Outer Cape Shark Mitigation Alternatives Analysis

Evaluating strategies to support regional decision making and public safety efforts

October 2019

Prepared for:
The Towns of Chatham, Orleans, Eastham, Wellfleet, Truro, and Provincetown*,
The Cape Cod National Seashore**, in partnership with
The Atlantic White Shark Conservancy

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To help support public officials, this study was commissioned as a joint stakeholder effort to compile information and perform an independent technical review of various shark mitigation alternatives. The intent is to provide a consolidated resource where information can be obtained by stakeholders to review when considering alternatives. Results are provided in this report, including a set of comparative evaluation tables to support decision-makers who are considering investing in measures to manage the public safety risk resulting from the increasing presence of white sharks in the Outer Cape waters. Findings in this report do not endorse any particular method or product, and are not intended to provide specific recommendations for methods to employ. That decision is complex and lies with stakeholders faced with varying levels of risk exposure, public assets, available resources, site-specific environment, and use patterns. The findings in this report also are not intended to assume any liability or responsibility for injuries that may occur regardless of whether mitigation alternatives are employed or not. There is no solution available that can ensure 100% safety for individuals who choose to enter the water.

Table of Contents

List of Figures

List of Tables

1.0 INTRODUCTION AND SCOPE OF WORK

This technical report summarizes the results of an evaluation of shark mitigation strategies conducted on behalf of the Outer Cape Cod, Massachusetts Towns of Chatham, Orleans, Eastham, Wellfleet, Truro, and Provincetown in partnership with the Cape Cod National Seashore (CCNS) and the Atlantic White Shark Conservancy (AWSC). Over the past several decades, regional gray seal (*Halichoerus grypus atlantica*) and great white shark (*Carcharodon carcharias*) populations have increased along Cape Cod's dynamic shoreline. Great white shark activity in close proximity to public bathing beaches has resulted in a very real threat to public safety and has become a focus of concern for regional beach managers and municipal decision-makers. Over the past several years, research efforts by the Massachusetts Division of Marine Fisheries (DMF) and public outreach and education campaigns led by the AWSC and promoted by local municipalities have steadily increased public awareness and understanding of the ecology and natural history of both species (Figures 1, 2).

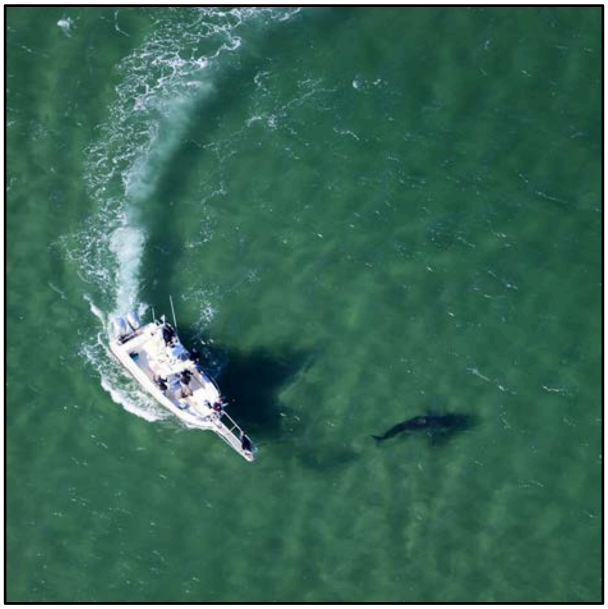
A series of shark-human interactions during the summer of 2018, which resulted in the severe injury of a swimmer, and the death of 26-year-old boogie boarder, Arthur Medici, prompted municipal beach managers and municipal authorities to take decisive, coordinated action to explore all available strategies to increase both public safety and public awareness along regional beaches. During the fall of 2018, a series of open forums were hosted by local municipalities to allow members of the public to comment on the increased presence of white sharks along Cape Cod's beaches and to discuss shark mitigation strategies to reduce shark-human interactions and improve public safety (Figure 3). Suggestions ranged from a "do-nothing" approach (allow nature to take its course), to technology-based alternatives (increased tagging efforts, utilizing drones, employing spotters, deploying sonar detection buoys, installing real-time alert-based systems, etc.), barrier-based alternatives (nets, enclosures, (electro)magnetic deterrents, etc.), and biological-based alternatives (active management (culling) of the regional shark and/or seal population, modifying human behavior to mitigate risk, etc.). Municipal decision-makers and regional stakeholders also hosted and solicited proposals from vendors, organizations, and individuals who led discussions and demonstrations of various mitigation strategies along local public beaches.

To help support public officials, this study was commissioned as a joint stakeholder effort to compile information and perform an independent technical review of various shark mitigation alternatives. The intent is to provide a consolidated resource where information can be obtained by stakeholders to review when considering alternatives. Results are provided in this report, including a set of comparative evaluation tables to support decision-makers who are considering investing in measures to manage the public safety risk resulting from the increasing presence of white sharks in the Outer Cape waters. Findings in this report do not endorse any particular method or product, and are not intended to provide specific recommendations for methods to employ. That decision is complex and lies with stakeholders faced with varying levels of risk exposure, public assets, available resources, site-specific environment, and use patterns. The findings in this report also are not intended to assume any liability or responsibility for injuries that may occur regardless of whether mitigation alternatives are employed or not. There is no solution available that can ensure 100% safety for individuals who choose to enter the water.

1.1 PRELIMINARY ASSESSMENT

As a regional stakeholder with knowledge of the local environment and marine technologies, Woods Hole Group monitored and participated in the 2018 discussions. After conducting a cursory, initial assessment of proposed mitigation strategies, Woods Hole Group contacted and met with municipal officials and the DMF Research Team to discuss initial impressions, which are listed below:

1. **There are no *silver bullet* solutions** to ensure 100% safety for individuals who choose to enter the water;
2. It is likely that the most effective solution(s) will:
    - Be regional in nature;
    - Incorporate input from diverse stakeholders; and
    - Have a foundation in the ongoing research to better understand the ecology and natural history of local shark and seal populations.
3. Several immediately actionable items that do not require extensive permitting or legislative approval could be implemented, including but not limited to:
    - Improved communication networks;
    - Improved emergency response and first-aid care;
    - Expanded lifeguarding efforts;
    - Updated signage and safety protocols;
    - Expanded education and outreach efforts;
    - "Stop-the-Bleed" trainings for beachgoers and municipal officials;
    - Improved availability of first aid supplies; and
    - Modifying human behaviors to mitigate risk.
4. Lastly, additional research should be conducted prior to the deployment of any technology-based, barrier-based, or biologically-based shark mitigation strategy. Prior to deployment, it would be critical to understand the required environmental regulatory review and permit approvals required, initial and long-term costs, potential adverse environmental impacts, potential adverse human impacts, realistic expectations for the level of effectiveness, and site-specific suitability.



Figures 1 & 2. Since 2009, Massachusetts DMF research and tagging efforts have focused on developing a better understanding of the ecology, natural history, and population dynamics of the local shark population, (left). Updated signage and communication at regional beaches have increased public awareness of shark activity and steps that can be taken to reduce risk (right). Photo credit (left): Wayne Davis, AWSC.

1.2 THE QUESTIONS BEING ADDRESSED

Following these initial discussions, it became clear that an initial independent, third party evaluation of available shark mitigation alternatives was both needed and warranted prior to the selection and/or deployment of any technology-based, barrier-based, or biological-based alternative(s). The Woods Hole Group prepared and presented a proposal for a preliminary alternatives analysis to the Outer Cape affiliates of the Regional Shark Working Group (RSWG), made up of municipal beach managers, harbormasters, and public safety officials, CCNS leadership, and staff from the AWSC. The proposed project was designed to provide members of the Working Group as well as the public with a greater understanding of each proposed mitigation strategy to help inform future discussions, regional decision making, and public safety efforts on the Outer Cape.

1.3 ACKNOWLEDGEMENT OF FUNDING

Funding for the project was provided by the Outer Cape Towns' of Chatham, Orleans, Eastham, Wellfleet, Truro, and Provincetown in partnership with the Cape Cod National Seashore and the Atlantic White Shark Conservancy. The 6 communities would like to acknowledge $15,000 in grant funding provided by the Department of Housing and Community Development's District Local Technical Assistance Program through the Cape Cod Commission, Barnstable, MA. The

Cape Cod National Seashore would like to acknowledge the financial contribution made by the Friends of the Cape Cod National Seashore.

Figure 3. Members of the public engage municipal officials and members of the regional scientific community at a public forum held in the Town of Wellfleet, September 2018. Photo credit: Sarah Tan, WCAI. Retrieved from: https://www.capeandislands.org/post/wellfleet-officials-hold-forum-discuss-shark-safety#stream/0 15 September 2019.

1.4 TASKS ASSIGNED TO THE WOODS HOLE GROUP

Woods Hole Group, an international environmental services and products organization headquartered in Bourne Massachusetts, was contracted by the Outer Cape Towns, the CCNS, and the AWSC to conduct an alternatives analysis of various shark mitigation strategies. Woods Hole Group offers a range of coastal, ecological, and oceanographic consulting services, along with products for collecting ocean measurements, ocean forecasting, tracking wildlife with satellite communications, and vessel monitoring systems (VMS) for fisheries management. The Company has operated on Cape Cod since 1986, and has worked nationally and internationally; thus, lending strong local experience balanced by exposure to global environments and technologies.

Woods Hole Group Coastal Scientists, Coastal Geologists, Coastal and Oceanographic Engineers, and Oceanographers have extensive experience permitting, designing, installing, operating, and maintaining near-shore and offshore ocean measurement systems and coastal engineering structures in challenging environments. Woods Hole Group also has demonstrated experience evaluating alternatives, assessing site-specific feasibility, and developing comprehensive decision-support tools to aid and guide project implementation. Working closely with regional stakeholders, Woods Hole Group developed and completed the following Tasks.

Task 1. Meetings and Stakeholder Engagement

- February 2019 – Woods Hole Group met with the Outer Cape affiliates of the RSWG to review the geographic scope of the project (a total of 6 Towns: Chatham, Orleans, Eastham, Wellfleet, Truro, Provincetown), to review the proposed scope of work, and to understand how stakeholder goals and objectives differ throughout the region. RSWG representatives articulated site-specific goals, objectives, and mitigation technologies of interest to their respective communities to ensure inclusion of all known viable alternative(s). Refer to Appendix A for a copy of the meeting agenda.
- April 2019 – Woods Hole Group met with Town Administration and CCNS leadership to review the proposed scope of work, clarify funding mechanisms, and field questions about project goals and objectives.
- July 2019 – An update meeting was held with the Outer Cape RSWG, Town Administration, and CCNS leadership to review project deliverables, discuss the results of the alternatives assessment, and review the intended format for the technical report. Refer to Appendices B and C for copies of the agenda and the Woods Hole Group PowerPoint Presentation.
- September 2019 – A meeting was held to review findings, recommendations, and next steps outlined in the technical report.

Engagement with Scientific and Regulatory Community

In addition to meetings held with the Outer Cape RSWG, Town Administration, and CCNS leadership, Woods Hole Group engaged regional shark and seal experts, State and Federal permitting agencies, and public education and outreach officials. A summary of ancillary meetings hosted or attended by Woods Hole Group is included below:

- April 2019 – Conducted an informational meeting with Kim Wolfenden, Shark Mitigation Strategy, Department of Primary Industries, New South Wales, Australia.
- April 2019 – Facilitated a round-table discussion with members of the local scientific community, including scientists from: Massachusetts DMF, National Oceanic and Atmospheric Administration Protected Species Branch (NOAA), Center for Coastal Studies (CCS), and Woods Hole Oceanographic Institution (WHOI). Refer to Appendix D for a copy of the meeting agenda.
- May-June 2019 – Conducted a series of inter-agency conference calls with State and Federal permitting and regulatory agencies including Massachusetts DMF, Massachusetts Coastal Zone Management Office (CZM), Massachusetts Department of Environmental Protection (DEP), Massachusetts Natural Heritage Program (NHESP), Massachusetts Chapter 91 Office, United States Environmental Protection Agency (EPA), CCNS Planning Division, NOAA Fisheries, and the United States Army Corps of Engineers (USACE). Refer to Appendix E for a copy of the meeting agenda.

Task 2. Data Collection, Review of Available Technologies

Woods Hole Group conducted a literature and product review of immediately actionable alternatives undertaken by local Towns in 2019, as well as various technology-based, barrier-based, and biological-based alternatives for future consideration. To supplement the literature review, Woods Hole Group identified possible: environmental permitting requirements; estimated cost of procuring assets, deployment, and maintenance; potential environmental and human impacts; and documented effectiveness of various alternatives. Chapter 8 provides a list of references for readers interested in gathering more detail about the mitigation strategies discussed in this report.

Task 3. Alternatives Analysis

Once the available data were reviewed, Woods Hole Group conducted an independent alternatives analysis of available technologies and alternatives for shark mitigation. The alternatives analysis included the development of comprehensive evaluation criteria. Each alternative was then evaluated against each criterion, generating an alternatives analysis matrix, designed to support municipal decision making.

Task 4. Technical Report

A technical report was prepared to summarize the data collected and analyzed in Tasks 1 through 3 and includes the following sections:

- Summary of existing, regional meteorological and oceanographic (metocean) data;
- A summary of immediately actionable alternatives undertaken by the Towns in 2019;
- Results of the literature and product review for each technology-based, barrier-based, and biology-based alternative;
- Means, methods, and results of the alternatives analysis;
- Assumptions made in generating these data;
- Considerations and next steps for future work.

Task 5. Executive Summary / Mitigation Strategy Fact Sheets

Woods Hole Group recognizes the need for continued public outreach and education and will continue to work with the RSWG to develop an executive summary of project results, including a series of illustrated fact sheets describing each category of shark mitigation alternative described in the technical report. Fact sheets describing shark-seal interactions in the near-shore and human behavior in the near-shore will also be developed. Executive summary and mitigation fact sheets will be made available to members of the public and regional stakeholders.

2.0 GEOGRAPHIC SCOPE AND METOCEAN SUMMARY

Assessments of emerging shark mitigation strategies and technologies have been conducted elsewhere around the world (e.g., NSW Department of Primary Industries, 2015; QLD Department of Aquaculture and Fisheries, 2019), but never within the context of the Outer Cape's unique coastal environment. The following sections provide a summary of baseline environmental and meteorological conditions characteristic of Outer Cape beaches and nearshore areas that were considered in this evaluation of various shark mitigation strategies. Dr. Greg Skomal, of the Massachusetts Division of Marine Fisheries provided the following statement regarding great white shark aggregations and the utilization of unique nearshore habitat features along the Outer Cape shoreline:

From a habitat perspective, Cape Cod differs broadly from other white shark aggregation areas in terms of its geology, bathymetry, and hydrography. Created about 15,000 years ago from the retreat of the glacial sheet at the end of the last ice age, Cape Cod remains a geologically active landform, which provides the raw material for the continued growth of the continental margin (reviewed by Geise et al. 2015). As a result, the coastline of Cape Cod changes annually. The eastern shoreline of Cape Cod, known as the Outer Cape, is about 50 km from north to south with seaward exposure to the Atlantic Ocean. This exposure creates a substantial surf zone with rip currents and dynamic nearshore circulation, resulting in expansive ever-shifting sandbars and barrier beaches (Geise et al. 2015). The dynamic geology of the Outer Cape has created a coastline characterized by glacial bluffs, dunes, sandy backshores and foreshores, tidal inlets, barrier beaches, sand spits, and islands (Geise et al. 2015). Peak white shark abundance in this area occurs from August through October (Skomal, unpublished data). During this period, white shark distribution overlaps with that of the gray seals, which can be found in haul outs on fringing beaches, near tidal inlets, on sandbars, and in the neritic waters along the entire length of this coastline. Shoaling results in highly variable depths along the coast of Cape Cod, and white sharks are frequently observed within 1 km of the shoreline. There is also heavy spatial and temporal overlap with humans, who utilize these nearshore areas for recreational activities.

2.1 GEOGRAPHIC SCOPE

The Woods Hole Group worked with the Outer Cape affiliates of the RSWG to develop the geographic scope for the shark mitigation alternatives analysis. For the purposes of this project, the scope was limited to the 6 Outer Cape Towns' of Chatham, Orleans, Eastham, Wellfleet, Truro, and Provincetown, all of which own and maintain lands within CCNS boundaries. Within the 6 coastal Towns on the Outer Cape, the project team identified a total of 17 Atlantic Ocean beaches, 28 Cape Cod Bay and/or Nantucket Sound beaches, and 9 estuarine (Pleasant Bay and Nauset Estuary) beaches that are currently managed, staffed and/or maintained by local Towns and/or the CCNS (Figure 4). Beaches within the geographic scope of the project were classified as either ocean, bay/sound, or estuarine due to the unique and variable environmental and marine conditions found within the open Atlantic Ocean, in Cape Cod Bay and Nantucket Sound, and in distal estuaries (Tables 1-3). These classifications were defined to help facilitate the alternatives analysis in Chapter 6.

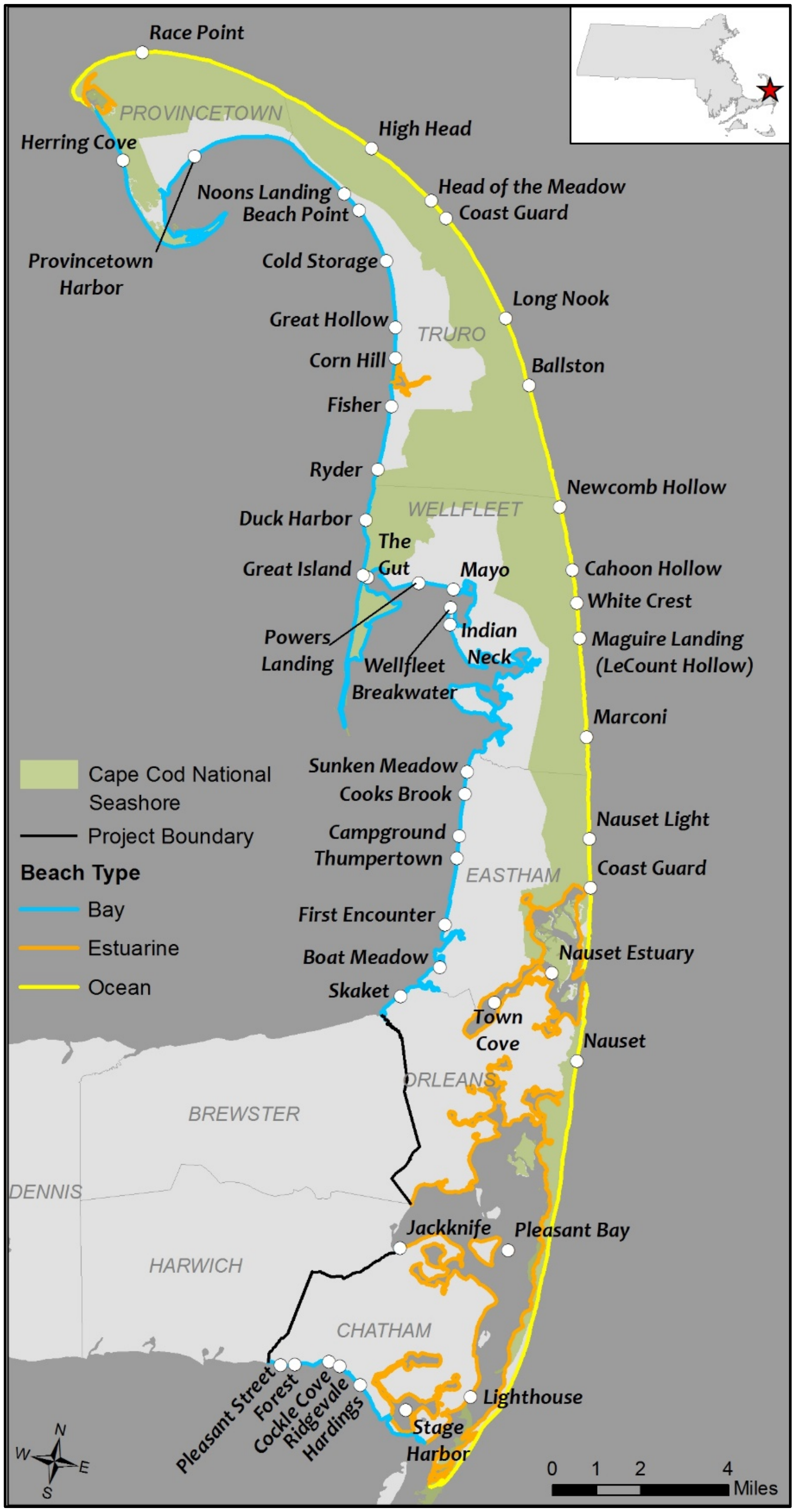


Figure 4. Locus map of the Project Area and associated ocean, bay, and estuarine beaches.

Table 1. Atlantic Ocean Beaches within the Geographic Scope of the project.

Town	Beach Name	Beach Classification	Beach Management*
Chatham	Outer Beach	Ocean	Town / Federal
Chatham	Monomoy	Ocean	Town / Federal
Orleans	Nauset Beach	Ocean	Town / Federal
Eastham	Nauset Beach North	Ocean	Town / Federal
Eastham	Nauset Light	Ocean	Town / Federal
Eastham	Coast Guard	Ocean	Town / Federal
Wellfleet	Marconi	Ocean	Federal
Wellfleet	Maguire Landing (LeCount Hollow)	Ocean	Town / Federal
Wellfleet	White Crest	Ocean	Town / Federal
Wellfleet	Cahoon Hollow	Ocean	Town / Federal
Wellfleet	Newcomb Hollow	Ocean	Town / Federal
Truro	Ballston	Ocean	Town / Federal
Truro	Long Nook	Ocean	Town / Federal
Truro	Coast Guard	Ocean	Town / Federal
Truro	Head of the Meadow	Ocean	Town / Federal
Truro	High Head	Ocean	Federal
Provincetown	Race Point	Ocean	Federal

***Town/Federal Management assigned to account for Federal mgmt. of areas between Town-owned parcels.**

Table 2. Cape Cod Bay and Nantucket Sound Beaches within the Geographic Scope of the project.

Town	Beach Name	Beach Classification	Beach Management*
Chatham	Hardings	Sound	Town
Chatham	Cockle Cove	Sound	Town
Chatham	Ridgevale	Sound	Town
Chatham	Forest	Sound	Town
Chatham	Pleasant Street	Sound	Town
Orleans	Skaket Beach	Bay	Town
Eastham	Sunken Meadow	Bay	Town
Eastham	Cooks Brook	Bay	Town
Eastham	Campground	Bay	Town
Eastham	Thumpertown	Bay	Town
Eastham	First Encounter	Bay	Town
Eastham	Boat Meadow	Bay	Town
Wellfleet	Great Island	Bay	Town / Federal
Wellfleet	The Gut	Bay	Town / Federal
Wellfleet	Duck Harbor	Bay	Town / Federal

Wellfleet	Powers Landing	Bay	Town
Wellfleet	Mayo Beach	Bay	Town
Wellfleet	Indian Neck Beach	Bay	Town
Wellfleet	Wellfleet Breakwater	Bay	Town
Truro	Beach Point	Bay	Town
Truro	Cold Storage	Bay	Town
Truro	Corn Hill	Bay	Town
Truro	Fisher	Bay	Town
Truro	Ryder	Bay	Town
Truro	Great Hollow	Bay	Town
Truro	Noons Landing	Bay	Town
Provincetown	Herring Cove	Bay	Federal
Provincetown	Provincetown Harbor	Bay	Town

***Town/Federal Management assigned to account for Federal mgmt. of areas between Town-owned parcels.**

Table 3. Estuarine Beaches within the Geographic Scope of the project.

Town	Beach Name	Beach Classification	Beach Management
Chatham	Pleasant Bay	Estuarine	Town
Chatham	Jackknife Cove	Estuarine	Town
Chatham	Lighthouse Beach	Estuarine	Town
Chatham	Stage Harbor	Estuarine	Town
Orleans	Nauset Estuary	Estuarine	Town
Orleans	Town Cove	Estuarine	Town
Orleans	Pleasant Bay	Estuarine	Town
Eastham	Nauset Estuary	Estuarine	Town
Eastham	Town Cove	Estuarine	Town

The project team acknowledges that additional, unstaffed and unmaintained sections of beach exist between designated Town and/or Federal beach access points, which may not have been included in the preceding Tables. Further, the project team acknowledges that many Towns along the South Shore, South Coast, Upper Cape, and Mid-Cape have also participated in RSWG meetings and placed a high priority on public safety. However, extending the geographic range of the project beyond the 6 Outer Cape Town's was beyond the scope of this initial assessment.

In order to develop a better understanding of the environmental and marine conditions impacting Outer Cape beaches and, subsequently, any shark mitigation alternative that may be deployed in the future, the Woods Hole Group conducted a cursory review of available meteorological and oceanographic datasets for the region. The following section provides an overview of regional topo-bathymetric data, tidal regimes, seasonal visibility (fog) conditions, wind climate, wave climate, and general rates of shoreline change and sediment transport.

2.2 OUTER CAPE COD METOCEAN SUMMARY

The Outer Cape encompasses a myriad of different coastal environments along the coastlines of the Atlantic Ocean, Cape Cod Bay, and their associated harbors and estuaries, each with varying physical environments and meteorological and oceanographic (metocean) climates. This section provides an overview of both the physical environment and the metocean conditions for the coastlines of the Atlantic Ocean, Cape Cod Bay, and the major estuaries and harbors that may influence the behavior of sharks and their prey and, subsequently, the selection of shark mitigation alternatives. Specifically, this section provides a look into elevation/depths, tides, visibility, winds, waves, and sediment transport around Outer Cape Cod. Each of these categories has bearing on the potential effectiveness of various shark mitigation measures, and helped provide a technical basis for the alternatives analysis in Chapter 6.

Topo-Bathymetry

Available topographic and bathymetric survey data were combined into a single topo-bathymetric data set for the region referenced to the North American Vertical Datum of 1988 (NAVD) in units of feet. The resulting topo-bathymetry is shown in Figure 5 as colored contours ranging from 5.0 ft-NAVD to the -50.0 ft-NAVD contour. This map gives a general sense of the variability of water depths along the coastline of the Outer Cape and identifies where deep-water transit corridors and shallow water bars and flats exist. For instance, the Atlantic facing beaches drop off more steeply to -50 ft-NAVD, while Cape Cod Bay has extensive shallow tidal flats extending from Jeremy Point in Wellfleet along Billingsgate Shoal. Estuarine environments generally provide enough water depth (depending on tide) to support the movement of sharks and/or seals. Variable bathymetry between beach types has the potential to influence shark and/or seal behavior and may affect the deployment of various mitigation strategies.

Tidal Regime

The tide regime is highly variable between Cape Cod Bay and the Atlantic Ocean as well as their associated estuarine environments. Tide data was compiled from various data sources, including the National Ocean and Atmospheric Administration (NOAA) tidal stations, prior Woods Hole Group tide studies for Pleasant Bay, Nauset Harbor, and Wellfleet, and the Applied Coastal Research and Engineering study conducted for the Town of Chatham (ACRE, July 2019). Table 4 provides a summary of mean tidal range (MTR) in feet, the difference in tide between Mean Low Water (MLW) and Mean High Water (MHW), for various locations around the Outer Cape. The MTR in Cape Cod Bay is very large and relatively uniform, ranging from 9.29 ft. to 10.31 ft., and then drops precipitously south of Race Point along the Atlantic Coast to Chatham where the MTR is 7.02 ft. Within the estuarine systems in Cape Cod Bay, such as Rock Harbor, Wellfleet Harbor, and Pamet River, there is little dampening of the tides from Cape Cod Bay. On the Atlantic Coast, Nauset Harbor and Pleasant Bay experience more tidal dampening that reduces the 7 ft. tidal range off Chatham to 3.14 ft. to 5.77 ft. in the estuaries.

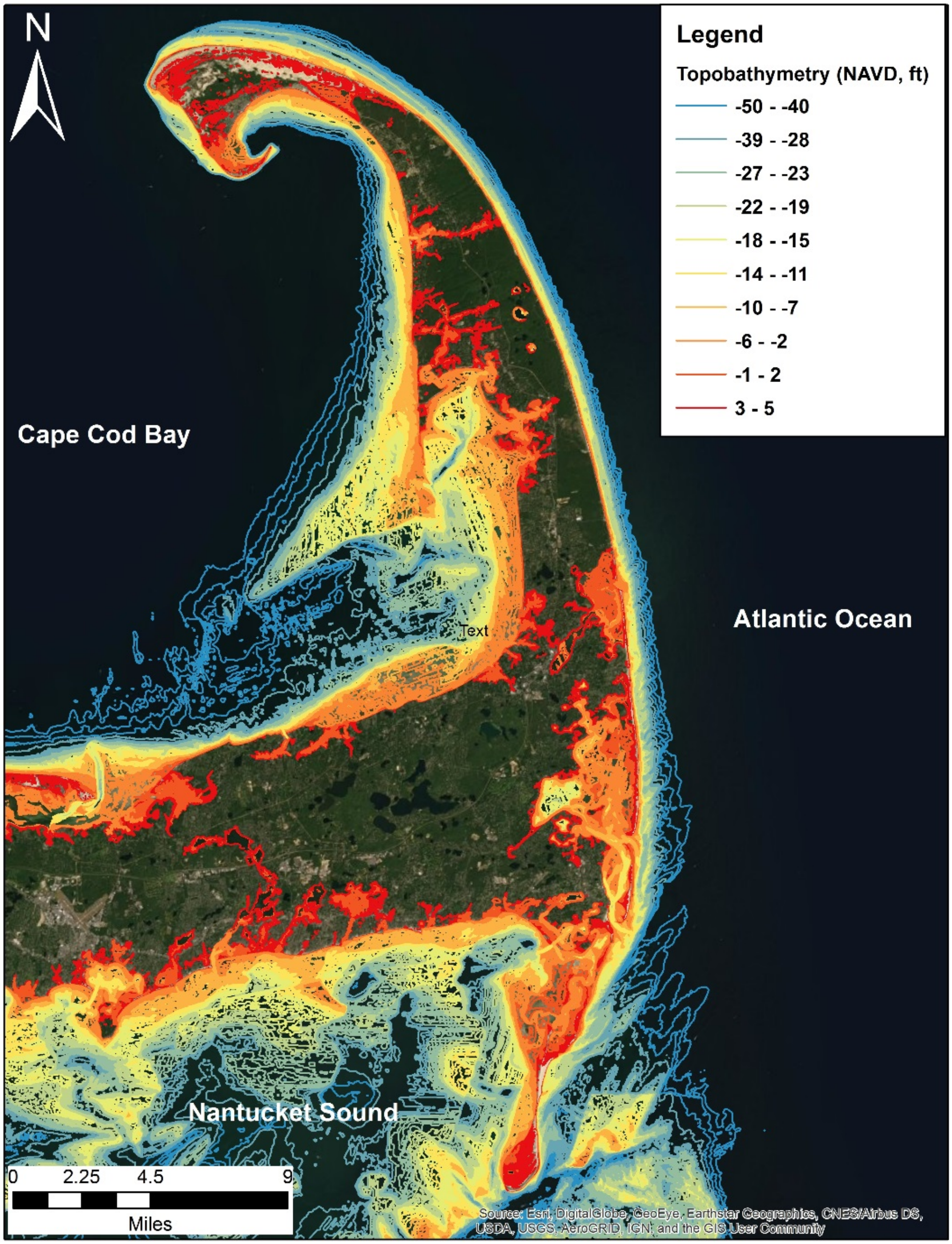


Figure 5. Combined topographic and topo-bathymetric contour map (ft, NAVD88) for Outer Cape Cod.

Table 4. Mean tide ranges for various locations along Atlantic Ocean and Cape Cod Bay as well as their estuaries.

Location	Station – Data Source	Mean Tidal Range (ft)
Atlantic Ocean	Chatham Offshore - ACRE	7.02
Cape Cod Bay	Sesuit Harbor - NOAA 8447241	9.29
Cape Cod Bay	Wellfleet Harbor Old Saw - WHG	10.31
Cape Cod Bay - Estuarine	Pamet River - WHG	9.62
Cape Cod Bay	Provincetown - NOAA 8446121	9.73
Atlantic - Estuarine	Nauset Harbor at Salt Pond - WHG	3.14
Atlantic -Estuarine	Pleasant Bay - WHG	4.08
Atlantic -Estuarine	Aunt Lydia Cove - NOAA 8447435	4.95
Atlantic -Estuarine	Chatham Harbor - NOAA	5.77
Atlantic -Estuarine	Stage Harbor - NOAA 8447505	4.58

Visibility and Fog

Airport Meteorological Aerodrome Report (METAR) data sets were downloaded for both the Chatham Municipal Airport (CQX), dating back to 1975, and Provincetown Municipal Airport (PVC), dating back to 1988. Airport METAR data sets contain a number of measurements, including air temperature, dew point, visibility, weather codes, wind speed and wind direction. Woods Hole Group first evaluated the percentage of time the airports recorded either fog or low visibility (less than 1 mile), conditions that would prevent or hinder visual detection of sharks. Low visibility conditions occurred only 4% of the time at Provincetown and 6% of the time at Chatham, which are relatively low occurrence rates. The Chatham Airport is located 3 miles from the Atlantic Coast and is not entirely representative of conditions at the coast, especially relative to visibility (fog). The Provincetown Airport is located less than a one-half mile from Race Point and should be more representative of conditions at Race Point Beach. Of course, transient conditions at the land-sea interface may produce localized reductions in visibility that are not captured by the airport data.

Wind Climate

The Airport METAR data for Chatham and Provincetown Airports were next processed to evaluate wind statistics and generate wind roses showing the directional distribution of the wind speed (mph) for Chatham, dating back to 1975 (Figure 6), and for Provincetown, dating back to 1988 (Figure 7). The color sidebar indicates the magnitude of the wind speed (mph). The circular axis denotes the direction of wind approach (coming from) relative to true north (0°) collected in 22.5° bins. The radial lines indicate the percent occurrence within each magnitude and direction band.

The two wind roses are similar and indicate winds are predominantly from the southwest and south. However, the strongest winds, sustained speeds over 25 mph, come from the northwest, north, and northeast. These high sustained winds are particularly prevalent at

Provincetown Airport. The least frequent wind direction for both airports is from the southeast. The mean wind speed is 8.9 mph at Chatham Airport and 12.1 mph at Provincetown Airport. The Provincetown Airport also records more storm winds, possibly because Chatham Airport, at 3 miles from the coast, is slightly less exposed, and experiences more dampening from land, buildings, trees, etc.

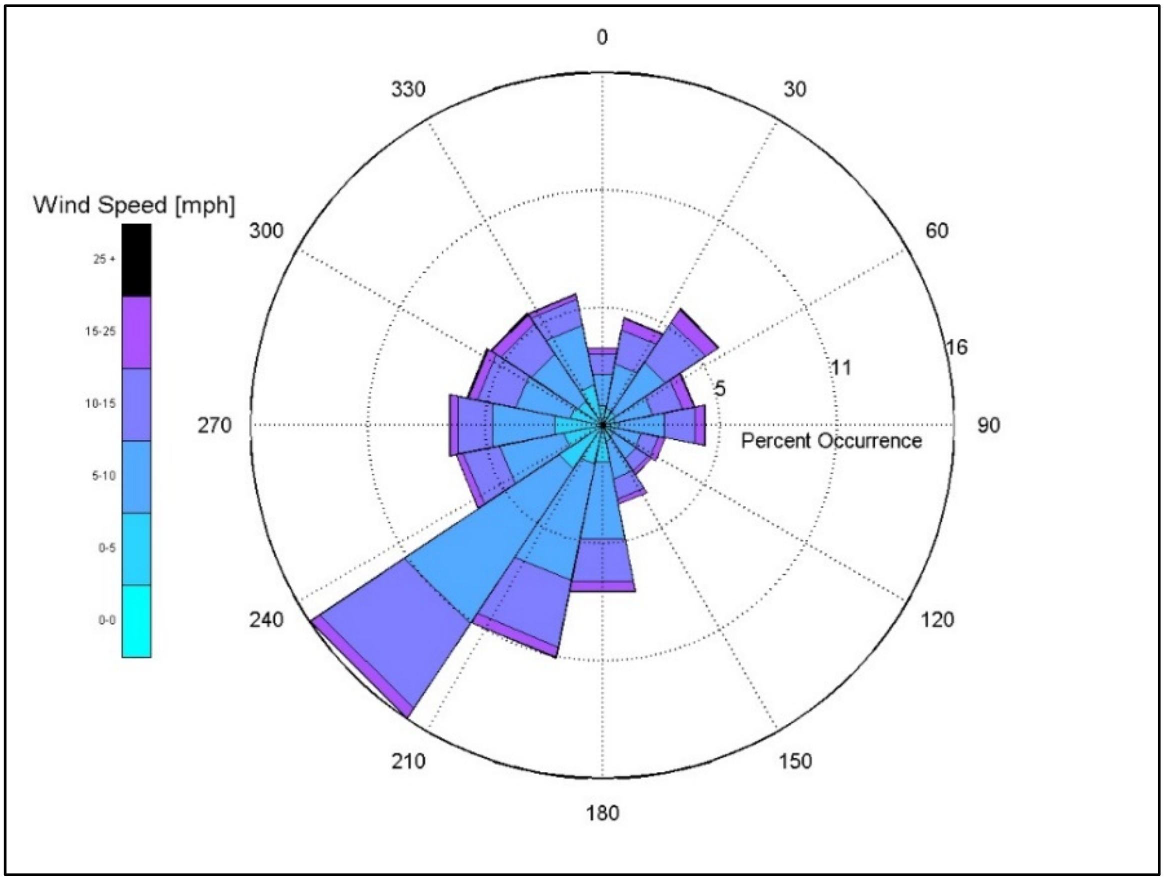


Figure 6. Wind Rose (mph) for Chatham Municipal Airport (CQX) from 1975 to present.

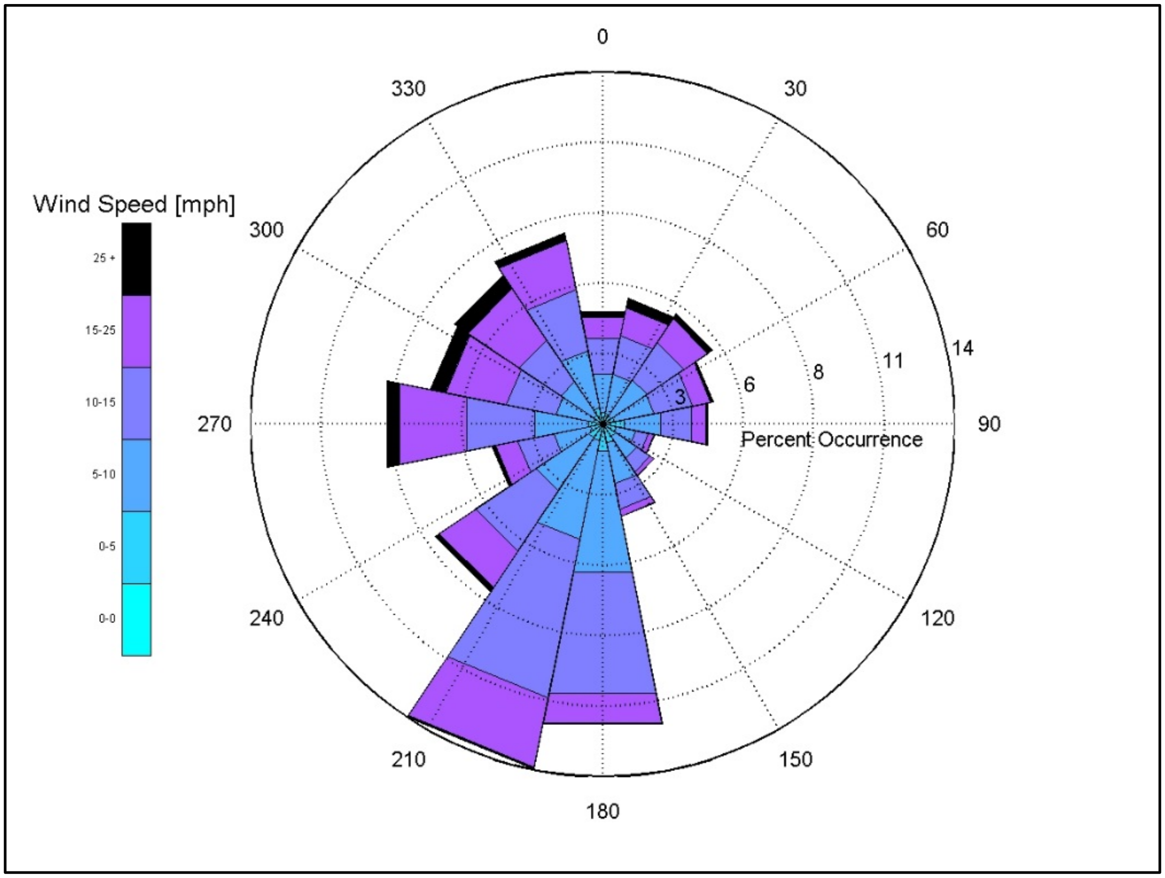


Figure 7. Wind rose (mph) for Provincetown Municipal Airport (PVC) from 1988 to present.

In addition to the land-based METAR measurements, offshore wind data from U. S. Army Corps of Engineers (USACE) Wave Information Study (WIS) stations, located offshore of the Atlantic facing coastline of Cape Cod, were evaluated. WIS "stations" are based on wave hindcasting. Wave conditions are generated at a model node, the station, using high quality wind fields in a numerical wave model. WIS stations 63057, 63064, and 63070 are located off Provincetown, Nauset, and Chatham. The Nauset WIS station wind rose for 1980 to 2014 is shown in Figure 8.

Winds from the west and northwest dominate, particularly during the winter months. This is also the direction of the strongest, over 25 mph, sustained winds. Winds from the southwest are also common, particularly during the summer. As with the METAR data, winds from the southeast are the least frequent. The mean wind speed is 15.1 mph. Not unexpectedly, winds are stronger at the offshore WIS station than at either airport.

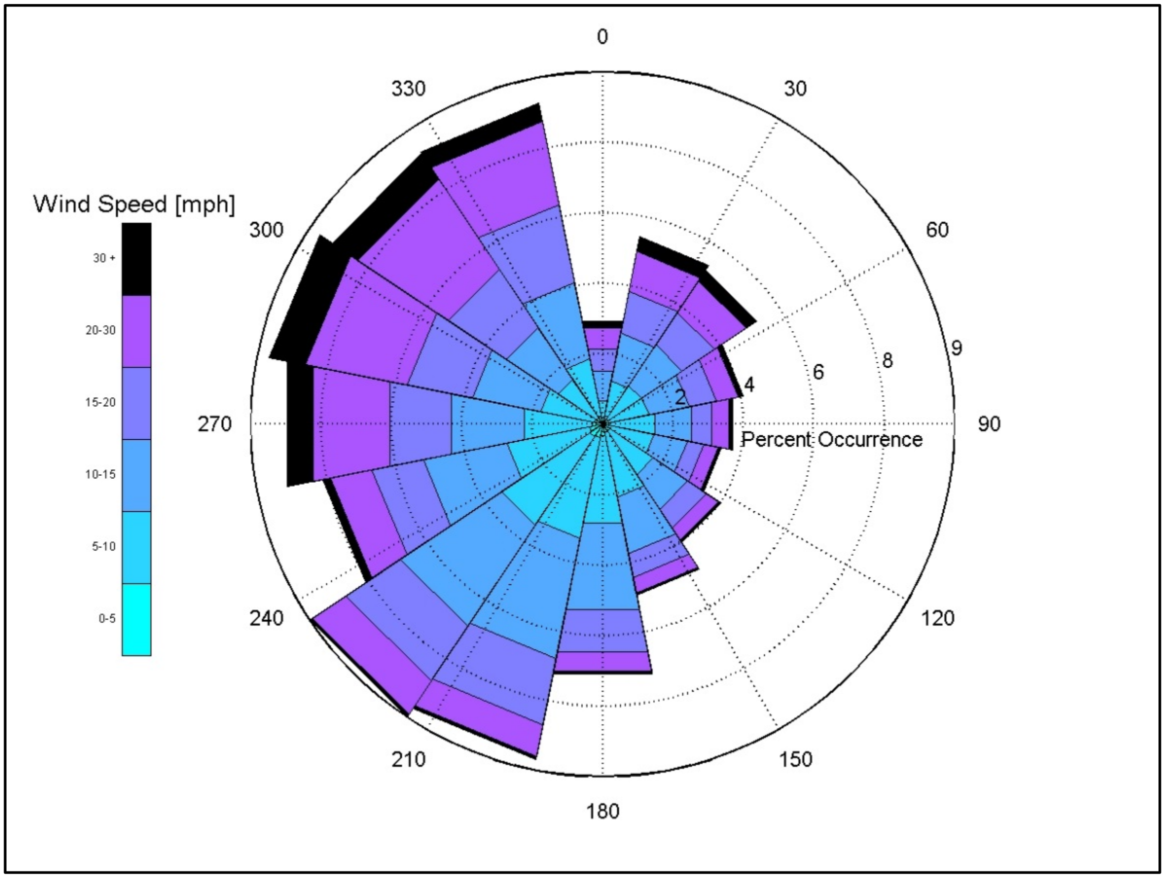


Figure 8. Wind Rose for WIS Station 63064 from January 1, 1980 to December 31, 2014.

Wave Climate

The wave climate is highly variable along the Outer Cape Cod coastline. Atlantic facing beaches are subject to both offshore swell waves and locally generated wind waves. Bayside beaches generally see only wind waves, generated by winds blowing over the Bay itself. The estuarine systems are generally low wave energy environments, subject to fetch-limited wind-waves generated within each system. The Outer Cape wave climate is a critical input to any analysis of the coastal processes that shape the always changing beaches, bars, and troughs, habitat features used by both predators and prey. That constantly changing environment is also where physical mitigation measures, such as bottom mounted sensors and physical barriers, must be able to function reliably over prolonged periods.

There are two main sources of local wave data. Real-time measurements are available from National Data Buoy Center (NDBC) Stations 44018, located ~9 nm north of Provincetown, and 44090, located ~9 nm north of Barnstable Harbor in Cape Cod Bay. In addition to the NDBC buoys, model waves for the Atlantic facing beaches are available from USACE WIS Station 63064, offshore Nauset.

The wave roses in Figures 9, 10, and 11 show the directional distribution of the wave height (ft) for NDBC Station 44090 in Cape Cod Bay for May 2016 to present, NDBC Station 44018 north of Provincetown for April 2018 to present, and WIS Station 33064 offshore Nauset for 1980 to 2014. The color sidebar indicates the magnitude of the wave height (ft). The circular axis represents the direction of wave approach (coming from) relative to true north (0°) collected in 22.5° bins. The radial lines indicate the percent occurrence within each magnitude and direction band. Statistics calculated using the data set indicate that the mean wave height and period in Cape Cod Bay were 2.3 ft. and 3.9 seconds, indicative of locally generated, fetch limited waves, predominantly from the northwest. During the summer months, 1-3 ft waves from the southwest were recorded. More swell wave energy was apparent offshore the Atlantic facing coastline, with wave heights of 3.3 ft. and periods of 7.1 seconds north of Provincetown and wave heights of 3.8 ft. and wave periods of 8.1 seconds east of Nauset. The predominant wave direction also shifted to an east to south-southeasterly direction, almost completely opposite to the Cape Cod Bay station. The wave climate data is summarized in Table 5.

Table 5. Wave height and period for various locations around Outer Cape Cod.

Water Body	Location	Station ID	Average Wave Height (ft)	Average Wave Period (sec)	Predominant Direction (°N)
Cape Cod Bay	Barnstable	NDBC 44090	2.32	3.91	N-NW
Atlantic Ocean	Provincetown	NDBC 44018	3.29	7.05	SSE-E
Atlantic Ocean	Nauset	WIS 63064	3.82	8.11	SSE-E

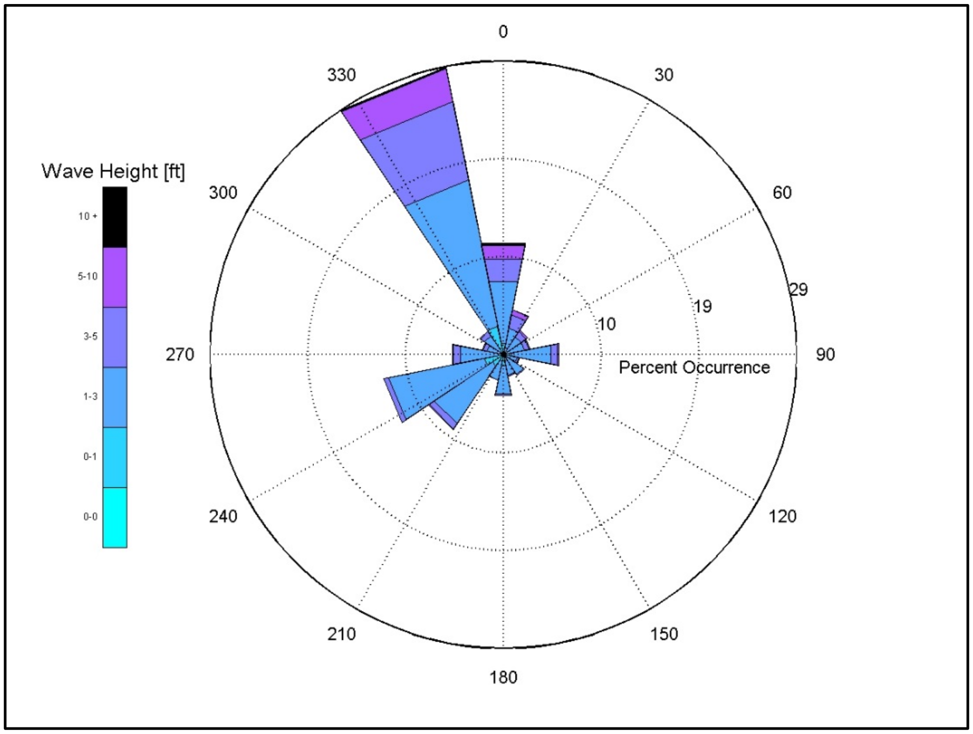


Figure 9. Wave Rose (feet) for Station 44090 in Cape Cod Bay from May 23, 2016 to present.

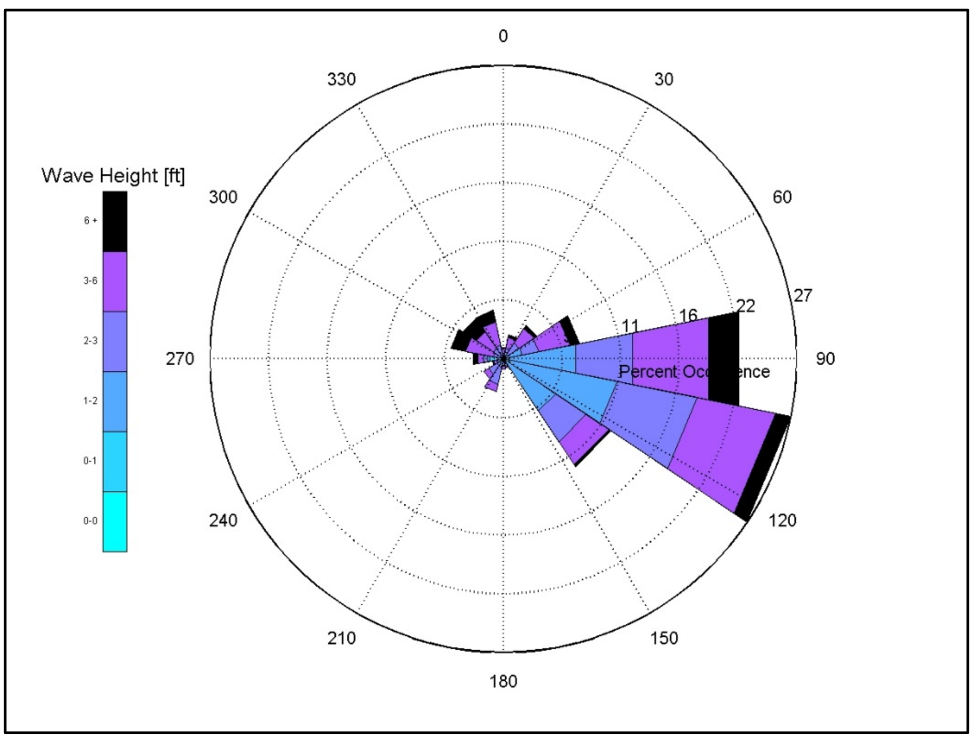


Figure 10. Wave rose (feet) for NDBC Station 44018 from April 18, 2018 to present.

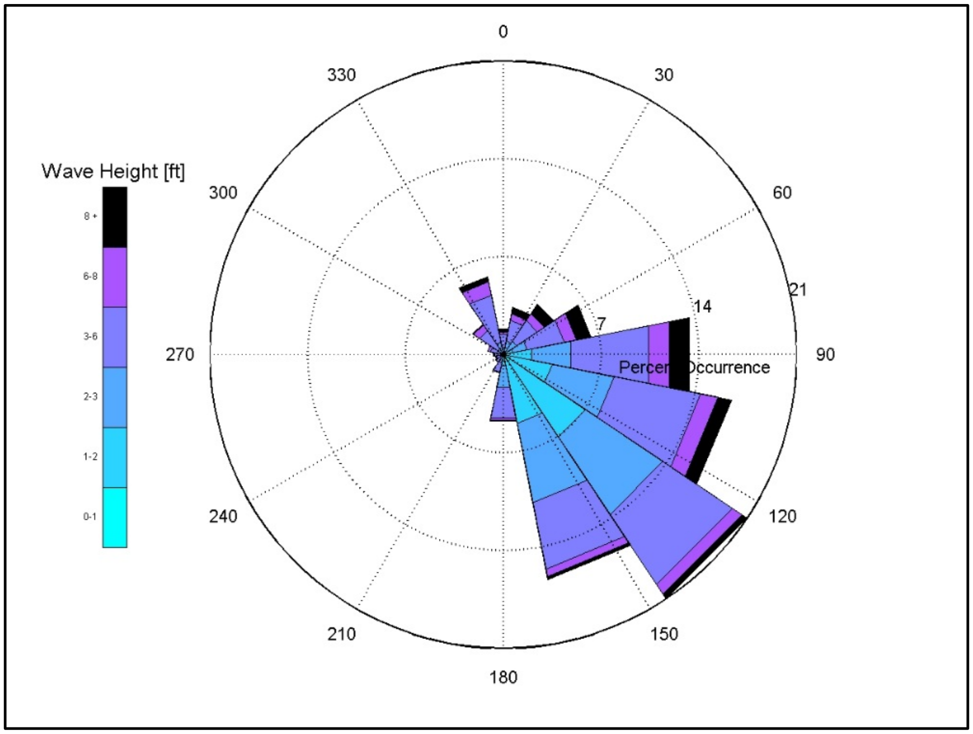


Figure 11. Wave rose for WIS Station 63064 in offshore Atlantic from January 1, 1980 to December 31, 2014.

Sediment Transport

The coastline of Outer Cape Cod is very dynamic. The tides, winds, and waves discussed above all influence regional sediment transport and coastline erosion and accretion. There is a need to recognize and understand these processes because year to year, and even season to season, they are changing the habitat of marine life and their prey. This is not a simple task, though we can get a general sense of its magnitude looking at the historic rates of shoreline change. Figure 12 below shows both the long-term (78+ year) and the short term (<30-year) rates of erosion and accretion for the Outer Cape. The source for these data is the United States Geological Survey (USGS) Coastal Change Hazard Portal. As can be seen, the majority of the Outer Cape is eroding at 1 to 2 m/yr. (3 to 7 ft/yr.) as indicated by the yellow to orange shaded sections of shoreline, with the exception of the green and blue shaded areas at Race Point in Provincetown and portions of Monomoy Island. The rates of erosion are generally greater along the Atlantic facing beaches than the Cape Cod Bay beaches or estuaries, which have the smallest rates of shoreline change. These rate of change maps also highlight areas of inlet migration, such as the 2007 North Cut and the 1987 Channel, located along Chatham's outer, Atlantic Ocean-facing beach. Sediment transport alters the nearshore bathymetry, creating, moving, and removing the deeper pools and bars, habitat utilized by both sharks and seals. The lack of bottom stability also limits the effectiveness of some mitigation measures, including mooring and bottom mounted sensors and barriers.

These shoreline change trends are also documented in Geise et. al. (2014), which quantifies multi-decadal coastal change along the Outer Cape in cubic meters of sand/sediment per meter of beach front per year (m^3/m/yr.). Geise determined that the erosion rate on the Atlantic Coast averages 20-25 m^3/m/yr. in Chatham and increases to 30-40 m^3/m/yr. off Wellfleet before tapering off north of Truro where the erosional losses turn into accretional gains. On the Cape Cod Bay coastline, erosion rates were lower, on the order of 5 m^3/m/yr., because the Bayside is sheltered from open ocean swell, although the erosion rate does reach 15 m^3/m/yr. in northern Wellfleet.

Figure 12. Aerial Images showing shoreline change rates (+/- in meters per year) from the USGS Coastal Hazard Viewer.

3.0 STATUS OF GRAY SEALS AND WHITE SHARKS; HISTORY OF UNPROVOKED ATTACKS

3.1 STATUS OF THE NORTH WESTERN ATLANTIC GRAY SEAL

Healthy populations of pinnipeds, including gray seals (*Halichoerus grypus atlantica*) and harbor seals (*Phoca vitulina*), are important contributors to New England's unique coastal environment and to the greater Northwest Atlantic trophic structure (Link, J., 2002). Historically, populations of gray seals and harbor seals were extirpated from New England waters, the result of bounty programs in Maine and Massachusetts that lasted from 1880 to 1962. It is estimated that between 72,284 and 135,498 seals were slaughtered as a direct result of bounty hunting programs (Lelli et. al. 2009). The removal of carnivores from regions where they naturally occur has the potential to cause top-down trophic cascades, destabilizing regional food webs and impacting predator-prey relationships and regional nutrient cycles (Bowen, W.D., 1997). As such, the State of Massachusetts established protections for pinnipeds in 1965. Federal protections were granted in 1972 with the passage of the Marine Mammal Protection Act (MMPA). Since protections were granted, regional seal populations have recovered. Recent stock assessments (2017) estimate the minimum number of gray seals in the U.S. during the breeding season to be about 27,000 animals (Hayes et al. 2019), but this does not reflect seasonal changes in abundance for this transboundary stock, as seals move between U.S. and Canadian waters to forage and reproduce. For instance, there were 28,000 – 40,000 estimated gray seals in southeastern Massachusetts alone in 2015, based on correction factors applied to seal counts visible in Google Earth imagery (Moxley et. al. 2017). This represents just a fraction of the greater Western North Atlantic gray seal population, estimated at over 424,000 (DFO 2017). Despite the large number of seals currently residing in the greater Northwestern Atlantic region, there is evidence to suggest that the population of pinnipeds in New England waters prior to the start of the bounty programs was actually larger and more diverse than what currently exists (Cammen et. al. 2018).

Gray seals, due to their large size, have few predators (Bowen, W.D., 2011). In the Northwestern Atlantic, natural predators may include killer whales (*Orcinus orca*), blue sharks (*Prionace glauca*), shortfin mako sharks (*Isurus oxyrinchus*), Greenland sharks (*Somniosus microcephalus*), and most notably, great white sharks (*Carcharodon carcharias*). Bowen, 2011, hypothesizes that the recent increase in the Northwestern Atlantic seal population may be due to a number of natural factors, including low predation rates (a result of declining regional shark populations between 1986-2000), reduced competition for food with other seal species, changes in the area and quality of ice habitat used for rearing offspring, and/or the utilization of Sable Island, NS, Canada as an undisturbed breeding colony. It is also reasonable to assume that State and Federal protections for populations of pinnipeds and wildlife habitat have helped to facilitate the recovery of regional pinniped populations. Despite this recent recovery, it is worth noting that 48% of documented gray seal mortality was due to human interaction, with the number of annual mortalities often approaching the species' potential biological removal (PBR) threshold of 1,389 animals per year (Bogomolni et al. 2010; Hayes, et al. 2019). Per NOAA Fisheries (2019), PBR refers to the *maximum number of animals, not including natural* *mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population*.

Although white sharks and seals have been documented in New England waters for hundreds of years, the number of sightings and documented predations in recent years has garnered the attention and curiosity of residents and seasonal visitors. As a result, regional marine mammal and fisheries experts from Woods Hole Oceanographic Institution, the NOAA Northeast Fisheries Science Center Protected Species Branch, the Center for Coastal Studies, and the Massachusetts DMF Shark Research Program have made a concerted effort to better understand the role of each species in the greater Northeastern Atlantic ecosystem.

3.2 STATUS OF THE WHITE SHARK RESEARCH IN MASSACHUSETTS

In response to declining stocks, great white sharks were designated as a prohibited species by the National Marine Fisheries Service in U.S. Atlantic waters in 1997 (NMFS, 1997; USDC, 1997). Protections for white sharks were extended to Massachusetts waters in 2005 by the Marine Fisheries Advisory Commission as per (322 CMR 6.37) (CMR, 2005; Division of Marine Fisheries, 2005). Dr. Greg Skomal of the Massachusetts Division of Marine Fisheries provided the following update regarding the status of the local great white shark population and ongoing research in Massachusetts:

> *Since 2009, DMF Marine Fisheries biologists have been examining the movement ecology, behavior, natural history, and population dynamics of this species through its Shark Research Project. To date, agency staff have tagged more than 180 white sharks with a variety of high-tech tags to study their fine- and broad-scale movements. Most of these sharks (93%) were tagged off Cape Cod, but others were tagged off New York, Florida, New Jersey, and South Carolina. The sharks ranged in total length from 4.0-17.5 ft and were comprised of juveniles, subadults, and adults of both sexes.*
>
> *The agency has also been working with the Atlantic White Shark Conservancy and SMAST to examine the relative abundance and population size of white sharks off the coast of Massachusetts using spatial capture-recapture models. The objective of this project has been to estimate the abundance and relative density of white sharks off Cape Cod from photographic mark-recapture, aerial line survey, and acoustic telemetry data. To date, we have tabulated >350 individual white sharks over the last five years. The field component of this study was completed in 2018 and subsequent analyses are ongoing.*
>
> *Building on work conducted to date and in light of the growing presence of this species in our nearshore waters, DMF Marine Fisheries is intensifying our research to understand the predatory behavior of this species with particular emphasis on public safety. The aggregation of white sharks off the coast of Cape Cod is one of only a handful of "hotspots" in the world and unique along the east coast of the US. As such, the state of Massachusetts and, in particular, the towns on Cape Cod are faced with a growing potential for negative*

interactions between this species and people utilizing our coastal waters. This potential has already been manifested in an increase in attacks on humans – the most recent causing fatal injury to a boogie boarder off Wellfleet in September, 2018. Therefore, intensive research on the local movements and behavior of white sharks while in Cape Cod waters is warranted. Specifically, we need to know where, when, and how these sharks hunt seals, the frequency of feeding events, and environmental factors that drive the behavior of these animals. With adequate information related to these topics, we can develop, for the first time anywhere, predictive models that can be used to forecast the presence of this species so as to enhance public safety.

Fine-scale Behavior

Using a suite of tagging technologies, we are going to examine white shark residency, habitat selection, site fidelity, local offshore distribution, social interactions, and foraging behavior. The high-resolution data collected by these tags will be used to better understand fine-scale movements in areas of high shark-human overlap and will be used to identify factors correlated with both alongshore and onshore-offshore movements, which will better inform public safety practices. In doing so, we will be expanding our tagging efforts to include Cape Cod Bay, an area of increased white shark activity in recent years.

Coupled with these efforts, we will be developing a near real-time white shark forecast based on sightings, real-time detections from acoustic buoys, and the results of habitat models currently being developed. We envision the development of weekly forecast maps that could be disseminated to beach managers and posted at public beaches to alert beachgoers when conditions indicate a high likelihood of white shark presence.

In addition, data from these tags will be used to derive estimates of feeding frequency, which will provide a basis for assessing the intensity of white shark predation on gray seals. This is of certain interest to both commercial and recreational fishermen, as well as beach managers. Given our current assessment of the white shark population size, we will be able to estimate how many seals may be consumed by this species annually and the extent to which white sharks may potentially control seal population growth. This research, when strengthened by strong collaborations, will produce new, revelatory information about the white shark in the North Atlantic and, specifically, off the coast of Massachusetts. This information will not only provide the basis for sustainable conservation and management of this species, but also produce viable information for science-based decision making as it relates to public safety.

3.3 HISTORY OF UNPROVOKED SHARK ATTACKS IN THE STATE OF MASSACHUSETTS

It is worth noting that while unprovoked shark-human interactions in the State of Massachusetts are exceedingly rare, they do occasionally occur. The first unprovoked, fatal interaction in Massachusetts was documented in 1751, with 10 additional interactions recorded from 1830-2018 (GSAF, 2019). Of the 11 total unprovoked shark-human interactions recorded in Massachusetts, a total of 5 fatalities have occurred. Most recently in September 2018, and preceded by fatalities in 1936, 1897, 1830, and 1751. A summary of unprovoked shark-human interactions in the state of Massachusetts documented by the Global Shark Attack File is included in Figure 13. The GSAF records presented in Figure 13, as well as the GSAF cumulative totals listed above, do not include the unprovoked encounter involving two kayakers, whose kayaks were overturned by a white shark off Plymouth, MA in 2014.

Case Number	Date	Year	Type	Country	Area	Location	Activity	Name	Sex	Age	Injury	Fatal (Y/N)	Time	Species	Investigator or Source
2018.09.15	15-Sep-2018	2018	Unprovoked	USA	Massachusetts	Newcomb Hollow Beach, Wellfleet, Barnstable County	Boogie boarding	Arthur Medici	M	26	FATAL	Y	12h00	White shark	M. Michaelson, GSAF
2018.08.15.a	15-Aug-2018	2018	Unprovoked	USA	Massachusetts	Longnook Beach, Truro, Barnstable County	Swimming	William Lytton	M	61	Lacerations to leg, hip and hand	N	16h00	White shark	M. Michaelson, GSAF
2017.08.23	23-Aug-2017	2017	Unprovoked	USA	Massachusetts	Marconi Beach, Wellfleet, Barnstable County	SUP	Cleveland Bigelow	M	69	Not injured by shark but board bitten	N	10h00	White shark, 5' to 7'	Cape Cod Times, 8/23/2017
2012.07.30.a	30-Jul-2012	2012	Unprovoked	USA	Massachusetts	Ballston Beach, Truro, Cape Cod	Body surfing	Chris Myers	M	50	Lacerations to both legs below the knees	N	15h30	Thought to involve a white shark	A. Costellano, ABC News, 7/31/202
1996.07.21	21-Jul-1996	1996	Unprovoked	USA	Massachusetts	Truro (Cape Cod), Barnstable County	Swimming	James Orlowski	M	46	Lacerations to left leg & right foot	N		6' shark	Associated Press, 7/23/1996
1965.02.04	04-Feb-1965	1965	Unprovoked	USA	Massachusetts	Granite Pier, Rockport	Scuba diving	Ronald R. Powell	M	18	Punctures on left thigh	N	14h30	1.2 m [4'] shark	R. Powell; Boston Traveler 2/11/1965; H.D. Baldridge, p.184
1936.07.25	25-Jul-1936	1936	Unprovoked	USA	Massachusetts	Hollywood Beach, just above Mattapoisett Harbor, Buzzards Bay	Swimming crawl stroke	Joseph Troy, Jr	M	16	FATAL, finger severed, thigh bitten He died during the surgical amputation of his leg	Y	15h30	White shark (identified by Dr. Hugh Smith)	B. R. Tilden, M.D.; NY Times, 7/26/1936, p.2; E.W. Gudger (1950); V.M. Coppleson (1958), pp. 150 & 253; H.D. Baldridge, p. 35
1897.03.15.a.R	Reported 15-Mar-1897	1897	Unprovoked	USA	Massachusetts	30 miles south of Lynn	Fishing	male	M		FATAL	Y			Daily Northwestern, 5/15/1897
1847.09.10	10-Sep-1847	1847	Unprovoked	USA	Massachusetts	Chelsea Beach, Suffolk County	Wading	Amos Thompson	M		Lacerations to arm	N			Louisville Daily Courier. 9/16/1847
1830.07.26	26-Jul-1830	1830	Unprovoked	USA	Massachusetts	Swampscott, Essex County	Fishing from dory, shark upset boat & he fell into the water	Joseph Blaney	M	52	FATAL	Y			Huron Sun, 8/3/1830
1751.07.27	27-Jul-1751	1751	Unprovoked	USA	Massachusetts		Swimming	male	M		FATAL	Y			Pennsylvania Gazette, 8/15/1751

Figure 13. **Global Shark Attack File Incident Log of Unprovoked Shark Attacks in the State of Massachusetts 1751-present. Retrieved from http://www.sharkattackfile.net/incidentlog.htm 15 September 2019.**

4.0 DEPLOYMENT OF IMMEDIATELY ACTIONABLE ITEMS

4.1 IMMEDIATELY ACTIONABLE ITEMS AND IDENTIFICATION OF ALTERNATIVES FOR FUTURE CONSIDERATION

In light of the series of fatal and non-fatal shark-human interactions documented in Massachusetts between 2012 and 2018, the Outer Cape Towns and the CCNS have worked diligently to further their commitment to public education and public safety along Outer Cape Cod beaches by reviewing, improving, and updating existing safety protocols, internal and external communication networks, first-aid training requirements and supplies, and educational materials. A key element of any mitigation strategy to reduce the chances of an unprovoked shark-human interaction is a strong commitment to education and outreach.

The Towns of Orleans, Wellfleet, and Provincetown provided the following statements regarding their commitment to safety during the 2019 summer season:

Town of Orleans Preparedness Statement

For the upcoming season, the Town of Orleans beach protection is based on the principles of education, partnerships, and training. The most effective way to minimize the risk of another fatality is for beachgoers to change their behavior during the peak shark activity season. The Town plans to continue to educate the public about sharks by providing them with current research data compiled by Dr. Greg Skomal and the Atlantic White Shark Conservancy. Information about sharks will be displayed on new signs posted at the beach and printed in brochures to be handed out during the season.

Research shows that most white shark bite victims survive because of first aid initiated from by-standers. Throughout the year, the Town has been actively educating the public by conducting monthly Stop the Bleed classes and to date has trained approximately 250 residents. All beach staff will be Stop the Bleed trained and provided direct access to first aid supplies. Staff will also be trained on protocols of how to manage a shark bite emergency. Roving EMTs will continue to patrol the most at risk sections of the beach (remote areas with highest numbers of people recreating) during the summer season and the Town will deploy shark bite first aid response kits (hemostatic bandages, tourniquets, etc.) at remote sections of the beach and at the public beach during off-hours. A landline 9-1-1 call box and a cellphone repeater have been installed at Nauset Beach to improve communications in an emergency.

Finally, the Town will continue to manage the protected sections (lifeguards on duty) of the public beach with the knowledge that there are sharks present at all times during the peak shark activity season. Prior to the season, lifeguards will participate in training provided by Dr. Skomal in an effort to educate staff on shark behavior and how to effectively direct beachgoers to minimize the chances of an interaction. Orleans Fire Department and Natural Resources will continue to provide Open Ocean Rescue Boat training for Nauset Beach Lifeguards, Nauset Beach EMTs, and Seasonal Harbormaster Patrol and the Zodiac rescue *boat will be staged at the beach ready for ocean rescues when larger assets are unable to respond due to tidal limitations in our inlets.*

Town of Wellfleet Preparedness Statement

Although they have existed for several years the presence of great white sharks on the Outer Cape and their interaction with humans is a relatively new phenomenon. The number of white sharks coming close to shore to feed on seals at swimming beaches is increasing. Since 2012, there have been five significant incidents involving white sharks and humans, including a life-threatening injury and a fatal attack in 2018. With the growing seal population drawing additional white sharks to the region each year, it is anticipated that the potential for increased human-shark interaction will grow as well.

The Town of Wellfleet acknowledges that there isn't one 'solution' that will make swimmers and surfers 100% safe. No ocean community anywhere on the East Coast can make that claim. We can continue to research shark and seal behavior and we can continue to improve our response to a shark-human interaction.

While acknowledging that there will always be a risk of a shark-human interaction for anyone in the water anywhere on the East Coast we are working to improve our response to a shark-human interaction through: Stop the Bleed Training; Extended Life Guard Monitoring; Emergency Call Boxes; Specialized and Dedicated Life Saving Equipment at Beaches; Ongoing, Consistent messaging regarding the presence of sharks and ongoing public education; Equipping Town Vehicles with Stop the Bleed Kits; and Uniform Beach Signage.

Town of Provincetown Beach Preparedness Statement

Provincetown is implementing a number of immediately actionable items this season. In fact, like the other Towns involved, our actions build on work we have been doing for several years. We are continuing with support for DMF's Greg Skomal and the Atlantic White Shark Conservancy by deploying detection buoys in our area; We will provide our boat and staff for up to 10 research trips in Cape Cod Bay this season; We have a new suite of signage and brochures for public education in keeping with the overall look and messaging of the National Seashore and other towns; Our "Stop the Bleed" classes are scheduled to start next week and continue through the summer for staff and the public; All town vehicles and vessels will have hemorrhage control kits in place; We will be reviewing our emergency procedures for responding to substantial hemorrhage events as part of our annual all hazards review and training with staff.

4.2 DEPLOYMENT OF IMMEDIATELY ACTIONABLE ITEMS

Across all 6 Towns, a consistent and uniform effort was made to improve public safety during the 2019 summer season, with all 6 municipalities, in partnership with the CCNS, implementing the following immediately actionable items to improve public safety and awareness along Outer Cape beaches:

- **Improved Communications Infrastructure** – Municipalities and the CCNS worked together to expand cellular coverage along Outer Cape beaches through the installation of cellular repeaters. Satellite phones were provided to public safety officials and beach managers patrolling remote stretches of beach to improve internal communications. New, expanded radio systems and repeaters were introduced to better enhance communications between public safety officials during emergency response on beaches. External communications were improved through the widespread installation of direct-dial, hardwired, satellite, cellular callboxes at remote beaches to seamlessly connect beachgoers to first responders in the event of an emergency.
- **Expanded Lifeguarding Presence** – Municipalities expanded existing lifeguarding hours into the shoulder season. Municipalities and the CCNS expanded first-aid training requirements for beach personnel. In certain locations, taller lifeguard stands were installed. The use of polarized sunglasses by beach personnel was promoted to help cut glare and improve spotting efficacy.
- **Expanded First-Aid Trainings** – Municipal and CCNS lifeguards and support staff completed the American Red Cross "Stop the Bleed" course designed to train, equip, and empower individuals to help in the event of a severe bleeding emergency. Municipalities encouraged beach goers to participate in the training by offering the course free-of-charge at fire departments and community centers across the Outer Cape.
- **Investment in Medical Response Supplies** – Municipalities and the CCNS invested in beach stretchers, ORVs, hemorrhage control kits, hemostatic (clotting) bandages, and tourniquets to improve first response.
- **Uniform Signage and Safety Protocols** – Municipalities and the CCNS, in partnership with the AWSC worked to update existing educational signage and pamphlets designed to raise public awareness of the presence of white sharks, providing uniform messaging across all Town and CCNS beaches. Efforts were expanded to include data regarding peak shark activity on pamphlets and signage. The AWSC funded regular programming at Lighthouse Beach in Chatham, where representatives were made available to answer questions from the public pertaining to white shark research and beach safety. All parties have continued to emphasize the utilization of *Shark Smart Behaviors*. The CCNS has developed *Shark Smart* video materials, facilitated weekly shark-seal walks to discuss the dynamics between the species, and founded the *Seal Education Team* in 2009, which is regularly stationed at seal haul outs within the CCNS.
- **Improved Response Time** – Municipalities and the CCNS took steps to improve vehicular, boat, and/or pedestrian access to remote beaches, or, placed ORVs, ATVs, or UTVs on the beach to facilitate rapid first response in an emergency and expand patrols.

- **Expanded Research Efforts** – Expansion of Massachusetts DMF research and tagging efforts to include Cape Cod Bay. Expansion of research focus to include how sharks and seals utilize unique near-shore habitat features to help inform public safety protocols, educational materials, and expanded awareness.
- **Expanded Real-Time Alert** – Utilization of real-time data from acoustic tags to alert beachgoers to the presence of a tagged shark. Real-time alert buoys were deployed for field testing during the summer of 2019. The buoys are currently providing real-time alerts to beachgoers via the AWSC Sharktivity mobile application.
- **Modifying Human Behavior to Minimize Risk** – Municipal and CCNS public safety officials have worked closely with the AWSC and with the DMF Shark Research Program to develop a series of *Shark Smart Behaviors* to reduce the likelihood of shark-human interaction. These recommendations have been revised and posted at nearly all beach access points within the geographic scope of the project. Reducing the chances of unprovoked attacks on humans requires a strong commitment to education and outreach, which can produce behavioral changes. For the most recent publications from the AWSC and CCNS regarding *Shark Smart Behaviors*, refer to Appendix F.

4.3 ACKNOWLEDGEMENT OF STATE FUNDING

To assist local municipalities with this considerable effort, State of Massachusetts Senator Julian Cyr and State Representative Sarah Peake worked with the Massachusetts Statehouse, the Baker-Polity Administration, and the Massachusetts Executive Office of Public Safety to secure $383,000 in funding to assist with the deployment of immediately actionable items for the summer 2019 beach season. Funds granted to the 6 Outer Cape Towns were used to offset costs associated with the installation of hardwired cellular and satellite callboxes, radio and cellular repeaters, the purchase of satellite phones, and the deployment of medical response supplies to regional beaches. The 6 Towns would like to formally acknowledge this contribution and the Commonwealth of Massachusetts' commitment to public safety.

Additional Actionable Items

- Although not currently installed, **public address systems** (sirens, PA's, loudspeakers, etc.) to clearly alert and/or communicate with beachgoers regarding the presence of dangerous marine life could potentially be deployed without the need for extensive permitting or legislative review. Such systems may also be useful to facilitate first response during or immediately following an incident.

5.0 REVIEW OF SHARK MITIGATION ALTERNATIVES

Message from Dan Hoort, Wellfleet Town Administrator

> *Shortly after the fatal attack during the fall of 2018, the 6 Outer Cape Towns and the CCNS were inundated with possible deterrent and detection systems claiming to be effective. To the best of our knowledge, there isn't a 100% effective mitigation strategy and the effectiveness of any one strategy is dependent on a myriad of factors. As we know, no Outer Cape beach is the same.*

The Woods Hole Group worked with the Outer Cape affiliates of the RSWG to establish and expand upon the list of technology-based, barrier-based, and biological-based alternatives to be included in this study. The comprehensive list of alternatives was developed based on:

- Researching strategies that had been implemented elsewhere around the world;
- Feedback from local Towns regarding alternatives that had been suggested or presented to municipal leadership by citizens, vendors, and/or stakeholder groups;
- Strategies suggested through a public survey to solicit feedback and ensure that all available alternatives received equal consideration, the results of which are described below.

5.1 PUBLIC SURVEY RESULTS

Results of the public survey proved critical to the development of this comprehensive list of alternatives. The survey was made available to the public from February 15th – February 19th, 2019 via a web link published online and in local newspapers. During the 5-day period that the survey was available, the project team received a total of 573 individual responses. Year-round residents provided the greatest number of responses, representing 50.1% of the total. Seasonal residents made up the second largest demographic, with 28.1% of responses. Of the individuals responding to the survey, 50.5% identified themselves as beachgoers, 23.9% as surfers / wave riders, and 11.7% as recreational boaters, with commercial fishermen, first responders, distance swimmers, and "other users" making up the remaining percentage. The demographics described above are illustrated in Figure 14.

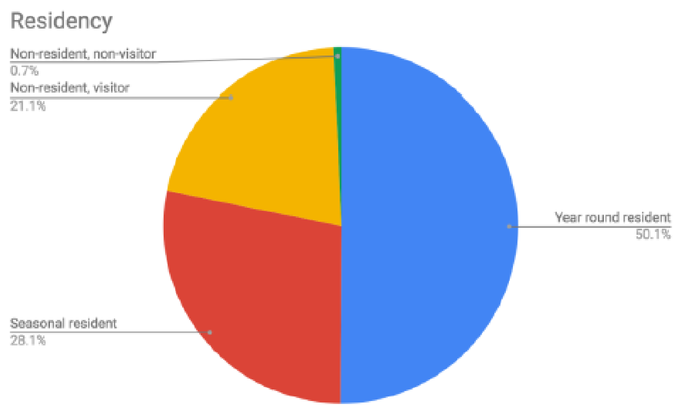
Of the 573 responses, 50.1% of individuals stated a preference for a technology-based alternative (tagging, spotting, bottom-mounted sonar, remote detection, etc.), 38.6% of respondents stated a preference for a biological-based alternative (population management, culling, etc.), and 16.2% of respondents stated a preference for a barrier-based alternative (nets, enclosures, etc.) to mitigate shark-human interactions on the Outer Cape. Interestingly, 176 respondents, or 30.7% of the total, stated a preference for an alternative that considered the human dimensions of the problem i.e. engage in S*hark Smart Behaviors*, measure risk before entering the water, avoid water activities during peak shark season, etc. A summary of proposed mitigation strategy by type is included in Figure 15.

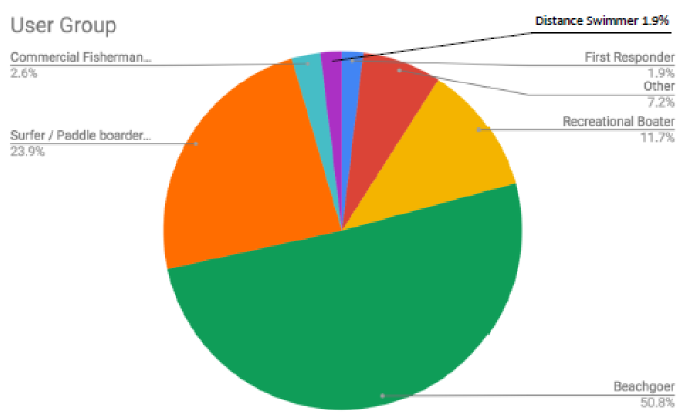
Of the 573 responses received, 7 responses included alternatives that were not previously considered by the project team. Those 7 responses were included for consideration in the alternatives analysis or were added to the list of immediately actionable items that could be deployed without legislative approval or additional permitting. A list of the 7 unique responses that were included in the alternatives analysis is included in Table 6. The additional 566 individual responses, which overlapped with proposed ideas or alternatives that were already under consideration are included in Appendix G.

Shark and Human Mitigation Strategies
Public Input Forum Responses

Total Number of Responses
573 Responses

Participant Demographics

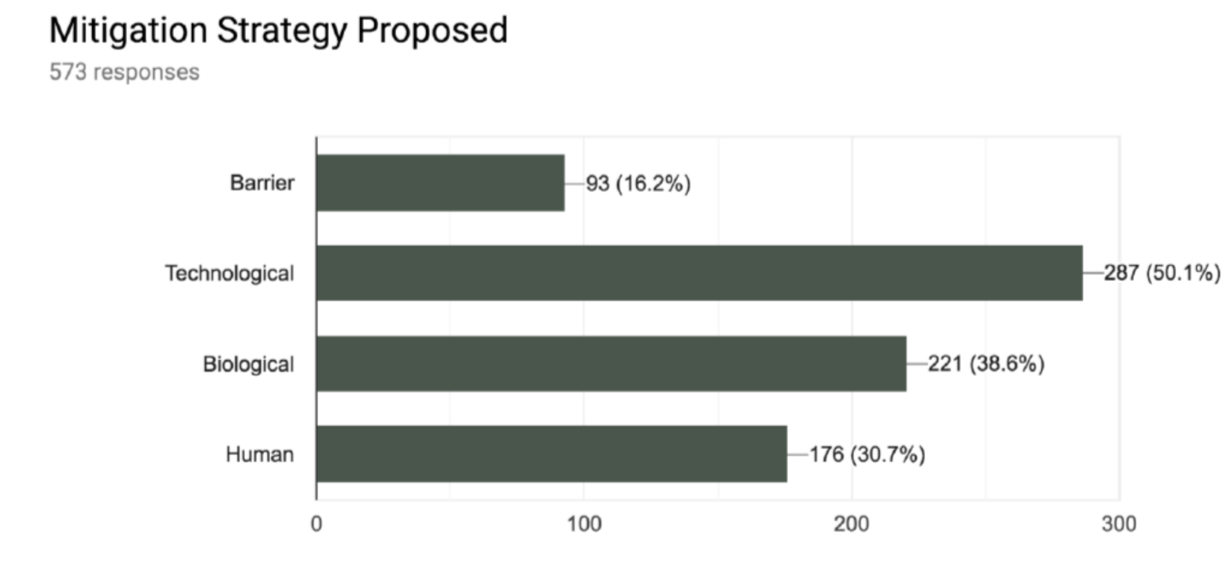




People who cited 'Other' above (16 Total), described themselves as being one of the following:

Body Surfer	Staff an environmental non-profit (APCC)	Fisherman	Scuba Diver
Ocean Lifeguard	Wildlife rehabilitator/ environmentalist	National Park Service Lifeguard	Clammer
Shellfishermen	Avid fishermen	Kayaker	Commercial Scuba Diver

Figure 14. Demographics of Shark-Human Mitigation Strategy Survey respondents.



Each response could include multiple strategies.

Figure 15. Preferred mitigation strategies of Shark-Human Mitigation Strategy Survey respondents.

Table 6. Responses received from the Shark-Human Mitigation Strategy Survey that were not previously included in the comprehensive list of alternatives or immediately actionable items.

Conduct research on the human dimensions of the problem as well as the efficacy of outreach/education efforts.
Display the number and location of recent beach closures due to shark sightings at every beach to increase awareness.
Ban surfing (and other board sports) during peak shark season.
Encourage orcas to feed on seals and sharks.
Forecast white shark presence based on research results.
Train sharks to avoid the area using negative reinforcement - proposed electrocution when tags are detected (presumably by the buoy) or by placing a series of seal decoys that would electrocute the sharks when bitten.
Polarized sunglasses for lifeguards to increase spotting efficiency.

After careful review, a total of 27 alternatives were identified for inclusion in this study. The comprehensive list of the 27 alternatives is included in Table 7. The remainder of this Chapter provides a summary of all technology, barrier, and biological-based alternatives identified for consideration in this study.

Table 7. Comprehensive list of Tech-based, Barrier-based, and Biological-based alternatives included in the scope of this Alternatives Analysis.

Technology-Based	Barrier-Based	Biological-Based
Tagging (Acoustic, real time alert)	Flexible Exclusion Barrier	(Smart) Drum Lines
Tagging (Satellite, real time alert)	Rigid Exclusion Barrier	Cull Nets
Visual Detection (planes, helicopters)	Semi-Rigid Exclusion Barrier	Seal Contraception
Visual Detection (tower-based)	Bubble Curtains	Seal Culling
Visual Detection (balloons)	Live Kelp Forests	Indigenous Harvest
Visual Detection (drones, tethered drones)	Simulated Kelp Barrier	Electric Shock
Acoustic Detection (sonar buoy, real time alert)	Electrical Deterrents	Scent-Smell
Electromagnetic (active, wearable/mountable)	Electromagnetic Deterrents	Modify Behavior
Magnetic (passive, wearable/mountable)	Acoustic Barriers	
Adaptive Camouflage		

5.2 TECHNOLOGY-BASED ALTERNATIVES

Tracking Sharks with Acoustic and Satellite Tags

The Massachusetts Division of Marine Fisheries has been conducting a study of the Cape Cod shark population since 2009. The program includes attaching acoustic and a limited number of satellite tags to sharks (Figure 16). The program has also placed a network of approximately 100 acoustic monitoring buoys in Cape and regional waters. Tagging and study programs have also been conducted by other organizations. Some characteristics of these tags are described below. Understanding the capabilities and the limitations of these technologies is important, as there are substantial data gaps and errors to consider in the context of any real-time warning system.

At the present time we do not know what percentage of the Cape shark population has an active tag. Nearly 200 tags have been attached to sharks, but the total population is not accurately known. It is hoped the DMF analysis will shed more light on this in the near future. Population churn, whether a tagged shark regularly returns to Cape waters, is also uncertain and the DMF study may shed light here as well. Battery endurance should be several years, but tags will eventually go silent, either because of a depleted battery, some physical damage, or detachment from the shark. A sustained effort would be required to maintain or raise the percentage of tagged sharks, but there will always be some, perhaps many, untagged sharks.

While the portion of the population that is tagged is unknown, the substantial number of tagged sharks does shed light on regional population dynamics. For example, some sharks have been shown by DMF to return to the Cape five years in a row, the current duration of the study. These “regulars” are more likely to be tagged, because they spend more time in Cape waters than non-returning sharks. Overall, tagging provides insight into population trends, such as times and seasons of peak activity, which are critical inputs for public outreach and education programs and for public safety efforts.

The acoustic tags each broadcast an individual signal (a unique serial number) at regular intervals of 1 to 2 minutes. A buoy in the network will be able to “hear” the signal if the shark is closer than, roughly, 350m (~1,200 ft.) when the ping is broadcast (Figure 17). The buoys are not directional or ranging, so the shark is localized only to the mooring location. The majority of buoys are also not real-time; the identity of the tag and the time of the ping are stored internally and must be manually downloaded by boat at some regular servicing interval. Using the tag identifier and the DMF tagging database, the identity and characteristics of the shark are determined, but that information is only available days to weeks (or longer) after the event. Note that this network is designed to support the research study; it was never intended to be a warning system. Recently, DMF has trialed real-time acoustic reporting buoys within the network to assist in the development of real-time forecasting of shark activity.

Additional real-time buoys could be deployed in the vicinity of selected beaches to provide real-time shark alerts to swimmers and surfers. Importantly, that local network or single buoy would only provide a warning for sharks swimming with an active acoustic tag. Untagged sharks would not be detected and could approach swimmers without warning. However, the regular alerts to date from the real-time buoys serve an important function by reminding swimmers of the ongoing presence of sharks in close proximity to Cape beaches and the importance of continuing to practice safe swimming behaviors.

The satellite tags record information about shark behavior (e.g., estimated position, water temperature) and are able to transmit that information via satellite, but only when the shark is at the surface with the tag above water long enough for the tag to connect to a satellite and transfer the data. It is a real-time system in the limited sense of reporting the current location of a shark when that shark is on the surface, but not otherwise.

While tagging is not strongly limited by environmental conditions and does provide regional coverage, it only samples a portion of the shark population and is thus not well suited for use as a stand-alone real-time warning system. If a real-time or internally recording buoy is deployed near a beach, it should be made very clear to swimmers and surfers that the buoy does not detect all sharks and does not provide significant protection or otherwise strongly enhance safety. Swimmers and surfers should be encouraged to continue observing the recommended best practices when in the water.

Tagging is best and most effectively used as part of a long-term research program, which may lead to greater insight into shark behavior and be used to inform safer human behaviors. Real-time detections of tagged sharks during times of peak human presence is also intended to serve as a reminder that sharks are commonly present, potentially reducing complacent behavior and contributing to overall public education and outreach.

Figures 16 & 17. DMF Shark Research Program staff applying acoustic tag to free-swimming great white shark (left). Acoustic buoys prepared for deployment (right). Photo credits to PS King/AWSC and Massachusetts DMF, respectively.

Visual Detection: Planes, Helicopters, Drones, Balloons, Towers; Direct Human Observation; Human and Computer Observation via Camera.

Various forms of aerial survey have been suggested and promoted as means of preventing shark attacks on Cape Cod and elsewhere. Significantly, all forms of visual detection may potentially act as real-time warning systems. There is often a strong expectation that visual spotting, whether by eye or through a camera, by humans, particularly trained observers, or by humans with the assistance of computer software, will invariably identify large sharks and provide a warning to swimmers and surfers. In 2013, those expectations were tested under controlled conditions in Australia (Robbins, et al., 2014).

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. Experienced human observers in fixed wing aircraft and inexperienced human observers in helicopters flew transects over the area without prior knowledge of the locations of the moored analogs. These locations were changed at random between trials. Interestingly, there was no significant performance difference between the experienced and inexperienced observers. The inexperienced observers actually did better in some circumstances.

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

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). At optimal angles, without sun glint, cat's paws, and other interference, spotting efficiency topped out at 33% for all observers. Over the full range of viewing angles, the overall detection rate was 9%. In summary, working in relatively ideal conditions, the observers consistently missed at least two-thirds of the near-surface shark analogs. Over the full area of observation, they commonly missed 90% of the targets, including 100% of those located 3m or more below the surface. It is likely that this level of performance will carry across all methods of visual detection.

There are other limitations for visual detection. Aircraft typically patrol along the coast and can remain airborne for several hours at a time. They cover a fair amount of ground, but do not provide observations for any one particular beach for a significant period. Even when a shark might be visible near the surface, the patrolling plane or helicopter is probably not present. Planes are certainly able to spot large sharks, but it must be recognized that they are missing the vast majority.

Drones, balloons, and towers (elevated structures with human spotters) have the advantage of being able to focus 100% on a particular beach, but that also means sightings are of sharks that are already quite close to swimmers and surfers. Drones can adjust viewing position to optimize the angle and to reduce the effects of sun glint and possibly wind (Figure 18). They can also maneuver for closer inspection if broad area observation detects something of interest. However, flight time is very limited. Twenty minutes between battery changes is typical. A tethered drone can remain in the air for long periods (hours to days), but maneuvering ability and range are limited by the tether. High wind speed will ground drones and balloons, but might also keep people out of the water.

Balloons are less maneuverable than drones (Figure 19). They can change height, which may allow improvement in viewing angle. They can also be based on a boat or vehicle, allowing movement of the base station within constraints. 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.

Realistically, tower height, whether a lifeguard chair, dedicated spotting tower, or cherry-picker, is limited compared to a balloon or drone. This will typically push the viewing angle out of the optimal range, possibly limiting detections to sharks actually on the surface or very close to the beach. Some Outer Cape beaches are backed by bluffs, which could be utilized to gain additional elevation, though this also moves the observer further away from the water. In the

Shark Spotter Program in Cape Town, South Africa, people use binoculars to observe beaches from elevated positions and warn officials of sightings. The program spotted 770 sharks between 2007 and 2014, however, there is no way to quantify the number of sharks they did not spot.

Computer algorithms may help winnow voluminous camera-based observations, mitigating errors due to human observer fatigue. Machine learning technologies are advancing, as evidenced by, for example, the success in some applications of facial recognition technology. However, these techniques are not infallible (e.g., notable failures of facial recognition technology) and at best function as an aid to human observers. When we consider the highly refined pattern recognition capabilities of humans, and the difficulty computers still have with that task (consider the use of images to reliably detect humans and block robots on the internet), it is unlikely that computer algorithms will significantly improve visual spotting efficiency in the near future.

There is a role for visual observation, possibly implementing a system of defensive layers. For example, outer layer broad area survey by fixed wing aircraft, sustained local observation by balloons or tethered drones, and short duration responsive observation by free-flying drones at the innermost layer. Some sharks will be spotted some of the time and swimmers, who might or might not be at risk of attack, (there is no way to know), can be alerted and removed from the water. Reactive, free flying drones might also have utility for lifeguards aiding or locating a swimmer in distress, independent of the shark threat.

The important point to understand is that it is unrealistic to think that any form of visual observation will detect all sharks or eliminate attacks. The assumption that visual observation alone makes beaches safe may itself be dangerous, because it allows people to more easily rationalize unsafe behavior. There is, in fact, no certainty that visual observation will have any real or measurable effect on reducing such statistically rare events. Visual observation simply does not spot most of the sharks, even under ideal conditions, 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. 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.

Figures 18 & 19. Example of surveillance drone, offered by the RipperGroup (left). Balloons, offered by Altametry, Inc. trialed along Outer Cape beaches, August 2017. Photo credits to the RipperGroup and Altametry, Inc., respectively.

Acoustic Detection of Sharks

The main, perhaps only, product in this market is Clever Buoy (CB), manufactured by Smart Marine Systems (SMS) in Australia. There has been considerable interest in and discussion of this system on Cape Cod. Importantly, there have been a number of independent and semi-independent evaluations and trials of CB in both Australia and the US, providing considerable information about actual system performance. We focused primarily, but not exclusively, on the Gladstone and Halphide reports, which are listed in the references.

A basic CB system includes a surface buoy, possibly a shore station, and one or more sonar units mounted in frames jetted into the bottom. The sonars are connected by cable to the buoy or to the shore for power and communications. The sonar units need to be accurately placed, oriented, and fixed on a stable bottom during deployment. In principle, the sonar beam illuminates objects in the water column, creating a series of images that are analyzed by software algorithms. The algorithms are intended to classify the imaged objects, identify which objects, if any, are large sharks, and then provide an alert to operators in near-real-time. There are several variations on the basic configuration, but these are not relevant to an evaluation of system performance.

Water depth, tide range, and active sand transport on Cape Cod beaches will limit the effectiveness of CB, independent of software performance. Near-shore water depths along Outer Cape beaches seldom exceeds 3m (10ft). This limits the range of the sonar units to 30m at most (theoretical calculation), and probably less in practice. Closer to shore, in shallower water, the range will be further reduced. Given the need for overlapping coverage (SMS recommends up to 20m of overlap), many sonar nodes would be needed to provide full coverage to even a 100m section of beach to a distance of 50m offshore. High tidal ranges and gradual slopes, particularly on bayside beaches, could expose nodes at low tide, resulting in no protective coverage, or could force nodes impractically far offshore so they could stay submerged. The enormously energetic along-shore and cross-shore transport of sand around Cape Cod can very quickly bury structures on the bottom, disabling or damaging sonar nodes. These characteristics of the Cape environment are not trivial obstacles when deploying and trying to maintain what is intended to be a safety critical system.

System performance under relatively controlled conditions was evaluated by Gladstone. In that study, an array of frames equipped with video cameras and baited to attract sharks was deployed in the field of view of a CB system. The sonar image record and the algorithmic output of CB were compared to the video record, the latter considered to be ground truth in the clear waters of the test area. The effective range of the system, based on actual detections, was uniformly shorter than the specified theoretical range, even after a correction for the actual angular width of the sonar beam.

When, according to the video record, no sharks were present, CB accurately reported no sharks ~90% of that time. However, CB incorrectly reported sharks were present 10% of the time when no sharks were present. In a beach safety protocol based on Clever Buoy, a determination that a shark was present might be the trigger for swimmers to leave the water. A false report would bring people out of the water unnecessarily, though there would be no independent way to confirm it was a false alarm. However, ~10% might be considered an acceptable level, a conservative and not overly burdensome response intended to prevent or reduce injuries.

Of the shark detections reported by CB, only ~40% appeared to actually be sharks, while ~60% were other objects, most commonly the baited video stations, which were stationary, or schools of smaller fish, which were moving. Of particular note, when, according to the video record, sharks were present, CB accurately detected them only ~40% of the time and failed to detect them ~60% of the time. These values are an average over the theoretical range of the sonar. Performance degraded with increasing range from the sonar node; performance was better within, for example, 20m, and fell off significantly at ranges of 30m to 40m. A false negative rate, failing to report that sharks are present, of that magnitude is problematic for a system intended to warn swimmers and surfers of an imminent threat.

The experience of Newport Beach, California, was consistent with the results of the Gladstone report. SMS installed and supported a trial CB system around the city's Balboa Pier for four months in 2018 and 2019 (Figure 20). Newport Beach Lifeguards, who are employees of the city's Fire Department, worked with the SMS personnel on a daily basis. The Chief Lifeguard, Mike Halphide, was closely involved throughout and authored the Newport Beach report evaluating system performance.

During the trial, alerts were sent to the lifeguards each time the CB system determined that a shark was present. The system produced 39 alerts during the trial period. Lifeguards were able to respond to 22 of these events, in person and/or with drones, in an effort to visually confirm the detections. In total, there were zero visual confirmations of CB shark detections over the four months of the trial.

During the trial, there was one confirmed visual detection of a shark near the pier and within the sensing area of the CB array. The CB system did not detect the shark, possibly due to failed communications between the sonar and shore. Additionally, lifeguard divers swimming in the CB array to clean biofouling off the sonar transducers were continuously tracked and continuously identified throughout the dive as large sharks. Such misidentification might apply to swimmers or seals, clearing the water unnecessarily.

The assessment from the Newport Beach lifeguards after completion of the trial was that it had produced no actionable data, that "*it is producing multiple false positives and has proven unreliable to assist in decisions affecting public safety*." Based on the trial results, Newport Beach decided against purchase or lease of a Clever Buoy system.

We note here that this sort of algorithmic image analysis is a very complex and difficult problem and is an active area of leading-edge research in academic, government, and commercial institutions around the world. Working with the fuzzy, low resolution, inconsistent images coming back from a sonar does not make the job easier. In the longer term this is a promising approach and performance is improving, but it is unlikely to be the sort of system that produces actionable data in the near future.

Beach characteristics alone make installation and use of the SMS/CB system on ocean and bayside Cape Cod beaches problematic, though not impossible. The system might be better matched to an estuary with a relatively deep and well-defined channel entrance. Unfortunately, the documented performance does not remotely approach the promise of the system. This creates a danger that swimmers and surfers in the vicinity of a system will relax their vigilance and fail to consistently follow safe practices, assuming that this system is protecting them to a far greater extent than it does. It should also be recognized that, even if the system does provide an accurate warning, the shark is already very close to the beach.

Figure 20. Clever buoy deployment, Newport Beach, CA. Photo credit Smart Marine Systems. Retrieved from https://www.smartmarinesystems.com/ 15 September 2019.

Personal Shark Deterrents

A growing number of personal shark deterrent devices are commercially available. Some are intended to be worn while others are to be attached to surfboards or similar equipment (Figures 21 & 22). The deterrents fall into two main categories: electromagnetic (EM) devices and camouflage. The EM devices include active (battery powered) and passive (permanent magnet) types that are either worn or are attached to surfboards. Camouflaging patterns are either wearable (wet suits) or applied to surfboards (decals, paint).

All of the EM devices are intended to confuse or repel a shark by causing pain or discomfort to the EM sensitive structures, the ampullae of Lorenzini, in the shark's snout. These electroreceptors allow sharks to sense weak EM fields in the water, including the electrical field produced by the muscle contractions of prey species. The fields produced by the personal shark deterrent devices are intended to, in some sense, overwhelm the ampullae of Lorenzini, causing distress or pain that repels the shark.

The EM devices, both active and passive, create an EM field with active electrodes (modulated voltages applied by the device) or with permanent magnets. The effective zone of possible protection is the volume within which the EM field strength is sufficiently strong to be detectable by the shark and to possibly cause distress. The single most important characteristic of these devices is their extremely limited range, a distance measured in inches or possibly feet, not yards. For example, an active device intended to be worn on the ankle (and with all of the electrodes on the anklet) will produce a field that is likely only strong enough to have some effect on a shark up to the knee or possibly mid-thigh (child or smaller adult). Torso, arms, and head are outside the field and receive no benefit, even if the shin is "safe".

Some EM devices spread the electrodes out along a flexible umbilical that might trail behind a swimmer or surfer from an anklet. The electrode separation (possibly coupled with an increase in power to the electrodes) increases the size of the field, possibly to the point it could fully envelop an adult swimmer. However, the trailing umbilical places that larger zone behind or below the wearer. Divers might attach the free end of the umbilical up near their shoulders, effectively enclosing themselves in the zone, but divers normally wear a non-conductive neoprene wetsuit that isolates them from the electrodes in the umbilical. Absent a wetsuit, many users report an unacceptable level of discomfort or pain when the electrodes in the umbilical contact or get close to bare skin. Trailing the umbilical is the preferred configuration, even though that places the swimmer partially outside the zone. Placing well separated electrodes on the bottom of a surfboard similarly produces a larger zone and the board and the air/water interface provide effective isolation for the user.

Testing EM devices typically involves putting them next to bait on a frame to see if sharks attracted by the scent will take the bait or be repelled by the device. Reported manufacturer trials may show sharks taking the bait when the device is off and turning away at the last moment if the device is on, at least most of the time. Independent tests and comparisons tend to reveal less definitive results. Several accessible studies, listed in the references in Chapter 8, are Huveneers 2018, Egeberg 2019, Huveneers 2013, Kempster 2016, and Smit 2003. These studies include evaluations and comparisons of commercially available products.

Several comments on the tests are in order. First, all of the trials kept the device on or off throughout a run. No trials involved starting with the device on, recording a shark turning away from the bait one or more times, and then taking the bait after the device was turned off. This would have provided stronger evidence that the repelled shark was actively hunting rather than merely passing by and thus stronger evidence that the device provided reliable protection. Very few trials showed any repellent effect on a shark that had fully committed to an aggressive attack vector. Turning away from a relatively slow approach to the bait was the normal observation. The very limited size of the protected volume may explain this difference; a massive 2m to 3m shark may not be able to stop in the last few inches of a fast, committed attack.

Second, it was also common for sharks to approach the bait multiple times, getting closer each time before turning away or otherwise reacting. It may be that sharks acclimate to the EM field or simply become more willing to ignore the discomfort after some investigation and experience. A device that was initially somewhat effective may not remain so. A device might reduce the severity of an attack, even though it did not block contact, but not prevent serious injury.

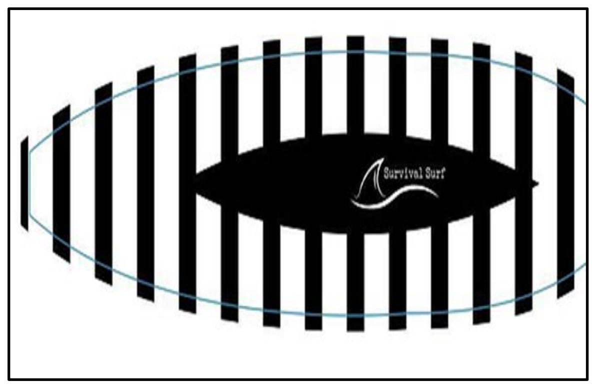
Third, superficially similar devices produced by different manufactures and compared in an independent trial performed differently. One brand, an active device worn on the wrist, might show some deterrent effect while another brand, also active and also worn on the wrist, might show none in the same circumstances of a comparative test. While similar in construction, the devices used different frequencies and pulse rates to excite the electrodes and generate the EM field. Whether by chance or design (the sensors in the snout of sharks are not well understood or characterized), one EM field had a stronger effect on the sharks in the test. EM shark deterrent devices are all based on the same general principal, but they are not equally effective. “Sort of works” versus “doesn’t work at all” are both real possibilities and independent evaluations and comparisons of EM devices that are superficially similar are important.

Finally, despite persistent concerns, there is no evidence that these EM devices attract sharks.

The evidence for the efficacy of camouflage, whether worn or applied to a surfboard, is limited and inconclusive. We note that claims for camouflage tend towards statements that the swimmer or surfer is less likely to be noticed by a curious shark that just happens to be swimming in the area. This as opposed to statements that the camouflage will prevent the attack of a shark that is actively hunting for a meal.

It is critically important to recognize that these are personal purchases, not a form of regional or beach protection provided by a governmental or other organization. The existing research suggests that some of these devices may be somewhat effective some of the time. Individuals should take their personal responsibility to evaluate these devices, should they choose to use them, very seriously. We strongly recommend reading the very accessible peer reviewed papers that have come out of independent studies, several of which directly compare different brands. Then, conduct a realistic personal risk assessment before purchase or use. Where and how will you use the device? Is there any evidence from independent studies that it will be useful under those conditions? Are you likely to change your behavior, possibly ignoring some tenets of best practice for safety in the water, just because you are using such a device? These are serious questions and they need to be considered objectively in your personal assessment.

We would not, ourselves, base that personal risk assessment purely on manufacturer's claims. Look to the independent research and testing that has been conducted. We would always keep in mind that none of these devices provide anywhere near 100% protection under any realistic circumstances. Finally, from a large shark already on an attack trajectory, arguably none of these devices will provide any meaningful protection at all.



Figures 21 & 22. Personal tech, active shark deterrent wristband (left) and passive surfboard camouflage striping (right). Photo credits Sharkbanz and Survival Surf, respectively.

5.3 BARRIER-BASED ALTERNATIVES

Barrier-based alternatives can be divided into two (2) main categories including 1) physical barriers that physically separate sharks and humans (such as a net) and 2) virtual barriers that are intended to deter sharks from entering a given area due to acoustic, visual, tactile, or other sensory stimuli. Pros and cons, and characteristics of different alternatives are discussed. These criteria are further defined in the alternatives analysis (Chapter 6).

Flexible Exclusion Net

Flexible exclusion nets are typically made of nylon rope, often the same material used in commercial fishing nets that are deployed to provide a physical barrier to exclude sharks from an area of high human use, thereby reducing risk of shark-human interactions. Being flexible, these nets can modulate with energetic surf conditions and large tide ranges. However, flexible nets carry the significant risk of entangling and killing non-target fish, marine mammals, turtles, and other marine life. As a result, they have fallen out of favor in many areas, especially where there exists sensitive marine life.

Exclusion nets require both land and boat-based construction crews utilizing divers to deploy or recover the net. The net is anchored to large mooring blocks or piles driven into the seafloor and weighted down with chain along its length. The net is then suspended through the water column using a series of surface floats that provide buoyancy. They come pre-fabricated in sections where the length, width, and mesh size can be customized to meet site-specific need. The sections are tapered towards shore and require either large anchors to be buried into the beach or anchors drilled into hard substrate. While these installations are successful at excluding sharks, there have only been a limited number of installations in Australia and Hong Kong.

Hong Kong was the first to install exclusion nets, called Shark Prevention Nets (SPN), in 1994 after a series of shark attacks and now has over 32 installations (Figures 23, 24) that were designed by Maritime Mechanic Ltd. (2014). While the Hong Kong installations have been successful, there has also been a dramatic drop in their shark population during this time that also may explain some of their success. In the Seychelles, an exclusion net was deployed at Anse Lazio Beach after several shark attacks, but was removed after 5 years due to frequent damage from storms and bathers ignoring safety concerns and swimming outside the net (Meriton, 2017). In Fish Hoek South Africa, an exclusion net has been in use on a portion of the beach since 2013. The net is deployed and retrieved on a daily basis, but is not deployed if there is high surf, greater than 2m, or presence of marine mammals (SOSF, 2014).

Exclusion nets are prone to generating incidental bycatch by entangling marine life. This is due in part to the small mesh size that does not allow marine life to safely pass through the net. This form of net also poses a risk of entanglement to swimmers and other beach users. Manufacturers claim the net could be removed/deployed on a seasonal basis and have a 10-year lifespan. Periodic cleaning of biofouling from growth, detritus, and debris in removal of bycatch (fish, marine mammals, etc.) would be necessary and likely require divers. The net would also have to be checked periodically, especially after storms, and repaired as needed. There have also been concerns voiced by the surfing community that these installations attenuate wave energy, thereby reducing wave heights. Permitting may prove challenging for a net-based system constructed both on the coastal beach and in subtidal waters.

While exclusion nets have had some success in embayments with protective headlands, they require frequent inspection, cleaning, and maintenance using divers and pose an entanglement risk to marine animals. They would not be a preferred option for open ocean beaches with high surf as they are susceptible to storm damage. The dismal environmental track record of shark nets in general has stymied the use and acceptance of exclusion nets in favor of more rigid barrier systems in parts of the world where nets are employed.

Figure 23. Fish Hoek exclusion net being deployed. Photo retrieved from: http://crfimmadagascar.org/en/environnement-marin/info-afrique-du-sud-un-filet-dexclusion-pour-les-requins-protege-la-plage-de-fish-hoek/ Retrieved 15 September 2019.

Figure 24. Exclusion Net at Fish Hoek beach. Photo retrieved from: https://www.sharkzone.co.za/blog/shark-spotters/ 15 September, 2019

Rigid Exclusion Barrier

A rigid exclusion barrier is a large mesh net made from a high-density plastic that forms a rigid physical barrier to exclude sharks from an area of high human use, thereby reducing risk of shark-human interactions (Figures 25 & 26). The intent behind the rigid barrier is to provide a more eco-friendly alternative by reducing the risk of entangling marine life by providing a stiff, large mesh that would not wrap around and entangle a large animal while also allowing smaller animals to pass through. The rigid barrier can be deployed either across a channel/harbor entrance or extended from the beach to a specified depth, and then run alongshore for a specified distance, creating a safe protected area for public use (Eco Shark Barrier; Global Marine Enclosures, 2019).

Rigid exclusion barriers require both land and boat-based construction crews utilizing divers to deploy or recover the barrier. The barrier is anchored to large mooring blocks or pilings driven into the seafloor and weighted down with chain along its length. The barrier is then suspended in the water column using a series of surface floats that provide buoyancy. The sections are tapered towards shore and require either large anchors to be buried into the beach or anchors drilled into hard substrate. Rigid exclusion barriers come pre-fabricated in sections that snap together. Deployment of a rigid exclusion barrier can take several days or more.

There have been a limited number of installations including Coogee Beach, Western Australia, and Lighthouse and Lennox Beaches in New South Wales, Australia (Eco Shark Barrier; Global Marine Enclosures, 2019). Of these three installations, only Coogee Beach is still operational, and has successfully excluded sharks since 2013 (Eco-Shark Barrier, 2019). It is likely that the Coogee Beach deployment has been successful because it is a protected beach with a relatively low energy wave environment, while the other two installations failed in more energetic wave environments. At Lighthouse Beach, the energetic surf conditions caused scouring around the moorings before the barrier could be fully installed, causing the moorings to shift and the enclosure to fail, a point of caution for considering the deployment of a rigid barrier in a high surf environment (Triple J Hack, 2016). The failed installations resulted in broken plastic fragments washing up along nearby shorelines.

Manufacturers claim that current installations have experienced no bycatch of marine life. While entanglements and bycatch are likely reduced when compared to traditional nylon nets, the risk of entanglement would require careful review of any proposed design and implementation protocol to further mitigate risk of impacts to marine life. Manufacturers also claim that rigid barriers have little effect on coastal processes. However, it is unlikely that such an installation off a Cape Cod beach would have no impact to coastal processes considering the scale of these structures and the amount of sand being transported along the shore. There have also been concerns voiced by the international surfing community, as these net/barrier installations attenuate wave energy, thereby reducing wave heights. The structures may also be viewed as an obstruction to surfing, resulting in recreation outside the safety barrier.

Manufacturers claim the system can be removed/deployed on a seasonal basis and should have a 3 to 10-year lifespan. Periodic cleaning of biofouling from growth, detritus, and debris will be necessary and will likely require divers. The barrier will also have to be checked periodically, especially after storms, and repaired as needed. Permitting for a barrier/net-based system constructed both on the coastal beach and in subtidal waters may prove challenging.

Rigid exclusion barriers have also fallen out of favor, due to their limited success rate in high-surf environments and with the development of more resilient, semi-rigid exclusion barriers.

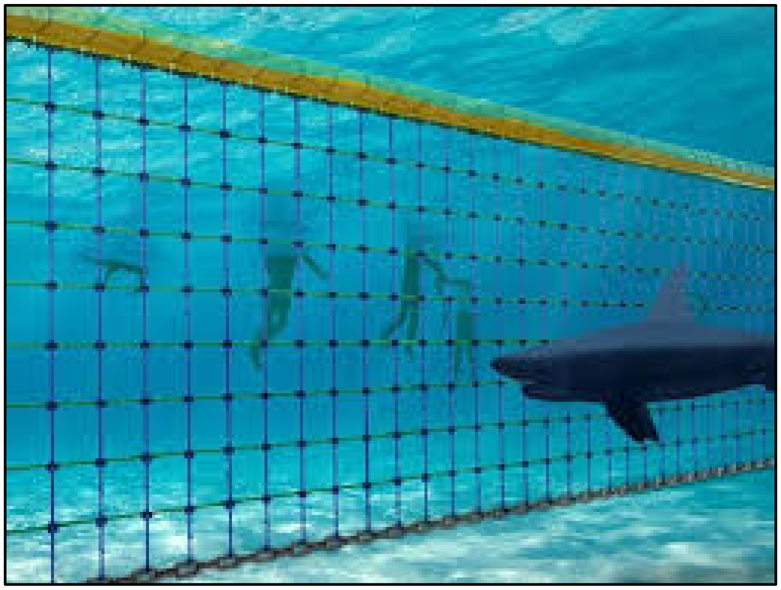


Figure 25. Rigid Exclusion Barrier. Photo retrieved from http://dpi.nsw.gov.au 15 September 2019.

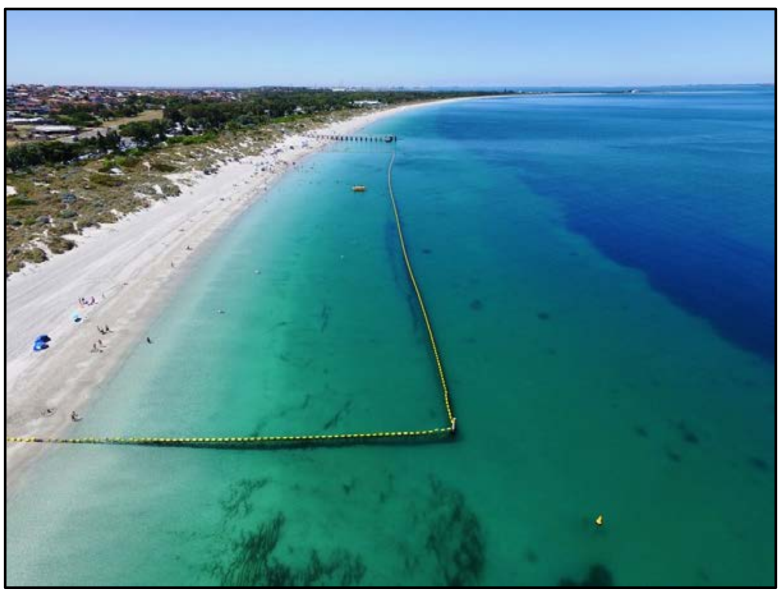


Figure 26. Eco-Shark Barrier installed at Coogee Beach, WA, Australia. Photo credit City of Cockburn, WA. Retrieved 15 September 2019 from https://comment.cockburn.wa.gov.au/shark-barrier-should-it-stay-at-coogee-beach

Semi-Rigid Exclusion Barrier

A semi-rigid exclusion barrier is a large mesh nylon exclusion net that is reinforced using plastic struts or joints to form a semi-rigid physical barrier to exclude sharks from an area of high human use, thereby reducing risk of shark-human interactions. The semi-rigid barrier is a hybrid design of a nylon exclusion net and a rigid barrier that is intended to be more ecofriendly by reducing the risk of entanglement of marine life (through increased rigidity) while maintaining elasticity to withstand waves, tides, and currents (Figure 27) (Eco Shark Barrier; Global Marine Enclosures, 2019). The design typically includes large diameter nylon rope in the longitudinal direction that can be sheathed in a dense vinyl hose material to increase durability and stiffness. These longitudinal sections are then connected together using plastic joints or struts that in turn create the mesh openings. The semi-rigid barrier can be deployed either across a channel or harbor entrance or to enclose an open-ended rectangular section of beach for public use.

Semi-rigid exclusion barriers require both land and boat-based construction crews utilizing divers to deploy or recover the barrier. The barrier is anchored to large mooring blocks or piling driven into the seafloor and then weighted down with chain along its length. The barrier is then suspended through the water column using a series of surface floats that provide buoyancy. The sections are tapered towards shore and require either large anchors to be buried into the beach or anchors drilled into hard substrate. They come pre-fabricated in sections that are connected together and can be rolled up for shipping.

There are a limited number of installations in Western Australia at Quinns Beach in Wanneroo, Middleton Beach in Albany, Sorrento Beach in Sorrento, and one planned for Cottesloe Beach in Perth (Figure 28) (Eco Shark Barrier; Global Marine Enclosures, 2019). According to the manufacturers, these installations have been successful at excluding sharks to date, and have withstood the wave climates within their respective coastal environments.

Manufacturers claim that current installations have experienced no bycatch of marine life due to the rigid nature of the product and larger diameter openings of 360 mm (~14.2 in). While entanglements and bycatch are likely reduced when compared to traditional nylon nets, the risk of entanglement would require careful review of any proposed design and implementation protocol to further mitigate risk of impacts to marine life. Manufacturers also claim that semi-rigid exclusion barriers have little effect on coastal processes; however, it is unlikely that such an installation off a Cape Cod beach would not have any impact to coastal processes considering the scale of these structures and the amount of sand moving along the shore. Exclusion Nets and barriers have been associated with dampening wave energy, impacting traditional surf breaks.

Manufacturers claim the system can be removed/deployed on a seasonal basis and should have a 5 to 10-year lifespan. Periodic cleaning of biofouling from growth, detritus, and debris will be necessary and will likely require divers. The barrier will also have to be checked periodically, especially after storms, and repaired as needed. Permitting for an enclosure constructed on the coastal beach and in subtidal waters may prove challenging.

According to manufacturers, semi-rigid exclusion barriers are gaining favor over rigid barriers with several recent installations in Australia; however, the failure of several rigid exclusion barrier installations and the dismal environmental track record of cull nets has stymied their widespread use and acceptance.

Figure 27. Detail view of Global Marine Enclosures semi-rigid net. Photo credit Global Marine Enclosures. Retrieved from https://www.globalmarineenclosures.com/ 15 September 2019.

Figure 28. Global Marine Enclosures “semi-rigid” barrier installation, Middleton Beach, WA. Photo credit Google Earth. Retrieved 15 September 2019.

Bubble Curtain Deterrent

Bubble curtains were originally developed as a way of providing a non-physical sound barrier to shield marine life, especially cetaceans (whales and dolphins), from the disruptive sounds associated with offshore drilling activities. More recently, bubble curtains have been used as a form of visual and physical deterrent to discourage marine life from entering sensitive areas such as power plant intakes, and have even been combined with high frequency acoustics and underwater strobe lights to create a more robust deterrent system (Fish Guidance Systems, 2019). Some research has suggested that bubble curtains can deter sharks as well, which has the potential to reduce the shark-human interactions without the use of physical nets or barriers. While there are no commercially available systems designed to specifically exclude sharks, the technologies are readily available.

A bubble curtain is powered by an air compressor, which pumps air down a perforated hose anchored to the seafloor. This produces a stream of bubbles along its length that rises in a curtain from the bottom (Figures 29 & 30). The hose can be laid out across a channel or harbor mouth or in a rectangular pattern from the shoreline. The systems require that the hose be hooked up to an air compressor on land to provide a continuous supply of compressed air. Air pressure, and subsequently the density of bubbles, decreases with distance.

While there is only limited research available, initial studies have demonstrated that in laboratory settings, bubble curtains have the ability to deter sharks. Scientists do not have a full understanding of the sensitivity mechanism, whether it is visual, touch, lateral line, or combination of sensory stimuli. Recent (2015) research by Hart and Collin has shown that, while there is an initial avoidance with bubble curtains, sharks eventually become acclimated to it. There are no active bubble curtain systems being used commercially to deter sharks at the time of this writing.

There is limited environmental impact associated with a pipe anchored to seafloor. Bubble curtains could potentially interfere with marine mammal communication on a localized basis. Bubble curtains can be deployed/removed on a seasonal basis and should have a 10-year lifetime with the proper maintenance. Periodic cleaning of biofouling from growth and uncovering sediment would be necessary using divers. The system is operated on an on-demand basis, such as during swimming hours, and can be shut off after hours or at the conclusion of the season.

Permitting for a bubble curtain in subtidal waters may prove challenging. This system also requires permitting to lay a hose through the intertidal zone, coastal beach, and dune to an air compressor located on-shore.

While there are no commercially available bubble curtains specifically targeting sharks, there are bubble curtains systems available for marine pile driving and drilling operations from various manufacturers. Fish Guidance Systems combines their bubble curtain systems with strobe lighting and acoustical sounds to create a robust non-physical deterrent system for fish, but have not been extensively tested for deterring sharks.

Bubble curtains are not recommended for open ocean beaches as performance would suffer as sand migrated over the pipe on the seafloor. While they may be useful in quiescent harbors, the deterrent effects may also be temporary as marine life becomes acclimated.

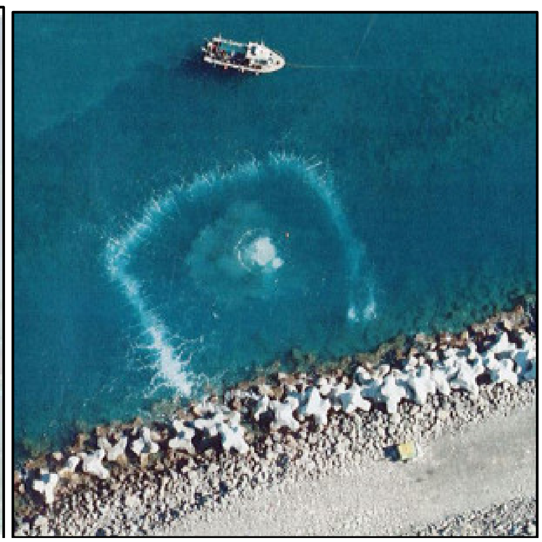



Figure 29 & 30. Bubble curtain setup on bottom (left) and aerial view (right). Photo credit Canadian Pond. Photos retrieved from https://canadianpond.ca/air-bubble-curtains-bubble-tubing/ 15 September 2019.

Live Kelp Forests

Kelp is a large, thick-stalked, leafy, photosynthetic algae, that grows from the sea floor and can reach the ocean surface. When conditions are optimal, it can grow in dense stands that resemble an underwater forest and harbor a variety of marine life. Historically, there was anecdotal evidence that great white sharks tended to avoid hunting in kelp forests where seals take refuge and, therefore, it was proposed that growing a kelp forests off the coast of Cape Cod could provide a natural physical and visual deterrent to great white sharks. A recent study by O'Connell et al. (2019) investigated the relationship between kelp forest density and white shark presence and found that white sharks avoided dense kelp forests where there was at least 1 stalk per 1 m^2 of seafloor was present, demonstrating that dense kelp forests could potentially act as a natural barrier. However, the same study also showed that great white sharks actively hunt in low to moderate density kelp forests, suggesting that the presence of kelp alone is not a sufficient deterrent. In addition, Murdoch University PhD student, Oliver Jewell, captured video footage of a great white shark actively hunting fur seals in a kelp forest off the South African coast (Jewell, 2019), which further supports the notion that kelp alone does not act as a sufficient deterrent.

To our knowledge, there have not been kelp forests/farms established for the specific purpose of providing a physical barrier to sharks. In order to grow a kelp forest where there is not one growing naturally, an aquaculture kelp farm would have to be established (Figure 31). There is substantial research and literature on growing kelp, including the *Kelp Farming Manual* (Flavin, 2013). Kelp seed stock could be purchased from a supplier and then the kelp could be grown from floating surface lines that are anchored on either end using a mooring (Bailey, 2019). Care would need to be taken to ensure the stalk spacing was at most, 1-meter along surface lines. The farm would have to be set up in deeper depths well outside the energetic surf zone. The stalks of kelp typically only grow about 6 – 8 ft. below the surface line due to the lack of sunlight found at deeper depths. The typical growing season is fall to late spring or early summer, as the kelp dies back during the summer months.

No major environmental impacts are expected from establishing a kelp forest; however, kelp is typically grown from floating surface lines that can pose a risk of entanglement for marine life. Limited maintenance is required after the kelp farm has been installed and seeded, however, periodic checking and cleaning would be required. The kelp would have to be reseeded and replaced on an annual basis and the plants only grow from fall to early summer, and then experience die back during the summer, coinciding with the height of the tourist season. Additionally, the kelp is being grown vertically from surface lines and typically does not extend to the bottom as there is not enough light to support growth. Therefore, a gap would exist between the maximum extent of the kelp and the seafloor. The permitting requirements would be for a kelp aquaculture farm, which is very similar to permitting a shellfish farm.

Establishing live kelp forests is not likely to be an effective shark mitigation strategy for several reasons. First, kelp does not grow well in shallow, turbid, surf zone environments. Additionally, the species of kelp that is native to the northeast, sugar kelp, does not naturally grow in dense kelp forests that are common along the pacific coast and elsewhere around the world. Therefore, the kelp would have to be farmed in order to produce dense stands of kelp that could form a barrier hanging from a surface line. The nutrient content of the water, especially nitrogen, may not be high enough to sustain a kelp farm on the Outer Cape and would require additional research and testing. Further, sugar kelp only grows down vertically from the surface line and is limited based the availability of sunlight. As a result, kelp would likely not extend to the bottom and sharks could swim under or around it since the kelp cannot be effectively cultivated in the shallows. Additionally, the growing season for native sugar kelp is between fall and late spring/early summer at which point it dies back, during the period of time when protection is most needed.

Figure 31. Sugar Kelp being grown from surface lines in Milford, CT. Photo retrieved from https://www.fisheries.noaa.gov/feature-story/milford-lab-takes-sugar-kelp-cultivation 15 September 2019.

Simulated Kelp Barrier

Simulated kelp barriers have been developed as a method of reducing the risk of shark-human interactions. The simulated kelp provides the visual deterrence of kelp while also being a physical barrier to sharks without the bycatch risk associated with nets (O'Connell, 2017). This is a relatively new technology that has been in the research and development phase for several years with installations in South Africa, the Bahamas, and most recently Reunion Island, France. The simulated kelp is typically constructed out of PVC piping with foam insulation to provide flotation, and the pipes are anchored to mooring blocks (Figure 32) (Shark Safe Barrier, 2019). Permanent C-9 Barium ferrite static (non-electric/passive) magnets have also been installed into the simulated kelp to provide an additional sensory deterrent (O'Connell, 2014), however, the effective range of a static electric field is small, on the order of 0.5 m (1.6 ft.) or less. The simulated kelp has joints that allows it to flex with the waves, currents, and tides.

Simulated kelp requires boat support with divers to deploy and recover, and the systems are considered a permanent installation. Each simulated kelp stand is attached to mooring blocks/anchors and arranged in a row spaced 0.5 to 1m apart, and then in staggered in 3 to 4 rows. This spacing, while not impenetrable to sharks, is designed to discourage regular movement through the array. The first row of kelp has the permanent (passive) magnets embedded in PVC to provide additional deterrence. Typically, they are deployed at depths greater than 2m (6.56 ft.). In water less than 2m, an exclusion net may be used to connect the system to the shore.

There has been a lot of supporting research conducted on these systems in South Africa, Bahamas, and most recently Reunion Island to demonstrate their effectiveness (O'Connell, 2014). This includes videos of sharks being deterred from taking bait behind the simulated kelp barrier. The simulated kelp has been successfully tested in some high surf environments as well. These systems contain many different materials, components, and mooring block, which have a large footprint on the seafloor. Only small areas, roughly 15m x 15m (49.2ft. x 49.2ft.) have been enclosed in deeper water. There are concerns about scaling these systems up to protect large stretches of beaches due to the amount of materials and costs.

Manufacturers claim that current installations have not resulted in incidental bycatch of marine life due to the rigid, open nature of the product and that sea life, including seals, may actually be attracted to the installations. This may be undesirable if seals congregating in the kelp were to attract sharks to where the individuals are swimming. The risk of entanglement would require careful review of any proposed design and implementation protocol to further mitigate risk of impacts to marine life. Manufacturers also claim that simulated kelp has little effect on coastal processes however; it is unlikely that such an installation off a Cape Cod beach would not have any impact on coastal processes considering the scale of these structures and the amount of sand moving along Cape Cod's dynamic shoreline. The manufacturer discourages direct human/bather interaction with the system.

Manufacturers claim that the system is a permanent installation with a 10-year lifespan that is not seasonally removed. Periodic inspection and cleaning of biofouling and debris will be necessary using divers and repairs will need to be made as necessary, especially after storms. Permitting a large array in subtidal waters may prove difficult.

There has been substantial research conducted to demonstrate the effectiveness of simulated kelp barriers in controlled environments. While this type of barrier has been shown to be effective for creating small enclosures for protecting small stretches of coast, scaling the product up to protect large stretches of beach may not be cost effective at this time due to the quantity of materials and number of moorings required.

Figure 32. Artificial kelp pictured here, manufactured by Shark Safe Barrier, provides a visual and passive magnetic deterrent to sharks. Photo credit, Martha's Vineyard Times. Retrieved from https://www.mvtimes.com/2018/10/12/shark-safe-barrier-protect-local-swimmers/ 15 September 2019.

Electrical / Electromagnetic Deterrents

Sharks possess anterior electro-sensory pores called ampullae of Lorenzini on their snouts that they use to detect weak electromagnetic fields produced by prey at short distances (less than a meter). The intent behind electrical and electromagnetic deterrents is to exploit this sensory organ by overloading it with either a strong electric or electromagnetic field through a cabled or moored installation (Huveneers, 2018). The current generated by these products produces a low voltage and is therefore not dangerous to humans or marine life, but can be felt if the cable is touched.

One example consists of a cabled system composed of a main power line along the seafloor with floating electrical taglines suspended by surface buoys and spaced approximately 3 meters apart originally designed by the Kwazulu-Natal Sharks Board (KNSB) Maritime Center of Excellence (2019) (Figure 33). In addition to a sensory deterrent, the floating taglines provide a visual deterrent to a degree as well, but the tag line spacing is wide enough (3m) to allow sharks and other marine life to pass through. Another system consists of a series of stand-alone moorings that generate an electromagnetic field 15m deep with a 6-8m (19.7-26.2ft) radius using an antenna suspended vertically through the water column from the mooring (Ocean Guardian, 2019). However, the moored systems are not intended for surf zones or long-term deployments. Deploying either of these systems would require a constant power source, although the moored system has the ability to run off batteries with daily recharging.

While these systems are relatively new to the commercial market, the cabled systems have been in the research and development phase by KZNSB with installations at Glencairn and Seal Island in South Africa. There is also a deployment planned for the 2019-2020 summer season at Busselton Jetty, Western Australia.

Manufacturers claim that the electrical or electromagnetic currents do not pose a danger to marine life or beach goers that may come into contact with the electromagnetic field. Manufactures also claim that there is little risk of entanglement to marine life based on the current deployments due to the thick, stiff tagline cables that are spaced 3m apart. Some concerns over risks to people with pacemaker have been raised, and the manufacturer discourages human/bather interaction with the system.

The cabled systems would require both land and boat-based teams that utilize divers to deploy or recover the cable, which could be done on a seasonal basis. The cabled system would have to be hooked up to a constant source of power with a cable laid through the surf zone. The cabled system has an operating temperature of 53.6-104°F, and would only be operable during the summer season. The moored systems could be deployed and recovered from a boat and are designed for temporary, localized deployments (from a boat, around divers, etc.). Design lifetimes have not been adequately established for these products being that they are so new to the market. Periodic cleaning of biofouling from growth, detritus, and debris may be necessary and will likely require divers. The system is operated on demand basis, such as during swimming hours, and could be shut off after hours or after the season to save energy.

Permitting may prove to be difficult for a cabled system in subtidal waters. This system also requires a power cable laid through the intertidal zone, coastal beach, and dune to a power source such as a generator or electrical power source. Temporary, moored systems likely have fewer permitting constraints.

Electromagnetic / electrical deterrents may be more feasible in quiescent estuaries or shorelines with smaller tide ranges, but are likely less resilient in large surf or tidal zones.

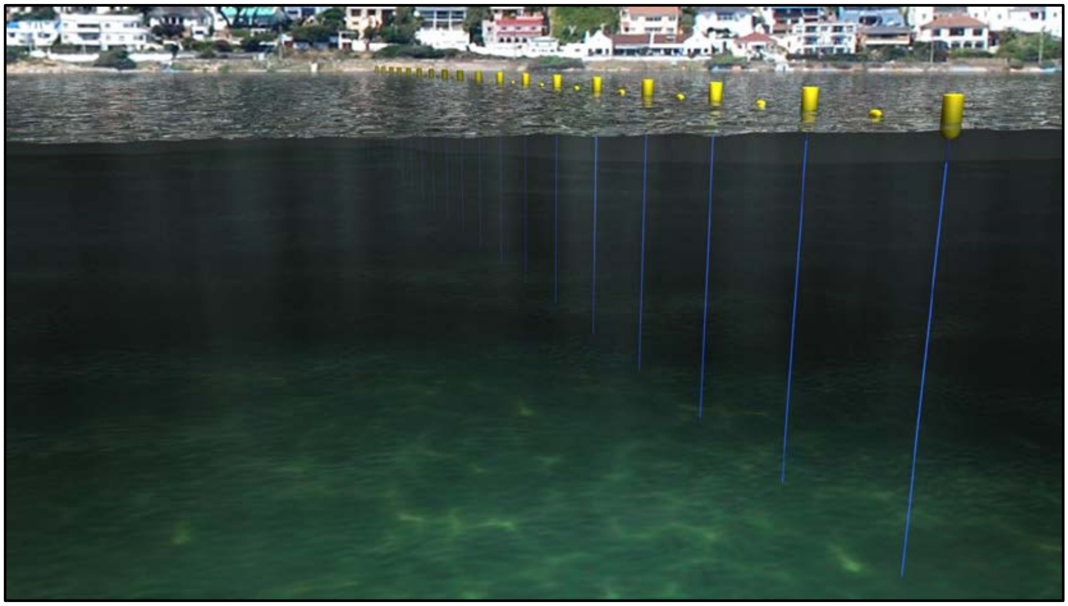


Figure 33. Electromagnetic deterrent array. Photo Credit KNSB.

Acoustic Deterrents

Acoustic deterrents are a class of audible deterrents designed to repel marine life such as fish, sharks, and marine mammals using sound. Sharks have an inner ear that can hear within frequencies ranging from 10Hz to 1kHz, and are especially responsive to sounds 500Hz or lower (Ryan, 2018). Commercially available acoustic systems are available to guide and/or deter fish and marine mammals from critical infrastructure such as power plant intakes or commercial fishing operations, and can be combined with underwater strobe lights and/or bubble curtains to create a multisensory deterrent system. However, several manufacturers indicated that their products are not designed to deter sharks, and there is only one commercial system available at the time of this writing that is specifically designed to repel sharks, using a combination of orca and high frequency sounds (Figure 34) (Sharkstopper, 2019).

Acoustic deterrent devices come as stand-alone units that would need to be individually deployed on a mooring or fixed location. Multiple devices and locations would likely be needed in order to create an array to protect a significant (100m; 328ft.) stretch of beach. In addition, these devices require a power source either in the form of an onboard battery that would need recharging or shore power to provide full-time protection, both of which have their drawbacks. These devices can be combined with underwater strobe lights and/or bubble curtains to create a more robust deterrent system.

The ability of acoustics to deter sharks from a beach may have a reduced effectiveness in the surf zone due to breaking waves that produce sound and bubbles that can drown out and dampen the sound from the deterrent. Some manufacturers of acoustic deterrents had theorized that since white sharks in South Africa are preyed upon by orcas, they would be sensitive to orca calls. In the northeast, the Orca population is very small and locally, only a lone individual is consistently documented feeding on fish offshore. It is not known whether white sharks in the northeast are deterred by orcas or their calls. Recently, researchers at the University of Western Australia (UWA) determined that orca calls had limited ability to deter white sharks during experiments in South Africa (Chapuis, 2019). They did find that certain high frequency sound ranges had a modest effect at modifying white shark behavior, but not to the level that it could be used as an effective white shark deterrent. The UWA researchers also found that adding underwater strobe lights to the acoustic deterrents had no noticeable effect on the white sharks. Several manufacturers of marine mammal and fish acoustic deterrent systems also indicated that their systems are not intended for use with sharks.

An acoustic deterrent set up at the head of a harbor or as a stand-alone mooring is not expected to have a significant environmental impact. It is possible the sound could interfere with or confuse marine mammal communication; however, the effects would likely be localized and would require further study.

Systems could be deployed/recovered on a seasonal basis and should have a 10-year lifespan with annual maintenance according to discussions with manufacturers. Periodic cleaning of biofouling from growth, detritus, and debris may be necessary. Permitting would likely be the same as for a permitting a single mooring deployment, however, a large mooring array would draw more scrutiny. Possible interference with marine mammals would require a careful review of proposed equipment, deployment, and retrieval protocols.

Acoustic deterrents are not likely to be a solution to effectively deter sharks, especially on their own, as they become acclimated to the sound and their effectiveness is only marginally increased when combined with underwater strobe lights and/or bubble curtains (Ryan, 2018).

Figure 34. **SharkStopper Acoustic Shark Repellent Device. Photo credit Shark Stopper. Retrieved from: http://www.sharkstopper.com/ 15 September 2019.**

5.4 BIOLOGICAL-BASED ALTERNATIVES

(Smart) Drum Lines

Drum lines, a method of culling or controlling the number of potentially dangerous sharks in an area of high human use, are intended to reduce the risk of shark-human interactions. Drum lines are comprised of baited hooks that are attached to a buoy floating at the water's surface (Curtis, et. al. 2012). The drumline buoy is attached to a second buoy that is anchored to the seafloor to prevent a hooked shark from displacing the gear. If the drum line is equipped with (Smart) technology, a triggering magnet trips a GPS beacon that sends a real time alert to officials when a shark is hooked (Figure 35). On traditional drum lines, large predators are unable to swim freely and die on the fixed line. (Smart) drum lines provide a real time alert once a large predator has been hooked, allowing officials to mobilize to the site, tag and release the predator away from the area of high human use.

Drum lines are not sensitive to weather conditions, but buoy-anchor systems may be impacted by marine conditions, waves, currents, coastal storms, etc. Drum lines are commercially available and have been deployed in other regions, namely off the coast of Australia and South Africa (Curtis, et. al., 2012). (Smart) drum lines incur significant operations and maintenance costs annually to support a boat and crew, bait, removal and relocation of hooked sharks, and deployment, maintenance, and retrieval of the unit. Given their design, drum lines have high rates of incidental bycatch and if a substantial number of sharks are culled, or if drum lines are deployed in natural white shark aggregation sites, drum lines have the potential to trigger unintended trophic consequences (Curtis, et. al. 2012). The effectiveness of drum lines at reducing the risk of shark-human interaction is limited. Recent (2014) deployment of drum lines off the coast of Western Australia captured a total of 180 marine animals (Dept. Fisheries, 2014). Of the animals caught, only 50 (28%) of the total were of the target species (considered to be a danger to humans) and size (in excess of 3m). None of the 180 marine animals captured during the 2014 deployment were white sharks, despite white sharks being most strongly associated with human fatality (Gibbs & Warren, 2015). Despite the number of sharks captured or killed, attacks on humans have still occurred. It should also be noted that baited drum lines were the most strongly opposed shark management strategy in Western Australia during the deployment period (Gibbs & Warren, 2015). The electrification of baited drum lines was also proposed by regional stakeholders, to discourage sharks from approaching baits through negative reinforcement. There does not appear to be empirical evidence available to support this methodology. The culling of great white sharks is not currently permittable given existing regulations. Great white sharks were designated as a prohibited species in federal U.S. Atlantic waters in 1997 and in Massachusetts waters in 2005.

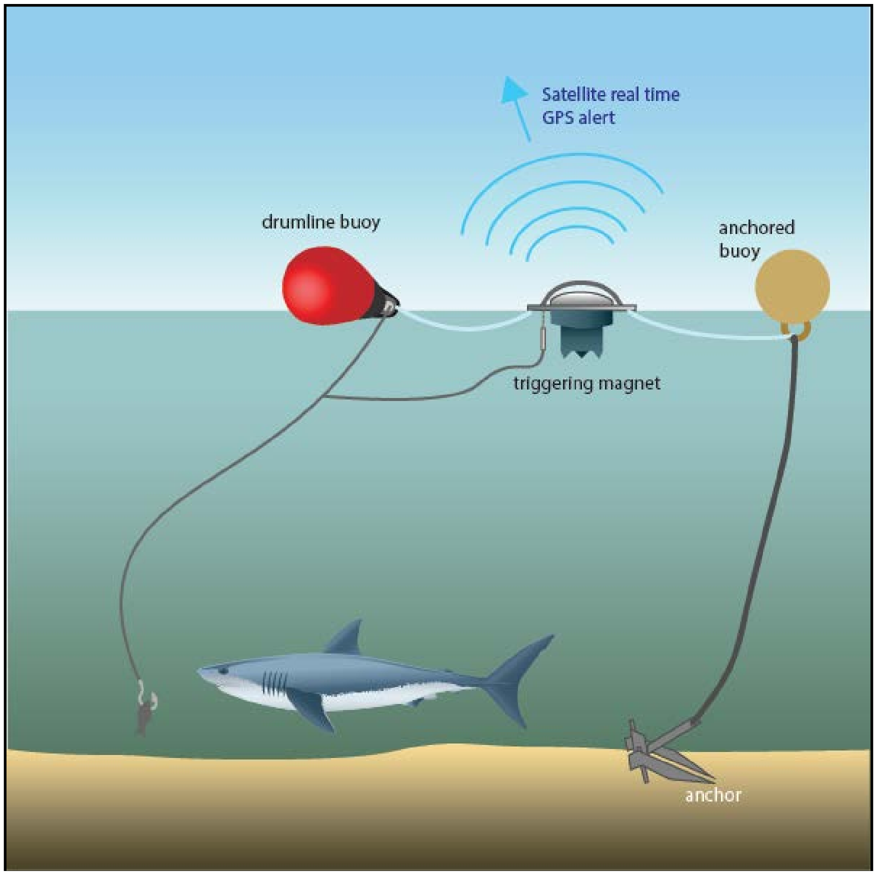


Figure 35. (Smart) drum line configuration. Standard drum line would not include triggering magnet or satellite real-time GPS alert and would result in higher levels of shark mortality. NSW Department of Primary Industries. Retrieved from https://www.abc.net.au/news/2017-10-09/how-smart-drumlines-work/9029780 15 September 2019.

Shark Cull Nets

Shark cull nets are a mitigation strategy designed to catch and kill sharks swimming in close proximity to popular bathing beaches and are intended to reduce the risk of shark-human interaction (QLD Department of Agriculture and Fisheries, 2015). Unlike rigid plastic mesh barriers, semi-rigid barriers, and flexible exclusion barriers, shark cull nets do not form a rectangular enclosure around bathing beaches and, therefore, do not form a physical barrier between sharks and humans. Instead, they are deployed in strategic locations in close proximity to bathing beaches to intercept, entangle, and ultimately kill free swimming sharks. The net is comprised of flexible mesh, and is deployed over several hundred meters adjacent to the shoreline, relative to observed environmental and marine conditions. The net is anchored to the seafloor using leaded rope or chain, and is suspended in the water column (either at the surface, or along the bottom) using floats and marker buoys (QLD Department of Agriculture and Fisheries, 2015), (Figure 36). Nets are shackled to anchors to ensure that the net remains in place if a shark is entangled. Nets must be monitored by a boat-based crew on a regular basis and any entangled sharks or other marine life must be removed on a regular basis.

Shark cull nets are not sensitive to weather conditions, but anchored nets may be impacted by marine conditions, waves, currents, coastal storms, etc., similar to fixed commercial fishing gear. Cull nets are constructed using commercially available materials and have been deployed in other regions, namely off the coast of Queensland, Australia, New South Wales, Australia (QLD Department of Agriculture and Fisheries, 2015; Reid, D.D., et al., 2011). Nets incur significant operational and maintenance costs to support a boat and crew, removal of entangled sharks and bycatch, and deployment, maintenance, and retrieval of the net. Given their design, cull nets have high rates of incidental bycatch and pose an entanglement risk to other forms of marine life, including marine mammals, sea turtles, fish, seabirds, and non-target (non-dangerous) shark species. The Australia Fisheries Scientific Committee identified loggerhead sea turtles (*Caretta caretta*), green sea turtles (*Chelonia mydas*), leatherback sea turtles (*Dermochelys coriacea*), humpback whales (*Megaptera novaeangliae*), and fur seals (*Arctocephalus pusillus dorferus*) as vulnerable and threatened species indiscriminately caught and often killed in cull nets deployed in New South Wales waters (Fisheries Scientific Committee, 2005). Although the Committee stopped short of recommending the removal of all cull nets from New South Wales waters, it determined that continued utilization of cull nets represents a key threatening process, which may cause species, populations, or ecological communities not currently threatened to become threatened (Fisheries Scientific Committee, 2005). The effectiveness of cull nets at reducing shark-human interaction is limited. Despite the deployment of nets off the New South Wales coast as early as the year 1937, 38 shark attacks and 1 fatality still occurred between 1937-2009 (NSW Department of Primary Industries, 2009). Further, Wetherbee et. al. (1994) determined that the deployment of shark culling programs in Hawaiian waters did not appear to have a measurable effect on the rate of shark attacks. It should be noted that where deployed, shark cull nets remain highly controversial. The culling of great white sharks is not currently permittable given existing regulations. Great white sharks were designated as a prohibited species in federal U.S. Atlantic waters in 1997 and in Massachusetts waters in 2005.

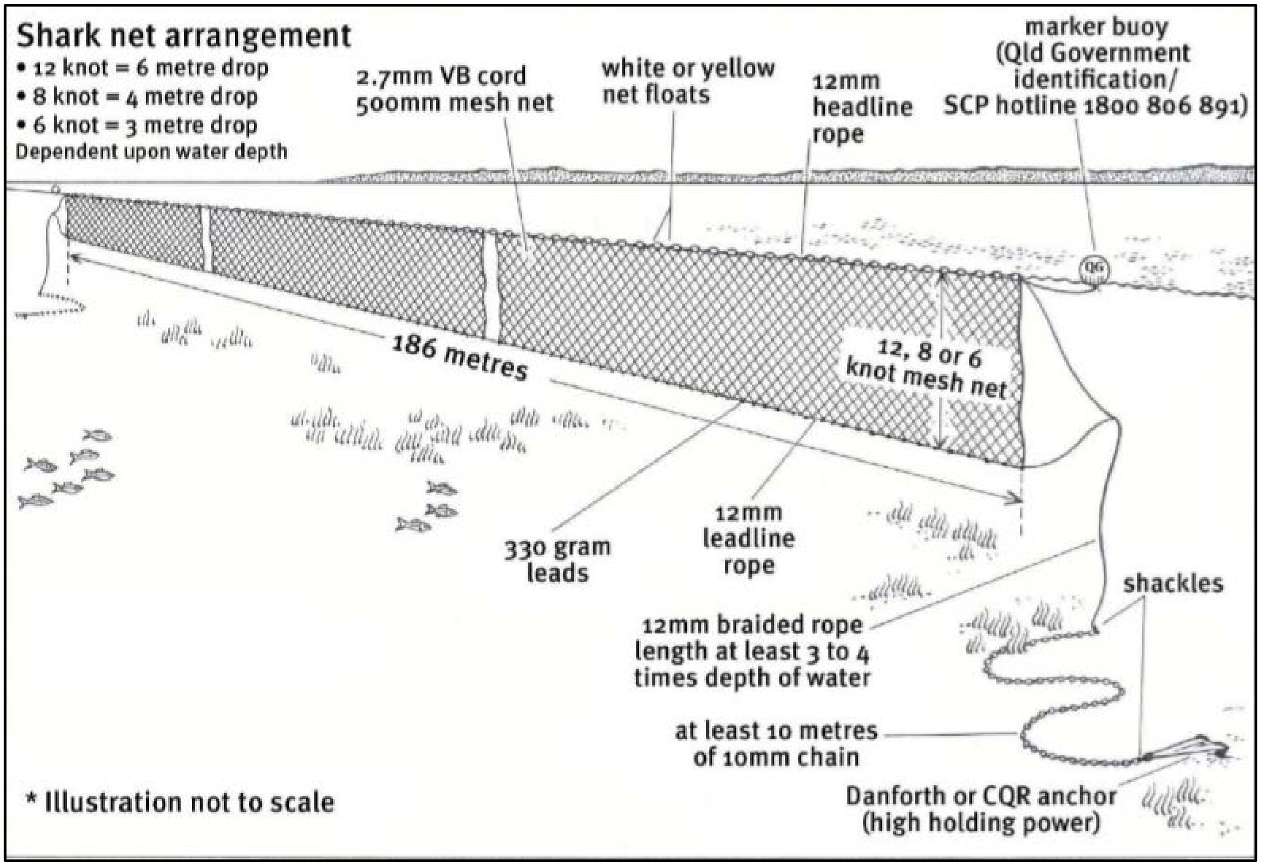


Figure 36. Shark net arrangement. Strategically deployed in close proximity to bathing beaches to catch and kill sharks. Net does not extend around bathing beaches and therefore, does not form a physical barrier between sharks and humans. Image retrieved from Queensland Department of Agriculture and Fisheries Great Barrier Reef Marine Parks Shark Control Program Public Information Package (2015).

Seal Contraception

Seal contraception, reducing the local gray seal population through strategic, non-lethal deployment of oral and/or intravenous wildlife contraception, has been proposed as a possible shark mitigation strategy. Local stakeholders have suggested that widespread deployment of wildlife contraception throughout the local gray seal population may result in a decrease in the local seal population and, subsequently, a reduction in the number of white sharks actively hunting for seals along regional bathing beaches. It is assumed that the deployment of wildlife contraception would involve the widespread placement of baits and/or the widespread sedation and oral and/or intravenous application of contraceptive drugs to wild gray seals. As previously mentioned, passage of the Marine Mammal Protection Act in 1972 placed a permanent moratorium on the harassment, capture, or cull of marine mammals, including gray seals. Since the passage of the Marine Mammal Protection Act, the population of gray seals has rebounded. Recent stock assessments (2017) estimate the minimum number of gray seals in the U.S. during the breeding season to be about 27,000 animals (Hayes et al. 2019), but this does not reflect seasonal changes in abundance. It should be noted that this population estimate represents only a fraction of the estimated 424,000 animals that make up the greater northwestern Atlantic gray seal population (DFO, 2019).

The deployment of seal contraception is not sensitive to weather or marine conditions. If widespread deployment of wildlife contraception were to occur, it would require significant effort and resources, potentially costing in excess of $7.5 million dollars annually to implement, assuming that one-half of the regional population (approximately 15,000 seals) is female, and that contraception could be deployed at a cost of $500 per dose per individual inclusive of a professional boat-based crew operating for 100 days per season. It is possible that widespread deployment of seal contraception would have a similar effect on the seal population as culling, because it would result in the selective removal of breeding adults from the wild population (i.e. trophic cascades, impacts to regional nutrient cycling, impacts to predator-prey relationships, and destabilization of marine community structure (Bowen, W.D., 1997). There is no empirical evidence to suggest that reducing the local gray seal population through the use of wildlife contraception would result in a subsequent decrease in the regional white shark population. Further, given the significant number of individual gray seals in New England and Canadian waters it is entirely plausible that a reduction in the local population would cause other seals from the greater northwestern Atlantic population to move into the region to occupy the available habitat. It should be noted that the deployment of wildlife contraception is exceedingly rare, but has been trialed in wild populations of seals located in and around Sable Island, Canada in the mid-1990s (Brown, R.G., et. al., 1997) but is more commonly associated with controlling populations of wild horses, deer, and elephants (Fox, D., 2007). The application of contraception to wild populations of gray seals is not currently permittable given existing regulations. Gray seals were designated as a protected species in Massachusetts waters in 1962 and at the federal level through the passage of the Marine Mammal Protection Act in 1972.

Seal Culling

Culling, or reducing a wildlife population through selective slaughter, has been proposed as a possible shark mitigation strategy. Local stakeholders have suggested that reducing the local gray seal population may result in a subsequent reduction in the number of white sharks actively hunting for seals along regional bathing beaches. It is assumed that culling of the local gray seal population would involve active hunting of adult gray seals along stretches of beach where the animals haul out and offshore where large numbers of gray seals actively transit between New England and Canadian Waters. Between 1888-1962 seals were actively hunted in Massachusetts waters, with a bounty of up to $5 per seal paid to citizens who presented the nose of their quarry to Town officials (Lelli, B., Harris, D.E., Abouecissa, A.M., 2009). In total, it is estimated that between 72,284 and 135,498 seals were killed as part of the bounty program, enough to account for steep regional declines in the greater northwestern Atlantic population (Lelli, B., Harris, D.E., Abouecissa, A.M., 2009). Passage of the Marine Mammal Protection Act in 1972 placed a permanent moratorium on the harassment, capture, or cull of marine mammals, including gray seals. Since the passage of the Marine Mammal Protection Act, the population of gray seals has rebounded. Recent stock assessments (2017) estimate the minimum number of gray seals in the U.S. during the breeding season to be about 27,000 animals (Hayes et al. 2019), but this does not reflect seasonal changes in abundance (Figure 37). It should be noted that represents just a fraction of the greater Western North Atlantic gray seal population, estimated at over 424,000 (DFO 2017).

Culling of gray seals is not sensitive to weather or marine conditions. If widespread culling were to occur, it would require significant effort, potentially costing in excess of $100,000 per 100m public bathing beach, or in excess of $1.5 million dollars annually to implement, assuming a total of 3 professional boat-based crews operating for 100 days per season. It is possible that widespread culling of gray seals would have an impact on the local marine ecosystem, potentially resulting in trophic cascades, impacts to regional nutrient cycling, impacts to predator-prey relationships, and destabilization of marine community structure (Bowen, W.D., 1997). There is no empirical evidence to suggest that culling of the local gray seal population would lead to a subsequent decrease in the regional white shark population. Further, given the significant number of individual gray seals in New England and Canadian waters, it is entirely plausible that a reduction in the local population would cause other seals from the greater northwestern Atlantic population to move into the region to occupy the available habitat. It should be noted that culling has been implemented elsewhere in North America, but has generally involved the selective removal of an individual or individuals actively feeding near fish passage structures along coastal rivers (Flaccus, G., 2019) or as a tool to reduce pressure on commercially viable fish species, though there is little evidence to support the effectiveness of such measures (Bowen, W.D., Lidgard, D. 2013; Senate Committee on Fisheries and Oceans, 2012). Widespread culling of wild populations of gray seals is not currently permittable given existing regulations. Gray seals were designated as a protected species in Massachusetts waters in 1962 and at the federal level through the passage of the Marine Mammal Protection Act in 1972.

Figure 37. Photo of Head of the Meadow, Truro, MA seal haul out, June 2014, photo taken by Center for Coastal Studies under NOAA Permit No. 17670. Photo retrieved from http://nasrc.whoi.edu/research/populations 15 September 2019.

Indigenous Harvest

Indigenous harvest or subsistence hunting of seals by Native American or First Nations communities has been proposed as a possible shark mitigation strategy. Stakeholders have suggested that reducing the gray seal population through indigenous harvest may result in a subsequent decrease in the local seal population and a reduction in the number of white sharks actively hunting for seals along regional bathing beaches. Our research did not reveal any stated interest, pending proposals, or plans to harvest gray seals from local indigenous communities. It is assumed that indigenous harvest of seals would involve active hunting and beneficial reuse of seal carcasses for food and/or commercial products. As previously mentioned, passage of the Marine Mammal Protection Act in 1972 placed a permanent moratorium on the harassment, capture, or cull of marine mammals, including gray seals.

Indigenous harvest as a shark mitigation strategy is not sensitive to weather or marine conditions. If indigenous harvest were to occur, it would require significant effort and resources. It is possible that if a sufficient number of seals were harvested, it would result in unintended trophic cascades, impacts to regional nutrient cycling, impacts to predator-prey relationships, and destabilization of marine community structure (Bowen, W.D., 1997). There is no empirical evidence to suggest that reducing the local gray seal population through indigenous harvest would result in a subsequent decrease in the regional white shark population. Further, the number of gray seals that would need to be harvested to have an impact on the greater Northwestern Atlantic population likely exceeds the number of seals that could be beneficially used by local indigenous communities. It should be noted that localized indigenous harvest of marine mammals (including seals and whales) does still occur in remote Native American and First Nations settlements in the United States and Canada (Ahmasuk, A. et. al., 2008; Hovelsrud, et. al., 2008). However, annual take limits and hunts are carefully managed and the number of individual animals harvested on an annual basis are relatively low. Indigenous harvest of wild gray seals is not currently permittable given existing regulations.

Scent / Smell Deterrents

Shark repellents, which often include chemical surfactants, are designed to repel sharks from a given area, which may reduce the risk of shark-human interaction. In addition to active shark repellents, some local stakeholders have anecdotally suggested that sharks may avoid areas where dead sharks are present, and seals may avoid areas where dead seals are present. Shark repellents form no physical barrier between sharks and humans and were first researched and deployed by the U.S. Navy during World War II as a means of protecting servicemen and airmen who may find themselves adrift at sea. However, extensive research into the effectiveness of chemical shark repellents determined that none of the tested chemicals produced the desired repellent response (Sisneros, J.A., Nelson, D.R., 2001). Research then shifted to chemical surfactants, including biological secretions from other marine organisms, which were limited by natural sources (limited quantity), difficult synthesis, and limited shelf-life ((Sisneros, J.A., Nelson, D.R., 2001). Sisneros and Nelson have researched the efficacy of more modern alternatives, which have exhibited some promise in controlled environments and over exceedingly short distances. However, the experiments did not include species-specific testing on Great White Sharks, or widespread testing in open-ocean environments.

Chemical surfactant shark repellents are not sensitive to weather conditions as they are typically deployed over a short distance and in direct response to an immediate threat. Chemical surfactant shark repellents likely have a very limited range and therefore, are likely not suitable for the protection of a large, bathing beach. It is unlikely that small-scale dispersal of shark repellents would have a significant environmental or human impact. Chemical surfactant shark repellents should not be relied upon as a stand-alone measure to increase public safety. Further, there is no empirical evidence to suggest that sharks may be deterred by the presence of other dead sharks or seals by the presence of dead seals. It should be noted that sharks are scavengers and may be drawn to areas where they may be able to opportunistically feed on the carcasses of dead marine life.

Modify Human Behavior

Modifying human behavior and avoiding water activities during periods of peak risk has been proposed as a means of reducing shark-human interaction. Avoiding behaviors that may put an individual at a heighted risk of attack has been suggested by the DMF Shark Research Program, the State of Hawaii Department of Land and Natural Resources, the Western Australian Government, the Global Shark Attack File, and the Atlantic White Shark Conservancy, among many other government and non-government organizations. Local safety recommendations include swimming close to shore and not venturing beyond waist-deep water, avoiding swimming in groups, never alone, and avoiding water activities in close proximity to seals, among others. While following these measures alone certainly does not guarantee the safety of all beachgoers and user groups, it is likely that following the posted recommendations and best management practices reduces some risk. Choosing not to enter the water at all allows individuals to mitigate nearly all risk of shark-human interaction. Other, more extreme measures have implemented elsewhere around the world, specifically, Reunion Island, a French island in the Indian ocean where in-water activities are heavily restricted due to shark activity.

Modifying human behavior, adopting best management practices and *Shark Smart Behaviors*, or choosing to avoid all water activities is not sensitive to environmental or weather conditions, does not require permitting or legislative approval, and does not result in any environmental or human impacts. This is the most effective strategy to avoid shark-human interaction. Bear in mind that no alternative or suite of alternatives can provide 100% bather safety. If water activities are avoided, the risk of attack is effectively eliminated. If water activities are not avoided, but best management practices and *Shark Smart Behaviors* are widely adopted, the risk of attack may be substantially reduced. All individuals choosing to engage in water activities should think carefully about the level of risk associated with their preferred activity and be comfortable with that level of risk before choosing to enter the water. The decision to enter the water and assume the risk of shark-human interaction is made at the sole discretion of the individual.

6.0 ALTERNATIVES ANALYSIS

6.1 ALTERNATIVES ANALYSIS MEANS AND METHODS

An alternatives analysis is the identification and evaluation of different choices available to achieve a particular objective. Such an evaluation is designed to compile a diverse set of data about the alternatives being considered in such a way that various factors are considered together to facilitate decision-making or select a preferred alternative among available options. In this case, the goal is to identify and objectively evaluate the many and varied options for improving beachgoer safety and reducing shark-human interactions. This alternatives analysis includes relative comparisons of shark mitigation alternatives in terms of cost, feasibility, effectiveness and unintended adverse impacts. The alternatives analysis described below evaluates the 27 individual alternatives previously described in Chapter 5 using a total of 5 siting criteria and 22 evaluation criteria. The alternatives analysis was conducted by an independent, interdisciplinary panel of Woods Hole Group Coastal Scientists, Coastal Engineers, Ocean Engineers, and Environmental Scientists.

Step 1: Screen Alternatives Based on Beach Type Using Siting Criteria

The five siting criteria were used to screen out particular alternatives considered incompatible with average conditions present at ocean, bay, and/or estuarine beaches. For example, a rigid exclusion barrier would be unlikely to withstand the rigors of typical daily and storm wave action characteristic of the Outer Cape's ocean facing beaches. The five sighting criteria used in this analysis are:

1) Wind climate
2) Wave climate
3) Sediment transport
4) Turbidity (water clarity)
5) Tides

For the purposes of this analysis, and based on the summary of metocean data provided in Chapter 2, it was assumed that ***ocean beaches*** would have a high energy wind and wave environment, strong currents, high rates of sediment transport, moderate tidal ranges, higher turbidity, and direct exposure to storm impacts. It was assumed that ***bay beaches*** would have a moderate wind and wave energy environment, moderate currents, moderate rates of sediment transport and turbidity, high tidal ranges, and indirect exposure to storm impacts. It was assumed that ***estuarine beaches*** would have a low wind and wave energy environment, mild currents, low rates of sediment transport, low tidal ranges, and would be sheltered from storm impacts.

Although the majority of the alternatives evaluated could be implemented in any beach setting, based on the siting criteria screening, the following alternatives were deemed incompatible with average local conditions in the follow beach types:

Table 8. Alternatives deemed incompatible with various beach types based on the siting criterion screening.

Alternative	Incompatible at Ocean Beaches	Incompatible at Bay and Sound Beaches	Incompatible at Estuarine Beaches
Rigid Exclusion Barrier	X - Due to wave climate	X - Due to tides	
Bubble Curtains	X - Due to wave climate and sediment transport		
Live Kelp	X - Due to wave climate	X - Due to tides	
Simulated Kelp Forest		X - Due to tides	X - Due to turbidity
Electrical deterrents		X - Due to tides	
Electromagnetic deterrents		X - Due to tides	

The wave climate along ocean beaches was assumed to be high enough to irreparably damage rigid exclusion barriers. Bubble curtains were viewed as incompatible with wave climate and higher rates of sediment transport associated with ocean beaches that may clog or bury air ports and damage air lines. The wave climate along ocean beaches was also deemed too high to safely and reliably establish kelp on surface lines. At bay beaches, tide ranges are quite large relative to water depths; thus, several alternatives were incompatible since for large portions of the tidal cycle there would be no water present for the various systems to operate. Instead, system components would lie on exposed sand and mud flats subjecting them to damage. To avoid this exposure, systems would need to be deployed so far offshore that they would not provide adequate protection to the beach. High levels of variable turbidity at estuarine beaches were deemed incompatible with establishing kelp. These individual, screened out alternatives were not carried through the full alternatives analysis for that particular type of beach. For example, the rigid plastic mesh exclusion barrier was only evaluated within the context of an estuarine beach.

Step 2. Evaluate each remaining alternative using the 22 remaining criteria.

All remaining alternatives deemed potentially suitable at each of the three beach types were then evaluated using the 22 individual evaluation criteria. The 22 evaluation criteria were divided into 6 categories of criteria:

1) Limiting Factors: **6 criteria**
2) Permitting: **2 criteria**
3) Cost: **2 criteria**
4) Potential Adverse Environmental Impacts: **4 criteria**
5) Human Impacts: **5 criteria**
6) Effectiveness: **3 criteria**

For an explanation of what each evaluation criterion addresses and how each was scored, see Tables 9 through 14 below. Although each alternative was originally given a qualitative response for each criterion, in order to ultimately compare alternatives relative to each other, a numerical score was applied to each qualitative input. These numerical scores range from 1 to 5 for each criterion, with the most optimal responses (i.e., lowest cost, most effective, least adverse impacts, etc.) earning a score of 5. Note that not all evaluation criteria received the full suite of scores from 1 to 5. A written description of each qualitative score, relative to its assigned numerical score, is included in the *Evaluation Categories* column of Tables 9 through 14 below.

Note that because the analysis was performed separately for ocean, bay and estuarine beaches, there are three sets of results, each specific to one beach type. Therefore, scores for alternatives in one beach type are not directly comparable to scores for the same alternative for a different beach type.

Step 3. Normalize and weight scores by category.

Each of the 6 categories of evaluation criteria contains a different number of individual criteria. In order to ensure that the Limiting Factors category, which contained a total of 6 criteria, wasn't arbitrarily given three times as much weight as the Permitting category, which only contained 2 criteria, each category was normalized by the number of individual criteria it contained. This allowed each category of criteria to receive equal weighting, regardless of the number of individual criteria it contained. This approach was discussed with and approved by the project partners.

Table 9. Limiting Factors Criteria. Evaluation criteria in the "Limiting Factors" category represent factors affecting the feasibility of siting, maintaining, operating or acquiring particular alternatives.

Criteria Category	Evaluation Criteria	Explanation	Evaluation Categories
Limiting Factors	Weather	This criterion is a qualitative assessment of how sensitive each alternative is to various weather conditions, such as fog, rain, wind, and sun. Alternatives that rely on visibility can be significantly impacted by weather conditions.	5 - Not sensitive 2 - Highly sensitive to fog, sun angle, rain 1 – Highly sensitive to fog, sun angle, rain, wind
	Marine Conditions	This criterion is a qualitative assessment of how sensitive each alternative is to various marine conditions, such as waves, currents, turbidity, bubble fraction and sediment transport. Alternatives that involve deploying a structure in the water or rely on visibility can be significantly impacted by these conditions.	5 – Not sensitive 3 – Sensitive to waves, currents 2 – Highly sensitive to waves, turbidity, bubble fraction 1 – Highly sensitive to sediment transport; Sensitive to waves, bubble fraction
	Effective Range	This criterion addresses the spatial extent over which an alternative is designed to function, ranging from regional (multiple beaches and/or Towns) to personal (a device intended to protect only the wearer).	5 – Regional 3 – Local (i.e., a single beach) 1 – Personal
	Effective Depth	This criterion addresses the water depth through which an alternative is designed to function, ranging from at the surface only to throughout the entire water column regardless of depth.	5 – Full water column; Independent of depth 3 – Within ~2.5m of surface 1 – Surface only
	Resilience to Storm Impacts	This criterion differs from "Weather" and "Marine Conditions" criteria and is focused on extreme events rather than typical daily conditions. It is a qualitative assessment of how resilient each alternative is to storm impacts (i.e., likelihood that the alternative will weather storm conditions without any infrastructure damage). Alternatives that can be removed or are plannable actions were classified as "removable" or "N/A".	5 – N/A 4 – Removable 3 – High 2 – Medium 1 – Low
	Commercial Availability	Commercially available is defined as something that Towns could purpose on the commercial market today, as opposed to something that is still in development or a theoretical concept. This criterion distinguishes between alternatives that are currently commercially available and those that are not. Alternatives that would not require the purchase of any equipment/ infrastructure are classified as "N/A".	5 – Yes; N/A 1 – No

Table 10. Permitting Criteria. Evaluation criteria in the "Permitting" category represent factors that should be considered with regards to the permittability of each alternative. If an alternative if not currently permittable or prohibited under existing laws and regulations, the permitting process will be much more complex and take significantly more time while variances or exceptions are pursued or attempts are made to rewrite regulations. Increased complexity and time to permit a project increases the amount of time until an alternative can be installed and put to use.

Criteria Category	Evaluation Criteria	Explanation	Evaluation Categories
Permitting	Permitting Complexity	This criterion addresses the permitting complexity of the various alternatives, which relates to the number of local, state and federal permits that would have to be obtained, as well as to the complexity of the issues and sensitivity of the environmental resources that would need to be addressed by each permit. Any alternative that would not require permits was scored "N/A". Alternatives that are not allowable or prohibited under current regulations, and would therefore require a variance or a rewrite of the regulations, are scored as "Not currently permittable".	5 – N/A 4 – Low (L) 3 – Medium (M) 2 – High (H) 1 – Not currently permittable
	Permitting Timeline	This criterion addresses how long it would take to receive permits to implement a particular alternative. Any alternative that would not require permits was scored "N/A". Alternatives that are not allowable under current regulations, and would therefore require extra time to pursue a variance or a rewrite of the regulations, are scored as "Very long – to pursue exemption". Although there are mandatory review and public notice periods involved in the regulatory process, the actual schedule for any particular regulatory review is subject to vast uncertainty depending upon complexity of policy, stakeholders, and environmental resources involved.	5 – N/A 4 – Short (S) 3 – Medium (M) 2 – Long (L) 1 – Very long - to pursue exemption

Table 11. Cost Criteria. Evaluation criteria in the "Cost" category quantify the various types of cost associated with each alternative. Permitting costs are scored independently. However, because the sum of the asset (whether the alternative is purchased or rented), maintenance and operating costs equal the total cost to utilize a particular alternative for a summer, detailed information is provided for each individual criteria to assist the Towns with cost planning, but ultimately they are scored as a single cumulative cost.

Criteria Category	Evaluation Criteria	Explanation	Evaluation Categories
Cost	Permitting Cost	Each permit application and review process required for a particular alternative would come with an associated cost. This criterion addresses the total relative cost associated with permitting among the alternatives based on experience with marine projects. Since these alternatives have not been permitted previously, exact data are not available. Any alternative that would not require permits was scored "N/A". Alternatives not allowable under current regulations, and would therefore require extra effort and cost to pursue a variance or a rewrite of the regulations, are scored as "Very high – to pursue exemption".	5 – N/A 4 – Low (L) 3 – Medium (M) 2 – High (H) 1 – Very high – to pursue exemption
	Asset Cost	This criterion documents the estimated cost associated with purchasing or renting the necessary equipment/material to implement a particular alternative.	A single score was given only to the Total Cost to the Town (i.e., the sum of asset, maintenance and operating costs), as this is the total estimated cost to implement a particular alternative for a summer, for a 100m beach, regardless of how those costs are divided. 5 – No cost to the Towns 4 – Less than \$100,000 3 – \$100,000 to \$200,000 2 – \$200,000 to \$300,000 1 – Greater than \$300,000
	Maintenance Cost	This criterion documents the estimated cost associated with the maintenance and upkeep of a particular alternative for a single season. Maintaining equipment in the rigors of the salt water environment with active wave and current energy and associated bottom movement is substantial and can require costly vessels, specialized equipment and personnel.	
	Operating Cost	This criterion documents the estimated cost of operating a particular alternative, including staff time, for a single season.	
	Total Cost to Town	This criterion is a summation of the asset, maintenance and operating costs previously documented. This is an estimated cost to implement a particular alternative for a single season.	

Table 12. Potential Adverse Environmental Impacts Criteria. Evaluation criteria in the "Potential Adverse Environmental Impacts" category address unintended ecological impacts that could result from implementing the evaluated alternatives.

Criteria Category	Evaluation Criteria	Explanation	Evaluation Categories
Potential Adverse Environmental Impacts	Bycatch	This criterion qualitatively addresses the likelihood that an alternative will result in bycatch (i.e., the unintended capture of non-target species). Any alternative with a buoy was considered to have a "Low" probability of bycatch (if the mooring line broke away and entangled marine mammals). Alternatives with a series of vertical lines (e.g., simulated kelp, electrical deterrents) were considered "Medium" due to the increased potential for entanglement. Alternatives with flexible netting were considered "High" due to the potential for fish and other marine species to swim into and become entangled in the net. Alternatives intentionally designed to catch and/or kill marine species were classified as a "Very high" likelihood of bycatch.	5 – None 4 – Low 3 – Medium 2 – High 1 – Very high
	Risk of Trophic Consequence	This criterion addresses the risk of trophic consequences (i.e., having a cascading impact on multiple marine food chain levels by adding, removing or significantly reducing the population of a key species). Most alternatives were classified as either "Yes" (likely to cause trophic impacts) or "No" (will not have trophic impacts). Alternatives involving targeted reduction of a species population risks initiating unintended trophic cascades. Where there was uncertainty, the alternative was classified as "Possible".	5 – No 3 – Possible 1 – Yes
	Risk of Interference	This criterion addresses the risk of interference to wildlife as it effects their use of habitat, their movement through an area, or their ability to communicate. Most alternatives were classified as either "Yes" (likely to cause interference) or "No" (no risk of interference). Any alternative that creates a barrier to movement in the water was classified as "Yes". Any use of drones or balloons was also classified as "Yes" due to the predator avoidance behavior those alternatives instigate in nesting shorebirds. Where there was uncertainty, the alternative was classified as "Possible".	5 – No 3 – Possible 1 – Yes
	Risk of Physical Impact to Habitat	This criterion addresses the risk of physical impact to habitat from each of the alternatives. Physical impact can result from the infrastructure required to install, secure and operate some of the alternatives. Alternatives were classified as having none, or low to high risk of causing physical impacts. Where possible, the likely cause of physical impact is listed for each alternative.	5 – None: no impact to bottom 4 – Low: single anchor 3 – Medium low: floats and cables 2 – Medium: anchors, piles, cables 1 – High: nets, piles, cables, anchors, full vertical array

Table 13. Human Impacts Criteria. Evaluation criteria in the "Human Impacts" category address potential adverse impacts to beachgoers, ranging from nuisance issues (e.g., aesthetics and noise), to alteration of the recreational experience (e.g., impacts to boating, swimming, surfing, bird watching, etc.), to potential health and safety impacts.

Criteria Category	Evaluation Criteria	Explanation	Evaluation Categories
Human Impacts	Aesthetics	Because it is difficult to judge what others will consider aesthetically pleasing or not, this criterion does not attempt to rank alternatives on aesthetic appeal. Instead, it qualitatively addresses the *magnitude* of visual change each alternative would produce to the average beachgoer, ranging from "None" to "High".	5 – None 4 – Very Low 3 – Low 2 – Medium 1 - High
	Noise	This alternative provides a comparative measure of how loud each alternative is, ranging from "None" to "High".	5 – None 4 – Low 3 – Possible 2 – Med-high: compressor; bubbles 1 – High
	Navigation	This criterion qualitatively addresses the level of impediment to boat navigation that could result from installing particular alternatives. In some instances, where the reason is not obvious, the cause of the adverse impact to navigation from a particular alternative is listed in the alternatives analysis table.	5 – None 4 – Low 3 – Medium 2 – Medium-high 1 – High
	Risk of Health Impacts	Because many of the alternatives will involve installing a structure or piece of equipment in the water, and in some cases will produce an electric or electromagnetic current, there is the potential to have adverse impacts to human health. This criterion qualitatively ranks the alternatives based on the potential for human health risk, and provides some indication about the type of risk associated with each alternative.	5 – None 4 – Very low: low potential of pacemaker interference 3 – Low: abrasions, cuts; potential pacemaker interference 2 – Medium: abrasions, cuts, entanglement 1 – High: abrasions, cuts, entanglement, likely pacemaker interference, electrical current
	Recreation	This criterion addresses whether or not each alternative will prevent or alter recreational experience. Recreational activities considered included surfing, kayaking, boogie boarding, SUP, swimming, sunbathing, fishing, kite flying, birding, and kite surfing. Examples of potential impacts to recreation include drones would interfere with kite flying, bird watching and kite surfing, and many of the barrier-based alternatives would interfere with swimming, surfing, kayaking, etc. due to the significant surface expression.	5 – No 1 – Yes

Table 14. Effectiveness Criteria. Evaluation criteria in the "Effectiveness" category address how effective the alternatives are likely to be in keeping the public safe from sharks.

Criteria Category	Evaluation Criteria	Explanation	Evaluation Categories
Effectiveness	Percent Time Covered	This criterion evaluates the alternatives based on the percent of time (during beach operating hours, in season) it is able to function under optimal conditions. Because many alternatives are regional approaches (i.e., a spotter plane that monitors the multiple beaches) or require the shark to be swimming at or near the surface to be detected, the percent time a particular beach can expect to receive an added benefit from a particular alternative will vary.	5 – 100% 4 – 76% to 99% 3 – 50% to 75% 2 – 11% to 49% 1 – 10% or less
	Shark/Human Interaction	This criterion classifies each alternative based on the type of benefit it provides, ranging from a physical barrier to separate humans from sharks to shark deterrents and predator reduction strategies.	5 – Physical barrier (plus) 4 – Physical barrier 3 – Detection 2 – Deterrent 1 – Predator reduction
	Documented Effectiveness	This criterion classifies each alternative in terms of its documented effectiveness, ranging from "High" to "Low". If an alternative has not been field tested yet, it was classified as "No Data" and conservatively given a low score (i.e., 1) since there is no documentation of effectiveness for that alternative.	5 – High 3 – Medium-low 1 – Low No Data

6.2 DISCUSSION

The alternatives analysis matrices provided in Tables 15 – 17 serve as an informational resource and a decision support tool for Towns. The columns at the end of each category of criteria provide composite scores for each category, with results color-coded green indicating an overall higher ranking alternative and results color-coded orange and red indicating overall lower relative ranking alternatives. Rather than highlighting a single preferred alternative for each beach type for all Towns, this matrix presents the tools and information necessary for Towns to make informed decisions based on the individual needs, resources, and risk tolerances specific to their locality. It is worth noting the best course of action may, in fact, be a combination of the alternatives presented here.

Removal of Low-Ranking Alternatives from Consideration

In addition to the complete matrices provided in Tables 15 - 17, the project partners requested a second set of matrices for consideration. The second set of matrices removed all low-ranking alternatives (i.e., any alternative that received a low, red-color coded, score in any category) from the ocean, bay, and estuarine matrices. This second set of matrices is included in Tables 18 – 20.

Assumptions and Limitations

This alternatives analysis provides a summary of all available data related to the 27 individual alternatives evaluated. However, because many of these alternatives have not yet been tested or are not currently commercially available, specific documentation related to effectiveness, limitations and costs were not always available. Specifically, data inputs related to cost are estimates based on best available knowledge and should be considered planning level estimates. All cost estimates assume the acquisition of the asset, deployment along a single, 100m (328 ft.) stretch of beach for an assumed 100-day summer season, maintenance costs, and removal costs.

While some evaluation criteria, such as cost and percent time coverage, could appropriately be treated as quantitative values, there are also a number of criteria that were evaluated on a qualitative basis instead (e.g., High – Medium – Low). Although there is substantial uncertainty with how many months (or in some cases years) it would take to permit individual alternatives for example, it is reasonable to rank them by order of permitting timeline based on the complexity and number of permits that may be required.

Table 15. Alternatives Analysis Matrix for Outer Cape Ocean Beaches.

OCEAN: High energy wave environment, high rates of sediment transport, moderate tidal range, cold temperatures, direct exposure to storm impacts, deeper near shore waters, strong currents	Limiting Factors: Weather	Marine Conditions	Effective Range	Effective Depth	Resilience to Storm Impacts	Commercial Availability	Category Score	Permitting: Permitting Complexity	Permitting Timeline	Category Score	Costs: Permitting Costs	Asset, Maint., Op. Cost to Town (per 100m beach)	Category Score	Potential Adverse Env. Impacts: Bycatch	Risk of trophic consequence	Risk of Interference	Risk of Physical Impact to Habitat	Category Score	Human Impacts: Aesthetics	Noise	Navigation	Risk of Health Impact	Recreation	Category Score	Effectiveness: % Time Covered	Shark/Human Interaction	Documented Effectiveness	Category Score
Technology-Based Alternatives:																												
Tagging (Acoustic, real time alert)	Not sensitive	Not sensitive	Regional	Full water column	Medium	Yes	High	L	S	High	L	$42,500	Med-High	Low	No	No	Low - anchor	High	Very Low	None	Low	None	No	High	<5%, only tagged sharks and shark must be within 300m-500m of one of the buoys	Detection	Low	Low
Tagging (Satellite, real time alert)	Not sensitive	Not sensitive	Regional	Surface only	High	Yes	High	L	S	High	L	$0	Med-High	None	No	No	None	High	None	None	None	None	No	High	<1%, only tagged sharks and shark must be on the surface long enough to establish a satellite link	Detection	Low	Low
Visual Detection (planes, helicopters)	Highly sensitive to fog, sun angle, rain; wind	Highly sensitive to waves, turbidity, bubble fraction	Regional	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	$28,500	Med-High	None	No	No	None	High	Low	Medium	None	None	No	High	1%-10% (as long as you want/can afford, patrolling, so not normally over any one particular beach)	Detection	Med-Low	Med Low
Visual Detection (tower-based)	Highly sensitive to fog, sun angle, rain	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	$97,000	Med-High	None	No	No	None	High	Low	Low	None	None	No	High	95% (as long as you want/can afford)	Detection	Med-Low	Med
Visual Detection (balloons)	Highly sensitive to fog, sun angle, rain, wind	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	$250,000	Med Low	None	No	Yes - shorebirds	None	High	Low	None	None	None	Yes	Med-High	95% (as long as you want/can afford)	Detection	Med-Low	Med
Visual Detection (drones)	Highly sensitive to fog, sun angle, rain, wind	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	$500,000	Med Low	None	No	Yes - shorebirds	None	High	Medium	High	None	None	Yes	Med Low	70% (as long as you want/can afford, but you can only remain in the air in 20 minute increments)	Detection	Med-Low	Med
Visual Detection (tethered drones)	Highly sensitive to fog, sun angle, rain, wind	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	$122,000	Med	None	No	Yes - shorebirds	None	High	Medium	High	None	None	Yes	Med Low	95% (as long as you want/can afford)	Detection	Med-Low	Med
Bottom-mounted sonar (buoy, alert)	Not sensitive	Highly sensitive to tides, sediment transport; Sensitive to waves, bubble fraction	Local - Beach	Full water column	Low	Yes	Med	M	M	Med	M	$255,000	Med Low	Low	No	No	Medium - anchors, piles, cables	High	Medium	None	Medium	Low - abrasions, cuts	No	Med-High	95%	Detection	Low	Med Low
Electromagnetic (active, wearable)	Not sensitive	Not sensitive	Personal	Independent of depth	N/A	Yes	Med-High	N/A	N/A	High	N/A	$0	High	None	No	No	None	High	None	None	None	Low - pacemaker interference	No	High	100% (continuously while in water)	Deterrent	Low	Med Low
Magnetic (passive, wearable)	Not sensitive	Not sensitive	Personal	Independent of depth	N/A	Yes	Med-High	N/A	N/A	High	N/A	$0	High	None	No	No	None	High	None	None	None	Very Low - pacemaker interference	No	High	100% (continuously while in water)	Deterrent	Low	Med Low
Adaptive Camouflage (passive)	Not sensitive	Highly sensitive to turbidity, bubble fraction	Personal	Independent of depth	N/A	Yes	Med	N/A	N/A	High	N/A	$0	High	None	No	No	None	High	None	None	None	None	No	High	100% (continuously while in water)	Deterrent	Low	Med Low
Barrier-Based Alternatives:																												
Flexible Net (exclusion)	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High	H	L	Med Low	H	$300,000	Low	High	Possible	Yes	High - net, piles, cables	Low	High	None	High	Medium - abrasions, cuts, entanglement	Yes	Med Low	100	Physical barrier	High	High
Semi-Rigid Net (with plastic struts)	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High	H	L	Med Low	H	$350,000	Low	Medium	Possible	Yes	High - net, piles, cables	Med Low	High	None	High	Medium - abrasions, cuts, entanglement	Yes	Med Low	100	Physical barrier	High	High
Simulated Kelp Forests	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High	H	L	Med Low	H	$825,000	Low	Medium	No	Yes	High - anchors, full vertical array	Med Low	High	None	High	High - abrasions, cuts, entanglement, pacemaker interference	Yes	Low	100	Deterrent	High	High
Electrical Deterrents	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High	H	L	Med Low	H	$425,000	Low	Medium	No	Yes	High - anchors, full vertical array	Med Low	Medium	None	High	High - abrasions, cuts, entanglement, pacemaker interference, electrical current	Yes	Med Low	100	Deterrent	Med-Low	Med
Electromagnetic Deterrents	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High	M	M	Med	M	$175,000	Med	Low	No	Yes	High - anchors, full vertical array	Med Low	Medium	None	Medium - series of moorings	High - abrasions, cuts, entanglement, pacemaker interference	Yes	Med Low	100	Deterrent	Med-Low	Med
Acoustic Barrier	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High	H	Long	Med Low	M	$200,000	Med Low	Low	Possible	Yes	Medium - anchors, piles, cables	Med Low	Medium	Possible	Medium - series of moorings	Low - moorings	No	Med	100	Deterrent	Low	Med Low
Biological-Based Alternatives:																												
Cull net	Not sensitive	Sensitive to waves, currents	Regional	Full water column	Medium	Yes	High	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$50,000	Med Low	Very High	Yes	Yes	High - net, piles, cables	Low	Medium	None	Medium-High	Low - abrasions, cuts, entanglement	Yes	Med Low	100	Predator reduction	Low	Med Low
(Smart) Drum Lines	Not sensitive	Sensitive to waves, currents	Regional	Independent of depth	Medium	Yes	High	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$110,000	Med Low	Very High	Yes	No	Medium	Med Low	Low	None	Low	Low - abrasions, cuts, entanglement	No	High	50	Predator reduction	Low	Low
Seal Culling	Not sensitive	Not sensitive	Regional	Independent of depth	N/A	N/A	High	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$225,000	Low	None	Yes	Possible - if on beach, shorebirds	None	Med-High	None	None	None	None	No	High	<5	Predator reduction	Low	Low
Seal Contraception	Not sensitive	Not sensitive	Regional	Independent of depth	N/A	Yes	High	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$1,060,000	Low	None	Yes	Possible - if on beach, shorebirds	None	Med-High	None	None	None	None	No	High	0	Predator reduction	Low	Low
Indigenous Harvest	Not sensitive	Not sensitive	Regional	Independent of depth	N/A	N/A	High	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$0	Med	None	Yes	Possible - if on beach, shorebirds	None	Med-High	None	None	None	None	No	High	<5	Predator reduction	Low	Low
Electric shock	Not sensitive	Sensitive to waves, currents	Local - Beach	Independent of depth	Medium	No	Med	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$110,000	Med Low	Low	No	Yes	Low - anchor	Med-High	Very Low	None	Low	Low - abrasions, cuts, electric shock	No	High	50	Deterrent	No data	Med Low
Scent/Smell	Not sensitive	Sensitive to waves, currents	Local - Beach	Independent of depth	Low	No	Med	M	M	Med	M	$110,000	Med	Low	No	Yes	Low - anchor	Med-High	Very Low	None	Low	Low - abrasions, cuts, entanglement	No	High	50	Deterrent	Low	Med Low
Modify Human Behavior	Not sensitive	Not sensitive	Regional	Full water column	N/A	N/A	High	N/A	N/A	High	N/A	$20,000	High	None	No	No	None	High	None	None	None	None	Yes	High	100	Physical Barrier PLUS	High	High

Table 16. Alternatives Analysis Matrix for Outer Cape Bayside Beaches.

	Limiting Factors							Permitting			Costs			Potential Adverse Env. Impacts					Human Impacts						Effectiveness			
BAY: Moderate wave energy environment, moderate rates of sediment transport and turbidity, high tidal range, warm temperatures, indirect exposure to storm impacts, shallower near shore waters, moderate currents	Weather	Marine Conditions	Effective Range	Effective Depth	Resilience to Storm Impacts	Commercial Availability	Category Score	Permitting Complexity	Permitting Timeline	Category Score	Permitting Costs	Asset, Maint., Op. Cost to Town (per 100m beach)	Category Score	Bycatch	Risk of trophic consequence	Risk of Interference	Risk of Physical Impact to Habitat	Category Score	Aesthetics	Noise	Navigation	Risk of Health Impact	Recreation	Category Score	% Time Covered	Shark/Human Interaction	Documented Effectiveness	Category Score
Technology-Based Alternatives:																												
Tagging (Acoustic, real time alert)	Not sensitive	Not Sensitive	Regional	Full water column	Medium	Yes	High	L	S	High	L	$42,500	Med High	Low	No	No	Low - anchor	High	Very Low	None	Low	None	No	High	<5%, only tagged sharks and shark must be within 300m-500m of one of the buoys	Detection	Low	Low
Tagging (Satellite, real time alert)	Not sensitive	Not sensitive	Regional	Surface only	High	Yes	High	L	S	High	L	$0	Med High	None	No	No	None	High	None	None	None	None	No	High	<1%, only tagged sharks and shark must be on the surface long enough to establish a satellite link	Detection	Low	Low
Visual Detection (planes, helicopters)	Highly sensitive to fog, sun angle, rain; wind, turbidity	Highly sensitive to waves, turbidity, bubble fraction	Regional	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	$14,285	Med High	None	No	No	None	High	Low	Medium	None	None	No	High	1%-10% (as long as you want/can afford, patrolling, so not normally over any one particular beach)	Detection	Med-Low	Med Low
Visual Detection (tower-based)	Highly sensitive to fog, sun angle, rain, turbidity	Highly sensitive to waves, turbidity, bubble fraction, horozontal tides	Local - Beach limited range	Within ~2.5m of surface	Removable	Yes	Med Low	M	M	Med	M	$97,000	Med High	None	No	No	None	High	Low	Low	None	None	No	High	45%	Detection	Med-Low	Med Low
Visual Detection (balloons)	Highly sensitive to fog, sun angle, rain, wind, turbidity	Highly sensitive to waves, turbidity, bubble fraction, horozontal tides	Local - Beach limited range	Within ~2.5m of surface	Removable	Yes	Med Low	M	M	Med	M	$250,000	Med Low	None	No	Yes - shorebirds	None	High	Low	None	None	None	Yes	Med High	45%	Detection	Med-Low	Med Low
Visual Detection (drones)	Highly sensitive to fog, sun angle, rain, wind, turbidity	Highly sensitive to waves, turbidity, bubble fraction, horozontal tides	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med Low	M	M	Med	M	$500,000	Med Low	None	No	Yes - shorebirds	None	High	Medium	High	None	None	Yes	Med Low	70% (as long as you want/can afford, but you can only remain in the air in 20 minute increments)	Detection	Med-Low	Med
Visual Detection (tethered drones)	Highly sensitive to fog, sun angle, rain, wind, turbidity	Highly sensitive to waves, turbidity, bubble fraction, horozontal tides	Local - Beach limited range	Within ~2.5m of surface	Removable	Yes	Med Low	M	M	Med	M	$122,000	Med	None	No	Yes - shorebirds	None	High	Medium	High	None	None	Yes	Med Low	45%	Detection	Med-Low	Med Low
Electromagnetic (active, wearable)	Not sensitive	Not sensitive	Personal	Independent of depth	N/A	Yes	Med High	N/A	N/A	High	N/A	$0	High	None	No	No	None	High	None	None	None	Low - pacemaker interference	No	High	100% (continuously while in water)	Deterrent	Low	Med Low
Magnetic (passive, wearable)	Not sensitive	Not sensitive	Personal	Independent of depth	N/A	Yes	Med High	N/A	N/A	High	N/A	$0	High	None	No	No	None	High	None	None	None	Very Low - pacemaker interference	No	High	100% (continuously while in water)	Deterrent	Low	Med Low
Adaptive Camouflage (passive)	Not sensitive	Highly sensitive to turbidity, bubble fraction	Personal	Independent of depth	N/A	Yes	Med	N/A	N/A	High	N/A	$0	High	None	No	No	None	High	None	None	None	None	No	High	100% (continuously while in water)	Deterrent	Low	Med Low
Barrier-Based Alternatives:																												
Flexible net (exclusion)	Not sensitive	Sensitive to waves, currents, tides	Local - Beach limited	Full water column	Medium	Yes	Med High	H	L	Med Low	H	$300,000	Low	High	Possible	Yes	High - net, piles, cables	Low	High	None	High	Medium - abrasions, cuts, entanglement	Yes	Med Low	50%	Physical barrier	Med-Low	Med
Semi-Rigid Net (With plastic struts)	Not sensitive	Sensitive to waves, currents, tides	Local - Beach limited	Full water column	Medium	Yes	Med High	H	L	Med Low	H	$350,000	Low	Medium	Possible	Yes	High - net, piles, cables	Med Low	High	None	High	Medium - abrasions, cuts, entanglement	Yes	Med Low	50%	Physical barrier	Med-Low	Med
Bubble curtains	Not sensitive	Sensitive to waves, currents, tides	Local - Beach limited	Full water column	Low	No	Med Low	M	M	Med	M	$425,000	Med Low	Low	No	Yes - sound barrier marine animals	Medium - bottom cable & anchors	Med	Medium	Medium-High - compressor; bubbles at surface	Low	Low	Yes	Med Low	50%	Deterrent	Low	Med Low
Acoustic Barrier	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High	H	L	Med Low	M	$200,000	Med Low	Low	Possible	Yes	Medium - anchors, piles, cables	Med Low	Medium	Possible	Medium - series of moorings	Low - moorings	No	Med	100	Deterrent	Low	Med Low
Biological-Based Alternatives:																												
Cull net	Not sensitive	Sensitive to waves, currents, tides	Regional	Full water column	Medium	Yes	High	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$50,000	Med Low	Very High	Yes	Yes	High - net, piles, cables	Low	Medium	None	Medium-High	Low - abrasions, cuts, entanglement	Yes	Med Low	100	Predator reduction	Low	Med Low
(Smart) Drum Lines	Not sensitive	Sensitive to waves, currents, tides	Regional	Independent of depth	Medium	Yes	High	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$110,000	Med Low	Very High	Yes	No	Medium - anchors, cable	Med Low	Low	None	Low	Low - abrasions, cuts, entanglement	No	High	50	Predator reduction	Low	Low
Seal Culling	Not sensitive	Not sensitive	Regional	Independent of depth	N/A	N/A	High	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$125,000	Med Low	None	Yes	Possible - if on beach, shorebirds	None	Med High	None	None	None	None	No	High	<5	Predator reduction	Low	Low
Seal Contraception	Not sensitive	Not sensitive	Regional	Independent of depth	N/A	Yes	High	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$691,000	Low	None	Yes	Possible - if on beach, shorebirds	None	Med High	None	None	None	None	No	High	0	Predator reduction	Low	Low
Indigenous Harvest	Not sensitive	Not sensitive	Regional	Independent of depth	N/A	N/A	High	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$0	Med	None	Yes	Possible - if on beach, shorebirds	None	Med High	None	None	None	None	No	High	<5	Predator reduction	Low	Low
Train Sharks – Electric shock	Not sensitive	Sensitive to waves, currents	Local - Beach	Independent of depth	Medium	No	Med	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$110,000	Med Low	Low	No	Yes	Low - anchor	Med High	Very Low	None	Low	Low - abrasions, cuts, electric shock	No	High	50	Deterrent	No data	Med Low
Scent/Smell	Not sensitive	Sensitive to waves, currents	Local - Beach limited	Independent of depth	Low	No	Med Low	M	M	Med	M	$110,000	Med	Low	No	Yes	Low - anchor	Med High	Very Low	None	Low	Low - abrasions, cuts, entanglement	No	High	50	Deterrent	Low	Med Low
Modify Human Behavior	Not sensitive	Not sensitive	Regional	Full water column	N/A	N/A	High	N/A	N/A	High	N/A	$20,000	High	None	No	No	None	High	None	None	None	None	Yes	High	100	Physical Barrier PLUS	High	High

Table 17. Alternatives Analysis Matrix for Outer Cape Estuarine Beaches.

	Limiting Factors							Permitting			Costs			Potential Adverse Env. Impacts					Human Impacts						Effectiveness			
ESTUARINE: Low wave energy environment, low rates of sediment transport, low tidal range, warm temperatures, sheltered from storm impacts, shallow near shore waters, low currents	Weather	Marine Conditions	Effective Range	Effective Depth	Resilience to Storm Impacts	Commercial Availability	Category Score	Permitting Complexity	Permitting Timeline	Category Score	Permitting Costs	Asset, Maint., Op. Cost to Town (Annual, per beach)	Category Score	Bycatch	Risk of trophic consequence	Risk of Interference	Risk of Physical Impact to Habitat	Category Score	Aesthetics	Noise	Navigation	Risk of Health Impact	Recreation	Category Score	% Time Covered	Shark/Human Interaction	Documented Effectiveness	Category Score
Technology-Based Alternatives:																												
Tagging (Acoustic, real time alert)	Not sensitive	Not sensitive	Regional	Full water column	High	Yes	High	L	S	High	L	$42,500	Med High	None	No	No	Low - anchor	High	Very Low	None	Low	None	No	High	<5%, only tagged sharks and shark must be within 300m-500m of one of the buoys	Detection	Low	Low
Tagging (Satellite, real time alert)	Not sensitive	Not sensitive	Regional	Surface only	High	Yes	High	L	S	High	L	$0	Med High	None	No	No	None	High	None	None	None	None	No	High	<1%, only tagged sharks and shark must be on the surface long enough to establish a satellite link	Detection	Low	Low
Visual Detection (planes, helicopters)	Highly sensitive to fog, sun angle, rain, turbidity	Highly sensitive to waves, turbidity, bubble fraction	Regional	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	$28,500	Med High	None	No	No	None	High	Low	Medium	None	None	No	High	1%-10% (as long as you want/can afford, patrolling, so not normally over any one particular beach)	Detection	Med-Low	Med Low
Visual Detection (tower-based)	Highly sensitive to fog, sun angle, rain, wind, turbidity	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	$97,000	Med High	None	No	No	None	High	Low	Low	None	None	No	High	95% (as long as you want/can afford)	Detection	Med-Low	Med
Visual Detection (balloons)	Highly sensitive to fog, sun angle, rain, wind, turbidity	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	$250,000	Med Low	None	No	Yes - shorebirds	None	High	Low	None	None	None	Yes	Med High	95% (as long as you want/can afford)	Detection	Med-Low	Med
Visual Detection (drones)	Highly sensitive to fog, sun angle, rain, wind, turbidity	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	$500,000	Med Low	None	No	Yes - shorebirds	None	High	Medium	High	None	None	Yes	Med Low	70% (as long as you want/can afford, but you can only remain in the air in 20 minute increments)	Detection	Med-Low	Med
Visual Detection (tethered drones)	Highly sensitive to fog, sun angle, rain, wind, turbidity	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	$122,000	Med	None	No	Yes - shorebirds	None	High	Medium	High	None	None	Yes	Med Low	95% (as long as you want/can afford)	Detection	Med-Low	Med
Bottom-mounted sonar (buoy, real time)	Not sensitive	Highly sensitive to tides, sediment transport; Sensitive to waves, bubble fraction	Local - Beach	Full Water Column	High	Yes	Med High	M	M	Med	M	$255,000	Med Low	None	No	No	Medium - anchors, piles, cables	High	Medium	None	Medium	Low - abrasions, cuts	No	Med High	95%	Detection	Low	Med Low
Electromagnetic (active, wearable)	Not sensitive	Not sensitive	Personal	Independent of depth	N/A	Yes	Med High	N/A	N/A	High	N/A	$0	High	None	No	No	None	High	None	None	None	ow - pacemaker interferenc	No	High	100% (continuously while in water)	Deterrent	Low	Med Low
Magnetic (passive, wearable)	Not sensitive	Not sensitive	Personal	Independent of depth	N/A	Yes	Med High	N/A	N/A	High	N/A	$0	High	None	No	No	None	High	None	None	None	y Low - pacemaker interfere	No	High	100% (continuously while in water)	Deterrent	Low	Med Low
Adaptive Camouflage (passive)	Not sensitive	Highly sensitive to turbidity, bubble fraction	Personal	Independent of depth	N/A	Yes	Med	N/A	N/A	High	N/A	$0	High	None	No	No	None	High	None	None	None	None	No	High	100% (continuously while in water)	Deterrent	Low	Med Low
Barrier-Based Alternatives:																												
Rigid Plastic Mesh (exclusion)	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	No	Med	H	Long	Med Low	H	$350,000	Low	Low	Low - Possible	Yes	High - net, piles, cables	Med Low	High	None	High	Medium - abrasions, cuts, entanglement	Yes	Med Low	100	Physical barrier	Med-Low	High
Flexible net (exclusion)	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	High	Yes	High	H	Long	Med Low	H	$300,000	Low	Medium	Low - Possible	Yes	High - net, piles, cables	Med Low	High	None	High	Medium - abrasions, cuts, entanglement	Yes	Med Low	100	Physical barrier	Med-Low	High
Semi-Rigid Net (With plastic struts)	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	High	Yes	High	H	Long	Med Low	H	$350,000	Low	Low	Low - Possible	Yes	High - net, piles, cables	Med Low	High	None	High	Medium - abrasions, cuts, entanglement	Yes	Med Low	100	Physical barrier	Med-Low	High
Bubble curtains	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	No	Med	M	M	Med	M	$425,000	Med Low	None	No	Yes - sound barrier marine animals	Medium - bottom cable & anchors	Med	Medium	Medium-High - compressor; bubbles at surface	Low	Low	Yes	Med Low	100	Deterrent	Low	Med Low
Live Kelp	Not sensitive	Sensitive to waves, currents	Local - Beach	Partial	Medium	No	Med Low	M	M	Med	M	$60,000	Med High	Medium	No	No	Medium Low - Floats and Cables	High	Low	None	Low	Low	No	High	100	Deterrent	Med-Low	Med
Electrical deterrents	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med High	H	Long	Med Low	H	$425,000	Low	Low	No	Yes	High - anchors, full vertical array	Med Low	Medium	None	High	High - abrasions, cuts, entanglement, pacemaker interference, electrical current	Yes	Med Low	100	Deterrent	Med-Low	Med
Electromagnetic deterrents	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med High	M	M	Med	M	$175,000	Med	None	No	Yes	High - anchors, full vertical array	Med	Medium	None	Medium - series of moorings	High - abrasions, cuts, entanglement, pacemaker interference	Yes	Med Low	100	Deterrent	Med-Low	Med
Acoustic Barrier	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High	H	Long	Med Low	M	$200,000	Med Low	Low	Possible	Yes	Medium - anchors, piles, cables	Med Low	Medium	Possible	Medium - series of moorings	Low - moorings	No	Med	100	Deterrent	Low	Med Low
Biological-Based Alternatives:																												
Cull net	Not sensitive	Sensitive to waves, currents	Regional	Full water column	High	Yes	High	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$50,000	Med Low	Very High	Yes	Yes	High - net, piles, cables	Low	Medium	None	Medium-High	Low - abrasions, cuts, entanglement	Yes	Med Low	100	Predator reduction	Low	Med Low
Shark Culling - Drum line	Not sensitive	Sensitive to waves, currents	Regional	Independent of depth	High	Yes	High	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$110,000	Med Low	Very High	Yes	No	Medium	Med Low	Low	None	Low	Low - abrasions, cuts, entanglement	No	High	50	Predator reduction	Low	Low
(Smart) Drum Lines	Not sensitive	Sensitive to waves, currents	Regional	Independent of depth	High	Yes	High	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$110,000	Med Low	Very High	Yes	No	Medium	Med Low	Low	None	Low	Low - abrasions, cuts, entanglement	No	High	50	Predator reduction	Low	Low
Seal Culling	Not sensitive	Not sensitive	Regional	Independent of depth	N/A	N/A	High	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$347,000	Low	None	Yes	Possible - if on beach, shorebirds	None	Med High	None	None	None	None	No	High	<5	Predator reduction	Low	Low
Seal Contraception	Not sensitive	Not sensitive	Regional	Independent of depth	N/A	Yes	High	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$1,999,000	Low	None	Yes	Possible - if on beach, shorebirds	None	Med High	None	None	None	None	No	High	0	Predator reduction	Low	Low
Indigenous Harvest	Not sensitive	Not sensitive	Regional	Independent of depth	N/A	N/A	High	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$0	Med	None	Yes	Possible - if on beach, shorebirds	None	Med High	None	None	None	None	No	High	<5	Predator reduction	Low	Low
Train Sharks – Electric shock	Not sensitive	Sensitive to waves, currents	Local - Beach	Independent of depth	Medium	No	Med	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$110,000	Med Low	Low	No	Yes	Low - anchor	Med High	Very Low	None	Low	Low - abrasions, cuts, electric shock	No	High	50	Deterrent	No data	Med Low
Scent/Smell	Not sensitive	Sensitive to waves, currents	Local - Beach	Independent of depth	Low	No	Med	M	M	Med	M	$110,000	Med	Low	No	Yes	Low - anchor	Med High	Very Low	None	Low	Low - abrasions, cuts, entanglement	No	High	50	Deterrent	Low	Med Low
Modify Human Behavior	Not sensitive	Not sensitive	Regional	Full water column	N/A	N/A	High	N/A	N/A	High	N/A	$20,000	High	None	No	No	None	High	None	None	None	None	Yes	High	100	Physical Barrier PLUS	High	High

Table 18. Alternatives Analysis Matrix for Outer Cape Ocean Beaches with low-ranking alternatives removed.

	Limiting Factors							Permitting			Costs			Potential Adverse Env. Impacts					Human Impacts						Effectiveness			
OCEAN: High energy wave environment, high rates of sediment transport, moderate tidal range, cold temperatures, direct exposure to storm impacts, deeper near shore waters, strong currents	Weather	Marine Conditions	Effective Range	Effective Depth	Resilience to Storm Impacts	Commercial Availability	Category Score	Permitting Complexity	Permitting Timeline	Category Score	Permitting Costs	Asset, Maint., Op. Cost to Town (per 100m beach)	Category Score	Bycatch	Risk of trophic consequence	Risk of Interference	Risk of Physical Impact to Habitat	Category Score	Aesthetics	Noise	Navigation	Risk of Health Impact	Recreation	Category Score	% Time Covered	Shark/Human Interaction	Documented Effectiveness	Category Score
Technology-Based Alternatives:																												
Visual Detection (planes, helicopters)	Highly sensitive to fog, sun angle, rain; wind	Highly sensitive to waves, turbidity, bubble fraction	Regional	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	$28,500	Med-High	None	No	No	None	High	Low	Medium	None	None	No	High	1%-10% (as long as you want/can afford, patrolling, so not normally over any one particular beach)	Detection	Med-Low	Med Low
Visual Detection (tower-based)	Highly sensitive to fog, sun angle, rain	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	$97,000	Med-High	None	No	No	None	High	Low	Low	None	None	No	High	95% (as long as you want/can afford)	Detection	Med-Low	Med
Visual Detection (balloons)	Highly sensitive to fog, sun angle, rain, wind	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	$250,000	Med Low	None	No	Yes - shorebirds	None	High	Low	None	None	None	Yes	Med-High	95% (as long as you want/can afford)	Detection	Med-Low	Med
Visual Detection (drones)	Highly sensitive to fog, sun angle, rain, wind	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	$500,000	Med Low	None	No	Yes - shorebirds	None	High	Medium	High	None	None	Yes	Med Low	70% (as long as you want/can afford, but you can only remain in the air in 20 minute increments)	Detection	Med-Low	Med
Visual Detection (tethered drones)	Highly sensitive to fog, sun angle, rain, wind	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	$122,000	Med	None	No	Yes - shorebirds	None	High	Medium	High	None	None	Yes	Med Low	95% (as long as you want/can afford)	Detection	Med-Low	Med
Bottom-mounted sonar (buoy, alert)	Not sensitive	Highly sensitive to tides, sediment transport; Sensitive to waves, bubble fraction	Local - Beach	Full water column	Low	Yes	Med	M	M	Med	M	$255,000	Med Low	Low	No	No	Medium - anchors, piles, cables	High	Medium	None	Medium	Low - abrasions, cuts	No	Med-High	95%	Detection	Low	Med Low
Electromagnetic (active, wearable)	Not sensitive	Not sensitive	Personal	Independent of depth	N/A	Yes	Med-High	N/A	N/A	High	N/A	$0	High	None	No	No	None	High	None	None	None	Low - pacemaker interference	No	High	100% (continuously while in water)	Deterrent	Low	Med Low
Magnetic (passive, wearable)	Not sensitive	Not sensitive	Personal	Independent of depth	N/A	Yes	Med-High	N/A	N/A	High	N/A	$0	High	None	No	No	None	High	None	None	None	Very Low - pacemaker interference	No	High	100% (continuously while in water)	Deterrent	Low	Med Low
Adaptive Camouflage (passive)	Not sensitive	Highly sensitive to turbidity, bubble fraction	Personal	Independent of depth	N/A	Yes	Med	N/A	N/A	High	N/A	$0	High	None	No	No	None	High	None	None	None	None	No	High	100% (continuously while in water)	Deterrent	Low	Med Low
Barrier-Based Alternatives:																												
Electromagnetic Deterrents	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High	M	M	Med	M	$175,000	Med	Low	No	Yes	High - anchors, full vertical array	Med Low	Medium	None	Medium - series of moorings	High - abrasions, cuts, entanglement, pacemaker interference	Yes	Med Low	100	Deterrent	Med-Low	Med
Acoustic Barrier	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High	H	Long	Med Low	M	$200,000	Med Low	Low	Possible	Yes	Medium - anchors, piles, cables	Med Low	Medium	Possible	Medium - series of moorings	Low - moorings	No	Med	100	Deterrent	Low	Med Low
Biological-Based Alternatives:																												
Scent/Smell	Not sensitive	Sensitive to waves, currents	Local - Beach	Independent of depth	Low	No	Med	M	M	Med	M	$110,000	Med	Low	No	Yes	Low - anchor	Med-High	Very Low	None	Low	Low - abrasions, cuts, entanglement	No	High	50	Deterrent	Low	Med Low
Modify Human Behavior	Not sensitive	Not sensitive	Regional	Full water column	N/A	N/A	High	N/A	N/A	High	N/A	$20,000	High	None	No	No	None	High	None	None	None	None	Yes	High	100	Physical Barrier PLUS	High	High

Table 19. Alternatives Analysis Matrix for Outer Cape Bayside Beaches with low-ranking alternatives removed.

	Limiting Factors							Permitting			Costs			Potential Adverse Env. Impacts					Human Impacts						Effectiveness			
BAY: Moderate wave energy environment, moderate rates of sediment transport and turbidity, high tidal range, warm temperatures, indirect exposure to storm impacts, shallower near shore waters, moderate currents	Weather	Marine Conditions	Effective Range	Effective Depth	Resilience to Storm Impacts	Commercial Availability	Category Score	Permitting Complexity	Permitting Timeline	Category Score	Permitting Costs	Asset, Maint., Op. Cost to Town (per 100m beach)	Category Score	Bycatch	Risk of trophic consequence	Risk of Interference	Risk of Physical Impact to Habitat	Category Score	Aesthetics	Noise	Navigation	Risk of Health Impact	Recreation	Category Score	% Time Covered	Shark/Human Interaction	Documented Effectiveness	Category Score
Technology-Based Alternatives:																												
Visual Detection (planes, helicopters)	Highly sensitive to fog, sun angle, rain; wind, turbidity	Highly sensitive to waves, turbidity, bubble fraction	Regional	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	$14,285	Med High	None	No	No	None	High	Low	Medium	None	None	No	High	1%-10% (as long as you want/can afford, patrolling, so not normally over any one particular beach)	Detection	Med-Low	Med Low
Visual Detection (tower-based)	Highly sensitive to fog, sun angle, rain, turbidity	Highly sensitive to waves, turbidity, bubble fraction, horozontal tides	Local - Beach limited range	Within ~2.5m of surface	Removable	Yes	Med Low	M	M	Med	M	$97,000	Med High	None	No	No	None	High	Low	Low	None	None	No	High	45%	Detection	Med-Low	Med Low
Visual Detection (balloons)	Highly sensitive to fog, sun angle, rain, wind, turbidity	Highly sensitive to waves, turbidity, bubble fraction, horozontal tides	Local - Beach limited range	Within ~2.5m of surface	Removable	Yes	Med Low	M	M	Med	M	$250,000	Med Low	None	No	Yes - shorebirds	None	High	Low	None	None	None	Yes	Med High	45%	Detection	Med-Low	Med Low
Visual Detection (drones)	Highly sensitive to fog, sun angle, rain, wind, turbidity	Highly sensitive to waves, turbidity, bubble fraction, horozontal tides	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med Low	M	M	Med	M	$500,000	Med Low	None	No	Yes - shorebirds	None	High	Medium	High	None	None	Yes	Med Low	70% (as long as you want/can afford, but you can only remain in the air in 20 minute increments)	Detection	Med-Low	Med
Visual Detection (tethered drones)	Highly sensitive to fog, sun angle, rain, wind, turbidity	Highly sensitive to waves, turbidity, bubble fraction, horozontal tides	Local - Beach limited range	Within ~2.5m of surface	Removable	Yes	Med Low	M	M	Med	M	$122,000	Med	None	No	Yes - shorebirds	None	High	Medium	High	None	None	Yes	Med Low	45%	Detection	Med-Low	Med Low
Electromagnetic (active, wearable)	Not sensitive	Not sensitive	Personal	Independent of depth	N/A	Yes	Med High	N/A	N/A	High	N/A	$0	High	None	No	No	None	High	None	None	None	Low - pacemaker interference	No	High	100% (continuously while in water)	Deterrent	Low	Med Low
Magnetic (passive, wearable)	Not sensitive	Not sensitive	Personal	Independent of depth	N/A	Yes	Med High	N/A	N/A	High	N/A	$0	High	None	No	No	None	High	None	None	None	Very Low - pacemaker interference	No	High	100% (continuously while in water)	Deterrent	Low	Med Low
Adaptive Camouflage (passive)	Not sensitive	Highly sensitive to turbidity, bubble fraction	Personal	Independent of depth	N/A	Yes	Med	N/A	N/A	High	N/A	$0	High	None	No	No	None	High	None	None	None	None	No	High	100% (continuously while in water)	Deterrent	Low	Med Low
Barrier-Based Alternatives:																												
Bubble curtains	Not sensitive	Sensitive to waves, currents, tides	Local - Beach limited	Full water column	Low	No	Med Low	M	M	Med	M	$425,000	Med Low	Low	No	Yes - sound barrier marine animals	Medium - bottom cable & anchors	Med	Medium	Medium-High - compressor; bubbles at surface	Low	Low	Yes	Med Low	50%	Deterrent	Low	Med Low
Acoustic Barrier	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High	H	L	Med Low	M	$200,000	Med Low	Low	Possible	Yes	Medium - anchors, piles, cables	Med Low	Medium	Possible	Medium - series of moorings	Low - moorings	No	Med	100	Deterrent	Low	Med Low
Biological-Based Alternatives:																												
Scent/Smell	Not sensitive	Sensitive to waves, currents	Local - Beach limited	Independent of depth	Low	No	Med Low	M	M	Med	M	$110,000	Med	Low	No	Yes	Low - anchor	Med High	Very Low	None	Low	Low - abrasions, cuts, entanglement	No	High	50	Deterrent	Low	Med Low
Modify Human Behavior	Not sensitive	Not sensitive	Regional	Full water column	N/A	N/A	High	N/A	N/A	High	N/A	$20,000	High	None	No	No	None	High	None	None	None	None	Yes	High	100	Physical Barrier PLUS	High	High

Table 20. Alternatives Analysis Matrix for Outer Cape Estuarine Beaches with low-ranking alternatives removed.

	Limiting Factors							Permitting			Costs			Potential Adverse Env. Impacts					Human Impacts						Effectiveness			
ESTUARINE: Low wave energy environment, low rates of sediment transport, low tidal range, warm temperatures, sheltered from storm impacts, shallow near shore waters, low currents	Weather	Marine Conditions	Effective Range	Effective Depth	Resilience to Storm Impacts	Commercial Availability	Category Score	Permitting Complexity	Permitting Timeline	Category Score	Permitting Costs	Asset, Maint., Op. Cost to Town (Annual, per beach)	Category Score	Bycatch	Risk of trophic consequence	Risk of Interference	Risk of Physical Impact to Habitat	Category Score	Aesthetics	Noise	Navigation	Risk of Health Impact	Recreation	Category Score	% Time Covered	Shark/Human Interaction	Documented Effectiveness	Category Score
Technology-Based Alternatives:																												
Visual Detection (planes, helicopters)	Highly sensitive to fog, sun angle, rain, turbidity	Highly sensitive to waves, turbidity, bubble fraction	Regional	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	$28,500	Med High	None	No	No	None	High	Low	Medium	None	None	No	High	1%-10% (as long as you want/can afford, patrolling, so not normally over any one particular beach)	Detection	Med-Low	Med Low
Visual Detection (tower-based)	Highly sensitive to fog, sun angle, rain, wind, turbidity	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	$97,000	Med High	None	No	No	None	High	Low	Low	None	None	No	High	95% (as long as you want/can afford)	Detection	Med-Low	Med
Visual Detection (balloons)	Highly sensitive to fog, sun angle, rain, wind, turbidity	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	$250,000	Med Low	None	No	Yes - shorebirds	None	High	Low	None	None	None	Yes	Med High	95% (as long as you want/can afford)	Detection	Med-Low	Med
Visual Detection (drones)	Highly sensitive to fog, sun angle, rain, wind, turbidity	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	$500,000	Med Low	None	No	Yes - shorebirds	None	High	Medium	High	None	None	Yes	Med Low	70% (as long as you want/can afford, but you can only remain in the air in 20 minute increments)	Detection	Med-Low	Med
Visual Detection (tethered drones)	Highly sensitive to fog, sun angle, rain, wind, turbidity	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	$122,000	Med	None	No	Yes - shorebirds	None	High	Medium	High	None	None	Yes	Med Low	95% (as long as you want/can afford)	Detection	Med-Low	Med
Bottom-mounted sonar (buoy, real time)	Not sensitive	Highly sensitive to tides, sediment transport; Sensitive to waves, bubble fraction	Local - Beach	Full Water Column	High	Yes	Med High	M	M	Med	M	$255,000	Med Low	None	No	No	Medium - anchors, piles, cables	High	Medium	None	Medium	Low - abrasions, cuts	No	Med High	95%	Detection	Low	Med Low
Electromagnetic (active, wearable)	Not sensitive	Not sensitive	Personal	Independent of depth	N/A	Yes	Med High	N/A	N/A	High	N/A	$0	High	None	No	No	None	High	None	None	None	ow - pacemaker interferenc	No	High	100% (continuously while in water)	Deterrent	Low	Med Low
Magnetic (passive, wearable)	Not sensitive	Not sensitive	Personal	Independent of depth	N/A	Yes	Med High	N/A	N/A	High	N/A	$0	High	None	No	No	None	High	None	None	None	y Low - pacemaker interfere	No	High	100% (continuously while in water)	Deterrent	Low	Med Low
Adaptive Camouflage (passive)	Not sensitive	Highly sensitive to turbidity, bubble fraction	Personal	Independent of depth	N/A	Yes	Med	N/A	N/A	High	N/A	$0	High	None	No	No	None	High	None	None	None	None	No	High	100% (continuously while in water)	Deterrent	Low	Med Low
Barrier-Based Alternatives:																												
Bubble curtains	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	No	Med	M	M	Med	M	$425,000	Med Low	None	No	Yes - sound barrier marine animals	Medium - bottom cable & anchors	Med	Medium	Medium-High - compressor; bubbles at surface	Low	Low	Yes	Med Low	100	Deterrent	Low	Med Low
Live Kelp	Not sensitive	Sensitive to waves, currents	Local - Beach	Partial	Medium	No	Med Low	M	M	Med	M	$60,000	Med High	Medium	No	No	Medium Low - Floats and Cables	High	Low	None	Low	Low	No	High	100	Deterrent	Med-Low	Med
Electromagnetic deterrents	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med High	M	M	Med	M	$175,000	Med	None	No	Yes	High - anchors, full vertical array	Med	Medium	None	Medium - series of moorings	High - abrasions, cuts, entanglement, pacemaker interference	Yes	Med Low	100	Deterrent	Med-Low	Med
Acoustic Barrier	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High	H	Long	Med Low	M	$200,000	Med Low	Low	Possible	Yes	Medium - anchors, piles, cables	Med Low	Medium	Possible	Medium - series of moorings	Low - moorings	No	Med	100	Deterrent	Low	Med Low
Biological-Based Alternatives:																												
Scent/Smell	Not sensitive	Sensitive to waves, currents	Local - Beach	Independent of depth	Low	No	Med	M	M	Med	M	$110,000	Med	Low	No	Yes	Low - anchor	Med High	Very Low	None	Low	Low - abrasions, cuts, entanglement	No	High	50	Deterrent	Low	Med Low
Modify Human Behavior	Not sensitive	Not sensitive	Regional	Full water column	N/A	N/A	High	N/A	N/A	High	N/A	$20,000	High	None	No	No	None	High	None	None	None	None	Yes	High	100	Physical Barrier PLUS	High	High

7.0 SUMMARY OF FINDINGS

The most important finding to emphasize from this preliminary assessment is that there is no single alternative or suite of alternatives that can 100% guarantee the safety of individuals who choose to enter the water. Further emphasis for the public and all stakeholders is to acknowledge that different behaviors (wading v. swimming v. surfing) pose different levels of risk, and members of all user groups should exercise caution, follow established best management practices (i.e., *Shark Smart Behaviors*), and be willing to assume the level of risk associated with their behavior prior to entering the water. Based on the information gathered for this study, Woods Hole Group firmly believes that the *immediately actionable items* summarized in this report and deployed by municipalities and the CCNS are improving public awareness of the presence of sharks and seals and are actively contributing to a safer visitor experience for all user groups. Since no mitigation alternative can provide 100% safety, reducing chances of unprovoked attacks on humans requires a strong commitment to education and outreach, which can result in the adoption of behaviors that may reduce the risk of a shark-human interaction.

Future deployment of any shark mitigation alternative must be carefully considered by regional, and in some cases, individual stakeholders. Members of the public, State and local officials, and other associated regional stakeholders must take the time to educate themselves on the advantages and inherent disadvantages of various mitigation strategies. It would also be prudent to review the lessons learned from pilot studies and deployments of shark mitigation strategies elsewhere around the world. Dealing with shark-human interaction is a global issue, not one that is isolated to our region. The objective alternatives analysis presented in this report is intended to help facilitate this education and decision-making process. It is likely that the most effective alternatives and strategies will be regional in nature, and will utilize the most current, scientifically defensible data regarding the dynamics of the local shark and seal populations provided by the Massachusetts DMF Shark Research Program and their regional partners. Prior to the deployment of any alternative, it will be critical to develop a regional consensus regarding the most appropriate pathway forward. To work towards a regional consensus, Woods Hole Group recommends the continued expansion of education and outreach efforts and open dialogue between stakeholder groups.

7.1 REGARDING TECHNOLOGY-BASED ALTERNATIVES

Various technology-based alternatives (tagging, remote detection, acoustic detection, personal deterrents) were evaluated as part of this initial study. Preliminary findings are summarized below.

- Tagging efforts only sample a portion of the shark population, but they do effectively identify and detect those particular sharks.
- Tags provide regional coverage and an expanded tagging program will improve our understanding of the shark population, which may inform safer human behavior.
- Real-time buoys may have a role in improving public safety as part of a wider response strategy. However, if real-time buoys are deployed near a beach, it should be made

very clear to swimmers and surfers that the buoy does not mean they can stop employing *Shark Smart Behaviors*.

- The success rate for visual observations is limited, even under ideal conditions. While various forms of visual observation may alert beachgoers to the presence of a shark, that shark is already very close to or already inside the swimming area. *Shark Smart* behavior remains essential.
- Sonar detection systems have not yet lived up to their potential. They may have a role in improving public safety at beaches that meet certain characteristics, but must not be allowed to justify or rationalize unsafe behavior by swimmers. Even if the system does provide an accurate real-time alert, the shark is already in close proximity to the swimmers.
- Tagging, visual detection, and acoustic detection alternatives coupled with real-time transmission simply alert beachgoers to the presence of a shark. There is no certainty that these alternatives would have a measurable effect on reducing attacks.
- Very few trials showed any repellent effect of wearable shark mitigation technologies on a shark that had fully committed to an aggressive attack vector. However, some of these devices may provide some protection from more casual interest.
- Wearable mitigation devices that may be somewhat effective may not remain so over time, as sharks acclimate to the presence of the active or passive electromagnetic field.
- Evidence for the efficacy of camouflage, whether worn or applied to a surfboard, is limited and inconclusive.
- Wearable technologies are personal purchases, not a form of regional or beach protection provided by a government or other organization. Individuals should take their personal responsibility to evaluate these devices, should they choose to use them, very seriously.
- No technology-based alternatives physically separate sharks from humans.
- Permitting of certain technology-based alternatives may prove challenging (e.g. drones, etc. within the CCNS).

7.2 REGARDING BARRIER-BASED ALTERNATIVES

Various barrier-based alternatives (exclusion nets, (simulated) kelp, bubble curtains, electromagnetic deterrents, and acoustic deterrents) were evaluated as a part of this initial study. Preliminary findings are summarized below.

- Flexible exclusion nets pose a high risk of entanglement to marine life and possibly swimmers and other beach users as well. As a result, they have fallen out of favor.
- Rigid exclusion barriers reduce the risk of entangling marine life by providing a stiff, large hard-plastic mesh that is less likely to wrap around and entangle an animal while allowing still allowing smaller animals to pass through.
- Rigid exclusion barrier deployments have had modest success on protected beaches with relatively low energy wave environments, but have failed in more energetic wave environments due to scouring of moorings and lack of flex in the rigid plastic mesh.

- Semi-rigid exclusion barriers are a newer, hybrid design between a rigid barrier and exclusion net, and have largely replaced flexible and rigid exclusion barriers/nets in Australia. The design includes a large mesh nylon net reinforced with plastic struts or joints to form a semi-rigid physical barrier intended to reduce the risk of entangling marine life while still providing elasticity in more energetic surf environments.
- The limited number of semi-rigid barrier installations in Australia have been effective at excluding sharks, but would likely have a long permitting timelines and high costs if proposed locally.
- To our knowledge, there have been no kelp forests/farms established for the specific purpose of providing a physical barrier to sharks.
- Simulated kelp forests, while not impenetrable to sharks, discourage regular movement through the array due to the high density of the gear and passive magnetic fields. There has been a lot of supporting research demonstrating the effectiveness of simulated kelp at enclosing small areas (15mx15m), however, installations require a significant number of anchors and gear suspended in the water column that elevate costs while still posing some risks to marine life and benthic habitat.
- Electrical and electromagnetic deterrents may be cabled together to protect larger areas, or moored to provide more limited, personal protection. They are not likely to be successful on an exposed, ocean-facing beach.
- Acoustic deterrents have a limited impact on shark behavior and should not be relied upon as a stand-alone solution. They can be paired with visual and/or sensory deterrents to increase effectiveness, but even then, level of effectiveness may be limited.
- All physical barriers have the potential to attenuate wave energy, thereby reducing wave heights, raising concern among the international surfing community.
- All physical barriers pose some risk of entanglement, requiring a careful review of any proposed design and implementation protocol to mitigate impacts to marine life.
- All physical barriers require frequent cleaning, inspection, and repair.
- The permitting of any barrier may prove challenging.

7.3 REGARDING BIOLOGICAL-BASED ALTERNATIVES

Various biological-based alternatives (cull nets, (smart) drum lines, seal culling, seal contraception, indigenous harvest, and scent/smell deterrents) were evaluated as a part of this initial study. Preliminary findings are summarized below.

- The culling of great white sharks is not currently permittable given existing regulations. Great white sharks were designated as a prohibited species in federal U.S. Atlantic waters in 1997 and in Massachusetts waters in 2005.
- The culling, application of contraception, or indigenous harvest of wild populations of gray seals are not currently permittable given existing regulations. Gray seals were designated as a protected species in Massachusetts waters in 1962 and at the federal level through the passage of the Marine Mammal Protection Act in 1972.

- (Smart) drum lines incur significant operations and maintenance costs annually to support a boat and crew, bait, removal and relocation of hooked sharks, and deployment, maintenance, and retrieval of the unit.
- (Smart) drum lines have high rates of incidental bycatch and if a substantial number of sharks are culled, or if drum lines are deployed in natural white shark aggregation sites, drum lines have the potential to trigger unintended trophic consequences.
- The effectiveness of (smart) drum lines at catching target species of shark and reducing the risk of shark-human interaction is limited.
- Drum lines were the most strongly opposed shark management strategy in Western Australia during the deployment period.
- Cull nets have high rates of incidental bycatch and pose an entanglement risk to other forms of marine life including marine mammals, sea turtles, fish, seabirds, and non-target (non-dangerous) shark species.
- The Australia Fisheries Scientific Committee determined that continued utilization of cull nets represents a key threatening process, which may cause species, populations, or ecological communities not currently threatened to become threatened.
- The effectiveness of cull nets at reducing shark-human interaction is limited. Despite the deployment of nets off the New South Wales coast as early as the year 1937, 38 shark attacks and 1 fatality still occurred between 1937-2009.
- The deployment of seal contraception would be extremely costly.
- Widespread deployment of seal contraception may have a similar effect on the seal population as culling, because it would result in the selective removal of breeding adults from the wild population (i.e. trophic cascades, impacts to regional nutrient cycling, impacts to predator-prey relationships, and destabilization of marine community structure).
- There is no empirical evidence to suggest that reducing the local gray seal population through the use of wildlife contraception would result in a subsequent decrease in the regional white shark population.
- Culling of gray seals would be extremely costly.
- It is possible that widespread culling of gray seals would have an impact on the local marine ecosystem, potentially resulting in trophic cascades, impacts to regional nutrient cycling, impacts to predator-prey relationships, and destabilization of marine community structure
- There is no empirical evidence to suggest that culling of the local gray seal population would lead to a subsequent decrease in the regional white shark population.
- The number of gray seals that would need to be harvested to have an impact on the greater Northwestern Atlantic population likely exceeds the number of seals that could be beneficially used by local indigenous communities.
- It is plausible that a reduction in the local gray seal population may cause other seals from the greater northwestern Atlantic population to move into the region to occupy the available habitat.

7.4 ALTERNATIVES ANALYSIS

The alternatives analysis considered various mitigation alternatives and strategies within the context of ocean, bay, and estuarine conditions. Ultimately, resilience to limiting factors, various permitting requirements, costs, potential environmental and human impacts, and level of effectiveness were similar across all matrices, with minor exceptions, mainly resilience to variable environmental and marine conditions between ocean, bay, and estuarine conditions. Based on the results of the alternatives analysis, several alternatives were removed from consideration. It should be noted that alternatives removed from consideration may still be proposed, however, proponents should carefully consider the permittability, costs, potential adverse environmental impacts, potential adverse human impacts, and documented level of effectiveness associated with each alternative carefully, prior to developing a formal, written proposal. None of these alternatives considered in this study should be considered stand-alone solutions that will provide 100% bather safety. Please refer to the detailed description of these specific alternatives in Chapter 5 and the alternatives analysis matrices in Chapter 6 for additional information regarding the merits of each and the specific considerations that led to these determinations.

Both acoustic and satellite tagging received the lowest possible score for documented effectiveness. Although acoustic and satellite tagging is an important research tool and can effectively be used to track individual sharks, it is likely that only a small portion of the white shark population has been tagged. Relying solely on tagging and subsequent real-time-alert based systems would be irresponsible. However, tagging and real-time-alert based systems do notify beachgoers to the presence of some sharks, and when used in concert with other alternatives and best management practices, may provide some level of added safety. Further, the continued tagging of white sharks is important from a research perspective, to better understand shark behavior to better inform more responsible human behavior and public safety efforts.

The remaining technology-based alternatives include:

- Visual Detection (planes, helicopters)
- Visual Detection (tower-based)
- Visual Detection (balloons)
- Visual Detection (drones)
- Visual Detection (tethered drones)
- Bottom-mounted sonar (buoy, real time alert)
- Electromagnetic (active, wearable/mountable)
- Magnetic (passive, wearable/mountable)
- Adaptive Camouflage

These alternatives did not receive the lowest possible score in any evaluation category. It should be noted that none of these alternatives provide any physical separation between sharks and humans, and their deployment may not have any measurable effect on reducing the likelihood of attack. However, under ideal conditions, they may provide some level of advance warning to the presence of a shark, or under other circumstances, may provide limited protection to the wearer over an exceedingly short range. None of these alternatives should be considered stand-alone solutions that will provide 100% bather safety. Please refer to the detailed description of these specific alternatives in Chapter 5 and the alternatives analysis matrices in Chapter 6 for additional information regarding the merits of each and the specific considerations that led to this determination.

Barrier-based alternatives including flexible exclusion nets, rigid exclusion nets, and semi-rigid exclusion nets were removed from consideration, as they received the lowest possible scores for cost (all in excess of $300,000 for acquisition of the asset, operational, and maintenance costs in the first year), low scores with regard to potential adverse environmental impacts (flexible exclusion nets), and/or low scores with regard to potential human impacts (simulated kelp forests). Barrier-based alternatives have been deployed elsewhere in the world. In quiescent environments, barriers have generally performed well. However, in more energetic, ocean environments, the performance of barriers is more limited. Further, it will be critical to consult with local, state, and federal permitting agencies to determine if the risk of unintended bycatch and entanglement of marine life can be overcome.

The remaining barrier-based alternatives include:

- Electromagnetic deterrents
- Acoustic barriers

These alternatives did not receive the lowest possible score in any evaluation category. It should be noted that neither of these barrier-based alternatives provide any physical separation between sharks and humans; they simply act as sensory deterrents. There is evidence that sharks may acclimate to electromagnetic deterrents over the course of time, and deploying an array of cabled, electromagnetic nodes can be exceedingly expensive, while offering only limited, if any, bather protection. Single nodes can be deployed in proximity to small groups, but providing beach-level protection may prove challenging. Acoustic barriers can be coupled with other associated (visual) deterrents. There is evidence to suggest that sharks may acclimate to acoustic barriers over the course of time, and deploying an array that will encompass a bathing beach may prove challenging. Further, it will be important to consult with local, state, and federal agencies regarding potential adverse impacts of acoustic barriers on non-target species. None of these alternatives should be considered stand-alone solutions that will provide 100% bather safety. Please refer to the detailed description of these specific alternatives in Chapter 5 and the alternatives analysis matrices in Chapter 6 for additional information regarding the merits of each and the specific considerations that led to this determination.

Biological-based alternatives including cull nets, (smart) drum lines, seal culling, seal contraception, indigenous harvest, and electric shock were removed from consideration as they are not currently permittable given existing regulations prohibiting such alternatives.

Exemptions to state and federal protections for great white shark and gray seals may be sought, but it is likely that the timeline for pursuing such exemptions would be exceedingly long and the likelihood of securing an exemption would be very low. Seal culling and seal contraception were also eliminated due to the extremely high costs associated with implementing either alternative. (Smart) drum lines, seal culling, seal contraception, and indigenous harvest also received the lowest possible score for documented effectiveness. There is simply no empirical research to suggest that culling the regional seal population would have a measurable effect on the presence of white sharks.

The remaining biological-based alternatives include:

- Scent/Smell
- Modify Human Behavior

These alternatives did not receive the lowest-possible score in any category. However, it should be noted that scent/smell deterrents have a limited level of effectiveness and should not be relied upon as a stand-alone mitigation strategy. There is evidence to suggest that such measures are only effective over a short range, and sharks may develop a tolerance for the measures over the course of time. Modifying human behavior may be the most effective form of mitigating shark-human interaction. If water activities are avoided, the risk of attack drops to near 0%. If water activities are not eliminated, but best management practices and *Shark Smart Behaviors* are widely adopted, the risk of attack may be substantially reduced. All individuals choosing to engage in water activities should think carefully about the level of risk associated with their preferred activity before entering the water. The decision to enter the water and assume the risk of shark-human interaction is made at the sole discretion of the individual. None of these alternatives should be considered stand-alone solutions that will provide 100% bather safety. Please refer to the detailed description of these specific alternatives in Chapter 5 and the alternatives analysis matrices in Chapter 6 for additional information regarding the merits of each and the specific considerations that led to this determination.

7.5 REQUIRED PERMITTING

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:

Massachusetts Department of Environmental Protection (DEP), Wetlands & Waterways Division

- The State can only issue Emergency Declarations for weather related events. Emergency Certificates can be issued for public health and safety, but since the shark situation has been evolving over several years, it is unlikely to warrant a Certificate.

- Some technology-based alternatives would need to be reviewed under the Massachusetts Wetlands Protection Act (WPA), which would include a review by higher management from the Boston office, since these decisions would be precedent-setting.
- For floating or bottom anchored barriers, a Request for Determination of Applicability would need to be filed with the local Conservation Commission.
- For barriers using cable, requiring trenches, or heavy anchors, a Notice of Intent would need to be filed with the local Conservation Commission.
- It is likely that time-of-year restrictions would be imposed for marine mammals.
- Biological-based alternatives and some technology-based alternatives that do not result in physical impacts to coastal resource areas may not require review under the WPA.
- To calculate the area of impact from a barrier-based alternative, calculate the footprint of the anchor chain or mooring blocks plus the buffer from movement (not the entire area within a proposed enclosure).

Massachusetts Department of Environmental Protection (DEP), Chapter 91 Waterways Division

- All physical barriers will require some form of Chapter 91 authorization.
- For floating or bottom anchored barriers, the local harbormasters could grant an annual permit.
- For floating or bottom anchored barriers, an Annual Chapter 91 Permit would be the easiest to process; has a fifteen (15) day public comment period, does not require engineering plans, and is issued through the regional office.
- Any barrier-based alternatives considered a structure, (the laying of cables, simulated kelp forests, etc.), would need either a Chapter 91 License or Permit.

Massachusetts Coastal Zone Management (CZM)

- CZM would review potential impacts to resource areas from any proposed alternative, as well as how the alternative would be installed and removed.
- CZM regulations include Habitat Policies, which raise concerns about culling and impacts from culling.
- The Marine Mammal Protection Act prohibits the culling of seals.
- There is a large eco-tourism draw based on seals, and culling would impact this.
- There are concerns about any form of plastic in the water and what would happen to plastic debris in the water following a storm impact.
- Bubble curtains were used during the U.S. Army Corps of Engineers dredging of Boston Harbor, and were found to be ineffective. CZM is concerned about the Towns being able to afford and sustain bubble curtains as they require large compressors and generators.

Mass. Division of Fisheries & Wildlife/Natural Heritage & Endangered Species Program (NHESP)

- If any proposed project or activity will occur within *Priority Habitat* and *Estimated Habitat* as indicated in the current edition of the Massachusetts Natural Heritage Atlas, then a filing must be made with the Division's Natural Heritage & Endangered Species Program pursuant to the Massachusetts Endangered Species Act (MESA).

- The purpose of the Division's review under the MESA regulations is to determine whether a Take of state-listed species will result from the proposed project.
- A Take is defined as the following: In reference to animals, means to harass, harm, pursue, hunt, shoot, hound, kill, trap, capture, collect, process, disrupt the nesting, breeding, feeding or migratory activity or attempt to engage in any such conduct, or to assist such conduct, and in reference to plants, means to collect, pick, kill, transplant, cut or process or attempt to engage or to assist in any such conduct.
- Disruption of nesting, breeding, feeding or migratory activity may result from, but is not limited to, the modification, degradation or destruction of habitat.
- Review process is very specific to the proposed project, site conditions and the state-listed species utilizing the site.
- It is recommended that Towns or their representatives seek further consultation from the NHESP office (via a pre-filing consultation) to discuss any specific method in conjunction with the site/beach, pilot or otherwise, prior to submitting a formal filing pursuant to the MESA or the rare species section of the Wetlands Protection Act.
- Projects or activities on beaches with state-listed nesting species are subject to a Time-of-Year (TOY) restriction; a no work window from April 1 – August 31 to protect territorial birds, their nests and unfledged chicks.
- 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.
- The gray seal is a former state-listed species in Massachusetts. It was first listed as Special Concern in 1990 and delisted in 2002. It is a species that remains "watched" by the Division's NHESP. Significant declines in the population would be monitored closely.
- The use of vehicular patrols (e.g. ATV, UTV, truck, etc.) for "shark spotters" or emergency responders patrol (except in response to an emergency situation) are anticipated, it would require review with the Division and adherence to the Division's *Guidelines for Managing Recreational Use of Beaches to Protect Piping Plover, Terns and Their Habitats in Massachusetts* or, if applicable, the Town's Habitat Conservation Plan (issued by the Division).

<u>Mass. Division of Marine Fisheries (DMF)</u>

- DMF would take interest, since sharks and seals utilize nearshore habitat all around Cape Cod, including around the Outer Cape and in Cape Cod Bay (DMF is a commenting agency through MEPA and other processes).
- Barrier-based alternatives would prohibit the natural movement of sharks and seals along the shore.
- Installing physical barriers along the shoreline would be challenging, considering regional rates of sediment transport.
- State regulations mirror federal regulations, so there would be rigorous permitting requirements through DMF.

U.S. Army Corps of Engineers (USACE)

- Some form of USACE permitting is needed for work involving activity, structures or placement of fill in waters. The Corps regulates under Section 10 of the Rivers and Harbors Act of 1899 (work, structures, dredging) and Section 404 of the Clean Water Act (fill).
- See attached USACE Permitting Requirements for various proposed alternatives in Appendix H.
- Securing Individual Permits through the USACE can be a lengthy process and often include joint scoping and review from various federal agencies including the National Marine Fisheries Service (NMFS), EPA, and others.

National Marine Fisheries Service (NMFS)/NOAA Fisheries

- NMFS would be a primary commenting agency through any federal permitting process (NEPA, USACE, etc.).
- Any culling of great white sharks is inconsistent with federal regulations and cannot be performed within federal waters that extend beyond three (3) miles offshore.
- The Atlantic States Marine Fisheries Commission regulates the State waters, which extend from shorelines to three (3) miles offshore. The State regulations mirror the federal regulations.
- In order to perform shark culling, a proponent would need to obtain a permit or exemption from NOAA. Depending on the scope of impacts, an Essential Fish Habitat consultation would also likely be needed.
- Shark culling would require a letter of authorization from the DMF Director.
- Other local species, including sand tiger sharks, are also protected under federal regulations, so there are concerns about any culling alternatives that may affect non-target species.
- The Marine Mammal Protection Act prohibits seal culling, contraception and indigenous harvest.
- Some provisions allow for quantified "take limits" on an annual basis, while still allowing for species recovery. The current annual take limit for gray seals is approximately 1,000 protected animals. Annual take limits are often approached or exceeded through incidental bycatch of gray seals in fishing gear, boat strikes, etc. These provisional take limits would not apply to large, widespread culling of seals off the Cape and Islands.
- Under the Endangered Species Act, any proposed alternative would require Section 7 consultation with NOAA.
- NOAA is very concerned about the risk of entanglement posed to marine life, including sea turtles and whales.

U.S. Environmental Protection Agency (EPA)

- The EPA would be a primary commenting agency through any federal review process (NEPA, USACE, etc.)
- The EPA pointed out the important role that the Cape Cod National Seashore would play in permitting any alternative within the CCNS boundary.

- If any Town proposed in-water work within the CCNS boundary, review under the National Environmental Policy Act (NEPA) would be required.
- NEPA review would require the filing of an Environmental Assessment (EA) or Environmental Impact Statement (EIS).
- There would be many hoops to jump through to secure authorization, so Towns could not implement an alternative in a short timeframe. EPA recognizes this would not satisfy the public's immediate concerns.

Cape Cod National Seashore (CCNS)

- Any alternative would fall under CCNS jurisdiction if deployment is proposed on National Park Service land and/or in all water within the CCNS boundary, and would be subject to review and permitting under NEPA.
- The extent of NEPA compliance would depend on what specific alternatives might move forward for further evaluation.
- NEPA review would take at least one (1) year and would require review from the Washington DC office, decisions regarding NEPA would not be made locally.
- For the CCNS to be involved in funding a NEPA review for the deployment of an alternative within the CCNS boundary, the CCNS would need three (3) years to acquire federal funding.
- The CCNS provided the following graphic, which details ownership and jurisdiction of the shoreline on and around Cape Cod (Figure 38).
- Use of drones within the Cape Cod National Seashore requires the issuance of a permit. At present, drones, more technically known as unmanned aircraft systems (UAS), are banned from launching, landing or operating from lands and waters administered by the National Park Service within the boundaries of Cape Cod National Seashore.

In addition to the regulatory agencies listed above, Woods Hole Group expects permits and/or consultations would also be required from the following regulatory agencies:

- Local Conservation Commission
- Local Waterways Commission (if applicable)
- Local Harbormaster
- Cape Cod Commission
- Executive Office of Energy & Environmental Affairs – Massachusetts Environmental Policy Act Office (MEPA)
- Massachusetts DEP – Water Quality Certification
- Bureau of Underwater Archeological Resources (BUAR)
- United States Coast Guard (USCG)
- Federal Aviation Administration (FAA)

7.6 REGARDING PERMITTING, SCOPE, COSTS, AND TIMELINE

Based on the feedback received from the permitting agencies, the wide variety of alternatives being considered, and the precedent-setting nature of deploying said alternatives, permitting decisions are likely to occur on an extended timeline that may not satisfy the current needs of the public. Securing all necessary permits will be costly. Certain alternatives may not be permittable given the existing regulations, which are unlikely to change in the short-term. Exactly which permits will be required and the associated costs and timeline are specific and would need to be refined for each alternative formally proposed. For planning purposes, Woods Hole Group prepared the following permitting summary for alternatives not eliminated from the alternatives analysis matrices described in Chapter 6. The permitting summary, inclusive of all local, state, and federal permits and/or consultations that may be required for remaining alternatives is included in Table 21.

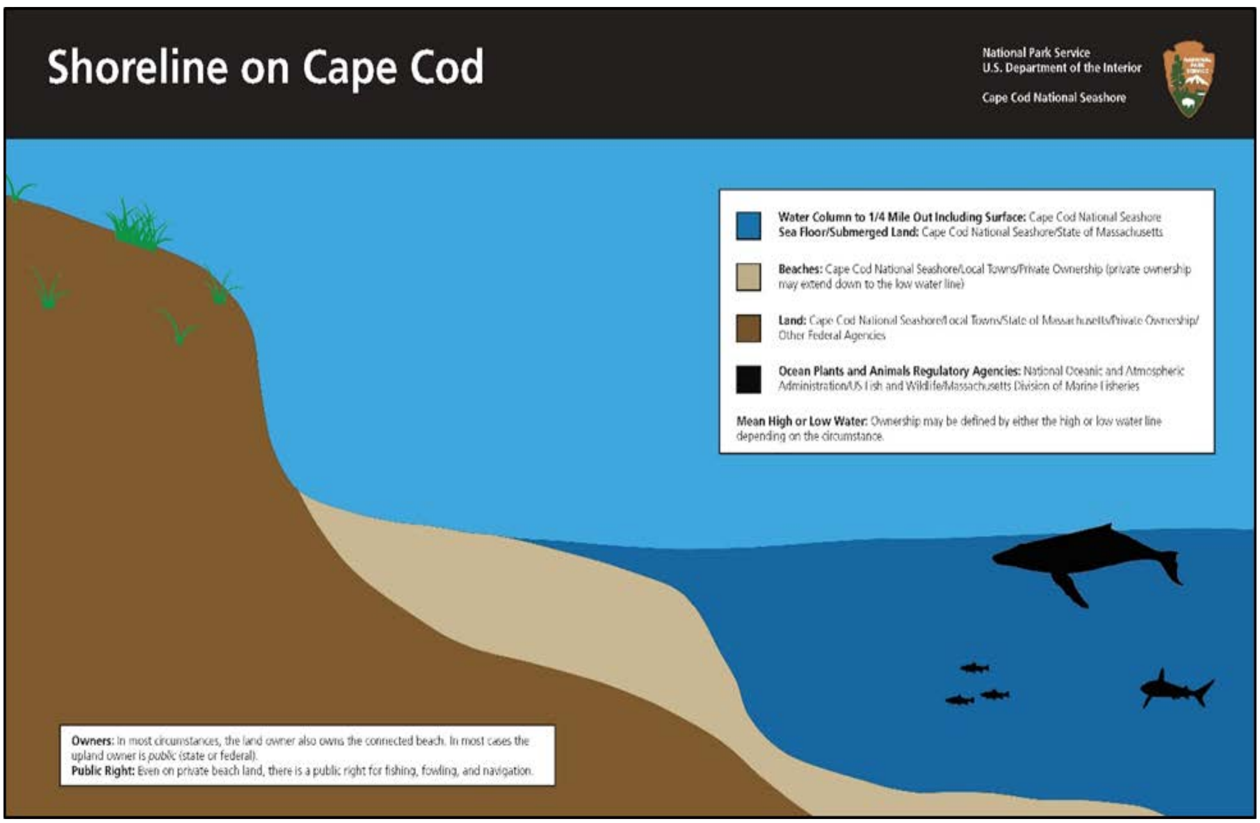


Figure 38. Regulatory boundaries of the Cape Cod National Seashore.

Table 21. Permitting summary for select mitigation alternatives, inclusive of all local, state, and federal permits and/or consultations that may be required.

Alternative	Local/County				State								Federal						
Technology-Based Alternatives	Conservation Commissions	Local Harbormasters	Local Waterways Divisions	Cape Cod Commission	DEP Wetlands & Waterways Div.	DEP Chap. 91 Waterways Div.	DEP/Water Quality Div.	MA Coastal Zone Management (CZM)	MA Environ. Policy Act Unit (MEPA)	MA Natural Heritage & Endangered Species Prog. (NHESP)	MA Div. of Marine Fisheries (DMF)	MA Bureau of Underwater Archaeology (BUAR)	US Army Corps of Engineers (USACE)	Cape Cod National Seashore (CCNS)	NOAA National Marine Fisheries Service (NMFS)	NOAA National Marine Fisheries Service Endangered Species Program (ESP)	US Coast Guard (USCG)	US Federal Avaiation Administration (FAA)	US Environmental Protection Agency (EPA)
Visual Detection (planes, helicopters)																		√	
Visual Detection (tower-based lull)	√				√			√	√	√				√		√		√	
Visual Detection (balloons)	√				√					√				√		√		√	
Visual Detection (drones)	√				√					√				√		√		√	
Visual Detection (tethered drones)	√				√					√				√		√		√	
Bottom-mounted sonar (buoy, real time alert)	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√
Electromagnetic (active, wearable/mountable)											√				√				
Magnetic (passive, wearable/mountable)											√				√				
Adaptive Camouflage																			
Barrier-Based Alternatives																			
Electromagnetic deterrents	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√
Acoustic Barrier	√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√		√
Biological-Based Alternatives																			
Scent/Smell											√			√	√				
Modify Human Behavior - Avoid water activities																			

7.7 CONSIDERATIONS AND NEXT STEPS

Communities choosing to further evaluate various shark mitigation alternatives and strategies should take into consider the following:

- No single alternative or suite of alternatives that can 100% guarantee the safety of individuals who choose to enter the water.
- Since no mitigation alternative can provide 100% safety, reducing the chances of unprovoked attacks on humans requires a strong commitment to education and outreach, which can result in the adoption of behaviors that may reduce the risk of an unprovoked shark-human interaction.
- If water activities are avoided, the risk of attack is effectively eliminated.
- If water activities are not avoided and best management practices and *Shark Smart Behaviors* are widely adopted, the risk of attack may be reduced, but not eliminated.
- All individuals choosing to engage in water activities should think carefully about the level of risk associated with their preferred activity, and be comfortable with that level of risk before choosing to enter the water.
- The decision to enter the water and assume the risk of shark-human interaction is made at the sole discretion of the individual.
- Continue to exercise a regional approach when considering shark mitigation alternatives and strategies – the most effective measures will likely be regional in nature.
- Continue to deploy *immediately actionable items* that require limited permitting and/or legislative approval and that provide immediate benefit in the event of an incident.
- Investing in alternatives or strategies that may not be permittable given current regulations, may be exceedingly expensive, may have high levels of adverse environmental or human impacts, or may not be effective at mitigating shark-human interaction may not allow the region to achieve desired outcomes.
- Carefully consider the liabilities associated with the deployment of various mitigation alternatives and strategies. Once an alternative or strategy has been implemented, it may not be easily removed.
- Expand stakeholder engagement efforts to ensure all user groups are informed of regional public safety efforts and considerations.
- If and/or when a preferred alternative is identified, conduct a site-specific feasibility assessment prior to implementation to evaluate, at a minimum, whether the preferred alternative:
    - Can be deployed in the preferred location;
    - Will remain resilient to site-specific environmental and marine conditions;
    - Can be permitted in the preferred location;
    - Will have site-specific environmental impacts;
    - Will have site-specific adverse human impacts;
    - Will be effective in the preferred location.

- If and/or when a preferred alternative is deployed, avoid fostering a false sense of security by communicating directly with beachgoers about the ongoing risk and uncertainty associated with water activities.
- If and/or when an alternative is deployed, implement a monitoring plan to gauge relative effectiveness and performance compared to expectations. Each alternative should have clearly defined performance criteria and expected budgets that provide the basis to measure success.

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1.0 Appendix A

Kick-Off Meeting Agenda

Woods Hole Group – Shark Mitigation Alternatives Analysis – February 13, 2019

Introductions and Understanding

- Woods Hole Group – Local Knowledge, Global Experience. Why Woods Hole Group?

Project History

- Attendance at public forums
- Meetings with Municipal Officials, DMF, AWSC, RSWG, Request for Proposal

Consistent Messaging

- Working with the Press and regional Stakeholders

Initial Assessment and Immediately Actionable Items

- <u>There are no silver bullet solutions</u>.
- Most effective solution(s) will be regional in nature, incorporate stakeholder engagement, will have a foundation in the science behind the local shark population and consider local environmental conditions.
- Several actionable items that do not require legislative approval could be deployed in 2019 (a regional approach, improved communications, expanded lifeguarding, improved response, education, outreach, and "stop-the-bleed" trainings).
- Additional research is required prior to the deployment of any technology-, barrier-, or biologically-based shark mitigation strategy.

Review Proposed Scope of Work (See attached Proposal)

- Review Timeline for Deliverables, method of invoicing

Review of Short and Long-Term Alternatives

- Immediately Actionable Alternatives (2019)
    - Regional stakeholder engagement
    - Improved communication
    - Expanded lifeguarding
    - Education and Outreach
    - First Aid "Stop the Bleed" Trainings
- **Technology Based Monitoring**
    - Tagging (Acoustic & Satellite)
    - Drones, Balloons, Spotters
    - Remote Detection (Sonar, Buoys, Alert Systems, etc.)
- **Barrier Systems**
    - Nets or Hard-Mesh
    - Bubble 'Nets', Kelp Forests
- **Biological Controls**
    - Culling, Indigenous Harvesting
    - Seal Contraceptive
    - (Smart) Drum Lines

Expand scope to include additional alternatives?

2.0 Appendix B

WOODS HOLE GROUP
FOR EARTH, FROM SPACE
A CLS COMPANY

Update Meeting Agenda

Shark Mitigation Alternatives Analysis - July 1, 2019

Project Update

- **Meetings and Project Coordination**
  - Conducted formal review of project deliverables with Municipal and NPS leadership.
- **Task 2 – Research and Data Collection**
  - Completed literature and product review of technology, barrier, and biological based alternatives.
  - Reviewed immediately actionable steps municipalities are taking in 2019.
  - Met with Kim Wolfenden, Shark Mitigation Strategy, NSW, Australia.
  - Facilitated round-table discussion with local scientific community (DMF, NOAA, CCS, WHOI).
  - Facilitated conference call with state, and federal permitting agencies (DMF, DEP, CZM, NHESP, EPA, ACOE, NPS, NOAA).
- **Task 3 – Alternatives Analysis**
  - Developed evaluation criteria to assess alternatives within context of oceans, bays, and estuaries.
  - Developed draft alternatives analysis matrix.

Review Mitigation Strategies (28 total)

- **Technology-Based Alternatives:** Tagging (Acoustic & Satellite); Visual Detection (Planes, Drones, Balloons, Spotters); Remote Detection (Buoy-based sonar); (Electro)Magnetic Deterrent(s) (Wearable Tech, Surfboard-Mounted); Adaptive Camouflage (board stripes, wetsuits)
- **Barrier-Based Alternatives:** Rigid Plastic Nets; Flexible Nets; Semi-Rigid Nets; Bubble Curtains; Live Kelp; Simulated Kelp Forests; Electrical Deterrents; Electromagnetic Deterrents; Sound Deterrents
- **Biological-Based Alternatives:** Cull Nets; (Smart) Drum Lines; Seal Culling; Seal Contraception; Indigenous Harvest; Condition Sharks (Shock); Recruit Orcas; Scent/Smell Deterrents; Modify Human Behavior

Review Evaluation Criteria (27 total)

- **Limiting Factors:** Weather, Marine Conditions, Effective Range, Effective Depth, Resilience to Storm Impacts, Commercial Availability
- **Permitting:** Permitting Complexity, Permitting Timeline
- **Costs:** Permitting Costs, Asset, Maintenance, Operational Cost to Town
- **Potential Adverse Environmental Impacts:** Bycatch, Risk of Trophic Consequence, Risk of Interference, Risk of Physical Impacts to Habitat
- **Human Impacts:** Aesthetics, Noise, Navigation, Risk of Health Impacts, Recreation
- **Effectiveness:** Percent time covered, Reduce Shark-Human Interaction, Documented Effectiveness

Review Draft Alternatives Analysis Matrices

- Means and Methods
- Interpreting Results

Consistent Messaging

- How best to present results to public?
- Press ←→ Regional Stakeholders

Questions, Comments, Discussion

3.0 Appendix C

Shark Mitigation Alternatives Analysis
Update Meeting
July 1, 2019

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Note: Photos Removed to Protect Copyright

Project Update – Spring 2019

Meetings and Project Coordination

- Conducted formal review of project deliverables with Municipal and NPS leadership.

Task 2 – Research and Data Collection

- Completed literature and product review of technology, barrier, and biological based alternatives.
- Reviewed immediately actionable steps municipalities are taking in 2019.
- Met with Kim Wolfenden, Shark Mitigation Strategy, NSW, Australia.
- Facilitated round-table discussion with local scientific community (DMF, NOAA, CCS, WHOI).
- Facilitated conference call with state, and federal permitting agencies (DMF, DEP, CZM, NHESP, EPA, ACOE, NPS, NOAA).
- Attended Stop the Bleed Training, Wellfleet Fire Department.

Task 3 – Alternatives Analysis

- Developed evaluation criteria (27) to assess alternatives (28) within context of oceans, bays, and estuaries.
- Developed draft alternatives analysis matrices.

Task 1 – Data Collection - Consider Alternatives within Context of:

Development of Evaluation Criteria

- Limiting Factors
- Permitting
- Costs
- Potential Adverse Environmental Impacts
- Human Impacts
- Effectiveness

Technology-based Alternatives

- **Tagging** (Acoustic & Satellite, Real-Time Alert)
- **Visual Detection** (Planes, Drones, Balloons, Towers)
- **Remote Detection** (Bottom-Mounted Sonar, Real-Time Alert)
- **Wearable Technologies** (Adaptive Camouflage, (Electro) Magnetic Deterrents, etc.)

Tagging - (Acoustic, Satellite, Real-Time Alert)

- **Limiting Factors** – Resilient to weather, marine conditions, regional range, full water column coverage, resilient to storm impacts, commercially available.
- **Permitting –** Low permitting complexity, short permitting timeline, low permitting costs.
- **Costs -** $42.5K per real-time buoy ($6.5k asset; $26k maint.; $10k deploy – recover).
- **Potential Adverse Environmental Impacts –** Low
- **Human Impacts** – Low
- **Level of Effectiveness** – Small percentage of population tagged, must be in close proximity to buoy, detection only, does not limit shark – human interaction.

Visual Detection - (Drones, Balloons, Spotter Planes)

- **Limiting Factors** – Highly sensitive to weather and marine conditions (fog, sun angle, wind, rain, waves, turbidity, etc.), local – regional range, effective to 2.5m depth, resilient to storms (removable), commercially available.
- **Permitting –** Medium permitting complexity, medium permitting timeline, medium costs.
- **Costs –** Per beach/per season: $30k plane, $250k balloon, $500k drone, 100k boom.
- **Potential Adverse Environmental Impacts –** Low – Medium (Shorebirds)
- **Human Impacts** – Medium – Low (aesthetics, noise, recreation)
- **Level of Effectiveness** – Coverage period from <10% (planes) to >95% (drones, balloons, boom), low percentage of sharks detected, does not limit shark – human interaction.

Remote Detection - (Bottom-mounted sonar, buoy, alert)

- **Limiting Factors** – Not sensitive to weather, highly sensitive to tides, sediment transport, waves, bubble fraction, local range, full water column coverage, low resilience to storm impacts, commercially available.
- **Permitting –** Medium permitting complexity, medium permitting timeline, medium cost.
- **Costs -** $255k per beach (lease equipment, $225k operational, $30k maint.)
- **Potential Adverse Environmental Impacts –** Low **–** Possible impacts to benthos
- **Human Impacts** – Medium – Low (cuts, abrasions, impacts to navigation)
- **Level of Effectiveness** – Up to 95% time covered, detection-based, low levels of documented effectiveness, does not limit shark-human interaction.

Wearable Technologies - ((Electro)Magnetic, Magnetic, Camo)

- **Limiting Factors** – Not sensitive to weather or marine conditions, limited range, operates independent of depth, commercially available.
- **Permitting –** Not Applicable
- **Costs – $**100 – 500 per unit (no cost to Town)
- **Potential Adverse Environmental Impacts –** None
- **Human Impacts** – Medium – (possible pacemaker interference)
- **Level of Effectiveness** – Covered up to 100% of the time, deterrent technology, low levels of documented effectiveness, may have limited effect on shark-human interaction.

Barrier-based Alternatives

- **Rigid Plastic Mesh**
- **Semi-Rigid Nets**
- **Bubble Curtains**
- **Electrical/Magnetic Barriers**
- **(Simulated) Kelp Forests**
- **Acoustic Barriers**

<u>Physical Barriers</u> – Rigid Plastic Mesh, Semi-Rigid Mesh

- **Limiting Factors** – Not sensitive to weather, sensitive to waves and currents, local range, covers full water column, low-medium resilience to storms, commercially available.
- **Permitting –** High permitting complexity, long timeline, high cost.
- **Costs –** $300k **-** $350K per 100m beach per season.
- **Potential Adverse Environmental Impacts –** High (nets, piles, cables), risk of entanglement, trophic consequence.
- **Human Impacts** – Medium (aesthetics, impacts to navigation, abrasions, entablement)
- **Level of Effectiveness** – Covered up to 100% of the time, physical barrier, high levels of documented effectiveness.

Visual/Sensory Barrier – Bubble Curtains

- **Limiting Factors** – Not sensitive to weather, sensitive to marine conditions, waves, currents, sediment transport, local range, covers full water column, low resilience to storm impacts, not commercially available.
- **Permitting –** Medium permitting complexity, medium timeline, medium cost.
- **Costs –** $425k per 100m beach per season
- **Potential Adverse Environmental Impacts –** Medium (impacts to benthos, bottom cables, anchors, etc.)
- **Human Impacts** – Medium (aesthetics, noise (compressor), recreation)
- **Level of Effectiveness** – Covered up to 100% of the time, visual/sensory deterrent only, does not limit shark-human interaction, low levels of documented effectiveness.

Visual/Sensory Barrier – Live Kelp

- **Limiting Factors** – Not sensitive to weather, sensitive to marine conditions, waves, currents, local range, covers part of water column, limited resilience to storms, not commercially available.
- **Permitting –** Medium permitting complexity, medium timeline, medium cost.
- **Costs –** $60k per 100m beach per season
- **Potential Adverse Environmental Impacts –** Medium-low (numerous floats, cables, no gear in water column)
- **Human Impacts** – Low
- **Level of Effectiveness** – Covered up to 100% of the time, deterrent, does not limit shark-human interaction, medium-low levels of documented effectiveness.

Sensory Barrier – Electrical Deterrent Cable

- **Limiting Factors** – Not sensitive to weather, sensitive to marine conditions, waves, currents, sediment transport, local range, covers full water column, moderate resilience to storms, commercially available.
- **Permitting –** High permitting complexity, long timeline, high cost.
- **Costs –** $425k per 100m beach per season
- **Potential Adverse Environmental Impacts –** Medium (entanglement, anchors in benthos, full vertical array)
- **Human Impacts** – Medium (aesthetics, navigation, recreation, pacemaker interference)
- **Level of Effectiveness** – Covered up to 100% of the time, deterrent, may limit shark-human interaction, medium-low levels of documented effectiveness.

Sensory Barrier – Magnetic / Electromagnetic

- **Limiting Factors** – Not sensitive to weather, sensitive to marine conditions, waves, currents, sediment transport, local range, covers full water column, moserate resilience to storm impacts, commercially available.
- **Permitting –** Medium permitting complexity, medium timeline, medium cost.
- **Costs –** $175k per 100m beach per season
- **Potential Adverse Environmental Impacts –** Low (limited gear in water column)
- **Human Impacts** – Medium (aesthetics, navigation, recreation)
- **Level of Effectiveness** – Covered up to 100% of the time, deterrent, may limit shark-human interaction, medium-low levels of documented effectiveness.

Sensory Barrier – Magnetic Fields / Artificial Kelp

- **Limiting Factors** – Not sensitive to weather, sensitive to marine conditions, waves, currents, local range, covers full water column, moderate resilience to storm impacts, commercially available.
- **Permitting –** High permitting complexity, long timeline, high cost.
- **Costs –** $825k per 100m beach per season
- **Potential Adverse Environmental Impacts –** Medium-high (numerous anchors, moorings, gear to support vertical array in water column)
- **Human Impacts** – Medium (aesthetics, navigation, recreation, abrasions, pacemaker risk)
- **Level of Effectiveness** – Covered up to 100% of the time, deterrent, may limit shark-human interaction, higher levels of documented effectiveness.

Acoustic Barrier - (Pingers, etc.)

- **Limiting Factors** – Not sensitive to weather, sensitive to marine conditions, waves, currents, local range, covers full water column, moderate resilience to storm impacts, commercially available.
- **Permitting –** High permitting complexity, long timeline, high cost (MMPA).
- **Costs –** $200k per 100m beach per season; exceeding $1M depending on features
- **Potential Adverse Environmental Impacts –** Medium (anchors, piles, cables)
- **Human Impacts** – Medium (aesthetics, noise)
- **Level of Effectiveness** – Covered up to 100% of the time, deterrent, may limit shark-human interaction, low levels of documented effectiveness.

Biological-based Alternatives

- **Shark Cull Net / (Smart) Drum Lines**
- **Seal Culling**
- **Seal Contraception**
- **Indigenous Harvest**
- **Modify Shark Behavior (Electric Shock)**
- **Scent/Smell Deterrent**
- **Recruit Orcas**
- **Modify Human Behavior**

Biological Control – Shark Cull Net / (Smart) Drum Lines

- **Limiting Factors** – Not sensitive to weather, sensitive to marine conditions, waves, currents, regional range, covers full water column, moderate resilience to storms, commercially available.
- **Permitting –** Not currently permittable, long timeline and costly to pursue exemption.
- **Costs –** $120k per net per beach; $110k per drum line (deploy and recover, bait, maintain)
- **Potential Adverse Environmental Impacts –** Very High (bycatch, entanglement, risk of trophic cascade, impacts to habitat)
- **Human Impacts** – Medium-low (aesthetics, navigation, abrasions)
- **Level of Effectiveness** – Covered 50-100% of the time, predator reduction does not significantly limit shark-human interaction, low levels of documented effectiveness.

Biological Control – Seal Culling / Contraception / Indigenous Harvest

- **Limiting Factors** – Not sensitive to weather, not sensitive to marine conditions, regional range, independent of depth, resilient to storm impacts, commercially available.
- **Permitting –** Not currently permittable, long timeline and costly to pursue exemption.
- **Costs –** Culling, $225k per beach; Contraception $1.7M per beach; indigenous harvest no cost to Town.
- **Potential Adverse Environmental Impacts –** Medium-high (risk of trophic cascade, possible impacts to shorebirds)
- **Human Impacts** – Low
- **Level of Effectiveness** – Covered <5% of the time (rapid repopulation), predator reduction does not significantly limit shark-human interaction, low levels of documented effectiveness.

Biological Control – Train Sharks – Electric Shock

- **Limiting Factors** – Not sensitive to weather, sensitive to marine conditions, waves, currents, local range, independent of depth, moderate resilience to storm impacts not commercially available.
- **Permitting –** Not currently permittable, long timeline and costly to pursue exemption.
- **Costs –** $110K per deployment
- **Potential Adverse Environmental Impacts –** Medium-high (risk of trophic cascade, possible impacts to shorebirds, benthos)
- **Human Impacts** – Low
- **Level of Effectiveness** – Covered <5% of the time, deterrent, no data regarding documented effectiveness.

Biological Control – Scent/Smell

- **Limiting Factors** – Not sensitive to weather, sensitive to marine conditions, waves, currents, local range, independent of depth, low resilience to storm impacts not commercially available.
- **Permitting –** Medium permitting complexity, permitting timeline, and permitting costs.
- **Costs –** $110K per deployment
- **Potential Adverse Environmental Impacts –** Medium-high (risk of interference with habitat use, impacts to benthos)
- **Human Impacts** – Low
- **Level of Effectiveness** – Covered <50% of the time, deterrent, does not limit shark-human interaction, low levels of documented effectiveness.

Biological Control – Scent/Smell

- **Limiting Factors** – Not sensitive to weather, not sensitive to marine conditions, regional range, independent of depth, not commercially available.
- **Permitting –** Not currently permittable, long timeline and costly to pursue exemption.
- **Costs –** Very Costly
- **Potential Adverse Environmental Impacts –** Medium-high (risk of trophic consequence, interference with habitat use)
- **Human Impacts** – Low
- **Level of Effectiveness** – Covered <5% of the time, predator reduction, does not significantly limit shark-human interaction, no data regarding effectiveness.

Modify Human Behavior – Avoid Water Activities

- **Limiting Factors** – Not sensitive to weather, not sensitive to marine conditions, regional range, covers full water column.
- **Permitting –** Not applicable
- **Costs –** $20k per beach (signage, educational materials)
- **Potential Adverse Environmental Impacts –** None
- **Human Impacts** – Low (recreation)
- **Level of Effectiveness** – Covered 100% of the time, physical barrier(+), limits all shark-human interaction, high levels of documented effectiveness.

Task 3: Alternatives Analysis Means and Methods

1. <u>Development of Evaluation Criteria</u>

- **Limiting Factors:** Weather, Marine Conditions, Effective Range, Effective Depth, Resilience to Storm Impacts, Commercial Availability
- **Permitting:** Permitting Complexity, Permitting Timeline
- **Costs:** Permitting Costs, Asset, Maintenance, Operational Cost to Town
- **Potential Adverse Environmental Impacts:** Bycatch, Risk of Trophic Consequence, Risk of Interference, Risk of Physical Impacts to Habitat
- **Human Impacts:** Aesthetics, Noise, Navigation, Risk of Health Impacts, Recreation
- **Effectiveness:** Percent time covered, Reduce Shark-Human Interaction, Documented Effectiveness

2. <u>Consider Each Alternative within Context of Siting Criteria</u>

- Wind Climate, Wave Climate, Sediment Transport, Turbidity, Tides
- <u>OCEAN</u>: High energy wave environment, high rates of sediment transport, moderate tidal range, cold temperatures, direct exposure to storm impacts, deeper near shore waters, strong currents
- <u>BAY</u>: Moderate wave energy environment, moderate rates of sediment transport and turbidity, high tidal range, warm temperatures, indirect exposure to storm impacts, shallower near shore waters, moderate currents
- <u>ESTUARINE</u>: Low wave energy environment, low rates of sediment transport, low tidal range, warm temperatures, sheltered from storm impacts, shallow near shore waters, low currents

Alternative Analysis Means and Methods

3. Eliminate Alternatives that do not Satisfy Siting Criteria

- OCEAN: Rigid Plastic Mesh; Bubble Curtains; Live Kelp eliminated
- BAY: Bottom-Mounted Sonar; Rigid Plastic Mesh; Live Kelp; Simulated Kelp Forests; Electrical Deterrents; Electromagnetic Deterrents eliminated
- ESTUARINE: Simulated Kelp Forests; Recruit Orcas eliminated

↓

4. **Weigh Remaining Alternatives Against Each Evaluation Criteria**

↓

5. Apply Numerical Score to Each Answer

↓

6. Standardize Weight Across Categories of Evaluation Criteria

↓

7. Analyze and Interpret Results

Ocean Matrix

OCEAN: High energy wave environment, high rates of sediment transport, moderate tidal range, cold temperatures, direct exposure to storm impacts, deeper near shore waters, strong currents	Limiting Factors							Permitting			Costs						Potential Adverse Env. Impacts					Human Impacts						Effectiveness			
	Weather	Marine Conditions	Effective Range	Effective Depth	Resilience to Storm Impacts	Commercial Availability	Category Score	Permitting Complexity	Permitting Timeline	Category Score	Permitting Costs	Asset Cost	Maintenance Cost	Operating Cost	Asset, Maint., Op. Cost to Town	Category Score	Bycatch	Risk of trophic consequence	Risk of Interference	Risk of Physical Impact to Habitat	Category Score	Aesthetics	Noise	Navigation	Risk of Health Impact	Recreation	Category Score	% Time Covered	Shark/Human Interaction	Documented Effectiveness	Category Score
Technology-Based Alternatives:																															
Tagging (Acoustic, real time alert)	Not sensitive	Not sensitive	Regional	Full water column	Medium	Yes	High	L	S	High	L	$6,500	$26,000	K/day for the	$42,500	Med-High	Low	No	No	Low - anchor	High	Very Low	None	Low	None	No	High	<5%, only tagged sharks and shark must be within 300m-500m of one of the buoys	Detection	Low	Low
Tagging (Satellite, real time alert)	Not sensitive	Not sensitive	Regional	Surface only	High	Yes	High	L	S	High	L	n does not i	0	S: $12/mont	$0	Med-High	None	No	No	None	High	None	None	None	None	No	High	<1%, only tagged sharks and shark must be on the surface long enough to establish a satellite link	Detection	Low	Low
Visual Detection (planes, helicopters)	Highly sensitive to fog, sun angle, rain; wind	Highly sensitive to waves, turbidity, bubble fraction	Regional	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	N/A (leased)	N/A (leased)	12,800-$28,50	$28,500	Med-High	None	No	No	None	High	Low	Medium	None	None	No	High	1%-10% (as long as you want/can afford, patrolling, so not normally over any one particular beach)	Detection	Med-Low	Med Low
Visual Detection (tower-based lull)	Highly sensitive to fog, sun angle, rain	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	50,000-$75,00	$10,000	$12,000	$97,000	Med-High	None	No	No	None	High	Low	Low	None	None	No	High	95% (as long as you want/can afford)	Detection	Med-Low	Med
Visual Detection (balloons)	Highly sensitive to fog, sun angle, rain, wind	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	N/A (leased)	N/A (leased)	$250,000	$250,000	Med Low	None	No	Yes - shorebirds	None	High	Low	None	None	None	Yes	Med-High	95% (as long as you want/can afford)	Detection	Med-Low	Med
Visual Detection (drones)	Highly sensitive to fog, sun angle, rain, wind	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	N/A (leased)	N/A (leased)	$500,000	$500,000	Med Low	None	No	Yes - shorebirds	None	High	Medium	High	None	None	Yes	Med Low	70% (as long as you want/can afford, but you can only remain in the air in 20 minute increments)	Detection	Med-Low	Med
Visual Detection (tethered drones)	Highly sensitive to fog, sun angle, rain, wind	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med	M	M	Med	M	0,000-$100,0	$10,000	$12,000	$122,000	Med	None	No	Yes - shorebirds	None	High	Medium	High	None	None	Yes	Med Low	95% (as long as you want/can afford)	Detection	Med-Low	Med
Bottom-mounted sonar (buoy, real time alert)	Not sensitive	Highly sensitive to tides, sediment transport; Sensitive to waves, bubble fraction	Local - Beach	Full water column	Low	Yes	Med	M	M	Med	M	N/A (leased)	$30,000	$225,000	$255,000	Med Low	Low	No	No	Medium - anchors, piles, cables	High	Medium	None	Medium	Low - abrasions, cuts	No	Med-High	95%	Detection	Low	
Electromagnetic (active, wearable/mountable)	Not sensitive	Not sensitive	Personal	Independent of depth	N/A	Yes	Med-High	N/A	N/A	High	N/A	$500/each	N/A	N/A	$0	High	None	No	No	None	High	None	None	None	Low - pacemaker interference	No	High	100% (continuously while in water)	Deterrent	Low	Med Low
Magnetic (passive, wearable/mountable)	Not sensitive	Not sensitive	Personal	Independent of depth	N/A	Yes	Med-High	N/A	N/A	High	N/A	$100/each	N/A	N/A	$0	High	None	No	No	None	High	None	None	None	Very Low - pacemaker interference	No	High	100% (continuously while in water)	Deterrent	Low	Med Low
Adaptive Camouflage	Not sensitive	Highly sensitive to turbidity, bubble fraction	Personal	Independent of depth	N/A	Yes	Med	N/A	N/A	High	N/A	110 for camo	N/A	N/A	$0	High	None	No	No	None	High	None	None	None	None	No	High	100% (continuously while in water)	Deterrent	Low	Med Low
Barrier-Based Alternatives:																															
Flexible net (exclusion)	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High	H	Long	Med Low	H	$50,000	$50,000	$200,000	$300,000	Low	High	Possible	Yes	High - net, piles, cables	Low	High	None	High	Medium - abrasions, cuts, entanglement	Yes	Med Low	100	Physical barrier	High	High
Semi-Rigid Net (Nylon Rope w. plastic struts and sti	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High	H	Long	Med Low	H	$100,000	$50,000	$200,000	$350,000	Low	Medium	Possible	Yes	High - net, piles, cables	Med Low	High	None	High	Medium - abrasions, cuts, entanglement	Yes	Med Low	100	Physical barrier	High	High
Simulated Kelp Forests w/ passive magnetic field	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High	H	Long	Med Low	H	$500,000	$75,000	$250,000	$825,000	Low	Medium	No	Yes	High - anchors, full vertical array	Med Low	High	None	High	High - abrasions, cuts, entanglement, pacemaker interference	Yes	Low	100	Deterrent	High	High
Electrical deterrents	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High	H	Long	Med Low	H	$100,000	$75,000	$250,000	$425,000	Low	Medium	No	Yes	High - anchors, full vertical array	Med Low	Medium	None	High	High - abrasions, cuts, entanglement, pacemaker interference, electrical current	Yes	Med Low	100	Deterrent	Med-Low	Med
Electromagnetic deterrents	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High	M	M	Med	M	$75,000	$50,000	$50,000	$175,000	Med	Low	No	Yes	High - anchors, full vertical array	Med Low	Medium	None	Medium - series of moorings	High - abrasions, cuts, entanglement, pacemaker interference	Yes	Med Low	100	Deterrent	Med-Low	Med
Acoustic Barrier	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High	H	Long	Med Low	M	$100,000	$50,000	$50,000	$200,000	Med Low	Low	Possible	Yes	Medium - anchors, piles, cables	Med Low	Medium	Possible	Medium - series of moorings	Low - moorings	No	Med	100	Deterrent	Low	Med Low
Biological-Based Alternatives:																															
Cull net	Not sensitive	Sensitive to waves, currents	Regional	Full water column	Medium	Yes	High	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$20,000	$50,000	$50,000	$120,000	Med Low	Very High	Yes	Yes	High - net, piles, cables	Low	Medium	None	Medium-High	Low - abrasions, cuts, entanglement	Yes	Med Low	100	Predator reduction	Low	Med Low
Shark Culling - Drum line	Not sensitive	Sensitive to waves, currents	Regional	Independent of depth	Medium	Yes	High	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$10,000	$50,000	$50,000	$110,000	Med Low	Very High	Yes	No	Medium	Med Low	Low	None	Low	Low - abrasions, cuts, entanglement	No	High	50	Predator reduction	Low	Low
(Smart) Drum Lines	Not sensitive	Sensitive to waves, currents	Regional	Independent of depth	Medium	Yes	High	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$10,000	$50,000	$50,000	$110,000	Med Low	Very High	Yes	No	Medium	Med Low	Low	None	Low	Low - abrasions, cuts, entanglement	No	High	50	Predator reduction	Low	Low
Seal Culling	Not sensitive	Not sensitive	Regional	Independent of depth	N/A	N/A	High	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$15,000	$105,000	$105,000	$225,000	Low	None	Yes	Possible - if on beach, shorebirds	None	Med-High	None	None	None	None	No	High	<5	Predator reduction	Low	Low
Seal Contraception	Not sensitive	Not sensitive	Regional	Independent of depth	N/A	Yes	High	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$625,000	$625,000	$35,000	$1,750,000	Low	None	Yes	Possible - if on beach, shorebirds	None	Med-High	None	None	None	None	No	High	0	Predator reduction	Low	Low
Indigenous Harvest	Not sensitive	Not sensitive	Regional	Independent of depth	N/A	N/A	High	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$0	$0	$0	$0	Med	None	Yes	Possible - if on beach, shorebirds	None	Med-High	None	None	None	None	No	High	<5	Predator reduction	Low	Low
Train Sharks – Electric shock	Not sensitive	Sensitive to waves, currents	Local - Beach	Independent of depth	Medium	No	Med	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	$10,000	$50,000	$50,000	$110,000	Med Low	Low	No	Yes	Low - anchor	Med-High	Very Low	None	Low	Low - abrasions, cuts, electric shock	No	High	50	Deterrent	No data	Med Low
Recruit Orcas	Not sensitive	Not sensitive	Regional	Independent of depth	N/A	No	High	Not Currently Permittable	Very Long - To Pursue Exemption	Low	Very High - To Pursue Exemption	Very Costly	Very Costly	Very Costly	Very Costly	Low	None	Yes	Yes	None	Med	None	None	None	None	No	High	<5	Predator reduction	No data	Low
Scent/Smell	Not sensitive	Sensitive to waves, currents	Local - Beach	Independent of depth	Low	No	Med	M	M	Med	M	$10,000	$50,000	$50,000	$110,000	Med	Low	No	Yes	Low - anchor	Med-High	Very Low	None	Low	Low - abrasions, cuts, entanglement	No	High	50	Deterrent	Low	Med Low
Modify Human Behavior - Avoid water activities	Not sensitive	Not sensitive	Regional	Full water column	N/A	N/A	High	N/A	N/A	High	N/A	$10,000	$5,000	$5,000	$20,000	High	None	No	No	None	High	None	None	None	None	Yes	High	100	Physical Barrier PLUS	High	High

Limiting Factors

OCEAN: High energy wave environment, high rates of sediment transport, moderate tidal range, cold temperatures, direct exposure to storm impacts, deeper near shore waters, strong currents	Weather	Marine Conditions	Effective Range	Effective Depth	Resilience to Storm Impacts	Commercial Availability	Category Score
Technology-Based Alternatives:							
Tagging (Acoustic, real time alert)	Not sensitive	Not sensitive	Regional	Full water column	Medium	Yes	High
Tagging (Satellite, real time alert)	Not sensitive	Not sensitive	Regional	Surface only	High	Yes	High
Visual Detection (planes, helicopters)	Highly sensitive to fog, sun angle, rain, wind	Highly sensitive to waves, turbidity, bubble fraction	Regional	Within ~2.5m of surface	Removable	Yes	Med
Visual Detection (tower-based lull)	Highly sensitive to fog, sun angle, rain	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med
Visual Detection (balloons)	Highly sensitive to fog, sun angle, rain, wind	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med
Visual Detection (drones)	Highly sensitive to fog, sun angle, rain, wind	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med
Visual Detection (tethered drones)	Highly sensitive to fog, sun angle, rain, wind	Highly sensitive to waves, turbidity, bubble fraction	Local - Beach	Within ~2.5m of surface	Removable	Yes	Med
Bottom-mounted sonar (buoy, real time alert)	Not sensitive	Highly sensitive to tides, sediment transport; Sensitive to waves, bubble fraction	Local - Beach	Full water column	Low	Yes	Med
Electromagnetic (active, wearable/mountable)	Not sensitive	Not sensitive	Personal	Independent of depth	N/A	Yes	Med-High
Magnetic (passive, wearable/mountable)	Not sensitive	Not sensitive	Personal	Independent of depth	N/A	Yes	Med-High
Adaptive Camouflage	Not sensitive	Highly sensitive to turbidity, bubble fraction	Personal	Independent of depth	N/A	Yes	Med
Barrier-Based Alternatives:							
Flexible net (exclusion)	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High
Semi-Rigid Net (Nylon Rope w. plastic strands and	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High
Simulated Kelp Forests w/ passive magnetic field	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High
Electrical deterrents	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High
Electromagnetic deterrents	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High
Acoustic Barrier	Not sensitive	Sensitive to waves, currents	Local - Beach	Full water column	Medium	Yes	Med-High
Biological-Based Alternatives:							
Cull net	Not sensitive	Sensitive to waves, currents	Regional	Full water column	Medium	Yes	High
Shark Culling - Drum line	Not sensitive	Sensitive to waves, currents	Regional	Independent of depth	Medium	Yes	High
(Smart) Drum Lines	Not sensitive	Sensitive to waves, currents	Regional	Independent of depth	Medium	Yes	High
Seal Culling	Not sensitive	Not sensitive	Regional	Independent of depth	N/A	N/A	High
Seal Contraception	Not sensitive	Not sensitive	Regional	Independent of depth	N/A	Yes	High
Indigenous Harvest	Not sensitive	Not sensitive	Regional	Independent of depth	N/A	N/A	High
Train Sharks - Electric shock	Not sensitive	Sensitive to waves, currents	Local - Beach	Independent of depth	Medium	No	Med
Recruit Orcas	Not sensitive	Not sensitive	Regional	Independent of depth	N/A	No	High
Scent/Smell	Not sensitive	Sensitive to waves, currents	Local - Beach	Independent of depth	Low	No	Med
Modify Human Behavior - Avoid water activities	Not sensitive	Not sensitive	Regional	Full water column	N/A	N/A	High

Permitting

Permitting Complexity	Permitting Timeline	Category Score
L	S	High
L	S	High
M	M	Med
M	M	Med
M	M	Med
M	M	Med
M	M	Med
M	M	Med
N/A	N/A	High
N/A	N/A	High
N/A	N/A	High
H	Long	Med/Low
H	Long	Med/Low
H	Long	Med/Low
H	Long	Med/Low
M	M	Med
H	Long	Med/Low
Not Currently Permittable	Very Long - To Pursue Exemption	Low
Not Currently Permittable	Very Long - To Pursue Exemption	Low
Not Currently Permittable	Very Long - To Pursue Exemption	Low
Not Currently Permittable	Very Long - To Pursue Exemption	Low
Not Currently Permittable	Very Long - To Pursue Exemption	Low
Not Currently Permittable	Very Long - To Pursue Exemption	Low
Not Currently Permittable	Very Long - To Pursue Exemption	Low
Not Currently Permittable	Very Long - To Pursue Exemption	Low
M	M	Med
N/A	N/A	High

Costs

Permitting Costs	Asset Cost	Maintenance Cost	Operating Cost	Asset, Maint., Op. Cost to To	Category Score
L	$6,500	$26,000	[illegible]	$42,500	Med-High
L	[illegible]	0	ICS: $12/m[illegible]	$0	Med-High
M	N/A (leased)	N/A (leased)	$2,000-$20,[illegible]	$20,500	Med-High
M	[illegible],000-$75,[illegible]	$10,000	$12,000	$97,000	Med-High
M	N/A (leased)	N/A (leased)	$250,000	$250,000	Med-Low
M	N/A (leased)	N/A (leased)	$500,000	$500,000	Med-Low
M	[illegible],000-$100,[illegible]	$10,000	$12,000	$122,000	Med
M	N/A (leased)	$30,000	$225,000	$255,000	Med-Low
N/A	$500/each	N/A	N/A	$0	High
N/A	$100/each	N/A	N/A	$0	High
N/A	$10 for [illegible]	N/A	N/A	$0	High
H	$50,000	$50,000	$200,000	$300,000	Low
H	$100,000	$50,000	$200,000	$350,000	Low
H	$500,000	$75,000	$250,000	$825,000	Low
H	$100,000	$75,000	$250,000	$425,000	Low
M	$75,000	$50,000	$50,000	$175,000	Med
M	$100,000	$50,000	$50,000	$200,000	Med-Low
Very High - To Pursue Exemption	$20,000	$50,000	$50,000	$120,000	Med-Low
Very High - To Pursue Exemption	$10,000	$50,000	$50,000	$110,000	Med-Low
Very High - To Pursue Exemption	$10,000	$50,000	$50,000	$110,000	Med-Low
Very High - To Pursue Exemption	$15,000	$105,000	$105,000	$225,000	Low
Very High - To Pursue Exemption	$625,000	$625,000	$95,000	$1,250,000	Low
Very High - To Pursue Exemption	$0	$0	$0	$0	Med
Very High - To Pursue Exemption	$10,000	$50,000	$50,000	$110,000	Med-Low
Very High - To Pursue Exemption	Very Costly	Very Costly	Very Costly	Very Costly	Low
M	$10,000	$50,000	$50,000	$110,000	Med
N/A	$10,000	$5,000	$5,000	$20,000	High

# Potential Adverse Environmental impacts	# Potential Adverse Human Impacts	# Documented Effectiveness

Potential Adverse Env. Impacts

*CCAM: High energy wave environment, high rates of sediment transport, moderate tidal range, cold temperatures, diurnal exposure to storm impacts, deeper nearshore waters, strong currents	Bycatch	Risk of trophic consequence	Risk of Interference	Risk of Physical Impact to Hab	Category Score
Technology-Based Alternatives:					
Tagging (Acoustic, real time alert)	Low	No	No	Low - anchor	High
Tagging (Satellite, real time alert)	None	No	No	None	High
Visual Detection (planes, helicopters)	None	No	No	None	High
Visual Detection (tower-based/lifeguards)	None	No	No	None	High
Visual Detection (balloons)	None	No	Yes - shorebirds	None	High
Visual Detection (drones)	None	No	Yes - shorebirds	None	High
Visual Detection (tethered drones)	None	No	Yes - shorebirds	None	High
Bottom-mounted sonar (buoy, real time alert)	Low	No	No	Medium - anchors, piles, cables	High
Electromagnetic (active, wearable/moveable)	None	No	No	None	High
Magnetic (passive, wearable/moveable)	None	No	No	None	High
Adaptive Camouflage	None	No	No	None	High
Barrier-Based Alternatives:					
Flexible net (exclusion)	High	Possible	Yes	High - net, piles, cables	Low
Semi-Rigid Net (Nylon Rope w. plastic struts and	Medium	Possible	Yes	High - net, piles, cables	Med Low
Simulated Kelp Forests of passive magnetic fiel	Medium	No	Yes	High - anchors, full sectional area	Med Low
Electrical deterrents	Medium	No	Yes	High - anchors, full sectional area	Med Low
Electromagnetic deterrents	Low	No	Yes	High - anchors, full sectional area	Med Low
Acoustic Barrier	Low	Possible	Yes	Medium - anchors, piles, cables	Med Low
Biological-Based Alternatives:					
Culling	Very High	Yes	Yes	High - net, piles, cables	Low
Shark Culling - Drum line	Very High	Yes	No	Medium	Med Low
(Smart) Drum Lines	Very High	Yes	No	Medium	Med Low
Seal Culling	None	Yes	Possible - if on beach, shorebirds	None	Med-High
Seal Contraception	None	Yes	Possible - if on beach, shorebirds	None	Med-High
Indigenous Harvest	None	Yes	Possible - if on beach, shorebirds	None	Med-High
Toxic Sharks - Electric shock	Low	No	Yes	Low - anchor	Med-High
Present Orcas	None	Yes	Yes	None	Med
Scent/Smell	Low	No	Yes	Low - anchor	Med-High
Modify Human Behavior - Avoid water activities	None	No	No	None	High

Human Impacts

Aesthetics	Noise	Navigation	Risk of Health Impact	Recreation	Category Score
Very Low	None	Low	None	No	High
None	None	None	None	No	High
Low	Medium	None	None	No	High
Low	Low	None	None	No	High
Low	None	None	None	Yes	Med-High
Medium	High	None	None	Yes	Med Low
Medium	High	None	None	Yes	Med Low
Medium	None	Medium	Low - abrasions, cuts	No	Med-High
None	None	None	Low - pacemaker interference	No	High
None	None	None	Very Low - pacemaker interference	No	High
None	None	None	None	No	High
High	None	High	Medium - abrasions, cuts, entanglement	Yes	Med Low
High	None	High	Medium - abrasions, cuts, entanglement	Yes	Med Low
High	None	High	High - abrasions, cuts, entanglement, pacemaker interference	Yes	Low
Medium	None	High	High - abrasions, cuts, entanglement, pacemaker interference, electrical current	Yes	Med Low
Medium	None	Medium - series of moorings	High - abrasions, cuts, entanglement, pacemaker interference	Yes	Med Low
Medium	Possible	Medium - series of moorings	Low - moorings	No	Med
Medium	None	Medium-High	Low - abrasions, cuts, entanglement	Yes	Med Low
Low	None	Low	Low - abrasions, cuts, entanglement	No	High
Low	None	Low	Low - abrasions, cuts, entanglement	No	High
None	None	None	None	No	High
None	None	None	None	No	High
None	None	None	None	No	High
Very Low	None	Low	Low - abrasions, cuts, electric shock	No	High
None	None	None	None	No	High
Very Low	None	Low	Low - abrasions, cuts, entanglement	No	High
None	None	None	None	Yes	High

Effectiveness

% Time Covered	Shark/Human Interaction	Documented Effectiveness	Category Score
<5%, only tagged sharks and shark must be within 300m-500m of one of the buoys	Detection	Low	Low
<1%, only tagged sharks and shark must be on the surface long enough to establish a satellite link	Detection	Low	Low
1%-10% (as long as you want/can afford, patrolling, so not normally over any one particular beach)	Detection	Med-Low	Med Low
95% (as long as you want/can afford)	Detection	Med-Low	Med
95% (as long as you want/can afford)	Detection	Med-Low	Med
70% (as long as you want/can afford, but you can only remain in the air in 20 minute increments)	Detection	Med-Low	Med
95% (as long as you want/can afford)	Detection	Med-Low	Med
95%	Detection	Low	
100% (continuously while in water)	Deterrent	Low	Med Low
100% (continuously while in water)	Deterrent	Low	Med Low
100% (continuously while in water)	Deterrent	Low	Med Low
100	Physical barrier	High	High
100	Physical barrier	High	High
100	Deterrent	High	High
100	Deterrent	Med-Low	Med
100	Deterrent	Med-Low	Med
100	Deterrent	Low	Med Low
100	Predator reduction	Low	Med Low
50	Predator reduction	Low	Low
50	Predator reduction	Low	Low
<5	Predator reduction	Low	Low
0	Predator reduction	Low	Low
<5	Predator reduction	Low	Low
50	Deterrent	No data	Med Low
<5	Predator reduction	No data	Low
50	Deterrent	Low	Med Low
100	Physical Barrier PLUS	High	High

Communicating and Interpreting Results

- How to best utilize results?
- How best to communicate results to public?
- How best to share preliminary results with press?
  - Updated press release?
  - Updated point-of-contact?

Timeline and Next Steps

- July – August 2019 – Complete Draft Technical Report
- August 2019 – Coordinate with AWSC, RSWG to draft executive summary and illustrated fact sheets
- September 2019 – Issue Draft Technical Report for Review and Comments

4.0 Appendix D

Shark Mitigation Alternatives Analysis
Shark-Seal Roundtable Discussion
25 April 2019

- **Introductions**

- **Project Overview**
  - Woods Hole Group Tasks and Deliverables

Overview by Regional Experts:

- **Shark Activity in the Near Shore**
  - Local Population Dynamics (% tagged?)
  - Characteristics that make local population unique
  - Dietary Preference / Foraging Behavior
  - Utilization of bathymetric / habitat features
  - Future research efforts

- **Seal Activity in the Near Shore**
  - Estimating historic/pre-colonial population(s)
  - History of seal bounty
  - Legislative protections
  - Post-bounty population growth
  - Local population dynamics (as a %-age of greater N. Atlantic population)
  - Dietary preference / Foraging Behavior
  - Utilization of bathymetric / habitat features (foraging)
  - Utilization of coastal resource areas (pupping / haul-out)
  - Future research efforts

- **Shark-Seal Interaction**
  - Behavior(s) that may lead to attack (seal)
  - Behavior(s) leading up to attach (shark)
  - Fight/flight mechanisms (seal)

- **Protected Species Considerations**
  - History of Legislative Protections / levels of protection (shark / seal)
  - Success of Protections (shark / seal; population increases)
  - How to measure success of conservation efforts?

- How to measure carrying capacity of local near-shore environment?

Alternatives Considered – Municipal, Stakeholder requests:

- **Biological Control / Bio-Based Mitigation Strategies**
  - Where has culling been attempted? (shark / seal)
  - Has culling proved successful?
  - Where have (smart) drum lines been deployed?
  - Have (smart) drum line deployments proved successful?

- **Other Alternative Considered**
  - Indigenous Harvest?
  - Seal Contraception?
  - Scent-based deterrents?
  - Dead Sharks / Seals in near shore to attract / deter others?
  - Electrocution / behavior modification?
  - Orcas?

- **Wrap-Up and Next Steps**
  - Peer-reviewed literature to consider? (shark/seal/protected species)

- **Adjourn**

5.0 Appendix E

Shark Mitigation Alternatives Analysis
Inter-Agency Conference Call
6 June 2019

1. **Project Overview**
   - Project History
     - Regional Approach ((6) Cape Cod Towns, NPS, Atlantic White Shark Conservancy)
     - Regional Shark Working Group Meetings
   - Woods Hole Group Tasks and Deliverables

2. **Review of Mitigation Alternatives**

   Please consider the following questions during review of shark mitigation alternatives:
   - Does the alternative fall into your jurisdiction?
   - Is the alternative prohibited under the current regulations?
   - If the alternative is not prohibited, are there special conditions or TOYs the Towns should consider when selecting a preferred alternative?

   - **Barrier-Based**
     - Rigid Plastic Mesh Nets
     - Semi-Rigid Nets
     - Bubble Curtains
     - Electrical/Magnetic Deterrents
     - Simulated Kelp Forests
   - **Technology-Based**
     - Tagging (Acoustic & Satellite, Real-Time Alert)
     - Visual Detection (Drones, Balloons, Spotter Planes)
     - Remote Detection (Bottom-Mounted Sonar, Buoy, Real-Time Alert)
     - Acoustic Mitigation Devices (Pingers, etc.)
   - **Biologically-Based**
     - Shark Cull Net / (Smart) Drum Lines
     - Seal Culling / Seal Contraception / Indigenous Harvest
     - Modify Shark Behavior (Electric Shock)

3. **Feedback and Initial Impressions**
   - NOAA
   - EPA
   - NHESP
   - CZM
   - USACOE

4. **Wrap-Up, Next Steps, and Adjourn**

6.0 Appendix F

National Park Service
U.S. Department of the Interior

Cape Cod National Seashore
www.nps.gov/caco

Cape Cod Great White Shark Safety

NPS/BILL FISHER

Cape Cod's waters are part of a natural and wild marine ecosystem with a rich diversity of sea life, including sharks. Seals are the major prey species for the great white shark, and as the seal population increases, great white sharks have become more numerous. In recent years there have been confirmed reports of great white sharks feeding on seals close to shore as well as great white shark sightings from spotter planes flying along the Outer Cape near swimming beaches. **People have been seriously injured and killed by white sharks along this coastline.**

BE SHARK SMART

To stay safe and to protect wildlife:

- Be aware sharks hunt for seals in shallow water.
- Stay close to shore where rescuers can reach you.
- Swim, paddle, kayak, and surf in groups. Don't isolate yourself.
- Avoid areas where seals are present.
- Avoid areas where schools of fish are visible.
- Avoid murky or low-visibility water.
- Limit splashing.
- Follow all signage and flag warnings at beaches and instructions of the lifeguards.

(over)

Shark Sightings

- Notify a lifeguard if a shark is spotted.
- Water will be temporarily closed to recreational activities.
- Beachgoers will be notified when they can reenter the water.

Shark Facts

- Sharks have existed for more than 400-million years.
- As top predators, sharks are critical for maintaining a healthy and balanced marine ecosystem.
- Great white shark numbers have increased on the Cape because of a growing seal population which has rebounded after being hunted to near extinction.

Other Resources

Massachusetts Shark Research program
Division of Marine Fisheries
www.mass.gov/marinefisheries

Supporting Local Shark Research and Education
Atlantic White Shark Conservancy
www.atlanticwhiteshark.org

Download the Sharktivity App for Apple and Android devices on the Atlantic White Shark Conservancy website.

For additional information, visit the Cape Cod National Seashore website at: go.nps.gov/sharksmart

Great White Shark Facts

- As top predators, sharks are critical for maintaining a healthy and balanced marine ecosystem. Great white sharks are the only natural predators of seals in our region.
- Sharks are slow growing, late to mature, and produce few offspring, making them extremely vulnerable and slow to recover from overexploitation.
- Great white shark populations declined dramatically in response to overfishing in the latter half of the twentieth century. As a result, the species was listed as a prohibited species by the United States in 1997 and by the state of Massachusetts in 2005. It is illegal to harvest them.
- Increases in white shark sightings in the past decade suggest regional abundance may be increasing, but the status of the population remains unknown.
- Researchers are currently conducting studies to better understand predatory behavior and to monitor the status of the population to inform public safety practices.

Be Shark Smart

While it is rare for a great white shark to bite a human, it has occurred in the waters off of Cape Cod.

Over the past decade, the coastal waters off Cape Cod have emerged as the newest **great white shark** hotspot. The now-predictable presence of the species is linked to the regional population recovery of grey seals, which are preyed upon by sharks close to shore. These predation events primarily occur in close proximity to the beaches of the outer Cape, where people swim, surf, boogie- and paddle-board, and kayak.

Other Resources:
Division of Marine Fisheries
Massachusetts Shark Research Program
www.mass.gov.marinefisheries

Atlantic White Shark Conservancy
Supporting Local Shark Research and Education
www.atlanticwhiteshark.org

Brochure created by
The Atlantic White Shark Conservancy and the towns of Cape Cod and The Islands
Cover photo credit: NPS/Bill Fisher

Be Shark Smart

Cape Cod and The Islands' waters are part of a natural and wild marine ecosystem with a rich diversity of sea life, including great white sharks.

Great white sharks come to Cape Cod to feed on seals. Sharks have been reported year-round, but peak activity occurs in the summer and fall when water temperatures are warmest.

Sharks hunt for seals in shallow water right along the beach. Seals stay as close to the beach as possible to evade sharks that are hunting them in water that can be less than 5 feet deep.

The only way to completely eliminate the risk of a shark bite is to remain on shore.

If you choose to enter the water:

- Be aware sharks hunt for seals in shallow water.
- Stay close to shore where rescuers can reach you.
- Swim, paddle, kayak and surf in groups – don't isolate yourself.
- Avoid areas where seals are present.
- Avoid areas where schools of fish are visible.
- Avoid murky or low visibility water.
- Limit splashing.
- Adhere to all signage and flag warnings at beaches. Follow instructions of the lifeguards.

Shark Sightings

If you spot a shark along the beach:

- Exit the water calmly and with minimal splashing.
- Notify others in the water around you.
- Notify a lifeguard or a parking lot attendant.
- All shark sightings will be investigated and waters will be closed to swimming and surfing/paddle boarding etc temporarily.
- Shark sightings can be submitted to the **Sharktivity** App. Available on the iPhone App Store | Android app on Google play

Purple Shark Flag

When the purple flag is flying great white sharks are in the area.

Dorsal fins frequently mistaken for great white sharks

Ocean Sunfish (pictured below) - not a shark, but a very large harmless fish that moves its fin up and down.

Basking shark - second largest living fish. A slow-moving, harmless shark that feeds on tiny shrimp-like plankton.

In addition to white and basking sharks, sand tiger sharks, sandbar sharks, smooth dogfish, and spiny dogfish frequently visit MA coastal waters. However, these species are not likely to be seen at the surface and pose minimal threat to humans.

First Aid Response

Most white shark bite victims survive because of first aid initiated from bystanders. White shark bites generally result in massive hemorrhaging, which requires immediate first aid in order to stop the blood loss. For first aid training opportunities and more information visit: www.atlanticwhiteshark.org/public-safety

Call 911

for Emergencies

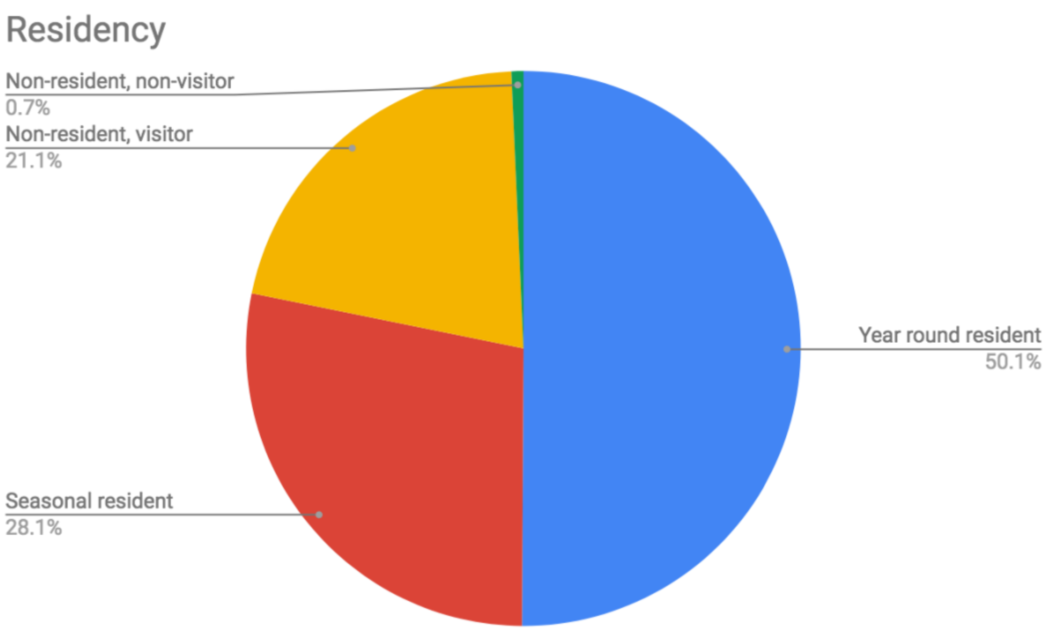
7.0 Appendix G

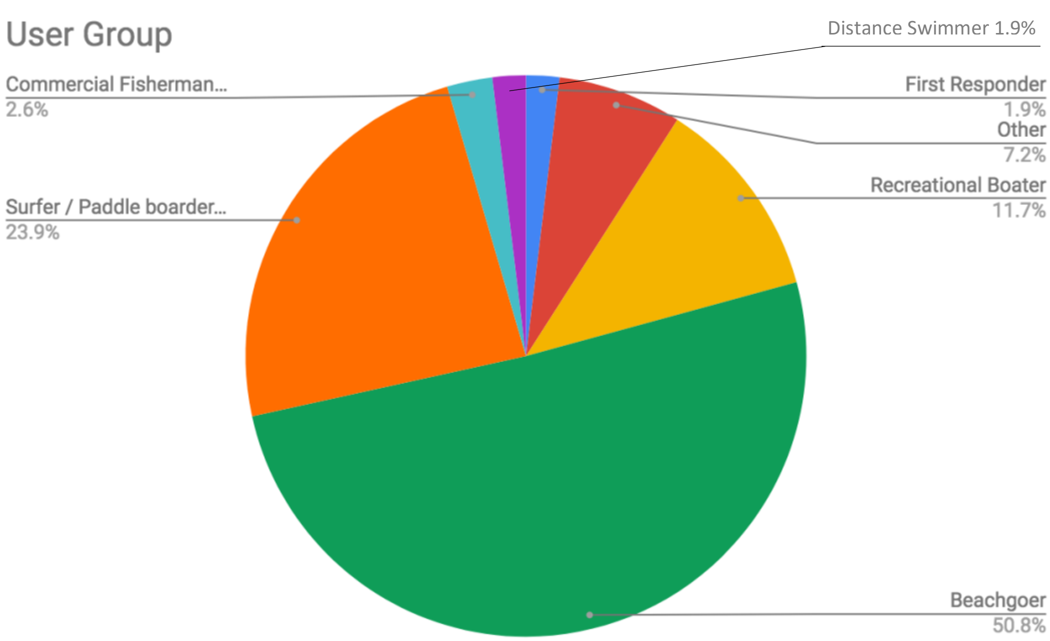
Shark and Human Mitigation Strategies
Public Input Forum Responses

Total Number of Responses

573 Responses

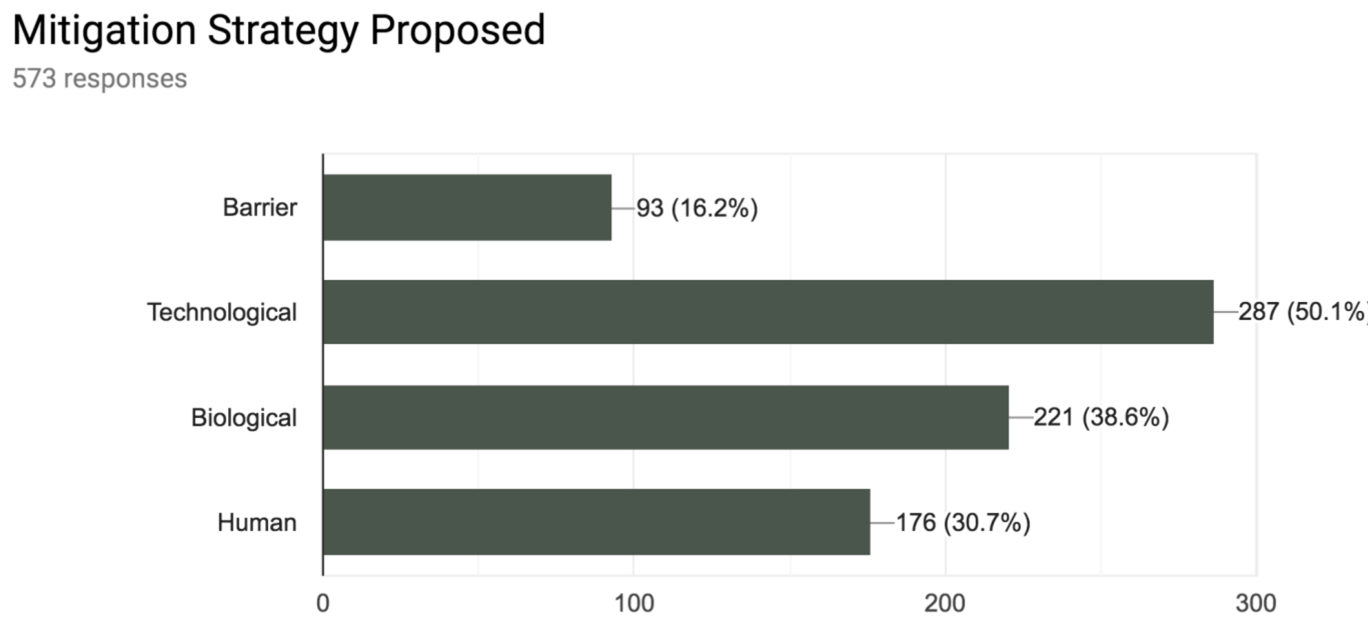
Participant Demographics





People who cited 'Other' above (16 Total), described themselves as being one of the following:

Body Surfer	Staff an environmental non-profit (APCC)	Fisherman	Scuba Diver
Ocean Lifeguard	Wildlife rehabilitator/ environmentalist	National Park Service Lifeguard	Clammer
Shellfishermen	Avid fishermen	Kayaker	Commercial Scuba Diver



Each response could include multiple strategies.

Mitigation Strategy Responses:
Strategies that are not included in the Alternative Analysis scope are summarized below. All other responses are provided on the following pages for you to review as well.

Public feedback on strategies not included in 2019 actionable items or Alternatives Analysis scope:

Conduct research on the human dimensions of the problem as well as the efficacy of outreach/education efforts. (Not a direct quote but what I gathered from their response)
Display the number and location of recent beach closures due to shark sightings at every beach to increase awareness.
Ban surfing (and other board sports) during peak shark season.
Rent orcas/encourage orcas to feed on seals and sharks.
Forecast white shark presence based on research results. (Note that we already have a proposal in the works to do just that.)
Train sharks to avoid the area using negative reinforcement - proposed electrocution when tags are detected (presumably by the buoy) or by placing a series of seal decoys that would electrocute the sharks when bitten.
Polarized sunglasses for lifeguards to increase spotting efficiency.

Public feedback which overlapped with proposed ideas:

Don't play with "Mother Nature". Remember that when you play with "Mother" she always bats last !
Lifeguards from Memorial Day to Columbus Day to watch for shark indications.
Risk-based decision making ---aka "common sense"!!
Risk based decision making
shark repellents
I think a combination strategy approach would work best. Combining technology and physical barriers. I would like to know how physical barriers would sffect the beaches and other wildlife.
Chemicals that mimic dead shawarma or seals . Has an environmental impact statement been done to determine the effects of this on the ecological community?
Human dimension research and education ! Why is this not included?
A combination of all approaches are necessary to resolve the problem.
It's the sharks waters! We are the visitors ...
Please don't start harming the seals or the sharks with barriers - we all know what nets do to our precious wildlife.
Risk-based decision making
I like the tagging/app idea but how do we know we got them all. Would chemical barriers have other implications (bad for humans or the environment?). All safety measures should be well marketed to prevent the loss of tourism due to sharks. Thanks for your work!!!!! I love Truro beaches but want to feel safe.
Not sure at this time
I have investigated and read many different resources on the most effective approach to improving the safety of the near shore waters along the Cape, and believe that ONLY a combination of approaches will be effective. As the Shark Conservancy made clear in a recent presentation, the combination must include a reduction in the seal population to be effective, or a further loss of human life will be inevitable and another horrific and avoidable tragedy.
"Real/live" kelp forest
Avoid being in the water with sharks. This can be aided by real-time shark alerts from tagged and spotted sharks as well as submitted sightings from fishermen/beachgoers/anyone. I support a seal birth control program as well.
person
Human: The strategy that I hope is being discussed involves EMS response. Treating the peak summer season -Memorial Day through Labor Day as a planned event, meaning preparedness for, and management of medical consequences in the event of a shark bite. Alerting lifeguards and EMS systems from Nauset to Herring Cove at the presence of a shark in the swimming area, and have that relayed to beach goers in the form of a flag or public P.A. system. Beach closures known to the public from Nauset to Herring Cove, maybe having a DCR style digital board display in the beach parking lots so people are aware of recent beach closures due to shark sightings, having a first responder asset stage at the parking lots of the immediate neighboring beaches of a closure or suspected/bite where landline telephone and cell reception is currently poor/ non -existent. Finally I hope Boston Med Flight is involved in the discussion of response. Early notification of suspected/confirmed bite with EMS assets having direct knowledge of nearest landing zones will cut down on the time to definitive care which will be at a level 1 trauma center located off the cape. Surfers: Should be encouraged to seek off cape locations during peak seasons, as they are the highest risk population. Real discussions of making Cape Cod off limits to surfers during this peak season in the name of Public Safety and related public safety costs. (I say this as a surfing enthusiast). Lastly, perhaps town officials can seek federal grant money for public safety initiatives directly related to the increased cost of hiring first responders and equipment for shark safety without having to pass that cost to the taxpayer. Thank you for your time. Robert Barnes

Occupation: EMS Lieutenant - Boston EMS.
Sharks are a part of the New England coastal ecosystem, as are humans. Frankly the humans need to be 'mitigated' mode than the sharks. Education for humans, and realistic expectation-setting so that humans understand that sharks are an acceptable and welcome part of the ecosystem, is the best course. Considering the far, far greater risk that humans have on humans via issues like car accidents it's a little shocking that there is even discussion about how/if to mitigate the sharks from their habitat, just because humans choose to enter that habitat. Humans need to adapt to sharks in the water, as they have been doing for millenia. The thought of putting barriers in to the ocean is beyond preposterous and an embarrassment.
A number of my friends were behaving unsafely in the water so I made them shirts for Xmas to remind them of the behavioral aspects that they should follow. Did you know that the bulletin boards at the beaches do not have behavioral recommendations pertaining to shark safety?! I'm a learning specialist with an MBA so I knew I needed to keep it short and sweet. So the shirts say: Swim, Surf, Kayak.....SAFER! with a behavioral component for each of the letters of safer and the ! It is like a walking billboard. A friend said that people will read it while standing waiting for groceries or hanging out at the cafe! Put it on the bulletin boards, put it on shirts, handouts. As an environmentalist, I believe that the sharks have been here for million years so it will be hard to change their behavior! People have to change theirs! I don't think I can send you a picture of the shirt but you can go to the home page of my website to see it. Anything can be put on the front and the list can be changed to reflect best practices as they evolve. www.naturenerdsrule.com Cheers, John Body
If a bear mauls someone, it is destroyed. If an alligator kills some one, it is hunted down and killed. If a shark kills someone, we invest in beach scooters and radios. What is wrong with this picture. KILL THE SHARKS AND CULL THE SEALS!
Intelligence machine
Let the sharks be! They live in the ocean, we do not. It is their home and we are taking the risk when we enter the ocean. One death amongst millions of swims by thousands of swimmers this summer? Your odds are better in the ocean than on Rt 6.
Whatever is environmentally sound and helps protects sharks and humans
Allow people to make their own decision as to whether they will take the risk of entering their environment. Obviously, the use of the ocean in these areas is one of pleasure and only used during the summer months. Trying to change what's occurring naturally is a fruitless effort that's been proven in the past in many areas. Humans are visitors of the ocean and should treat it as such. What's occurring is natural, why do we as humans believe we have the right to change their environment to suit us for our simple pleasures. There are those who believe we should do something because of the financial impacts. I have been fishing these areas for decades, by boat. I've also been an avid diver since the 1980s. I've seen these animals here in different areas of cape cod for many many years. It's their home, we are the visitors of their environment, warn people.
As humans we believe we have the right to change this animals environment to suit our pleasurable needs during the summer months? Also for monetary reasons. I have a question, what if these creatures were capable of entering our land environment and forced us to move from the area during a time when we grow our food for survival and they came here only for reasons of pleasure and monetary betterment? How would humans perceive this?
If you swim or enter the water during peak feeding season, you yourself should be held accountable for your decision to do so. Sharks are a necessary part of the ecosystem. From what I understand the first person bitten was swimming beyond where most people here would consider safe in shark sighted waters. The second guy was dressed in a black wetsuit from head to toe with flippers. Really??
Creating maritime recreational safety zones for passive recreation (swimming, surfing, suping, boogie boarding, body surfing). The best way to do this is through the clever buoy systems. The optimal solution would be an underwater shark deterrent that would turn on when the shark entered the designated area and turned off when it left. This two tiered system provides rescue personnel with real time information while at the same time removing the danger. The information these buoys are capable of providing to research organizations is invaluable.
I would like to learn more about this.
I like the talking points you've outlined and will decide after group discusion. Thank you for your leadership on a most important event.
It’s very important for people to be aware of sharks, seals and sea conditions to avoid contact with these sea creatures and to understand their behavior to avoid contact.
We need to be shark smart and realize we are entering their natural habitat and change our behaviors.
train for first aid and additional lifeguards, cell service, I love sharks (and seals). Let them manage their own ecosystem as much as possible
Public awareness of the risks and understanding that it is the sharks ocean. And, monitoring sharks to reduce interactions.

The sharks are there because of the seals. No seals = no sharks. More realistically, Fewer Seals = Fewer Sharks. I know Nova Scotia did a very detailed study a number of years ago: https://www.animalalliance.ca/wp-content/uploads/2016/04/2009-Sable_Island_seal_report_high_res_searchable.pdf Seal culling has also been studied on the West Coast https://nanaimonewsnow.com/article/589642/researchers-weigh-pros-and-cons-seal-cull https://globalnews.ca/news/4344527/new-group-seal-sea-lion-cull-bc-coast/ and in Denmark https://www.researchgate.net/publication/323961391_The_history_and_effects_of_seal-fishery_conflicts_in_Denmark Although shooting the seals would be the least costly, I think there would be no tolerance for this solution on the Cape. I see no way to move the seals. The only way that seems to make sense would be contraception. I don't know by what means or how expensive this would be, but it at least warrants study. I think it would be supported by liberal minded Americans as well. Family planning in humans is well accepted.
Human- We're in their environment and the public should be making informed decisions when entering the water. Biological- If repellents can be used to help mitigate the shark and seal population it would lessen the growing seal population and then hopefully lessen the shark population too.....hence less encounters with them.
When we enter the oceans we are entering their territory; they are not entering ours. They are apex predators that deserve to be respected. Over 17 million sharks are killed each year globally. Compare that with the number of fatal shark attacks on humans globally. Magnetic Barriers have been proven to work. Pheromone deterants have also been proven to work. The smell of a dead Great White off the Farallon Islands off California cleared White Sharks and really all sharks out of the area for months after an Ocra attack on a great white. The pheromone technique has also been tested in the Bahamas by the Bimini Shark Lab. Technoligical Barriers are a safe way to deter the sharks without harming them and letting humans swim and surf without fear of being attacked.
Avoid areas of seals, surf during seasons with shark activity
All of the Above! Take a small % of Beach Fees (and Boater fees?) and put to all these efforts - Technology and Research at the forefront.
Maybe this isn't a new concept, but what about people taking responsibilities for their own risks? I think continuing public education is key, but it isn't a 'right' to be 'risk free' in the Ocean.
I believe a mix of strategies may be needed but first and foremost humans need to know the risks of the ocean and exercise caution. Any biological measures should be within the most ecological conscious methods possible. If the science determines that seal populations have grown beyond a carrying capacity that's ecologically sustainable then a cull or other population control measures are reasonable to consider. More sharks may take care of that issue naturally and if that's the case, any shark repellent measures could be counterproductive. I'd like to weigh in more but withthought full knowledge of the in-depth science surrounding this issue I don't believe I have the right to suggest a solution. I trust the scientists to determine the best management plan for ecosystem.
Open to almost all ideas at this stage
If there is technology that could alter travel patterns of sharks, I would support that, as long as there is no harm to the sharks. We are, however, ignoring the obvious problem which is warming waters which attract the sharks north in greater numbers.
The overall mitigation plan needs to be a combination of all four strategies. However, if the size of the seal population is not curtailed, then a combination of detection such as Clever Buoy plus deterrence such as Shark Shield will probably be the best alternative.
Reduce the number of seals. Don't be stupid in the water, its theirs not ours.
Appropriate paddle craft selection and coloring. Could an acoustic signal be put on shark that is detected and alarms on human receiver due to proximity?
REMOTE DETECTION AND ACOUSTIC REPELLANTS. Heard about the sonar buoys - seems like a great idea! But how does one position them to encompass all tide cycles? Many swimmers and board users use large areas (from shoreline out to water areas over human height); it would seem to be a tall order to have that many sonobouys to cover all swimable areas of lifeguarded beaches. Totally AGAINST culling seals!!
We must take multi-strategy approach. People must be educated and change their behavior. Some areas should be off-limits to in-water activities. We should use all tech available to protect people who use the beaches. Repellant and sound-based tech would be easy enough to try. Barriers would be the best answer for high-use swimming beaches. We also must control the seal population (we should have started years ago). We

are the apex predator now. We must do our part in the ecosystem, and that means we must control the prey species that are overpopulating. A major culling of the seal population is in order, and then a system put in place to control it at a level that does not continue to attract numerous great white and other large sharks to the in-shore areas.
Get rid of 3/4ths of the seals, using repellants, contraception and culling over a 3 year period. Leave the sharks alone during the same period unless/until they have attacked more people and common sense prompts more aggressive action. If the suggested seal actions don't reduce seal numbers within 3 years, double the culling rate. Drone monitor the popular beaches, simultaneously download information to Sharktivity and use the Coast Guard Auxiliary as much as possible for patrolling beach perimeters by boat and on foot.
I'd like more info on these methods before making that decision. Such as cost, practicality, and efficiency. Maybe the solution spans more than one category! At this point human strategy may be the most effective way, that is if people are conscious of repercussions of their action.
Shouldn't drum lines be part of the barrier methodology? I would use a barrier biological approach...
I believe that drum lines are barrier type solution. I would use that along with some technology and biological.
all of the above, especially an examination of seal contraception and shark/seal culling
Nets with Orca recordings offshore of swimming, surfing beaches.
Stay out of the water!
Seal eradication
Stay out when seals are around
Biological
You forgot kayak fisherman. I think tech based is best option. Possibly using sound or smell markers (I guess this is bio based) that deter. Also, adding drones to lifeguard equipment would help.
Humans are entering the sharks home every time we swim. It is up to us to change our behavior.
I don't see an easy answer, water clarity is an issue with visual sightings, planes. electric surfboards sound good for surfers, but what about swimmers? Netted enclosures aren't feasible on the outer cape, with the shifting sand, on top of the astronomical expenses. There is not one cure all.
There's got to be a pheromone that sharks don't particularly like, so maybe if its put in our waters, it will divert them? I know there is a lot of different things to consider, with some of them being the production method, weather or not other sea life will be effected by said pheromone, but just an idea to put in the pool (heh, get it because we're talking about bodies of water and what not). Thank you for taking the time to look at this! Jake
Science is clear. Offensive mitigation toward nature's processes is ineffective and brings a host of unintended consequences. Humans must change their behavior. We need to improve warning strategies, as well as employ human behavior to minimize danger. Sharks attacks elicit primal fear, but we cannot over-react by killing off seals, and sharks. So what to do? Don't dress and behave like a seal in the water. Use warning bouys. Use defensive color patterns on surf and boogie boards. Nature must be allowed to control populations in order to maintain a healthy ecosystem. It is not just about seals and sharks but fish, crabs, plankton, and chemistry. Don't screw with mother nature.
Bayside and Oceanside. Bayside is left unprotected and it has seen many more sharks and we have zero to no surveillance or guards.
Humans are visitors in shark habitat. It is incumbent upon us to behave responsibly when entering shark habitats for recreation. Having said that, the seal population is beyond what conservation measures had initially anticipated. Culling or indigenous harvest might be necessary.
I plan on buying a shark repellent sonar for my board until a physical barrier is created.
So quint wanted $10000 to kill a shark in 1976, which is a bit over 43k with inflation today. Hire Sean Sullivan to kill all the sharks (43k a head) with a spotter plane and electricfied harpoon, but only after at least 95% of the seals are harvested. Not good solutions? I talked to someone professionally involved with the personal electric shark detorants, they do not work on mature great whites. So I did not waste my money. The striped boards and suits they are using down under are a win, should encourage that. I would say try the barrier systems. Going to be big exspenses involved, need to be removable before large storm systems. Let's not discuss killing seals if it not going to be a significant amount. It would be useless to kill less than 90%, so if that's not on the table, it's a waste of time. If you want to hire me to help figure out a workable set of solutions, feel free to call me at 774-216-1081. Thanks, Brendan Adams

Repellent that is not harmful to a human but keeps sharks away
some kind of warning system. otherwise leave the sharks and seals alone. They have been there alot longer than we have.
None...of above...as proven world wide...nothing is full proven. Common sense by swimmers, surfers, etc Do not swim surf near seals, do not swim or surf, early or late in day, nor in isolated locations... In Florida, they are complaining about low level of attacks as sign of reduced sharks...????
1) The problem is too far gone to only adopt a single pronged approach. 2) The seal population is out of control. 3) The negative externalities of the out of control seal population extend far beyond the fact that they are attracting sharks. 4) Rent orcas (like people rent goats to eat poison ivy). I kid, but ...
Prioritize strategy to focus on peoples use of beaches at the cost of invading anamal and bird species
Sonar buoy, underwater orca acoustics,jet ski rescue
People need to be smart and change their behavior, because we are entering the sharks territory.
I see this in 2 groups. Short term plans and Long term plans. Short term 1. Short term Sonar is possibly quickest. Use this to gather more data to inform the scale of the issue and remove rumors about shark counts and behavoirs 2. Flood the beach staff with reactive tools including but not limited to Jet Skis and trailers. Over come town objectives and challenges to this plan. 3. Fully Inform visitors to make an informed decision. "One in sixty years" is terrible guidance. Though i appreciate residents, business owners, restaurant owners maybe "dont know what to say...". 4. Hire project managers to communicate and drive what ever actions will be taken with accountability to the townspeople and leaders. Shark Conservancy and others unite as one urgently, include public this is a fine first step with this short term public input . Long term 1. Continue research to define the count, and the forecast of Great White Sharks on cape both bay and beach. That should inform any larger decisions. 2. Expand any of the short term that yielded the desired outcome 3. Attain funding for a fully matured plan from local, state and federal resources
Anything to prevent the overwhelming population of seals which attracts the sharks.
People need to make better decisions based on the fact that sharks and seals are here to stay. None of the other outlined strategies will be effective. Improved cellphone or emergency phone coverage on the outer beaches is also important.
Tech solutions can too easily fail. A surfer needs a strategy that works when the surf is up, not based on a man made schedule. Visual detection only works when someone is watching; drones, balloons, etc. may not be there early in the morning, in the evening, or anytime in the peak surf months of Sept, Oct. A multi pronged approach is needed. Reducing the seal and shark population should be considered. Neither the seals nor the sharks have any fear of humans. Barriers are a good idea but will they stay in place in ten foot swells?
Don’t swim during shark season
Train sharks using pavlovian response with negative reenforcement. Basically an invisible fence for sharks. Possible implementations: Use smart tags attached to sharks that electrocute the shark when a bouy is detected. Place such buoys near public beaches. Use stationary seal decoys that when bitten send out a powerful electronic shock. Place these near and around public beaches.

The idea is to train the sharks that hunting grounds around public beaches only cause pain and should be avoided.
Rigid Plastic Mesh Enclosures
Suggest to surfers that since they have a choice of land and sea environments, and sharks have no such choice, wouldn't it be smarter if the surfers chose not to surf where sharks have been seen. Also, since surfers' wetsuits are frequently dark or black and look very seal-like, wouldn't it be more sensible if surfers wore wetsuits that were bright-colored or patterned?
Be aware of the shark habitat that we venture into. Research their food resources and how abundant it is. Never go to the beach alone!!
I think you might actually need a combination of all the strategies to get to the safest solution. Likely testing of a few from each category, with a decision based on results that partner technology with barrier, technology and biological. In terms of human, this is a mandate - education, signage, stronger awareness of risks being taken by swimming in the waters.
Common sense education - no black wet suits, no black flippers, no bogey board; no swimming at dawn or dusk or in presence of seals, etc. Polarized sunglasses for lifeguards.
and cull the seal population
Shark repellant, mesh enclosures
No comment
Fencing
I believe no single method is sufficient but a combination of continuing to tag in concert with so-based alerts and visual detection would be effective. Second phase depending on effectiveness of above would to layer in chemical repellents in high concentration areas (people and sharks). I don’t believe in culling, I believe we’re fortunate to have sharks in our waters. And I strongly oppose barrier-based methods as I think keeping them in place is difficult, particularly on the backside of the Cape. I worry about potential environmental issues and unintended killing of birds, fish, etc.
We need a sense of urgency to employ the most effective techniques to keep waterman safe
We need to have more information on the sharks
Shark and / or Seal Culling, Indigenous Harvest
Be aware and use risk based decision making. Swim at your own risk.
Seal culling
step up patrols for sharks
Let nature take its course . To cull the seal population here would be futile . In very short time after doing so thousands more will have found there way here from the sable islands.
Deterants with out harm to any of the animals
Shark Attack Prevention
Let’s not invent anything new. Let’s look at the southeast coast of Africa and Australia, and implement what has been proven to protect swimmers in shark-infested waters there.
is it worth asking other places about their success with these various choices? I read that there is netting on some of the beaches in Australia? I am not sure what efforts have been made in Florida. Can the Cape consider good strategies which have worked from other cities dealing with the same white shark population? I swim at Lighthouse beach in Chatham. Now it is almost sealed off by the sands. Dealing with the number of seals seems like a long term project whereas putting up nets could be done more quickly? But do they work well. Not sure the fellow in Wellfleet was paying attention to all the warnings. But that is another issue. I also think Chatham (my town) should stop celebrating the sharks. Promoting the sharks. Trying to make it part of a tourism effort. We are sending the wrong message. Last summer should convince us of that. Thank you for your work and hope this study creates some solutions. Kim Atkins North Chatham
Modern electronics: short wave radio, observation/ communication towers, intensive early sighting, beach patrols, public information -print, internet, town forums. And finally federal, state and community budgets to sustain and propagate public awareness
Each of the strategies mentioned above seems to merit serious consideration

Enter at your own risk. People need to use their heads when in and around the water. Sharks are not new to the oceans. The oceans are their homes, we humans are the visitors.
I am realistic in thinking that never enough money will be allocated for true technology surveillance so I suggest at least for the first year there should be expanded lifeguard coverage and much better communication availability on all national seashore beaches
I have checked all of the strategies because I think we need a combination. Humans need to use caution, but I also think we should reduce the risk to humans. I would prioritize biological and technical. Among these, I'd advocate for controlled culling of seals and try contraception for seals. I'd also like to see barriers until we see that the biological methods reduce the shark population that is traveling close to shore from Chatham to Provincetown, and near the shore in the Cape Cod Bay. I don't know which of the barriers noted that I prefer since I have not studied the effectiveness of each.
Monitoring shark activity and alerting people where the sharks are. An alert system that will warn people that sharks are in the area both by a phone app and a system on the beach.
Seals and sharks are naturally occurring organisms of this ecosystem. Cape Cod is rapidly joining the likes of Capetown, South Africa, Australia, etc. as the Great White Shark capitals of the world. Inserting ourselves within a place of nature that is becoming a vital biological area is not the right option. These waters are no more ours than the sharks. It is the individual person's responsibility to make the decision as to whether or not enter the water.
Nets could harm marine life this seems like something to look in to -“Smart drumlines may be trialled in Western Australia”
Humans are visitors to a different habitat when playing in the ocean and have to respect that, therefore alterations to the habitat or to the food chain should not be made because of the butterfly effects those two mitigation tactics both have the potential to cause, wearable technology along with increased on shore efforts in regards to surveillance and response should be implemented.
Sharks are not new to the ocean, it’s their habitat. With the seal population growing, people need to be smarter when in & around the water. For example if wearing a full bodied black wet suit, know you are putting yourself at risk because you now resemble a seal. Be smart!
do this as kindly as possible
I feel the marine wildlife should be protected at all times. We are invading their space. Perhaps adding a few safe swim zones through some type of netting device could work. For surfers and paddle boarders that could not be contained by a safe swim zone, as in other parts of the world, you take your chances.
All strategies that allow us to swim and recreationally boat without fear of doing so. Have less focus on Chatham as a shark capital. Information is important but don't scare people from what beauty Chatham has. The spotter plane circling was also very useful especially near the outer beach.
Sharks were in the water long before us. Even if we are surprised by their recent resurgence in the Cape. It’s our responsibility to change our behavior and use non invasive tech to coexist with them.
Let nature take its course. People need to be educated. The shark and seal population will balance itself out.
I don’t think one approach is best. Using several strategies hopefully will overlap each other and cover the flaws of only using one remedy. I think at least 2-3 strategies working together would be more successful. For example sonar buoys, reducing seal population(culling or contraception) and some kind of barrier based method.
My family would feel safe to swim at our beaches if there were rigid barriers in place that keep the sharks in the rest of the ocean and let the humans swim safely
Humans need to practice smart swimming and other water activities. Sharks have been in Florida and California long before they came to Cape Cod. Black wet suits and fins are not the best idea in an area where seals are . Also the Cape could do better with cell towers and reception for emergency contact.
Prevention is the key for safe waters for all
Prevention is the key for safe waters for all
Force the seals further offshore
PUBLIC SAFETY
risk based
Leave the damned sharks alone. Humans do this all the time. Move into bear country, or alligator country, or mountain lion country-What's the first thing humans want to do? Kill all the animals. If stupid people want to go into the sharks' home, let them. Whatever results is the fault of the people, not the sharks. Humans can't seem to help themselves. We steal whole countries from their rightful inhabitants, now we want to steal what's left, so that even animals cannot exist. Leave the damned sharks alone.
I swim in the water at several beaches in lower cape. I was swimming about 100 yards to the south of the boogie boarder that was attacked and killed this summer. I think the ocean is home to many creatures large

and small, and as animals coexisting on earth, we need to share the space. If I want to go swimming in the ocean, I know I'm taking a risk. Just like hiking in the woods in the mountains. I know there is a risk I could encounter a bear or mountain lion. I do not believe any humans need to do anything to mitigate the wildlife- it's part of adventuring and being in the wild environment. I do not believe animals need any mitigation in their own habitats. It's part of the food chain & cycle of life. If people want to avoid getting attacked by a shark, then it's up to them to assess the risk and decide if they want to take it. Humans do not NEED to go into the ocean and swim and surf and recreate for survival so whatever mitigation gets decided upon, I hope it is the least harmful or invasive to sharks or any other animals simply existing in their own habitat.
Kelp
Use better judgment. Don’t swim too far out.
Wetsuits/Boards with Sea Snake/ Camo Patterns have been shown to be a low tech option. Also, people need to realize that if the seals are around, they shouldn't be swimming with them, that's why the sharks are there.
I believe it will require a combination of strategies to help alleviate this problem
Manage animals in responsible way that best deals with the overpopulation of them . The law protecting Seals needs to be revisited (like the other mammal laws in this country) to cull down the now grossly overpopulation of seals thus managing the seal population , which is attracting sharks into area and closer to shore than they normally would go .
We are swimming in their waters
Humans are invading their environment. Let them be. Humans should accept the risk of co-mingling with wild animals
It’s highly unlikely that a single strategy will solve the problem. The challenge is to come up with a set of strategies which complement each other to create a full proof protection system.
I believe it’s going to take a multi-layer strategy...not just one answer
sharks belong in the ocean. people need to make better decisions.
Leave nature alone and let it balance out. Stay out of the water.
Free hemorrhage control classes and tourniquets and wound packing supplies @ at all beaches. The sharks are there and the likelyhood of another attack is eminent the regular beach goers need to step it up and receive the training to help those who are attacked.
People swim at their own risk and use common sense. Do NOT kill the sharks. Killing sharks is not the answer. Controlling the seal population could help too.
I would be interested in trying Orca recordings, but believe it is up to humans to not swim in their environment, there are plenty of bays and safer areas where you don't see large sharks
As with any danger to individuals or our population, education is the best defense. The public is educated about drinking and driving, tick-bourne diseases, rip tides, etc. through radio, signs, videos, classes... you name it. Our resources will be best spent on a broad campaign of education, including educating people how to respond to a shark attack and how to help victims of an attack. I feel strongly that the other options will all have unavoidable faults which will leave ignorant vacationgoers in oblivious danger.
We have interfered with the natural balance through climate change, and there is precedence for success in wildlife management.
People need to be smart, we are entering the sharks natural habitat.
Analyses of all the above options that address immediate and long term mitigation proposals, their pros and cons with recommendations that consider regional cooperative efforts and specific town considerations.
education
I feel there should be more than one strategy. Besides a barrier also seal birth control to start cutting down on the overabundance of seals.
Not sure which is best
AND QUICKLY !!!
Reintroduce encourage existing endangered Killer Whale population to cull sharks and seals
I actually think we need to utilize a variety of mitigation strategies! There are certain cove beaches that will allow for barrier type enclosures, and that would be the most effective approach. However, it is also vital that we don’t mess with the marine ecology of the Cape. I’m not a Marine Biologist, and I think we need to rely on the Woods Hole Group to determine if any barriers can be used. After that determination, we need to move through all options and figure what options will work and where they can best be applied! Of course, there is also the funding factor. I think we should develope a master plan and then work with state and federal organizations to determine available “public” funds and then it will be a grassroots fundraising effort from there. As a former Chatham business owner, shark safety will have a

growing impact on our "Tourist" economics and businesses should be willing to work to a reasonable solution strategy!
let wellflestians surf with sharks and see if the resulting fatalities have a direct correlation on the number of future outer cape children that get vaccinated.
Physical barriers appear to be unrealistic and ultimately will create additional problems. Since the problem is caused by the current number of seals, it appears that the seal population needs to be managed. Selectively harvest of seals and/or providing seal contraceptives is the option that actually addresses the problem. In addition, tech-based alternatives must continue and information about risk-based decisions making should be provided to visitors to cape cod.
The ocean does not belong to humans. Sharks (and seals) have been here before us and they should be allowed to live uninhibited. If humans are smart about how they use the ocean and understand the risks then they should be safe. We should leave them be and modify our own behavior. I would protest any direct efforts to change the sharks' behavior, especially those that are barrier-based or biological-based.
Cull the top 1% of income earners from the New England area, then gradually extend the cull nationwide.
There are studies already using scents of a distressed great white than sends out an alarm to other sharks to leave the area This study was done off the coast of California So something in that order
However the seal population does need to be controlled either by birth control or culling.
Human
Having increased medical response available and increased information for beach goers is critical.
Whatever barriers would be effective and ecologically safe to people and other non-threatening animals in our ecosystem. Any biological solutions that would not adversely affect people, are non-threatening to other animals in our ecosystem (except the seals and sharks.) I swam in the waters of Harwich all of my life. We swam with sand sharks and could see Monomoy and at times were out there in boats. The seal population was allowed to get out of control attracting too many seals. As I've aged I have come to depend on the ocean for exercise but that has come to a screeching halt in recent years because of the sharks. In my mind this is a matter of balance that affects not only my access to the only source of exercise that I can safely do but the entire economy of the Cape. Without safe access to the Ocean Cape Cod is no longer what we have always been. I am and have been a responsible citizen in terms of the environment for all of my adult life. This problem requires thoughtful decisions before we have ruined our reputation as a safe place for families to vacation and to settle. It affects every part of our economy. I am not a scientist but I am sure the answer is out there if we can pull together and focus.
N/A
(I have to back to cut-and-paste the multiple-choice? Really?)
Vigilance, reporting sightings and crowd management by lifeguards, posting prominent warning signs, improved radio and telecom capabilities from some of the outer Cape beaches, signs and education efforts. NOT (not, not, not) lethal management of sharks OR seals.
I trust you guys :)
We cannot under any circumstances insititute shark culling in USvwaters. It is illegal and immoral.
I love going to and being at the beach. I do not go into the water at the beach- maybe only to my ankles. I know what is out there and I am cautious. I think that humans have to be cautious and educated that there are sharks in the water. That is their home. The best way to prevent shark attacks is the responsibility of humans not putting themselves at risk.
Avoid surfing and kiteboarding during the 3 months when sharks are most plentiful. Learn to share the environment with other life forms.
It's the Shark's habitat. Don't like the risk, stay out of the water
like to see how effective the replants and the Simulated Kelp Forests are
Leave the sharks alone
The number of encounters has increased, but we're visitors to shark's homes. the number of sharks is decreasingly at an alarming rate and we should only try to prevent that.

Education of all kinds! Make sharks and seals interesting! Look to other countries that have tried several methods to find what works best. Honestly, sharks live in the ocean we do not.
I believe in letting nature take it's course, and keeping the ecosystem safe. Learn what you can do to help the problem, be smart, read signs, follow direction.
Respect the ocean and its creatures. We do not own it, they do.
I moved away, permanently. I moved to Cape Cod for one reason... to surf. After 46 years of living full time on Cape Cod with the full intention of living out my life surfing there.... I moved to Portugal in December, looking for a place to relocate. I was fully comfortable surfing with the sharks until I found out that the majority are now "Juveniles" .... ie: young lions, learning to hunt. IMO, that is a deadly turn of events. No longer a reasonable risk. Detection buoys will tell the real tale, are you sure you really want people to know HOW many GW's are here now? My 2 cents = Beavers modify an entire landscape to provide themselves a safe habitat.... why am I less? Seals a cute, and I like surfing with them, but at what cost to OUR habitat? In Portugal, I see fish ALL the time when I am surfing.... not so on Cape Cod.
Education about the risks of entering shark habitat. Education about human over-population and the effects on eco-systems.
shark eyes, more spotters
Implement OMNA Tourniquet Surf Leashes with electronic deterrents.
I support the use of All the proposed actions that were suggested in your email.
I think to be effective all 4 strategies need to be employed simultaneously - Biological alternatives must be started ASAP but will take time - we should use the Technology and barrier equipment available for critical areas of concern and people need to use common sense and awareness in avoiding the existing dangers. One method alone will not suffice - it is time to take our heads out of the sand dunes!
In reality a strategy has to be multi-pronged. That is, we need to educate people about the problem and hazards; need to seek political change of the laws protecting seals; need to use technology to protect our beaches, including physical and technical barriers; tech to protect ourselves--like devices to disrupt/disturb shark attacks on humans; biological--seal reproductive control. All of these should be happening at the same time. One alone won't get the job done. The hazards to our tourist economy is too great!
Human: Risk Based Decison Making
Governance/Response/Communication Enhancement - Full time, high use season May to Nov. regional/county professional life guard corps. Technology clearinghouse system like Western Australia run through Woods Hole/UMass Dartmouth. Cell phone mini system "hot spots" for high use remote service areas. Water safety rescue training for user groups. Subsidy of stop the bleed kits for user groups.
Individual gets to choose whether or not they enter the water
Most listed above can be implemented with wildly varying degrees of reliablity in warning or protecting humans while recreating in our oceans and coastal waters. The only solution, as undesirable as it may be for some is the culling of the seal population. No one will be able to convince me that any other method will improve the water quality as their numbers grow and grow and grow and that the risk factors for humans will improve at all. Surfing adjacent the growing seal population at Coast Guard Beach in Eastham, with a west wind brings a putrid noxious wind that is very common now. Water quality and beach health are being affected significantly now. Sorry but the rest of the methods are well intended by good people but......
Return Cape Cod quickly to a safe place to be in the water by any and every means possible. Ultimately by including ourselves again in the balance of nature Culling is the only way. Sharks first then seals. (LIFO) Until that happens do the quickest things to keep people safe. Drones first then when there is the technology to connect smart bouys use them in addition. Birth control on seals and sharks also.
All of those mentioned esp alarms. tracking. board mounted tech and visual surveillance
Learning to swim responsibly in predator infested waters
Full range of above strategies.
Human control of lowering seal population, thus lowering natural food supply for sharks.
There didn’t seem to be a shark problem until there was an over population of seals. I believe that the seals should be relocated.
Leave the sharks alone, stop tagging, poking and prodding. Continue with first response education for beach goers and water people. Improve cell service. We’re in their house, let’s show some respect. That being said, the seals are over eating everything and I would not be opposed to them being thinned out.

Anything that will keep seals and sharks out of selected areas for recreational swimming, body boarding, surfing. Temporary nets, buoys between June and Oct. if they can't remain in the water year round due to changing sand bars (which usually happens dramatically during the wintertime). Decreasing seal population or keeping seals away from selected swimming beaches. Remove seals from the endangered marine mammals list. There as so many around the Outer Cape now including in Cape Cod Bay and they are coming closer to people and the shoreline more than they ever have before.
Everything described above and better cell service on the beaches. Why don’t we eat seal?
Journalist, covering the various issues.
don't surf near seals, and stay out when the water gets really warm
Don't go swimming. There is no other way to guarantee one's safety with literally hundreds of Great White sharks swimming on the backside, and another hundred or better in the Bay, and growing numbers in the Sound. "Don't swim with seals", fences, drones, are not solutions.
adaptive clothing and human risk-based decision making
Non invasive strategy that does not impact natural lifecycle of ocean life

Tagging/visual detection with real-time alert
I think the amount of seals in the Monomoy area should be addressed to create a balance
All elements of the Tech description have merit. Particularly tagging/tracking, detection using drones.
harvest
I have investigated and read many different resources on the most effective approach in returning the Cape waters to an environmentally, healthy and balanced state and at the same time improving the safety of our near shore waters. A combination of approaches will be necessary and effective. The gray seal population must be brought back to the healthy numbers that it once was somewhere around 1990. This would benefit all species and the ocean environment greatly from its current state. The great white shark would have to be reduced percentage wise to keep a balance and also insure the safety of ocean recreation. Final solution: A gray seal and great white shark management and mitigation plan insuring a healthy, balanced and safe ocean environment for all ocean species our future.
No harm should ever come to a shark, so using the tech based alternatives will minimize the interaction with the sharks. The risk-based decision making is needed in human and wild life interaction. So long as the public is educated about and respectful of these creatures, we should be able to live in peace. The tech is preventive while the human behavior is a necessity.
Visual detection
Cull the seals
Netted enclosures
Get rid of the food source and you’ll get rid of the sharks. The Cape doesn’t need 80,000 seals. That species is doing just fine.
Real time tracking and information as well as shark deterrent strategies
I BELIEVE IF THE SEAL POPULATION WOULD BE CONTROLLED WE WOULD NOT HAVE THIS PROBLEM FIGURINING OUT THE SEALS IS THE PROBLEM
Visual and remote detection, real-time alert, increased life guards
The tagging, real Time alert, visual alert, and accoustic methods seem the most effective and the least invasive to the sharks habitat
Seal Population control
I prefer technological or barrier methods that would not harm any sharks or sensitive sea life. Real time alerts, simulated kelp forests or other safe barriers.

I think the sharks are attracted to the seal population, which has grown over the years, hence the increased shark activity. Seal contraception is an interesting idea, but mostly I feel that people shouldn’t be in the water when sharks are around. The less seals we have, the less sharks will hang around our beaches.
Any or all of the items listed above in the Technological category, combined with educating the public about appropriate risk-based decision making.
Barriers that are not harmful to sharks or seals, technological warning systems
Culling and contraception
I think we should manage the seal population as we did in the 70s
Educate public Tagging Real time alerts Visual detection
Seal cull
Electronic bouy system
Tagging/alerts/drone monitoring
Culling seals, barrier sound waves to repel sharks
Seals are over populated an are the culprits. Tools with sound wave might deter the sharks??
I feel that further educating our beach patrons on SharkSafety Protocols combined with All of the above components may be necessary to enable safe waters.I believe there is not "one" solution to the Shark Issue.Thank you. Sincerely Sarah Rundquist
Commercial seal harvest for profit.
Educate the public that the sharks are here to stay. None of the options are 100% and most if not all of the options will provide false confidence. Do not change the sharks behavior, change the human behavior. These methods do not work around the world so why do we think they will work here????
Education about the behavior of sharks and seals and their value to the ecosystem as a whole.
As a surfer who spends hours at a time in the water what I think would be most beneficial is a combined real-time alert system that would combine shark tags that would trip buoys around surfing areas and aerial survey (drones/spotter planes with on the beach notification using a flag system. Ie. if a shark swims within a certain proximity to a surfing area, an alarm would sound and a flag would be raised. Cell phone app is of little use since I don't take my phone surfing with me. Please don't cull the sharks or seals. Let the ecosystem reach a healthy balance. I want to surf in a healthy ocean. Sharks and seals will work it out. If things get really gnarly (people start getting bit more frequently) I think a well designed net system could work with minimal negative impacts to the environment.
Kill many seals,the problem is at an insane level now,can't even reel in a fish from the beach without a seal grabbing it off your line and the seal numbers are way out of hand with no other solution then to cull thousands of them,the truth hurts PETA tree huggers
Use drones
Cull the seal population. Old laws protected the seals. It’s time to fix their mistake
Kill seals and eat them

Kill seals and eat them
Tagging
Tech based: I also believe the increased use of spotter pilots and the continued use of tags, with acoustic receivers should be used to keep track of shark movements.
bring back seal culling.
Spotter drones/planes, as well as manned elevated lookouts near popular swimming and surfing areas Nothing that may affect natural animal behaviors (other than drones)
Seal contraception/culling, magnetic/electric/acoustic repellents
Netting similar to what is used in Australia seems to be the most humane and effective.
Clever buoy system,increased cell phone coverage
buoy based sonar
Cull seals and seal contraception
Bouy warning system
Funding for research ie. tagging, real time alerts, remote detection.
I have been a lifeguard for over 40 years and a lifeguard instructor for much of that time. I designed the surf rescue course currently being used by Wellfleet. In my humble opinion, drone technology (possibly with pattern recognition and advanced optics) should be employed initially (and immediately ... there has been a sense of urgency within the lifeguard community for well over a decade). While reducing overall risk, the initial drone program will generate research data to further refine downstream methods. Drones (which I am not a fame of in general ... but you can't beat them when it comes to emergency/safety issues) don't have the maintenance problems associated with other ocean-based solutions. The other critical aspect of this technology is that if an 'attack' takes place, the operator can let the lifeguard/first responders know that the fish was seen swimming away (it's relatively safe to perform the rescue). I am concerned that other 'repellant' devices may have the opposite effect ... the electric/magnetic ones may even attract the attention of sharks and make things riskier for other swimmers/surfers in the area.
Least invasive option as possible, drones and more spotters, swim at your own risk.
The Clever Buoy system is perfect for Cape Cod. At least two per beach should be mandatory for all towns and parks. They can be supported by drones and spotters. Besides economic impact, this is a public safety issue! There can be no further delay. Nature changes, we change, we adapt. This will be part of our lives, our budgets moving forward. How many people will die before we take action?
Combination of education to change human understanding of sharks and realistic recreational behavior, and AI or other smart tech like Clever Buoy.
Visual- balloons-spotters-planes-spotters
i think we should increase the research and how many boats are out there tagging and also use the smart buoy systems!
seal cull
contraception
Reduce seal population
Seal contraception
Cull the seals by 95%.
Tagging, and real time alert!

Thinning of the food for the sharks. The Cape has felt the impact of families not coming to vacation here, with the recent shark attacks. The surfing community is almost lost on the outer Cape.
A combination of buoys based sonar, such as buoys forming a line undersea to detect sharks could feed live information to a smartphone application. People could could get alerts on the smartphone when a shark is near. If the app is impracticable, the buoys could be set up to give instant alerts to just the lifeguards via a radio chirp or transmitted alert. If sonar is not selective enough, buoys armed with artificial intelligence which detect the difference between dolphin and shark swimming patterns could be used to transmit alerts. This could be supplemented with drones flying over the general area. If towns can not afford to pay drone pilots, a volunteer network could be created which may be inspiring for those who want to contribute to their community in a meaningful way that also interests them. I own a drone and devoting an hour each day or even a couple of hours per week to shark surveillance in my town would be realistic. I wonder how many people on Cape Cod own a drone they invested hundreds of dollars or more in that simply sits collecting dust when it could possibly used to save someone's life. It may take incentivizing things to get people involved, but it may just be how you frame it for them.
Tagging
Seal culling
Cull seals
Use of drones
The use of drones for detection. One drone to scan several beaches - Ridgevale, Hardings area all the way west to Forest Beach.
Repellents
Seal population is the problem and needs to be controlled
I think this problem has been a long time coming. Not only has the seal population been destroying the commercial fishing industry for years but it has also brought natural predators to our shore. Growing up we never had to think about going boogie boarding or surfing at any ocean side beach. It was just rare to see a shark so frequently and so close to shore. Now it seems like there are videos of sharks thrashing seals a stones throw away from the beach.
Visual detection
Reduce seal population along with other proposals listed under Biological
Initially, I propose the sonar buoy system so that we can offer beachgoers better protection, immediately, for certain designated areas. Long term, the population of sharks and seals is exploding, and the cost to implement buoy systems everywhere that sharks swim is unrealistic and too costly. Also, as the number of shark detections and encounters increase, there will be less and less time that beachgoers can enjoy their time at the beach, so they will choose to go elsewhere off Cape. Statistics are already showing that to be the case as rentals and visitations to the Cape have been decreasing for the past couple of years. All of this will have a sizeable impact on the Cape Cod economy which affects anyone who lives, works and owns a property or business on Cape Cod.
Real-Time alert
I think we need to look at all available strategies to determine which ones will be most effective on the Cape. It seems unlikely that this analysis and any recommended mitigation measures will be done in time to have an impact for this year's shark season. As a short term measure, I think the CCNS ban on drones needs to be lifted, or for a ban to only be in place within a certain radius (100 yards?) of plover nests.
Your tech suggestions are good.
However, if the size of the seal population is not curtailed, then a combination of detection such as Clever Buoy plus deterrence such as Shark Shield will probably be the best alternative
I favor disrupting the seal population problem, specifically the pattern of seals swimming close to the shoreline from about Chatham to Truro every summer and fall day. I favor whatever would work to break up this pattern, including culling as a last resort. It is my opinion that as long as the seals keep moving along the

beach and closer to the swimmers, the sharks will follow...and in the surf close to shore the increasing number of sharks (seeking a meal) will increasingly result in incidents of sharks mistaking swimmers for seals.
Spotters and guards
a combination of drone/buoy and personal repellants such as shark shield, and reliable cellphone service at all beaches, down on the actual beach and not only in the parking lot so that warnings can be communicated
Technology easily upgraded for researchers and first responder training
Relocate the seal population (estimated time 2-5 years) to a remote island and the sharks will go away and the Cape will return to the way it was 20 years ago. Fisherman and business owners will benefit and the beaches will be safe again.
Real-Time Alert
Just as there are harvesting quotas on fish, deer, turkey, tuna, etc, there needs to be a harvesting quota for seals since there is an international market for the harvest.
Tech based
culling
Seal culling AND contraception
Seal Contraception
cull the seals
Drone monitor the popular beaches, simultaneously download information to Sharktivity
sonar buoys
Reducing number of seals might reduce number of sharks. Using bio-type tools might help in a relatively humane manner.
Netting around swimming areas
We need to stop protecting the seals, which have overrun the area. Seal contraception is a great first step
Seal culling
Technological strategies of any type, and risk reduction behaviors are best suited in my opinion. Barriers wont work in most cases, and biological strategies should be off the table because of their potential effect on the ecosystem.
Nets to ensure safety
Also, adding drones to lifeguard equipment would help.
drones
This is a risk we cannot eliminate but only mitigate. I agree with all technology/human proposed mitigation methods- but I strongly disagree with any form of biological culling. We must adapt to the presence of seals and sharks, not alter the ecological food web. More tagging and more buoys are needed. A comprehensive, and uniform education model should be produced for all Cape Town employees to follow. This would reduce the amount of misinformation produced, especially by the media. Lifeguards, NROs, Town officials, and other

employees should be equipped with the correct ecological, and biological information to correctly inform beach goers of the presence of white sharks and seals.
Shark repellent
Shark and / or Seal Culling, Indigenous Harvest
Use warning bouys.
Remote and visual detection
Any of the tech possibilities look good to me, and seem the least invasive.
tagging (acoustic and/or satellite tags) as long as organisms tagged without the use of chumming; real time alerts on apps like Sharktivity given that cell service on beaches has increased
Tagging, real time alerts, and further education to allow for better risk based decision making -- all make the most sense to me. This is in addition to the action items being addressed already.
Jet skis or boats for lifeguard. No, it is not preventative of an attack but let nature be nature and people can choose to take the risk - jet skis or the like might give lifeguards the greatest chance of helping someone survive an attacking and of getting people out of danger sooner.
I believe that an educated public would be better suited to make risk-based decisions on where to swim and when to swim.
Reduce the shark population
Mesh netting
More education about co-existing with ocean species, and what precautions to take. The ocean is their home - we are the ones intruding upon their habitat.
More education is needed, particularly for those from off-Cape, to prevent any potential attacks. We are, after all, intruding into their environment.
better understand shark behavior to learn how we can better avoid human/shark contact.
Buoy system that will detect sharks in area
Reduce the number of seals.
Cull
Cull seals
Put up nets using buoys that have technology that pings when a tagged shark is nearby. Sonar would benefit too, though may be too expensive. The seal population should also be culled— pay local fisherman to responsibly eliminate set numbers of seals. It would mitigate the shark problem and benefit the fishing community.
Seal contraception
No culling and no physical barriers that can harm marine life. More tagging and tracking and more human awareness. Learn to share.
Signage accurately describing the risks. Signs that advise if seals are there, stay away. Discourage looking like a seal (post pix to show how sharks can be confused between the two). If someone chooses to ignore the above, well, then....
Reduce the number of seals
Warning that a shark is in the area is what makes the most sense to me
Reduce the seal population also.
Bouys based sonar

Bouys based sonar
Seal contraception coupled with the Best Available shark and seal detection and deterrent mechanisms.... thus MUST be a multi pronged approach and the Towns are 6 months LATE in the process of decision making and implementation!!!! It is going to be EXPENSIVE and we need State and Federal assistance NOW! This as a very highly defective survey; results will not be reliable for action.
There should be a multi strategy using real time alerts, visual drones and remote detection.
Seal cull
The buoy technology is proving to be the best in areas where sharks are prevalent around the world. Human beings should understand that the ocean belongs to the fish and that for three months of the year killing sharks and seals seems to be only wanted by the ignorant and those who make money in the fishing and tourism industry Before I moved here are used to summer out here. I would not want to bring my children here anymore if this was a problem 20 years ago. I would only feel safe if technology was out there guarding my children along with surveillance by air and any other technology There should be a combined approach
tagging or remote and visual detection
Need all approaches. People vary in their ability to assess risks so this is not useful. I stopped swimming in the ocean 3 years ago. If people can't enjoy the water, there will be a HUGE impact on the Cape economy. Seal contraception will take a long time to work given the magnitude of the population but should be pursued as long as it won't contaminate the water any more than people contraception does. Technology is ideal but it is still developing and doesn't seem 'foolproof' yet. Barriers are likely to be limited in scope and could be costly to maintain but are available now. So we should pursue all approaches and continue to evolve the strategy over time.
I support use of technology and human behavior/education to keep this issue under control and allow both sharks (and seals) to live alongside people. I do NOT believe that people's recreational interests should supercede the ecological requirements of animals in this ecosystem - we can adapt, they cannot. Let's follow the good advice from other places that face similar issues and have been living with sharks for many years. Sharks have a right to be there.
Combination of visual detection, remote detection, and shark repellents
NO CULLING OF ANY SPECIES! This is their home not ours! Have we learned nothing? Culling frequently promotes more breeding much like coyotes. We have done enough destruction to their environment. People are the problem. Not the creatures!
Drones. Sensors, tagging, real time alerts. And maybe more for the seals and deterring them from certain areas by these methods as well. I am vehemently opposed to barriers if any kind and I am stunned this was even discussed. My dad gave me the best advice... “there is nothing in the ocean to fear. You need to respect all creatures in it because you are in their home” We have a people problem. I can’t tell you how many times I have told tourists to get out of the water with seals. We have seals We have sharks We have really stupid people and radicals that date to taunt an attack. If you come to the cape that’s the deal.
Combination of as many of the tech based alternatives listed about. It needs to be approached from all angles.
A combination of Monitoring, Tagging, Drones, Alerts, along with Human Risk Assessment.
seal control of course
I support a combination of tech based strategies. Tagging, buoys, electronic deterrents, apps, and spotters are all valuable.
Kill all the seals. There are millions and millions of seals around the world and humans life is much more important than the seals. If you do not consider this as an option, the tourist population will be reduced significantly. No need to build another bridge !!
Repellents and indigenous seal culling, relocation and maybe seal birth control.
Real-Time Alert, Visual Detection, Remote Detection, Seal Contraception

One single solution is probably not enough – – a combination is needed for example better alerts and warnings, which could be tied to either visual sightings such as from drones, or underwater detection, from smart bouys. There may need also to be a small netted area for small children. Surfers may need to be advised of best repellents,
Not sure yet, I definitely would like to learn more about any technique and it's results/ consequences. That said, I'm not sure barriers or biological tactics would work best in our environment.
Tag and have visual spotters and if sonar works, then that as well
get rid of some of the seal population and also use tech based strategies
More intensive use of spotters or drones seems like it would be an effective method, alongside the use of physical barriers like magnetic forces or a bubble net.
Shark repellents (Magnetic / Electric / Acoustic Deterrent, including Wearable or, Surfboard-Mounted Technology, Orca recordings)
Amend the Marine Mammal Protection Act to allow for the management of recovered populations (for example, manage instead of protect the grey seals in the Northeast Atlantic).
Magnetic post array, shark repellant - electric/magnetic - wearable & board mounted
Drones and radar alert sensors
Remove the food source, the Sharks will follow.
Need to limit seal population thru culling and contraception if possible. Natural balance is skewed, the sharks are just responding to the plethora of food . Unfortunately the sharks probably need to be culled as well otherwise they may turn to an alternate food source . My entire circle of family and friends frequented Cape Cod beaches in the past 60 years . This will be the first year that we are planning on traveling elsewhere because of the attack risk.
I would like to see a variety of tech approaches as well as perhaps a barrier. I have concerns with the board-based repellant tech devices and desensitization over time. I do have concerns about a barrier impacting other marine life, especially given the presence of species such as the Ridley Kemp turtles and North Atlantic Wright whales and would not support a barrier that poses a serious threat to endangered species. I am particularly interested in the real-time warnings that might come from a tech or tower approach, or combination of the two. I feel strongly that a seal cull will create more harm than good for a short time and would definitely not be getting in the water for a while if it happened (hungry sharks, you know?)
I would support a technological approach; for example of the type: https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/815866/evaluation-of-clever-buoy-shark-detection-system-summary.pdf that would minimally effect the other marine life in the in the vicinity while repelling the shark life into deeper water.
Visual and remote detection
Tagging and real time alert
mitigation of the seal population? keep aware of shark presence and alert public
Cull the seals, put seals on birth control
Technological
Technological
Seal & Shark Culling
I support (in addition to educational efforts and community outreach): • Tagging (Acoustic & Satellite) • Real-Time Alert (App-based, Alarm-based) • Visual Detection (Drones, Balloons, Spotter Plane, Towers) • Remote Detection (Buoy-based Sonar, Artificial Intelligence-Machine Learning)

Nets or hard barrier
sonar buoy
Smart buoys, spotters, and drones
The Clever Buoy system discussed at the Wellfleet forum sounded like a great idea.
I vote for whatever works! The drone technology seems promising and could be used on the beaches without lifeguards. Perhaps the drone could provide an alert with lights placed on the shore, or on buoys that are placed beyond the surf so swimmers could see that there's been a change in the threat level. Grateful that many great minds are thinking collectively about this issue - the sharks aren't going away and we need to adjust. Would hate to give up the Cape after enjoying many generations as part of it.
Call boxes/more medical staff, swim at own risk
Use drones
shark detection technologies
Based on choices presented, technology based proposal seems most sounds.
Combination of the above
Spotter planes from Chatham Airport. Sharks easy to see in shallow water near beaches. If sharks around warn people on beach from air. Only way to do it.
I am not for culling animals. Tagging & tracking with some sort of alert system sounds great to me. Don’t swim where the seals are is just common sense to me
Cull the seal heard!!!!!!
Warn people with signage during periods of high shark concentrations. This may deter them from going in the water. Let's try to keep wildlife and the environment in mind when making this decision.
Any of the technology-based strategies plus risk-based decision-making are preferred. The worst alternative would be use of barriers involving netting or other barriers that could result in bycatch of other species.
reduce shark food supply
Drone.
Drones
Apply for a public safety exemption under the Mammal Protection Act to cull/harvest the excess seal population
the standard logic on the outer cape has statistically been one lifeguard tower/chair/station per beach, centrally located. change that to one on either end of the official lifeguarded 'beach' zone. each station has a drone with shark biotelemetry software to detect them. put solar mats on top of the lifeguard stations and they have a power source to re-charge. they run 20 minute pre-programmed flight patterns between charges. they don't really require a pilot. lifeguards don't really have to maintain much, just set them up in the morning and they do their thing all day. fly loops, one north end, one south end, recharge when necessary. add an ipad in both of those lifeguard stations (powered by those solar mats) and then there's a direct alert system from the drones to the guards at least audio/visual wise on the ipad end. visualize it this way. you're a life guard, you go to work every morning, you turn on the drones and send them on their path. they fly whatever the most effective pattern is to survey the most amount of area, fly in on their own when they need to re-charge. granted, guards will have to manually plug batteries into chargers and send them back off. but if you're a guard, and all of a sudden, that drone that flys out there in a continual pattern has stopped moving and that ipad is giving off an warning alarm, it'd get you're attention. if you're drone detected a shark to the south moving north towards the 'beach', you'd be able to notify the populace at your end, before it got there, but also notify the other station of incoming. and vice versa. with the populace in between at twice the rate of protection than currently. due to the nature of the outer cape and it's north/south orientated shoreline, having some not-prohibitively expensive tech and doubling the life guards (which, admittedly will be a sticking point for most towns) seems not that hard. they're called lifeguards for a reason. and they're mostly young, tech-savvy, adults that care, and would love to have cool toys to protect people with. sharks are way too above use on the natural apex predator chart, our only defense is technology.

The only strategy that makes sense to me are the $30k buoys that relay real time alerts to beach patrols to make it possible to issue warnings to swimmers and surfers about the presence of sea life in excess of 6'. Surfers have to assume risk, as well as fishermen, to take measures to avoid attacks on their own, such as using long handled nets to land fish instead of hand lining them.
Need to improve cell service on the national shore line. One phone far away isn’t quicker than many people who have ready to use devices in their hands but cannot use them because of a lack of cell coverage.
Responsible reduction of the seal population must be on the table for discussion.
I'm a lifeguard on the outer cape, and had been spending my summers there my entire life. My first summer guarding was 2015, that was towards the start of the shark craze. It really does feel like things have changed since then. That summer we closed the beach only once due to a shark sighting, this past year we mus of closed the water over a dozen times and both attacks happened less than 6 miles away. This is going to continue. Public education can only do so much, we need to start doing something preventative about this. I will never be in favor of culling either the sharks or the seals, nor do I think we should tamper with the natural environment. I strongly believe the best strategy is to use drones. We had a private citizen that would come to the beach and fly his drone around and said he would see sharks almost every single time he put it in the air. These were all sharks we never saw with our eyes from our lifeguard stands. refer to this youtube video the citizen posted https://www.youtube.com/watch?v=3x6DqieGziM&t=8s Drones literally could save lives on the Cape. In Australia they have been doing this for years, and the drones they use are outfitted with technology that actively scans the water and can accurately detect and highlight sharks from other marine animals like dolphins. This technology needs to be invested in. I know the National Sea Shore doesn't allow drones unless operated by scientists but what is more important, a bird, or someones life.
Seal culling
Real-Time Alert (App-based, Alarm-based) • Visual Detection (Drones, Balloons, Spotter Plane, Towers) • Remote Detection (Buoy-based Sonar, Artificial Intelligence-Machine Learning) • Shark repellents (Magnetic / Electric / Acoustic Deterrent, including Wearable
• Visual Detection (Drones, Balloons, Spotter Plane, Towers)
• Remote Detection (Buoy-based Sonar, Artificial Intelligence-Machine Learning)
• Shark repellents (Magnetic / Electric / Acoustic Deterrent, including Wearable
Seal culling and harvest. The seals would move off shore.
Sonar Detection, alarms
Netted enclosures similar to those that have been used in Australia for decades.
Real time alerts that work 24 hours/day - 7 days/week
all listed under the two categories
improve public education & warning system
Enclosed swimming areas
Increase in education for beach goers, surfers, etc that is more widely available. Educational commercials, signs, ads on social media about shark safety but also why sharks are an important presence to our local waters, and the level of risk involved when sightings are reported and which actions people take.
This survey (unfortunately) requires chosing just one strategy when a multifacited approach drawing from each of these categories is a much better option to have an impact keeping beaches safe. I chose Technological in order to complete the survey. However, the vision I have is of in-ocean towers manned by guards or paid spotters connected to an easy to use by spotters) and understand (by beachgoers) alert system warning of nearby sharks and or hits. Real time data from bouys would be integrated into the alert system. the ban on drones in the national seashore would be lifted so that individuals could do their own surveilance (particularly needed in the offseason). And the guarded season would be extended to weekends through September. Acustic deterents lining the shore to add a layer of protection.
The magnetic post array only for the physical strategy. For the technical- ALL of them sound great. I do not at all want any animals harmed by interventions, but I also don’t want to have anxiety attacks letting my daughter and dog swim.

Have a "seal hunting season" similar to deer, to control population. With technology, have an electronic barrier or other repellent in addition to the sonar-buoys
Try them all! This is a huge huge problem.
Something must be done about the seal populations that are out of control. I recommend starting with the biological strategy and incorporating other strategies such as netted enclosures and visual detection.
Sharks and Seals were here in far greater numbers before the protection act. Inform the public through signage, educational marketing, visual shoreline monitoring, acoustic receivers, compare strategies to other communities like those in California who have accepted wildlife for what they are: wild. Culling is not acceptable in our modern times. Invasive technology will do more damage to the ecosystem than save one life from informed choices made to swim. Embrace safe and educational shark tourism. Support AWSC. Build usable data on shark and seal impact on fisheries. Educate fishermen that the days of Wild-West-style fishing are over. Enjoy Nature as it was intended!
Seal hunt/ eliminate food source
Technical shark repellants.
The seals are the problem. I think the seals should be both culled and deterred. I also think there should be better detecting and alerts
Visual detection plus repellents
encourage cost-effective and commercially proven methods that include technology based and enhanced public education
seal Culling
Educating beach goers and implement easier reporting of sightings.
Education about the benefits of a diverse ecosystem and how human activity can co-exist with seals and sharks.
Birth control for seals
Barrier safe for humans and sharks
Tech based alternatives - any
Physical barriers, and technology
Non-invasive technology based strategies
Tagging/real time alert with visual and remote detection.
Seal cull, remove the food source.
Visual, repellents, and camouflage.
reduction in seal population. removing the seals from the protected marine mammals list.
visual and buoy detection with tagging
some type of repellant.
Seal culling, shark culling too if necessary and seal contraception
I support a cull of the seals.
Shark Sheild buouy system
Seal culling... aka stop preserving the seal... this is what happens when you interfere with the food chain

From what I've read, I'm most interested in drones or balloons that could alert the public to nearby sharks. I thought the Clever Buoy was also designed to do this. Many things, such as fake kelp forests, strike me as impractical for the Cape. If there are shark deterrents that are shown to really work, I'm in favor of those too, but if as expensive as they are now, most won't use them. I also like the thought of cutting back on the seal/shark population by contraception if those are actually possible. Of the four categories above, the only one I don't support is barrier, since I don't see how you can do it on our vast and shifting shore.
Seal cull
Allow hunting of seals and other strategies to lessen the population. We need to save the people before the seals and the sharks, and get our safety back in the water!
Technological solutions to better identify the location of sharks and dissemination of that information, plus human risk-based decision making to avoid waters where sharks are present. I do not support culling sharks or seals.
An early warning system to alert anyone in the water of a shark in close proximity. Thank you for your efforts
Drones, apps, remote detection
All the new technology and alerts, along with repellants. No nets!! No harm to the sharks or other marine life
Reduce seal population
Drone monitoring
Cull
some sort of barrier that won't affect other aquatic life like a magnetic post array mixed with a certain buoy/visual alert system
I am a regular beachgoer and swimmer at Nauset beach. I am opposed to most barrier solutions though I am interested in the simulated kelp forest as a possible portion of the solution. I am very opposed to any rigid or netting type of barrier. That would destroy many beautiful aspects of the ocean close to the land. I support technological solutions including all that you listed except drones are not an attractive solution. I do believe that human risk evaluation is critical. When we go into the ocean we are in the habitat of sharks, seals and other animals. It’s their home. And we have a healthy ecosystem with top feeders (sharks) that I want to see preserved. Thanks for this survey.
The seals are hurting the fishing industry and attracting sharks at extraordinary rates. They are not endangered. They should be managed like we do with all wild-life to ensure a healthy population but prevent over-running. For the same reason we don't have wild-boar, deer and coyote overrunning our co-habitated environment, and in the same manner, we can have success with mitigated the seal population and thereby minimizing the shark/human interaction issues. If a pack of coyotes had killed a 15 year old Nauset runner on the bike trail, I'm doubtful there would be debate on whether there should be open hunting season. In this case, the sharks are endangered, but the seals aren't. And other than the desire to study, and the fascination with the sharks - we don't need to encourage them to be in our near-shore waters. Lessening the seal population (through hunting or birth control) is the easiest strategy. The marine mammal act can be petitioned against as it has been in Washington/Oregon for test strategies to control populations.
soundings for awareness of sharks in the area
A combined use of tagging, app alarms and drones
Although I feel something needs to be done about the seal population in this day and age there’s too many people that don’t educate themselves on hunting and what hunting does to benefit populations of species and I believe there would be too much backlash if culling seals was an option. Therefore I feel like tagging along with the visual detection and bouy-based sonar used with the real-time alerts is the best way to keep the public educated, safe and happy. As a hunter myself I do feel like the seal population should be treated no different than any other species that is hunted, with proper regulation there’s no reason the population can’t be kept in check to make it more of a benefit to the ecosystem instead of a nuisance.

Clever buoys, increased beach patrol hours and season, increase fiber optics, up date safety info all beaches, increase defensiveness / shark deterrents, openly share findings and shift to being more proactive in recreational swimming and surfing zones. Directly involve water men and women that are and have protecting the visitors when lifeguards are not around the other 9 months or before and after hours please to start just to name a few. Thanks for all you do too.
Return the grey seals to their levels circa 1990 by placing a bounty on them.
Harvest
Cull
repellants: chemical and acoustic deterrent and by word of mouth
Nets or culling
Drones and spotter planes
It is my understanding that barriers have worked fairly well in places like South Africa. I would not want to cull marine animals - just make the beaches safer for humans.
Combination of tagging, alerts, and shark repellants
I believe a combination of the tech based strategies would be best.
Cull!!
Shark sensors, drowns, ect
Explore dedicated swim and surf zones. Begin thinning seal herd. Let sharks be Sharks
Explore dedicated swim and surf zones - let sharks be sharks, begin culling herd
Dedicated swim and surf zone with nets or barriers - cull herd - let sharks be sharks
Detection and alerts
I like the idea of drones and apps letting you know about sightings and where they are. And we as humans need to respect the sharks, it’s their ocean and we need to be smart.
Lease sonar buoy arrays immediately @ the most populated beaches, along with humane culling of the seals- annually & humanely with the a group of sealers from Canada
Shark and or Seal Culling. Both populations are at very healthy levels now, the herds need to be thinned out to avoid so many probabilities of human encounters. I believe the only way to mitigate this is by bringing the populations down to a sustainable level and try to keep them there. At this point the seal population is so large that it's starting to damage the ecosystem with their diet and excrement. The shark population is only growing larger because of this and causing more probabilities of human encounters.
Seal contraception
drones
Rigid plasitci mesh enclosures, netted enclosures, bubble 'nets', magnetic post array and simulated kelp forests
Cull the seal population along with seal birth control to mitigate effect seal diet is having on endangered fish stocks such as the Atlantic salmon and other species.
Technology and human detection/surveillance. Also, shark deterrent technologies like magnetic bouys and the like.

• Shark and / or Seal Culling, Indigenous Harvest
Drone-based and public awareness. Drones should be used to monitor the shoreline at areas that are already staffed by lifeguards. The lifeguards would receive additional training and assume responsibility for a drone at that location. There would need to be minor infrastructure improvements made to accommodate power and A/V needs, estimated at less than $20K per location.
Some form of culling seals
Seal culling
All the tech ideas you've listed, except excessive use of near-shore drones, sound good.
cull seals. Great whites are drawn to the swim zone by overpopulated seals. Public fear of shark attack, left unaddressed, can cripple tourism. I have already decided to rent a cottage in Rhode Island in 2019 instead after the fatal shark attack in 2018. Culling does not have to be openly advertised, but it is certainly necessary at this point.
Control the seal population. Killing sharks is not the answer.
Contraception or culling of seals .
Netted Enclosures
I support both barrier and technology strategies but regardless of what is implemented, people have to take responsibility for their behavior. Common sense should tell you to only go in the water where lifeguards are on duty and pay attention to warning signs posted. The incidents last summer were tragic but, sadly, could have been avoided.
Australia style sensors and alarms
Population control of seals to return environment to levels that did not attract such extensive numbers of sharks. With fewer seals we should see fewer sharks eventually.
Seal cull
Hunt the sharks. They are hurting our human population and they are hurting our economy. I will not go to Nauset Beach or go into the ocean anymore after I saw a shark. This is not a movie (JAWS) this is the real deal. It must be addressed.change the Federal law to protect us!
Seal contraceptive would likely result in fewer births, fewer sharks. This would take many years but would have a positive effect on the fishing grounds, water pollution and predator attraction. This might be challenged by government as the seals are protected. This seems the most humane way to get at the root source of the problem.
seal contraceptives. Must reduce population of seals. I do believe that more than one strategy may be necessary.
Rid the Cape of its growing seal population through hunting or other more humane means.
Remote detection
high frequency radio or sound underwater that will repel sharks from entering certain areas Or low level electrical waves that will chase them off. Using whatever special biological system sharks have that detect such things.
Drones to monitor and send alerts to an app of shark sighting warnings in a more real time manner with accurate video of shark locations. Sharktivity app is helpful but is not accurate in real time sightings and some are questionable and can't be verified. This would be helpful to boaters who can acces more remote beach areas. If people don't have app then alert can be posted on an electronical solar powered sign at public beaches with written location of sightings. If a shark attack does occur there should be a clear plan of who to contact and can respond quickly. All lifeguards should be trained on what to do in a shark attic and have reliable communication to public safety officials who can assist.
Seal culling
Seal contraception and culling with tech alert based system
Cull seals!
Tagging and drone spotting. Communications improvements to allow for real-time app based tech to work in the remote areas of the outer cape. Call boxes, public safety and awareness training (stop the bleed). Perhaps

a free tourniquet day at a local fire Dept. Propose EZ pass tolls on both bridges inbound to pay for the new safety measures.
Either some sort or barrier or harvest.
Seal contraception
Magnetic repellents are proving useful in Australia, and human shark spotters in South Africa appear very beneficial.
Some type of technology that can either detect or deter sharks and protect humans so they can still be able to enjoy water sports
Reduce the # of seals. Put free wifi on all town beaches for quicker 911 calls. Use drones.
Seal culling
Discourage seal infestation
reduce seal population
Drones
We have too many seals. We need culling and contraception. People want to swim, surf, in the ocean when it's convenient for them, not just when seals are not nearby. The CC seashore is too big for barrier methods. Technology will help, and the idea of wearable tech is fascinating.
Visual and/or repellents
seal population reduction via various methods, including harvest.
Seal contraception combined with shark/seal culling for the first two years.
Cull the seal population now!
Culling on just the seals
I believe that controlling the seal population will control the shark population naturally. I am a believer in hunting animals for population control. I am aware that seals are protected but perhaps at this point there could be an amendment that does allow there to be a short hunting season for the appropriate hunter. Not an open season hunt- for anyone- just for certain fisherman that have experience in that area.
Enclosures, repellents, culling both
Repellent
Real time alert, drones ect
Visual detection
education and awareness - perhaps complemented with selectively-tested technological tools - is an approach i would support.
Tagging and alert systems, remote detection
We really need to cull the seal population in and around all of Cape Cod as they have grown out of control and are eating all our fish and that impacts the likelihood of our local fisherman. If we cut down on the seal population, hopefully that would also cut down on the number of sharks around our waters.
I would remove seals from protected lists. While I do not want to "cull the heard", and I don't think they should be hunted, I think it should be OK for people to scare them away from congregating on local beaches. The seals have become too comfortable with humans, so they stay near by. Lets balance the protections to represent current reality (they are far from endangered!). My next choice is a technology solution. I think barriers would be incredibly difficult in the sea conditions we have on the outer cape beaches.
cull and sterilize seals. it’s the only effective long term solution. in the meantime, we obviously need to implement more effective “human contact minimization” techniques to protect human life. however, without

seal culling/sterilization, the problem grows and other efforts become absurd. btw, this solution not only protects human life, but also our precious coastal and inner coastal fishing attractions.
The seal population has been handled irresponsibly creating an over population affecting a whole host of issues.
I believe it is the humans responsibility to know the area and dangers in that area when entering the water. I also believe the lifeguards need to know first responder shark aid! Technology meaning using the Sharktivity app and maybe checking receivers daily or every other day and report that information to the Sharktivity App. Also drones are a great form of defense. Biologically continuing the research and tagging of shark's in our area!! Barriers will cause harm to other marine life and studies have shown them to not be very effective in other areas of the world.
Continue educating public about shark smart tips. I also think drones and tagging should continue so we can continue to collect data and also alert public when a shark is nearby via APP.
Kill seals, contraception of seals
Cull seals and set up barriers to Oyster river and or Oyster pond
Use of aerial shark spotters, in conjunction with tracking the 'tagged' sharks to alert beachgoers of their presence. Improved cell phone coverage, training lifeguards to provide emergency first aid until ambulance arrives.
Tracking, warning, easy access to summon aid and common sense
Tech base it’s seems would be the most logical. Tagging and alerts for all.
Using technology such as drones to our advantage to monitor shores seems as though it could be helpful.
Time to get rid of some seals...get rid of the food source, limit sharks
All technological tools that are effective.
Seal culling
netted enclosure
Seal Culling, Indigenous Harvest
use of repellents, fake seal, etc.
Cull the seals.
Visual detection
Cull the seals, kill the sharks
I like all the tech based and barrier strategies. We need a multi-pronged approach.
Decrease number of seals which are the food source but also who are decimating our fish resources. Tag sharks so we know where they are. At Australian beaches there are fenced in areas for safe swimming.
Cull the seal herd. If we had not protected them originally, this problem would not be so overwhelming.
sonar buoys
Cull the seals. All this talk and show is a masking the truth. It is simple math and always has been. Less seals = less sharks. Do seals provide any good for humans besides looking cute? They are a competitor of humans in the food chain. They eat everything and the only species that eat them can not keep up with their numbers. Sharks are not the problem!
remote detection
Cullin to decrease seal population

Warning/alert system using tagging, cell phone alerts and beach side alarms. Culling/killing should be off the table in my opinion.
I support al the tech based strategies listed above. I do not support seal culling in any capacity.
Seal and shark culling
Seal contraception and seal/shark culling
Shark & Seal Culling first. Need to establish importance of returning population numbers to "normal"; populations will continue to grow out of control without human intervention & this will only increase danger of attacks on human life. Until populations are restored to manageable levels (likely further out on the timeline since decisions about such methods are likely to take longer to politically/publicly pass), technological & biological repellants/detection should be used.
drone surveillance
Reduce the seal population
Culling of seals
Clever buoy’s
Cull, it worked in 1950's, 60's & 70's
While barriers sound great, the biological diversity on Cape would suffer by way of other animals (dolphins, seals, turtles) getting caught in the nets- plus the ever shifting shoals. Technological strategies and the extension of lifeguard hours and season are our best bet. Both 2018 attacks happened on unguarded beaches- that can’t be ignored.
I think all of the Technological Strategies are good. If effective, Shark Repellents should be readily available.
Make medical kits available on high risk or all beaches that contain supplies/tools to control bleeding. Also provide classes to teach the public about shark safety and what to do in case of a shark attack. Another big issue for some beaches on cape cod is the cellular service, a telephone of some sort should be close by on all beaches so it is easy to get in touch with first responders.
Electronic warning and repellent devices
Culling the grey seal population.
Reduce the seal population
Cull the seal population - never saw one when I grew up on the Cape.
1. Remote detection 2. Visual detection 3. Real time alert? /Question: Have orca recordings been tested elsewhere?
No acoustic or sonar deterrent as harmful to other ocean life. Adaptive camouflage and real-time alerts
Tech: Tagging, Real-Time Alert, Visual & Remote Detection
I've read about the use of an electric field source to emit a low level of electrical impulses that will deter sharks from coming into a swimming area. Or at the very least a bubble or netting to give swimmers a little more protection than we have now.
Should both cull seals and increase use of spotters
Drones first then when there is the technology to connect smart bouys use them in addition.
drones
Cull the herd of seals and then shoot several large sharks. Sharks talk to each other and when "Harry" doesn't return home the word will get out and the bulk of the shark population will seek a "safer" environment where "Harry" doesn't get shot and killed.
Shark culling is ineffective, expensive, and seal culling is illegal. The great whites must be protected. I favor remote detection, tagging, and educating the public about their risk in the ocean.
The clear issue here is the seals. The numbers just continue to rise year after year and nothing is done about it. More seals, more sharks. More seals, less fish. More seals, more polluted water and beach closings. This

should really be a SEAL problem not a shark problem. Put a bounty on or figure out a way to cut the seal population. Only logical solution imo.
Don't swim near seals. Don't dress like a seal
Seals must be culled. In my 65 years of Cape Cod living, the rapid population rise of seals has been more than noticeable. 60 years ago, it was rare to see a seal on the water (We frequented Monomy). Until 20 years ago, there were hardly any seals around.
Culling of seals
The seal population needs to be reduced somehow. Thank you to letting me participate.
Smart bouys and acoustic deterrent for surfers and boarders. Acoustic deterrents can be provided by towns on rental basis Long term. Do we need to be this accomodating to our exploding seal population? Long term study needs to be done on seal impact on ecosystem. If they prove deterimental they should be discouraged from loafing on our shoreline. I Do not support culling as this will never obtain consensus
Buoys, nets, drones, or other tech solutions to deter, detect and warn when sharks present.
real time alert
reduce seal population
Barrier based - variance of netted enclosure
tag all sharks spotted
Seal culling
Magnetic post array, shark repellent - magnetic/electric - wearable & board mounted
Drones, tagging, apps
Clever Buoy System
I like the idea of using Shark repellent as long as it doesn’t hurt the shark!! Like a magnetic shock or something as long as it isn’t deadly or anything.

8.0 Appendix H

Shark Mitigation – U.S. Army Corps of Engineers Permitting Requirements

June 10, 2019

General Notes:

- Any permittable actions within the Cape Cod National Seashore will need a letter of no opposition/objection provided by NPS as part of the Corps permit application.
- The location of structures should be carefully considered in relation to federal navigation projects (FNP). Any proposed structures within an FNP or in buffer zones of the FNP (5x the depth of the FNP) will need additional review with the Corps through our Navigation Section.
- Some form of Corps permitting is needed for work, structures or placement of fill in waters. The Corps regulates under Section 10 of the Rivers and Harbors Act of 1899 (work, structures, dredging) and Section 404 of the Clean Water Act (fill).
    - The Corps jurisdictional boundary for Section 10 is the mean high water line.
    - The Corps jurisdictional boundary for Section 404 is the high tide line.
- Corps permitting falls into three categories:

Self-Verification (SV)	Pre-Construction Notification (PCN)	Individual
• Minimal impacts to waters of the U.S., no impacts to special aquatic sites (SAS) or resources of concern, and project meets all MA GP general conditions. • Permitting consists of the submittal of an SV form & project plans. • No review by the Corps, no authorization letter issued. • Once form has been submitted the project can proceed, you are self-verifying that you qualify. • SV project authorizations expire when the MA GP	• Minimal impacts to waters of the U.S., but project specific factors mean the project must be reviewed by Corps to confirm minimal impacts. • Permitting consists of the submittal of an application packet and 60 day review. • Corps issues an authorization letter at the conclusion of the review, which may include special conditions to further minimize impacts. • PCN project authorizations expire when the MA GP	• Impacts to waters of the U.S. are more than minimal or there is a public interest in the project. • Permitting consists of the submittal of an application packet, a 30 day public notice, and a 120 day review. • Corps issues an authorization letter at the conclusion of the review, which will include special conditions to minimize impacts. The permittee must sign and return the final permit prior to work starting. • Individual permit authorizations expire 5

expires (ex. April 5, 2023 for the current MA GP). • Projects that have been constructed can be maintained in good condition in perpetuity.	expires (ex. April 5, 2023 for the current MA GP). • Projects that have been constructed can be maintained in good condition in perpetuity.	years after the permit is issued, typically on December 31 of that year. Applicants can also request a 10 year permit.

Barrier Based Alternatives

- Rigid Plastic Mesh
  - Mesh considered S. 10, anchor placement considered S. 404 (backfilling to place anchors).
  - Likely qualifies as a PCN under GP 3: Structures in Navigable Waters of the U.S., GP 4: Aids to Navigation and Temporary Recreational Structures, and GP 5: Dredging, Disposal of Dredged Material, Beach Nourishment (burying anchors = beach nourishment).
  - PCN review is required due to endangered species concerns (entanglement, loss of usable habitat within net). Application review will require ESA consultation with NOAA.
- Semi-Rigid Nets
  - See “rigid plastic mesh” review above.
- Bubble Nets/Visual Barrier
  - Tubing and anchors associated with bubble curtain are considered S. 10.
  - Likely qualifies as a PCN under GP 3: Structures in Navigable Waters or GP 4: Aids to Navigation and Temporary Recreational Structures.
- Electrical Deterrent Cable
  - Cables considered S. 10
  - Likely qualifies as a PCN under GP 3: Structures in Navigable Waters.
  - PCN review is required due to endangered species concerns (entanglement, loss of habitat, and electrical current). Application review will require ESA consultation with NOAA.
- Magnetic/Electromagnetic Barrier
  - See “electrical deterrent cable” discussion above.
- Artificial Kelp/Magnetic Fields
  - Artificial kelp lines considered S. 10.
  - Would be reviewed under GP 3: Structures in Navigable Waters. May require an individual permit due to extensive impacts associated with large amounts of anchors.

Technology Based Alternatives

- Tagging
  - Tagging of sharks does not need a Corps permit. However, buoys deployed to track or collect data would need Corps permitting.
  - Buoys associated with tagging are considered S. 10.

    - Likely qualifies as self-verification under GP 2: Moorings or GP 18: Scientific Measurement Devices. Any permanent impacts would require a PCN, any buoy anchors impacting eelgrass over 100 sq. ft. require an individual permit.
- Visual Detection
    - No Corps regulatory authority above MHW/HTL. No permit required.
- Remote Detection
    - See "tagging" above, same permitting guidance.
- Acoustic Mitigation
    - See "tagging" above, proposed projects may require a PCN review due to potential ESA impacts (if pingers have been used to deter commercial fishing depredation, pingers could negatively affect ESA listed whales).

<u>Biological Based Alternatives</u>

- Shark Cull Net/Drum Lines (smart or otherwise)
    - Nets or drum lines considered S. 10
    - Would need to be reviewed as a PCN under GP 21: Fish and Wildlife Harvesting Devices and Activities. PCN required due to ESA impacts (entanglements).
- Indigenous Harvest
    - No Corps regulatory authority above MHW/HTL. No permit required.
    - Should a seal harvester wish to utilize something that does trigger Corps regulatory authority, individual must apply for a permit.
- Seal Culling
    - No Corps regulatory authority above MHW/HTL. No permit required.
- Seal Contraception
    - No Corps regulatory authority above MHW/HTL. No permit required (unless some sort of structure placed below MHW containing seal contraception).
- Modify Shark Behavior (electric shock)
    - Permitting requirements unknown. Structures would be S. 10. Depending on method may need to be PCN due to potential ESA concerns.

<u>Permitting Specifics:</u>

- As stated above, a self-verification notification consists solely of the SV form and project plans.
- A PCN application consists of ENG Form 4345, project plans, and notifications to historic resource agencies. Including a narrative about the installation and maintenance of the project is also useful.
- Reviews under the PCN category will likely result in special conditions being added to the final permit for the protection of endangered species. These conditions can vary, but would likely include lines always being kept under tension and periodic checks for ESA entanglement.