Group notes here (typically less than 10ft), actually greatly enhance the ability to visually detect sharks.. Swimming in these waters still poses a risk of shark attack as noted by Dr. Skomal in an interview with the Boston Herald in July of 2019.

"If you're on the Outer Cape and seals are nearby, just realize if there's more than 6 feet of water or 5 feet, sharks could be hunting seals in shallow waters." (Boston Herald Interview, July 2019)

In an interview with the Guardian published in June of 2019, Dr. Skomal is quoted as saying:

there are probably more great whites along the rest of New England's coast, but that Cape Cod's topography – like a giant sandbar sticking out in the ocean – means humans run into the sharks' hunting paths more often and that sharks get drawn into shallow water more easily.

The Woods Hole Report does not offer a full or accurate description of the unique environmental conditions found on Cape Cod and how these conditions may influence shark behavior, risk to swimmers or suitability of detection methods. Instead the Woods Hole Report appears to select and report only a very limited number of specific observations from Dr. Skomal and DMF that in isolation are of no real value. In isolation these comments may in fact be misrepresentative of the actual environment they are purporting to describe.

Of the near surface shark analogs in the Robbins study, the observers detected, on average, only 12% (experienced observers, fixed wing plane) to 17% (inexperienced observers, helicopter, wider field of view).

The term "near surface" is never used in the Robbins et al. study. It could be argued that the study did not include any near surface sharks. The distance study included only shark analogs

placed between 1.8m and 2.2m (~6ft - 7ft) below the surface. In ten feet of water this would make these sharks closer to the sea floor than to the surface.

In reference to the distance study the Woods Hole Report states that in optimal study conditions spotting efficiency tops out at 33%. This is simply not true. Robbins et al. report a best case scenario for fixed-wing aircraft of 33%. However, helicopters which traveled at a slower speed had a maximum efficiency of 50% at a distance of 100m from the flight path. This can be seen in Figure 2. (reprinted from Robbins et al. [red arrow added]). It is also explicitly stated in the text, “The optimal sighting range for the helicopter was 100 m from the flight path, at which half the deployed analogues were sighted.”

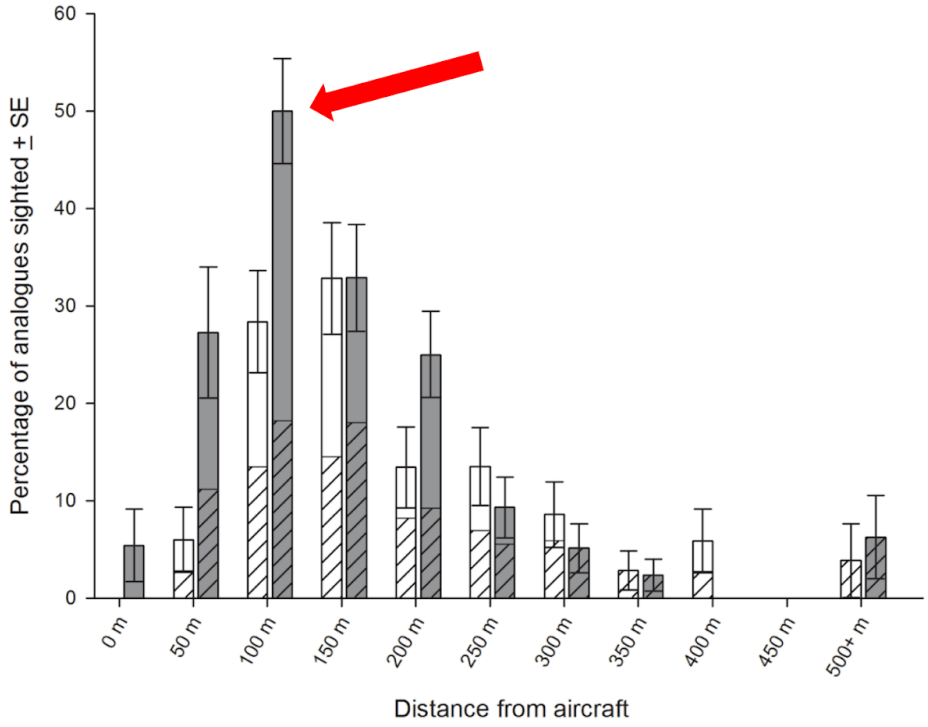

Figure 2. Percentage of validated analogue sightings per aircraft with the relative contribution of different trial treatments. Open bars indicate fixed-wing data, closed bars indicate helicopter sightings. Hashed bars indicates contribution of trials using standard methodology (cruising speed, no orbiting), non-hashed bars indicates contribution of alternative trials (orbiting permitted (fixed-wing), 100 kts airspeed (helicopter)). Contribution of each treatment type has been scaled to account for differences in sample size.
doi:10.1371/journal.pone.0083456.g002

The Woods Hole Report goes on to state that “Over the full range of viewing angles, the overall detection rate was 9%.” This is not true. The abstract states that neither aircraft observer sighted more than 9% of analogs deployed over 300m from their flight path. However, this is not the detection rate for observers “over the full range of viewing angles”.

The Woods Hole Report further states that “In summary, working in relatively ideal conditions, the observers consistently missed at least two-thirds of the near-surface shark analogs. “ The Woods Hole Report is again referring only to the performance of the plane and disregarding the

significantly better performance of the helicopter. The Woods Hole Report again refers to the 1.8m to 2.2m deep shark analogs as “near surface”.

The Woods Hole Group goes on to state:

“Over the full area of observation, they commonly missed 90% of the targets, including 100% of those located 3m or more below the surface.”

The observers did not commonly miss 90% of the targets over the full area of observation. This is simply not true. The authors report an overall sighting rate of 12.5% for planes and 17.1% for helicopters. In the discussion section of the Robbins et al. paper the authors mention “the low (<10%) distant sighting rates seen with the full-sized analogues.” However, when the authors reference “distant sighting rates” here they are again referring only to analogs placed 300m or more from the aircraft flight path.

It does not make sense for the Woods Hole Report to claim that the observers missed 100% of those analogs located 3m or more below the surface. The distance study did not include any analogs 3m or more below the surface. Again, it is not clear that the Woods Hole Group understands that the paper details what are essentially two separate studies. In the distance study all analogs were placed between 1.8m and 2.2m below the surface.

Even if we look at the depth study, which the Woods Hole Report does not appear to be referring to in this instance, analogs were sighted below 3m. This can be seen in Figure 1. (reprinted from Robbins et. al). This figure clearly shows instances of analogs being detected at depths over 4.0m. Additionally, Robbins et al. explicitly state “ The maximum depth of any individual sighting was 4.3m”.

- Erroneous application of Robbins et al. to other aerial observation platforms

Finally, after completely misrepresenting the results of the Robbins et al. study the Woods Hole Report goes on to state “It is likely that this level of performance will carry across all methods of visual detection”. They do not provide any evidence or any references for this assertion. Even with all the errors in the basic summary of the Robbins et al. results, this statement may be the most significant error yet. Beach patrols with airplanes and helicopters are probably not going to be the most promising solution to the shark problem or at least not as a stand alone solution. However, the Woods Hole Group’s attempt to extrapolate the results of this study to all other methods of visual detection including drones and balloons, demonstrates a lack of understanding of not only the Robbins et al study, but also of the physics involved in the problem.

The Robbins et al. study itself saw statistically significant differences in performance between observers in helicopters and planes. These methods are certainly more similar than manned aircraft compared to drones or balloons. Robbins et al. do not make the claim that the results of

their study should in any way carry over to drones or other aerial imaging platforms . In fact, Robbins et al. are very clear that their study is an evaluation of the use of manned aircraft for aerial beach patrols only and state in their discussion section, “Clearly, alternative safety measures to aerial beach patrols should be considered to protect the public from shark attacks.” They go on to specifically mention the potential use of drones and while referring to drones state, “The application of such methods to detect inshore sharks has yet to be determined, however they are worth further investigation.”

The results of the Robbins et al. study clearly suggest that drones may be expected to perform better than planes or helicopters. In their statistical analysis Robbins et al. note that “distance to the analogue, hour of day (sun position) and whether the observer was facing north (i.e. towards the northerly aspect of the sun) all had a negative impact on whether an analogue was sighted.” One of the primary advantages to the use of drones for aerial detection of sharks is the ability to position the drone so as minimize sun glitter while observing a fixed area and essentially enabling the optimization of all the parameters that were seen to affect results in the Robbins et al. distance study. If one were forced to take a single number from the Robbins et al. and use it as a baseline for the potential of drones to see analogs between 1.8m and 2.2m deep in 9m to 15m of relatively clear water it would make the most sense to use the 50% success rate for helicopters with analogs at 100m from the flight path simply because drones can be positioned so as to optimize viewing angle at all times. If the helicopter were able to optimize viewing angle at all times and patrol a limited area it would certainly be expected to perform even better.

There are a number of other ways in which drones may provide superior performance to observers in aircraft. Performance increases may result from the ability to perceive relative motion. Robbins et al. dismissed effect that the lack of movement of analogs may have on their study due to the fact that relative motion of actual sharks would be severely limited for observers in moving aircraft. This would not be the case for stationary or slow moving drones. Robbins et al. also noted the difficulty in analog detection at low sun angles where limited light penetration into water was thought to be the factor. Camera systems are likely to offer superior performance as compared to the naked eye in these conditions.

The Woods Hole Report notes that “Drones and balloons observe through cameras, which **may reduce** the ability of operators to spot sharks compared to direct human observation from a plane or helicopter.” [emphasis added] The authors provide no references, evidence or even theory for this suggestion. The sentence could have just as easily read “Drones and balloons observe through cameras, which **may increase** the ability of operators to spot sharks compared to direct human observation from a plane or helicopter.” In other words, this sentence says nothing about how drones or balloons may be expected to perform as compared to observers in aircraft. However, it may say something about a bias in the Woods Hole Report.

- Erroneous application of Robbins et al. to Cape Cod waters

It is important to understand that the imaging platform is only one part of the equation and we may in fact stand to see even greater performance gains under different environmental conditions. While the Robbins et al. study was conducted under various sky conditions, light to moderate winds and relatively clear water it was not conducted along coastal beaches. Water depths ranged from 9.4m to 15.3m (31 to 50 feet) in the distance study and 6m to 12m (20 to 40 feet) in the depth study.

In the depth study Robbins et al. examined the relationship between water depth and sighting depth concluding that under the conditions of their study water depth was unlikely to have any influence on analog sightings. This hypothesis was further confirmed in the distance study where no relationship was seen.

These results are due to the fact that the study was conducted in relatively deep water where reflections off of the bottom were minimal and as such variations in depth did not result in changes in observed reflections. The technical term for the condition in which light reflected from the benthic surface does not affect remotely sensed water leaving radiance is “optically deep”. For practical purposes the Robbins et al. study can be considered to have been conducted in optically deep water.

In the relatively shallow waters that are present at many Cape Cod beaches this is not the case. Swimming and small wave surfing activities typically take place in areas with sand bottoms and 10 feet (3m) of water or less with depths well below 20 feet (6m) continuing some further distance out before water depth increases significantly. The authors of the Woods Hole Report appear to be aware of this noting “Nearshore Cape waters are relatively shallow, typically less than 3m (10ft.)”. However they do not appear to be aware of the fact that these conditions greatly aid in the ability to detect underwater objects. At these shallower depths, provided sufficient water clarity, significant light is able to reflect off of the sand bottom and return to the camera or observer greatly enhancing contrast. These conditions may be referred to as “optically shallow”. A study such as Robbins et al. would not be expected to yield the same results were it conducted in the relatively shallow waters found at many Cape beaches. All else being the same, it would be expected to produce superior results.

While many Cape beaches will not generally have as clear a water as seen in the Robbins et al. study they will often have clear enough water to enable enhanced contrast via reflections off the bottom. This effect would be expected to be apparent at water clarity levels as low as the lowest clarity levels seen in the Robbins et al. study (2.0m Secchi depths).

The authors failure to recognize this is a gross oversight as its importance cannot be overstated for particular Cape Cod beaches and conditions. Robbins et al. clearly recognized the limitations of their study stating in the discussion section that “methods to detect inshore sharks have yet to

be determined" and noting that programs may be "most effective at sloping beaches with extended regions of shallow waters".

While the physics of subsurface aerial imaging in a marine environment are complicated, one does not need a full grasp of them in order to understand the limitations of the Robbins et al. study. Quite a bit can be learned from simple observation.

When writer, Erik Vance, was doing a story on sharks for National Geographic magazine he went up in a small plane out of Chatham to take a look for himself. He saw right away what the Woods Hole Group has failed to recognize, that is, the relatively shallow waters found in many areas of Cape Cod greatly enhance the ability to spot sharks from the air. Here is an excerpt from his July, 2016 story in National Geographic magazine.

One bright August morning I board a two-seater plane with Wayne Davis, a veteran spotter pilot for tuna and swordfish who now helps scientists track down white sharks. ***Unlike the hubs, the water here is so shallow that sharp eyes can spot them from the air****. In just 30 minutes of flying we see seven, all patrolling beaches where gray seals are foraging in open waters. On the way back Davis and I fly past several beaches a mile or so to the north packed with vacationers. [emphasis added]*

The Woods Hole Group did not fly with Wayne Davis or consult him during the drafting of the Woods Hole Report.

- Errors and omissions in concluding remarks

In their concluding remarks, the Woods Hole Group makes the following statement.

Visual observation simply does not spot most of the sharks, even under ideal conditions,

This statement is unfounded. It is a conclusion based on a single paper that looked only at the performance of observers in airplanes and helicopters under very different environmental conditions than those found on many Cape Cod beaches. Additionally, the distance study only looked at 2.5m shark analogs between 1.8m and 2.2m deep. Robbins et al. made no claims about typical shark swimming depths. The depths Robbins et al. used were deliberately chosen based on results from the separate depth study so as to make the task of spotting sharks somewhat difficult but not impossible. Without detailed knowledge of expected swimming depths there is no way to make this broad statement, the depths used in the study must be specified. The Woods Hole Report does not make any statements about shark swimming depth profiles or even median shark swimming depths. The Woods Hole Report again ignores water depths and misrepresents the conditions of the Robbins et al. study as being ideal. It is also worth noting that even if one were to disregard all the aforementioned problems with this statement and rely solely on the Robbins et al. study it is still false. Under the optimal conditions of the Robbins et

al. distance study observers in helicopters spotted 50% of shark analogs at 100m from the flightpath.

The Woods Hole Group goes on to state:

and performance falls off sharply when conditions (viewing angle, sun glint, fog, waves, wind/cat's paws, suspended bubbles, sand, and sediment, etc.) are less than ideal.

It is certainly true that environmental conditions can greatly influence performance. However, the quality of the conditions for the visual detection of sharks is something that can be measured in a relative manner and standardized. Any real discussion of the implementation of using local visualization methods such as drones or balloons would acknowledge this fact. If one of these methods were to be implemented it would be feasible and indeed imperative to include periodic monitoring of observation conditions allowing operators to cancel operations when conditions deteriorate below some predefined level.

Finally the Woods Hole Group concludes that:

Visual detection may be particularly prone to missing the sharks that are near the bottom hunting and the proximity of observations to swimmers may not provide sufficient time, even with real-time alert-based systems, to clear the water when a shark is spotted.

It is true that visual detection becomes less effective as sharks swim deeper. However, there appears to be clear evidence that sharks swimming at or near the surface also pose a risk to swimmers as they have been seen to attack seals. (Watenabe et al.) The shallow conditions at many beaches on Cape Cod makes seeing sharks near the bottom easier as a result of both increased contrast due to reflections off the bottom as well as the simple fact that the distance to the bottom is decreased as the water becomes more shallow.

In regards to the proximity of the point of detection of a shark to swimmers and the ability to get swimmers out of the water safely, this is a legitimate concern. However, it is also a problem for which relatively simple estimates can be made based on shark swimming speeds, surveillance coverage areas and human response times. The Woods Hole Report does not make any effort to provide these types of estimates. In the case of using drones or balloons the area covered can easily be expanded by increasing the number of drones or balloons. Although, it must be noted that this is not an entirely scalable problem as covering distances further offshore becomes less effective due to increasing water depth,

- Conclusions

The Woods Hole Report has failed to properly present the results of the single peer reviewed reference that it bases its entire analysis on. The Woods Hole Group misrepresents virtually every detail of the study and clearly does not understand the study. Even more importantly they

fail to recognize the severe limitations of the Robbins et al. study. The Robbins et al. study was conducted in relatively deep waters as compared to the relatively shallow waters present at many Cape beaches. Provided sufficient water clarity, shallow waters would be expected to result in enhanced contrast improving the ability to detect underwater objects. The attempt to extrapolate the results of Robbins et al. to all forms of visual observation is a further failure of the Woods Hole Report. The Woods Hole Report presents no evidence to support this assertion and in fact ignores the strong evidence to the contrary that is provided by the actual results of Robbins et al. as well as a host of other peer reviewed journal articles. The Woods Hole Report has severely misrepresented the potential of visual observation as a means of shark detection at Cape Cod beaches.

Analysis of Discussions at Nauset High School on October 17, 2019 (Visual Observation)

During the presentation of the Woods Hole Report at Nauset High School on October 17th, many of the erroneous numbers that the Woods Hole Report quotes from the Robbins et al. study are repeated again by Dr. Todd Morrison. Please see the**Technical Analysis of Section 5.2 (Visual Observation, pages 35-37)** in this document for more specific details and the actual results of Robbins et al. study.

At 48:30 Dr. Morrison describes the details of the Robbins et al. study, but again describes only the distance study and makes no mention of the depth study. It does not appear that he has any understanding of the actual details of the study.

At approximately 50:00 Dr. Morrison states that under ideal conditions observers in the Robbins et al. study saw at best ⅓ of all sharks. This is not true. At 50:20 he states that if the sharks were deeper than 2.5m they missed them entirely. This may be technically true but only because the study he is describing did not actually include any sharks below 2.5m. He then goes on to state “over the entire area the rate of detection was about 1 in 10 (9% seen and 90% missed)”. This is not true.

Dr. Morrison offers no commentary on possible ways that drones might provide different results from the manned aircraft study despite numerous questions about drones.

When asked about the typical size of a great white he does not appear to be cognizant of the fact that the 2.5m (~8 feet) analogs used in the Robbins et al. study would be considered below average size. He defers the question on shark size to Dr. Meghan Winton of the Atlantic White Shark Conservancy who notes that the typical sharks they see range in size from 8-12 feet. (49:30) The relatively small size of shark analogs used in the Robbins et al. study could in fact have had a large influence on the results. We simply do not know and this is not mentioned by Dr. Morrison during discussions on shark sizes.

At 48:38 Dr. Morrison makes the following comment

“We have all seen the lovely pictures from drones and airplanes”

He is referring to the many aerial photos that clearly show sharks easily discernible. He then goes on to dismiss these types of photos out of hand and tells us the problem is we don’t know how many sharks we don’t see. While this statement is true, Dr. Morrison fails to recognize that these types of photos actually contain very valuable information as many of them show large areas of water at some of our favorite Cape Cod beaches in which one can see clear to the ocean floor. These photos demonstrate that in the right conditions one will likely see nearly all sharks. Aerial surveillance could very easily be limited to favorable conditions only and discontinued when conditions turn unfavorable. This is a very simple and logical concept that is

never discussed in the Woods Hole Report or brought up by Dr. Morrison in the discussion. Instead the Woods Hole Report discussion remains focussed entirely on the Robbins et al. study and a few anecdotal stories from employees of the DMF and Atlantic White Shark Conservancy.

At 1:03:27 of the video Dr. Morrison is asked if the shark analogs in the Robbins et al. study were moving or fixed in place. The person asking the question suggests that moving sharks may be easier to see. Dr. Morrison replies “Possibly, but it’s complicated”. The reason that Robbins et al. dismissed the lack of shark analog movement as being a factor in their study is that relative shark movement for observers in fast moving aircraft would be minimal. Relative movement for observation via slow moving or stationary drones would not be minimal and could have a significant impact on detection. This is never discussed in the report and when it is brought up in the discussion the only response is “Possibly, but it’s complicated."

At 1:11:52 of the video The Woods Hole Group states that Dr. Meghan Winton was able to provide some very great feedback regarding spotting depth. As this was not included in the report none of us have any idea what is was other than the brief statements she made at the meeting. These included noting that sometimes their spotter pilot has an animal in site and then loses it. In describing this type of situation she goes on to state the following at 1:13:18 of the video

“our spotter pilot flies higher than a drone does so the chance that a drone would see that animal is really minimal”

An email was sent to the Atlantic White Shark Conservancy on October 20, 2019 requesting clarification on some of Dr. Winton’s comments as well as details regarding her experience in spotting sharks from aircraft and/or drones. As of this writing the only response has been an automated email saying that the message was received. Dr. Winton is a PhD biologist who currently works for the Atlantic White Shark Conservancy. Her expertise and experience in the area of aerial shark detection is not clear. In the context in which it was stated, Dr. Winton’s statement that because a plane flies higher than a drone it would be more likely to see a shark does not make any sense.

Dr. Winton’s comments here comparing drones to airplanes somewhat echo the statements found in the Woods Hole Report in which the only comparisons between drones and planes suggest inferior performance for the drone, but fail to provide any detailed explanation. In the report it is simply suggested that a camera system may perform worse than an observer. In this case, Dr Winton uses altitude differences to explain the expected superior performance of aircraft over drones, but her comments are simply incorrect. Because one imaging system (an eye or a camera) is farther away from an object than another imaging system does not make it more likely that that imaging system will see the object. In fact, all else being the same it makes it less likely. This is assuming both imaging systems have the object within their field of view which is the case in the context of this discussion. Dr. Winton is describing a situation in which

the DMF/Shark Conservancy spotter pilot loses a shark due to a patch of murky water. An airplane would be able to observe a larger area for a given angle of view as a result of flying at a higher altitude, but this does not appear to be the advantage Dr. Winton is describing. There is no reason to expect a drone to perform better in this situation, but also no reason to suggest that altitude provides any advantage for the plane in this situation.

Analysis of Specific Tables and Sections Related to Visual Observation

Cost Estimates for Drones (Tables 15-20)

The alternative analysis matrices (tables 15-20) list costs for each technology and it is explicitly states “data inputs related to cost are estimates based on best available knowledge” and that they are for a 100 day season. Unfortunately, the costs are not broken down for each technology. The cost listed for the use of drones to cover a single 100m section of beach is $500,000. On October 18, 2019, Adam Finkle of the Woods Hole Group was contacted in regards to these costs. Mr. Finkle broke the costs down and stated that the costs were based on estimates that they received from drone service providers which they have used for geo mapping work in the past. Mr. Finkle declined to name the specific companies. Cost breakdown is as follows:

- Costs based on 10hr day and and the 100 day season.
- Lease of one drone - $250 per hour
- Three personnel - $80-$120 per hour per person
- Total cost per day - $5000
- Total cost per season - $500,000

In response to a comment that these costs seemed high, Mr. Finkle reiterated that they had received estimates from companies specializing in geo mapping. He also mentioned that the drones these companies use include advanced sensing equipment such as LIDAR (a laser based range finding technology). These advanced sensing technologies are not applicable to shark spotting and The Woods Hole Group is aware of this. These cost estimates are simply not based on “the best available knowledge”.

Drones, Airplanes and Helicopters Permitting (Section 7.5 and Table 21)

In regards to the use of both drones and aircraft the report erroneously claims that permits would be needed. The report references permits from the Cape Cod National Seashore (CCNS) in three separate places and includes the statement “Use of drones within the Cape Cod National Seashore requires the issuance of a permit. “ (Section 7.5 Required Permitting). As pointed out at the meeting on October 17th at Nauset High School no permits would be needed from the CCNS to operate drones within the seashore. The CCNS has no greater control over airspace than any other private landowner. When this point was made at the meeting Adam Finkle replied that he could not speak for the park. Superintendent Brian Carlstrom then confirmed that he is aware of the fact that permits are not needed to fly within the CCNS and that permits are only needed to take off, land or control a drone from actual park property.

According to the Woods Hole Report information on permitting came directly from the various state and federal regulatory agencies. In Section 7.5 the report states the following:

To solicit direct feedback regarding the permitting requirements for all mitigation alternatives considered in this preliminary study, Woods Hole Group participated in two (2) conference calls with various state and federal regulatory agencies on May 16, 2019 and June 6, 2019, and received the following feedback regarding the permittability (i.e. regulatory feasibility) and merits of the various shark mitigation strategies included in this report:

Table 21 lists an additional five government agencies that may require consultation or permitting for the use of drones. It is not clear that any of these agencies would need to be consulted in regards to the operation of drones. Additionally, all alternative matrices (Tables 15-20) list permitting complexity and permitting timeline for the use of drones as medium and give drones a category score of medium. No permits would be required for towns to operate drones.

In regards to airplanes and helicopters Table 21 lists the US Federal Aviation Administration (FAA) as an agency that may require permits or consultation. Additionally, all alternative matrices (Tables 15-20) list permitting complexity and permitting timeline for the use of planes and helicopters as medium and give planes and helicopters a category score of medium. The use of aircraft for the purpose of spotting sharks would fall under FAA part 91 and would not require any permits.

Drones and Shorebird Interference (Table 12 and Section 7.5 Required Permitting)

The report examines potential adverse environmental impacts of various technologies. The impact criteria are explained in Table 12 where under “risk of interference” three categories are described. “Yes” is defined as likely to cause interference, “No” is defined as no interference and “Possible” is used where there is uncertainty. The table specifically mentions drones as an example stating “Any use of drones or balloons was also classified as “Yes” due to the predator avoidance behavior those alternatives instigate in nesting shorebirds”. Drones do have the potential to elicit a predator avoidance behavior in shorebirds. However, it is misinformed to classify this response as likely to occur. In fact, in Section 7.5 of the Woods Hole Report (required permitting) under the Mass. Division of Fisheries & Wildlife/Natural Heritage & Endangered Species Program (NHESP) section it states

“The use of drone or balloon technology may elicit predator reactions from shorebirds which could result in abandonment of the site or abandonment of nests. Thus, generally speaking, the use of these technologies may pose a concern during April 1 – August 31.”

This is a much more valid description as it uses the more accurate language of “may elicit” and “may pose a concern” rather than “likely to cause interference” There is a host of literature examining the effects of drones on nesting seabirds. Much of this literature has been put out by wildlife biologist and bird conservationists themselves.These groups have recognized the role that the use of drones can play in wildlife conservation and particularly bird conservation. They use drones to monitor bird populations and nesting sites recognizing that when used properly

drones do not harm birds. Guidelines are available for the proper use of drones around specific species of birds.

The literature does not appear to contain any evidence to suggest that drones not could be operated on most Cape Cod beaches with no negative effects on shorebirds. The altitudes that drones would be used at for shark detection are in the range of 300-400 feet and it would be easy to adjust takeoff and landing paths so as to avoid coming anywhere near nesting shorebirds.

References:

Robbins, W. D., et al. (2014). Experimental Evaluation of Shark Detection Rates by Aerial Observers, PLOS ONE (https://www.plosone.org), Volume 9, Issue 2, e83456, February 2014.

Yuuki Y. Watanabe, Nicholas L. Payne, Jayson M. Semmens, Andrew Fox, Charlie Huveneers (July, 2019) Hunting behaviour of white sharks recorded by animal-borne accelerometers and cameras, Marine Ecology Progress Series

Author Background:

Kristian Sexton grew up sailing and surfing the waters of Cape Cod. He has a background in both optical systems and aviation. He completed his PhD in biomedical engineering in the Optics in Medicine Lab at Dartmouth College with his research focused on the development of systems and methodologies for fluorescence guided surgery. He has spent most of the last ten years developing and testing optical systems through various positions in both academia and industry. In his most recent role, he led the development of optical tracking methods for the testing of a surgical robotics platform at Verb Surgical, a Google and Johnson & Johnson funded joint venture based in Silicon Valley. Dr. Sexton is also a commercial pilot and flight instructor with over 1400 flight hours in light single and twin engine fixed-wing aircraft including experience working as a spotter pilot for commercial fishing operations. He recently received the commercial remote pilot certificate and has in the vicinity of 200 flight hours testing drones over Cape Cod for the purpose of examining their potential use in shark detection. Preliminary results from these tests led Dr. Sexton to found Moosh Systems, LLC in August of 2019.