Community Science Project Options for Monitoring Coastal Change Effects on the Boston Harbor Islands

An Interactive Qualifying Project

Submitted to the Faculty of

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfilment of the requirements for the

Degree of Bachelor of Science by

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October 16th, 2020

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Abstract

The Boston Harbor Islands are places of special geological, historical, and natural significance. They are threatened by coastal change and climate change which could lead to damage or destruction if not anticipated. Community science programs have been successfully used in other areas to monitor impacts of coastal change while educating participants. Our project investigated important aspects of community science program design through interviews with program organizers and participants. Using our literature review and interview findings, we identified key aspects of community science program design and developed recommendations for community science programs that can serve as an early warning system for areas of the Boston Harbor Islands that are at risk of damage from coastal change.

Community Science Project Options for Monitoring Coastal Change Effects on the Boston Harbor Islands

Executive Summary

Introduction and Background

Coastal change is a natural phenomenon that affects shorelines all over the world; wind, waves, and currents transport sediment to and from different coastal environments, constantly reshaping the shoreline (Massachusetts Shoreline Change Project, n.d.). Boston Harbor is exposed to the harsh effects of coastal change, with the major threats being sea level rise, coastal erosion, and increasing storm intensity. Continued sea level rise poses the threat of total submersion to small islands in the harbor such as Sheep Island. The issue of rising sea levels also multiplies the impact of storm surges; the combination of abnormally high water levels with storm surges can worsen the damage from the flooding. Erosion impacts all of the islands, has damaged or destroyed historical and archeological resources across the park, and will continue to harm more if not anticipated and prepared for (National Park Service, 2019c). Those factors pose a critical threat to the islands, the important resources on them, and the ecosystems they support. Boston Harbor holds much historical significance; the islands are rich in archeological Native American history and are tied to several wars.

To monitor the state of the many valuable natural and cultural resources in the park, Boston Harbor Islands National and State Park (BOHA) hosts various research projects/studies in the park, but they do not have any focused specifically on tracking the effects of coastal change. The NPS objectives for research studies are scientific validity, relevance to park management, and providing an educational and enjoyable experience for participants (National Park Service, 2006). Community science (CS) is a promising approach to fulfill these objectives because it can provide large amounts of accurate and relevant data that can be used to inform management decisions as well as providing an educational and engaging experience for the participants (Velde et al., 2017; Evans et al., 2005). Community science has been used by BOHA, such as Stewardship Saturdays and the Coastal Breeding Bird Monitoring program (National Park Service, 2019e; National Park Service, 2019a). There are even more unaffiliated community science projects happening in the area around Boston, but there is a significant gap as well, with no projects focusing specifically on continued monitoring of the impact of coastal change on the Boston Harbor Islands.

Methods

The goal of this project was to create a rubric to evaluate community science programs and recommend community science programs to monitor coastal change in BOHA.

To accomplish this goal, we:

- Identified key aspects of community science program design as it relates to BOHA,
- Identified the questions CS can help answer about coastal change
- Developed Key Design Aspects of Community Science (KDACS),
- Conceptualized and evaluated community science program ideas with KDACS.

To accomplish these objectives, we conducted a literature review, interviewed people involved in all roles of community science, and had weekly meetings with our sponsor.

To identify key aspects of community science program design, we researched several existing community science programs that focus on coastal change as well as one that focuses on the Boston Harbor Islands specifically to provide us with local considerations. We reviewed the methodology of those programs, identified features that would work in BOHA and fulfill our sponsor's goals (or not), and gathered aspects that we wanted to focus on in our recommendations.

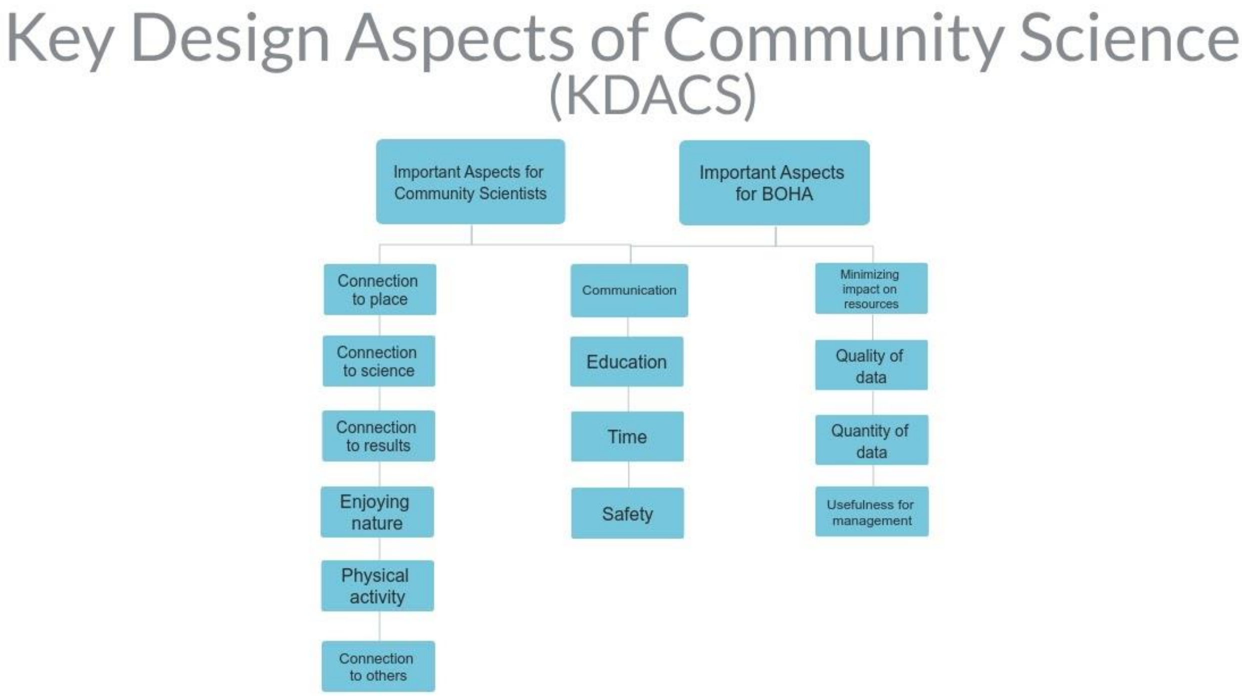
To identify the questions community science can help answer about coastal change, we reviewed literature focusing on the impact of coastal change on the Boston Harbor Islands and other coastal areas and we conducted several interviews of several local scientists and professionals that focus their efforts on measuring and evaluating the impact of coastal change. We also held weekly meetings with our sponsor which helped us understand and refine exactly what BOHA was looking to gain through answering these questions.

To develop KDACS, we conducted a literature review focused on the experiences and outcomes of participation in community science programs as well as interviews of several organizers and participants of community science programs. In the interviews with participants, we asked about the aspects of CS programs that participants enjoyed most, anything they'd change, and what their draw was to participating in the first place. For the interviews with organizers, we focused on the challenges of and considerations for organizing a community science program.

To develop our final recommendations, we went back through meeting minutes from meetings with our sponsor as well as with the professionals that we met with. We identified common themes that we could design a program around, or ideas that had been specifically recommended by anyone we spoke with. We then reviewed programs that are being conducted elsewhere in the New England region to determine if they could be implemented in BOHA. We created a list of all of these possible ideas, and evaluated them with KDACS to pare the list down to recommendations our team felt fit the criteria best and could feasibly be implemented.

KDACS

This research led us to creating KDACS, seen below in its simplified form. KDACS lays out the most important aspects we've identified for participants in community science programs, BOHA, as well as aspects that are important to both.



E.S. 1: Key Design Aspects of Community Science (KDACS)

Recommendations for community science programs in BOHA

We developed three community science program recommendations that could be implemented by BOHA. All three are different with distinct goals and methodologies, but they all contribute to the overarching goal of using community science programs to create an early warning system for erosion that can help inform park management's efforts to protect the islands.

Coastal Change Photo Hunt. The main idea of this program would be for BOHA to put posts with signs labelling various landmarks on the islands as photo spots. These photo spots would be located in places at high risk of coastal change. Participants could either pick up a map listing the photo spots and walk throughout the park on their own to visit however many of the spots they choose, or go on a guided tour led by a Park employee, and either way upload the photos they take to a curated database. The database would allow experts to observe changes in the shorelines of these locations and create a visual record of coastal change related damage for Park management. The main feasibility concerns for this project in general are the upkeep of the posts and signs, such as keeping them clean and repairing them from wear and tear, and the curation of the database to ensure quality of data. Some concerns specific to the guided tour are the scheduling aspect, as participants would most likely do tours outside of their work week and the tour schedule would have to accommodate that.

Mapping Island Risk. This program aims to create a detailed, dynamic map of all of the islands, and this required transportation to these islands. We recommend that an open faced landing boat is chartered to take a small group of participants are taken around the islands. The participants would land on certain islands to survey the effects of erosion, or lack thereof, on that island. They would receive training on identifying erosion prior to completing their first survey, and the first couple boat trips will be accompanied by a guide. This survey would ultimately be a simple form that the participants fill out where they identify spots which are eroding, spots which are at risk of eroding, and spots that are not eroding/have a low risk of eroding. This program is highly dependent on two factors; the weather and boat scheduling. Harsh weather in the harbor can make it unsafe for the participants to be out on the boat, and on the islands themselves. Secondly, there would need to be a boat chartered to take the participants out to the islands, as many are not accessible by public ferry. This means that the schedule for the program would be based around the boat availability.

Revealing Island Profiles. This program will follow preexisting methods, specifically the Emery Method used by countless other beach profiling projects. Beach profiling is a survey technique which measures the contour of a beach. By tracking the contour of the beach over time, the patterns of change in the beach contour can be revealed, indicating rates and locations of erosion or accretion. Groups of volunteers will take a public ferry out to the Boston Harbor Islands where they will conduct the data collection. Measuring the profile of a beach at low tide is preferable because that exposes as much of the beach as possible, allowing volunteers to create the most complete beach profile they can without getting wet. The data collection itself is quite simple, requiring only two vertical stakes, a rope or tape measure, and a view of the horizon. There are several feasibility concerns for this recommendation: tides, the ferry, and the profiling locations. The organizers of this program would have to schedule beach visits based on ferry availability, tide cycles, and volunteer schedules. Additionally, this project would require the chartering of a private boat in the winter when the ferry no longer runs and storms are more frequent. When selecting profiling areas, organizers would have to identify areas that aren’t too steep to be profiled, aren’t too rocky, and have stable locations to start profiling from each time to ensure the data from different dates can be compared.

Conclusion

The National Parks of Boston makes education a priority in their parks, as well as preservation of cultural, historical, and natural resources. Community science can integrate these priorities as well as providing scientifically valid information which can help inform park management's efforts to protect the islands. Our project goal was to recommend community science programs focused on monitoring coastal change in the Boston Harbor Islands.

We proposed three programs which share a common goal to reveal coastal change effects in BHI that can allow for action and engage park participants. Each of these recommendations meet BOHA's three main goals relating to community science (scientific validity, relevance to park management, and providing an educational/enjoyable experience for participants) as well as meeting several of the Key Design Aspects of Community Science. Each recommended program offers additional opportunities to integrate in each program to elevate the overall value for both BOHA and program participants. Our team believes that integration of these programs will have a lasting positive impact on the Boston Harbor Islands and those who enjoy them.

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List of Acronyms

BHI – Boston Harbor Islands
BOHA – Boston Harbor Islands National and State Park
CS – Community science
KDACS – Key Design Aspects of Community Science

Authorship

§1: Introduction

Dana and Sam were primarily responsible for the writing of this chapter, and Issy was responsible for part of the editing.

§2: Background and Literature Review

Though each team member did research for each aspect of this chapter, Dana was primarily responsible for the research and writing of aspects specific to BOHA. Issy was primarily responsible for climate/coastal change research. Lastly, Sam was primarily responsible for research specific to community science and shared the writing of those sections with Dana.

§3: Research Methods

In this chapter, Dana was responsible for the writing of section 3.1, Identify key aspects of community science program design as it relates to BOHA, while both Dana and Sam were responsible for the editing. Issy was responsible for the writing of section 3.2, Identify the questions about coastal change that CS can help answer or provide data towards. Dana and Sam wrote and edited section 3.3, Road to Recommendations.

§4: Developing KDACS

Sam was responsible for the writing and editing of section 4.1, Iterations of KDACS. Sam and Dana were responsible for the writing and editing of section 4.2, KDACS; Dana wrote and edited the section that focused on Important factors for community scientists while Sam wrote and edited the section that focused on Important factors for BOHA.

§5: Final Recommendations

Sam and Dana were responsible for the writing and Issy was partially responsible for the editing of the first recommendation, Coastal Change Photo Hunt. Dana was responsible for the writing of Mapping Island Risk, and Sam assisted Dana with editing of the archeological considerations. Sam was responsible for the writing and editing of Revealing Island Profiles.

§6: Conclusion

Dana was responsible for the writing, and Sam and Issy were responsible for the editing of this chapter.

Acknowledgements

Our team would like to thank our sponsor, Marc Albert from the National Parks of Boston. Marc Albert and the National Parks of Boston helped and guided our team with the development of this project. Mr. Albert's initial contacts and introductions to other organizations and professionals were essential to the success of our work.

We would also like to thank Dr. Zoe Hughes, Dr. Colleen Hitchcock, Joe Bagley, Carol Trocki, and Emily Greene for their invaluable contributions and recommendations during our interviews and meetings.

We would also like to thank the community scientists we interviewed, George, Judy, and Betsy. Their experiences and feedback helped guide our project and ensure that our recommendations would be useful to the community scientists who will hopefully take part in those programs someday.

Finally, we'd like to thank our advisors, Seth Tuler and Qingshuo Song, from Worcester Polytechnic Institute, for making the transition to fully online smooth and enjoyable.

§1: Introduction

Coastal change is a natural phenomenon that affects shorelines all over the world; wind, waves, and currents transport sediment to and from different coastal environments, constantly reshaping the shoreline (*Massachusetts Shoreline Change Project, n.d.*). Boston Harbor is exposed to the harsh effects of coastal change, with the major threats being sea level rise, coastal erosion, and increasing storm intensity. One example of how significant these threats are is that over the last few years, the city of Boston has been designing plans to protect several areas of Boston which are threatened by coastal flooding and rising seas. As sea level rise poses such a serious threat to the urban part of Boston, it could be even worse for the Harbor Islands. An NPS report finds that slopes being eroded by waves retreat faster than those being eroded by other forms of water exposure; the first type of retreat occurs at an average rate of 0.21 meters per year, where the second occurs at an average rate of 0.13 meters per year (Thornberry-Ehrlich, T. L. 2017). As sea levels rise and waves can reach farther up the shore, the bluffs will be more exposed and erode faster. An example of how significantly bluff erosion has already impacted the islands are the images below of Lovells Island from 2004 and 2008, respectively.

Figure 1: Erosion on Lovells Island

Note: by Zoe Hughes

These phenomena pose a critical threat to the islands, the important resources on them, and the ecosystems they support. Boston Harbor holds much historical significance. The islands are rich in archeological Native American history and are tied to the Revolutionary and Civil Wars (National Park Service, 2015a; National Park Service, 2019f). The islands were home to several Native American tribes, and as such they still contain many archeological sites of interest which can be affected by coastal change. For example, shell middens, which are a collection of shellfish remains and soil, can point to areas of temporary settlements of the Native Americans. There are often artifacts left behind in these shell middens that tell the story of Native Americans who lived there through the tools and bones found in these shell middens (Massachusetts Historical Commission, 2014). One of these shell middens which is being eroded can be found on Spectacle Island, shown in Figure 2. Loss of these resources can lead to loss of the living history of the islands.

Figure 2: Shell Midden on Spectacle Island

Note: by Massachusetts Historical Commission, 2014.

The islands are also very geographically unique. The Boston Harbor Islands are one of the very few locations worldwide that are formed from a geological structure known as a partially drowned drumlin field (National Park Service, 2015b). The Boston Harbor Islands hold geological significance as they are the only partially drowned drumlin field in the United States. As such, the park contains many resources which, if left unmonitored, could be lost due to coastal change.

The NPS looks for research studies that "support the NPS mission by providing the Service, the scientific community, and the public with an understanding of park resources, processes, values, and uses that will be cumulative and constantly refined. This approach will provide a scientific and scholarly basis for park planning, development, operations, management, education, and interpretive activities." (National Park Service, 2006). One method of study to support those goals is community science, also known as citizen science: the participation of the public in the collection and analysis of scientific data (U.S. General Services Administration, n.d.). While citizen science is a more common name, community science is a more accurate and inclusive one. People participate because they have a passion for conservation and want to help their community with the issues it faces. Their legal status as a citizen is unimportant. Community science (CS) is a promising approach to fulfill NPS objectives because it can provide large amounts of accurate and relevant data (Velde et al., 2017) that can be used to inform management decisions as well as providing an educational and engaging experience for the participants (Evans et al., 2005). Research studies done exclusively by professional researchers can result in the same scientific understandings, but a community science project can be more valuable because it directly involves the public in the scientific process, providing them with a deeper education and a more engaging experience (Evans et al., 2005). Community science has been used by BOHA in several projects, such as Stewardship Saturdays (National Park Service, 2019) as well as the Coastal Breeding Bird Monitoring program (National Park

Service, 2019a). However, BOHA has not implemented community science studies about coastal change.

The goal of our IQP was to recommend community science programs focused on monitoring coastal change in the Boston Harbor Island area. Our team conducted both a literature review on relevant topics as well as several interviews on the best practices for community science. This research led us to identifying key design aspects for community science to assess CS programs. Our baseline for this chart were concerns which our sponsor, the National Parks of Boston, shared with us: scientific validity, relevance to park management, and the educational and enjoyment value to participants of the program. Our team was able to build on these concerns with the information gathered from the interviews we conducted and literature we read. Our team then formulated recommendations for CS programs that could be implemented in the park. The data collected from these proposed programs will help park management make informed decisions about how best to preserve or protect the islands and their important resources, and our key design aspects can be used in the future for evaluating other related programs. While each project is separate, they all share a common overarching goal: to reveal coastal change effects on a park scale that can allow for action and engage park participants.

§2: Background and Literature Review

Threats from coastal change in the Boston Harbor Islands are a significant concern to the park management of BOHA and park visitors. Community science can be used to monitor the effects of coastal change, helping park management make informed decisions as to how best to protect the islands going forward. In this chapter, we will give context for the importance of the aforementioned resources and describe the manifestations of coastal change more specifically. This chapter will conclude with a review of community science and how it can be used to help the park, as well as projects that have been successfully implemented to track coastal change in BOHA and other places in the New England Coast area.

§2.1: Boston Harbor Islands National and State Park

In the 104th meeting of Congress, a bill was brought to the floor to establish the Boston Harbor Islands as a national recreational area. Boston, Massachusetts has long stood as the cultural center of New England and has helped shaped the region to what it is today. The city, and the areas which surround it, contain history dating back long before the colonial times. Due to the Boston Harbor Islands' proximity to the urban area, they have had mixed use through their long history; unfortunately, there was a period of misuse of the islands which led to poor water quality in the Boston Harbor. BOHA is a collaboration between government agencies, non-profits, as well as municipal partners. The entities involved in this partnership are shown in Appendix A. The purpose of establishing the park was to preserve the land and waters for public use, to manage the area with the private sector, and to improve the access to the islands (H. R. 2763, 1995).

Figure 1 shows the 34 islands, highlighted in orange, that make up the Boston Harbor Islands and BOHA. To the west of the islands is Boston, Massachusetts, and to the east of the islands is the Massachusetts Bay, which leads to the Atlantic Ocean (Google, n.d.).

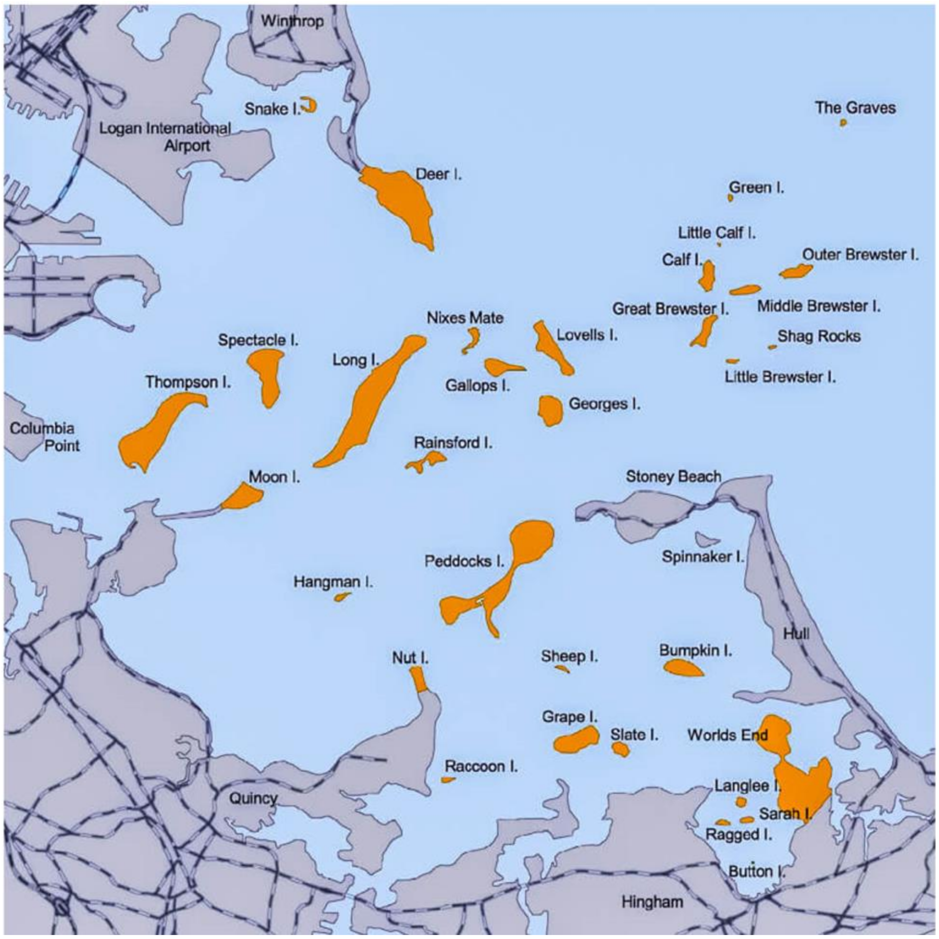

Figure 3: Map of Boston Harbor Islands

Note: by National Fisheries Service, n.d.

Many of the islands are recreational areas open to the public for part or most of the year, and can be used as such for activities like camping, hiking, etc. (Boston Harbor Islands, n.d.a). Specific island accessibility designations are explained in Appendix B.

§2.1.1: Cultural, Historical and Geological Park Significance

The Boston Harbor Islands are important in many ways, primarily culturally, historically, and geologically. This is represented in Congress' designated purpose of the park, "to preserve and protect a drumlin island system within Boston Harbor, along with associated natural, cultural, and historic resources; to tell the islands' individual stories and enhance public understanding and appreciation of the island system as a whole, including the history of American Indian use and involvement; and to provide public access, where appropriate, to the islands and surrounding waters for the education, enjoyment, and scientific and scholarly research of this and future generations" (Boston Support Office of the Northeast Region National Park Service, 2002).

There were many Native groups that lived on the islands for thousands of years before the British came to America. As a result, there are many archaeological sites still on the islands today which are protected by the Native groups (National Park Service, 2019h). The islands were surrounded by plenty of plant, animal, and sea life that the Indigenous Peoples used to support themselves on the islands during the seasons they used the land. This rich history left many culturally significant artifacts behind, and protecting them is important to their descendants as well as historians and archeologists. However, in 1675 European colonists started a war between native groups which eventually drove them off the islands. Several islands were used as coastal defense stations, from the Civil war all the way until World War II. Fort Warren, located on Georges Island, was completed right after the Civil war started. It was used as a training facility for Union soldiers, and as a prison for both Confederate soldiers and government officials (Boston Harbor Islands, n.d.b). Fort Andrews, located on Peddocks Islands, was used as a coastal artillery post, it was home to military residents, and in World War II it held Italian prisoners of war. Both forts were decommissioned in the late 1940's after the end of World War II (Boston Harbor Islands, n.d.c).

Another notable historical landmark is Boston Light, located on Little Brewster Island. It is the oldest working lighthouse in the United States, originally built in 1716. It was severely damaged and rebuilt in 1783 after the Revolutionary War. Since then, there have been several changes to the lighthouse to modernize it, such as automating the light itself. To this day, the lighthouse still runs and is staffed by a civilian keeper (National Park Service, 2019g).

The Boston Harbor Islands also hold geological significance due to their unique morphology. The Boston Harbor Islands are comprised of a partially drowned drumlin field (Thornberry-Ehrlich, T. L., 2017). Drumlins are formed by glacial silt being moved into a mound or hill shape through glacial flow, shown in Figure 4. There are many drumlin fields around the world, but there are less than five that are partially submerged; most drumlin fields are either fully submerged or not submerged at all. Around four thousand years ago, the sea level rose and submerged much of present-day Boston Harbor, but left the drumlins partially exposed.

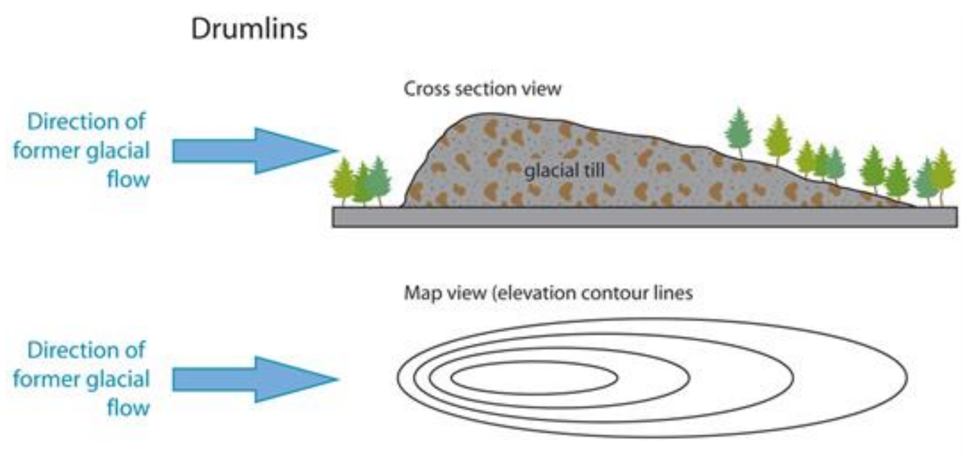

Figure 4: Formation of Drumlin

Note: by National Snow and Ice Data Center, 2020

§2.2: Coastal Change Processes and Climate Change Threats

The two main processes of coastal change are erosion, the removal of sediment, and accretion, the deposition of sediment. Gradual coastal change through tides, currents, and waves has been always been a natural occurrence. This type of coastal change is not particularly harmful, as the ecosystem has time to respond to the changes, unlike with severe, episodic coastal change. For example, geologists have been hypothesizing for decades that sediment accretion and/or erosion play a key role in the formation of drumlins like the ones in BOHA, which formed several millennia ago (Patterson, Hooke, 2017). On a large scale, coastal change is simply the product of millennia of waves, currents, and storms. However, new threats come from anthropogenic climate change, the result of human emissions into the atmosphere causing the Earth's surface to warm. As the temperature of the Earth's surface increases, sea ice melts and the water gets warmer; causing sea levels to rise and allowing hurricanes and tropical storms to become more frequent and severe. When severe weather, abnormally large/strong waves, or storm surges cause an abrupt and drastic shift in the shoreline, the rapid change in conditions can be highly destructive to the coastal vegetation, taking away a primary food source and disrupting the ecosystem. And as these environmental conditions worsen, the destruction will be more extensive; especially on islands like the ones in BOHA, due to their constant exposure to wind and water. Two significant threats to the islands from the ocean are sea level rise and storm surge.

Figure 5: Storm Damage to Deer Island

Note: by Boston Harbor Islands Partnership

§2.2.1 Sea level rise

With the surface temperature of the planet increasing, glaciers and sea ice are melting, causing sea levels to rise worldwide. United Nations data shows that unabated sea level rise could irreversibly affect the morphology of low-lying islands and coastal areas, such as the Boston Harbor Islands (Oppenheimer et al., 2019). Continuous sea level rise poses the threat of total submersion to small islands in BOHA such as Sheep Island. As seen in Figure 6, the relative sea level of Boston has been consistently rising for the past 100 years (National Oceanic and Atmospheric Administration). NOAA has found that Boston is experiencing a relative sea level rise of approximately 2.86 millimeters per year, not factoring in regular season fluctuations resulting from ocean temperature change, atmospheric conditions, and other conditions. The chart below shows that between 1921 and 2019, Boston has incurred a relative sea level rise of 0.94 feet, and this will continue to increase as the climate changes and more sea ice melts.

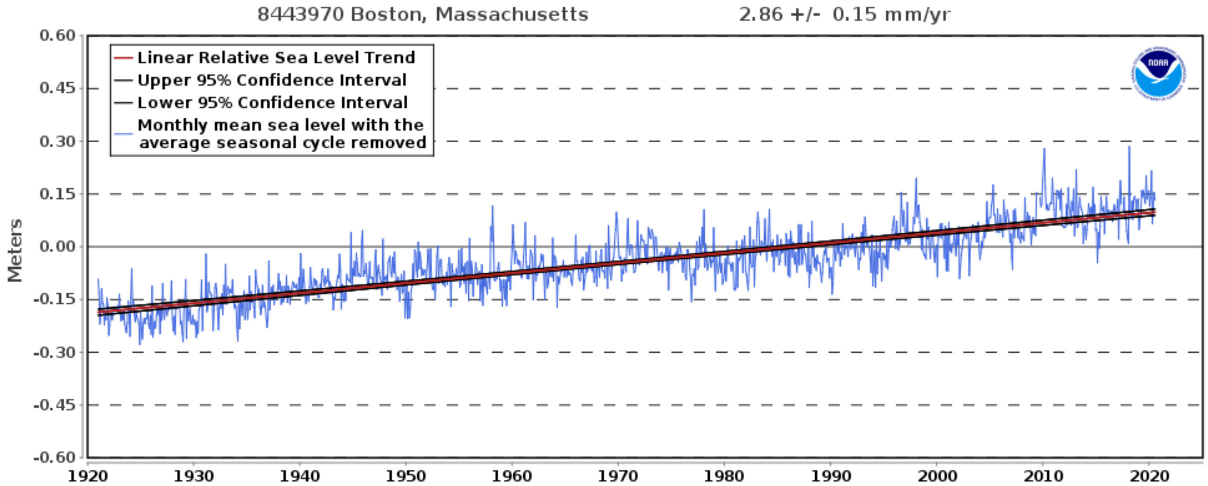

Figure 6: Relative Sea Level Trend in Boston

Note: by National Oceanic and Atmospheric Association, 2019

§2.2.2 Storm surge

Storm surges are the result of high winds from a storm pushing a great amount of water towards the coast. When a storm surge occurs at high tide, such as with Hurricane Sandy in 2012, it can raise the sea level 20 or more feet and cause severe flooding in both coastal and inland areas (National Oceanic and Atmospheric Administration, 2020). In coastal areas such as the Boston Harbor Islands, surges at either high or low tide can critically damage habitats and erode the islands' shorelines, as the water hits the coasts like a battering ram (National Oceanic and Atmospheric Administration, 2020). Historical records of past storm surges, tide data, and sea levels led Tufts University professor Andrew Kemp and his research team to the conclusion rising seas are a huge part of why storm surges are becoming more intense, such as the nor'easters in January and March of 2018 (Talke, Kemp, Woodruff, 2018). Data collected in the 19th and 20th centuries show that sea level rise has been worsening storm surges, as current records in the 21st century show a direct correlation between the height of the surges with sea level rise, and experts believe these phenomena will both become even bigger problems in the future (Talke, Kemp, Woodruff, 2018).

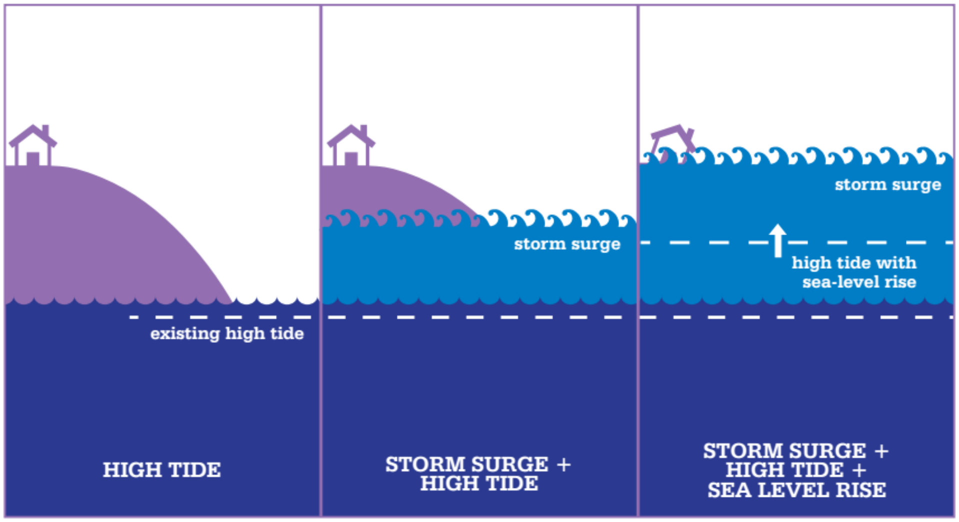

Figure 7: Storm Surge

Note: by Australian Climate Counsel, 2014

§2.2.3 Erosion

As a phenomenon, erosion is partially independent from climate change. Figure 9 shows a diagram of how erosion occurs. Erosion generally occurs very gradually due to waves/water and wind wearing down coasts/rock over significant amounts of time; but severe storms can cause sudden and large change, such as the creation of South Beach Island by a Nor'easter in 1987. The aspect of erosion that relates to climate change is that as storms become stronger and flooding more severe, episodic erosion will worsen. As a coastal city, Boston is at high risk of damage due to storms and flooding as a result of climate change, and the Harbor Islands even more so. Because of this, episodic erosion is a critical threat, as it can change the morphology of the islands, and by extent threaten the wildlife of these islands with habitat loss. For example, a researcher we interviewed mentioned that Sheep Island's continuous erosion poses a risk of complete submersion, which will prevent the birds living in the center from nesting there.

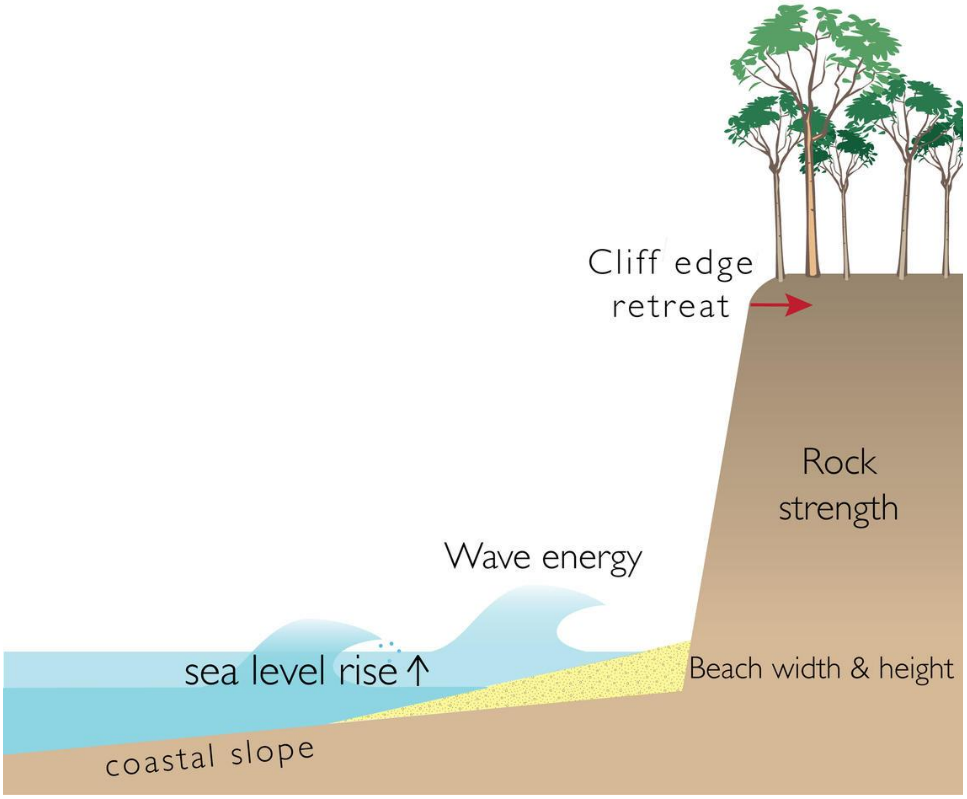

Figure 8: Erosion

Note: by Deep Maps

One example of the powerful impact of erosion can be seen in the images produced by the NASA Earth Observatory. The NASA Earth Observatory has been tracking coastal change in Cape Cod, less than 100 miles south of Boston, with Landsat instruments over the last 30 years. This tracking demonstrates that most changes to the shoreline occur fairly steadily, such as the gradual movement of sand from the northern part of the coast to the southern part. However, the images also show that severe storms can cause dramatic changes, such as in 1987 when a Nor'easter created a new island by splitting a previously existing one with a new inlet of ocean water. Figure 9 below was taken on June 18, 1986 (left) and September 24, 1987 (right).

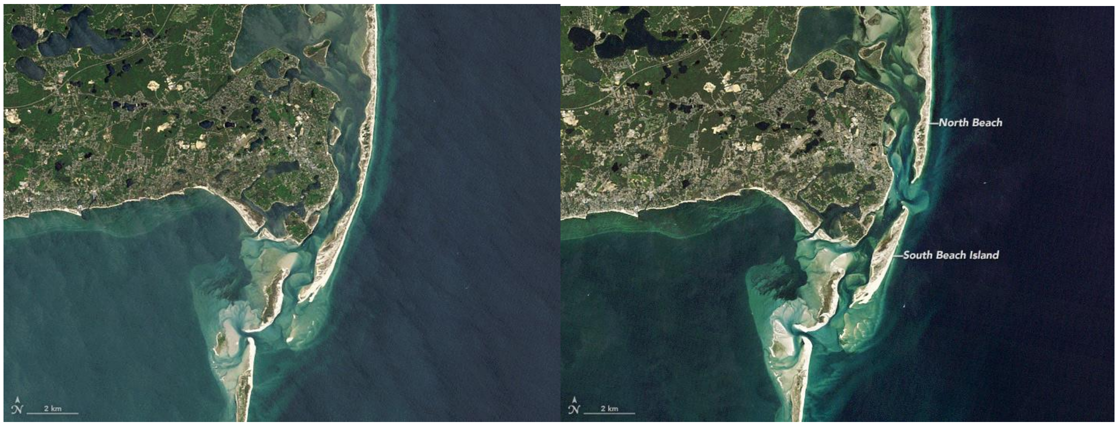

Figure 9: Erosion in Cape Cod

Note: by NASA Earth Observatory, 2020

§2.3: Community Science

The following sections will discuss why community science is useful and will introduce programs that are successfully being conducted both in BOHA and in other coastal communities. We analyzed these projects to determine how community science is being used by other groups for similar purposes, providing a base to build our recommendations on.

§2.3.1: Why Community Science?

Community science is a method of research that involves the general public in data collection. Community science, even though it involves non-professionals collecting data, can produce data of comparable accuracy to that obtained by professional researchers (Velde et al., 2017). It can also provide significant educational and engagement benefits over traditional research by involving members of the community in the collection and interpretation of data; instead of simply seeing the results of research in a report or on a sign, they are actually part of the process of doing that research. This involvement can result in not just a more thorough education, but also increased feelings of efficacy and satisfaction having participated (Evans et al., 2005). The NPS' management policies mention education and engagement of visitors as a key goal for parks as a whole, as well as specifically with respect to research (National Park Service, 2006). Community science programs can fulfill those goals better than traditional research if designed appropriately. There are a number of advantages over traditional research and challenges to consider when designing community science programs, and these are summarized in Tables 1 and 2

Table 1: Advantages of Community Science

Advantages of Community Science
Possibility of collecting large amounts of data, more than small scale professional research.
Projects in BOHA are open to a large demographic because they are a park that draws many visitors, and because they are situated outside of an urban area.
Interest, self-awareness, communication, and responsibility are more important than knowledge. Almost anyone can take part.
Volunteer retention doesn't seem to be that much of a challenge with smaller, more committed groups.
Email lists are a good way to keep in touch, make it personable in addition to having useful information.

Table 2: Challenges of Community Science

Challenges of Community Science
Higher participant count could disturb the ecosystem more than a smaller traditional research program.
There are a lot of moving parts; scheduling multiple volunteers is hard, especially since anything around BOHA is dependent on a boat ride and good enough weather.
Training can be very challenging/not as effective if not done in person or one-to-one.
Erosion is episodic instead of constant • Mostly happens after large storms
Programs with more volunteer engagement require more constant effort from organizer(s).

§2.3.2: Coastal Change Community Science Programs

In addition to the projects BOHA is currently involved in, there are unaffiliated community science projects running across New England focusing on monitoring coastal change. These projects have similarities in that they use simple data collection tools to track the physical changes that occur in their respective landscapes as a result of coastal change. Table 3 below addresses the programs, their purpose, and which aspects of their design we thought could be incorporated into our recommendations.

Table 3: Coastal Change Community Science Programs

Name of Program	What is the purpose?	Useful design aspects for BOHA.
Southern Maine Volunteer Beach Profile Monitoring Program (SeaGrant) (Southern Maine Volunteer Beach Profile Monitoring Program, (n.d.).).	Monitor the slope of beaches to track how sand is being brought to or taken from the beaches	Very simple data collection, two sticks and a string can tell scientists not just if erosion is occurring or not, but exactly how sand is being brought to or taken from the beaches.
The King Tide Tracker (MA King Tides Initiative. (n.d.).)	A website/app that collects photos to view the effects of extreme tides on different parts of the coastline	Only requires a volunteer and a camera, no training, and photos from anywhere can be submitted
Fluker Post (The Fluker Post Project. (n.d.).)	Gather photos over time from specific locations and directions	Doesn't require any training and only minimal upkeep if the posts get knocked over or something

There are many community science projects happening in the area around Boston, but there is a significant gap as well, with no projects focusing specifically on continued monitoring of the impact of coastal change on the Boston Harbor Islands.

§2.3.3: BOHA Citizen Science Programs

Community science is being successfully used in BOHA to inform research tracking biodiversity patterns in the park relating to their wildlife and plant life. Many of these projects have different designs and have all been running for several years. Table 4 below shows the purpose of the programs as well as aspects we thought we could incorporate into our recommendations.

Table 4: BOHA Citizen Science Programs

Name of Program	What is the purpose?	Useful design aspects for BOHA.
Phenology Monitoring (National Parks Service, 2015d).	This program monitors recurring life cycles of wildlife to understand the ecology of the park and how the ecosystems are responding to climate change	This program is one that any park visitor can participate in. Visitors collect data and submit it to an online database called Nature's Notebook, they make their own account and have their own observation page. Ideally, the design of this project is to have data being entered at least weekly about a particular site once a participant signs up, as this is a part of a larger research initiative of the New England Region.
eBird (National Park Service, 2019a).	This program monitors BHI bird species distribution as well as their movement patterns across the islands.	Any park visitor can contribute to collecting this data because it is entered into a larger database called eBird.
Coastal Breeding Bird Monitoring (National Park Service, 2019a).	This program focuses on the movements of thirteen breeding waterbirds specifically. BHI is a designated Massachusetts important bird area, so tracking the movement patterns of these specific birds helps park management know about the overall wellbeing of the islands	Carol Trocki, who is the head researcher, takes out a small group of four volunteers during the nesting season to collect date for this project. The smaller group aspect of this project is ideal so as not to disturb the actual habitats they are studying.
All Taxa Biodiversity Inventory (ATBI) (National Park Service, 2019d).	This program is focused on creating an inventory of biodiversity, including insect and invertebrate species, in the islands.	This program is very interactive for participants. Participants generally collect data alongside scientist in what is called a BioBlitz day, where scientists and participants go into the field to collect and analyze data samples.
Marine Invasive Monitoring Information Collaborative (MIMIC) (National Park Service, 2015c).	This program aims to identify new invasive species on the islands as well as track the movements of existing species.	Volunteers are trained specifically to identify these species and they then go out on Stewardship Saturdays, which are days where volunteers can specifically work with park rangers, to go identify these species (National Park Service, 2019e). These days usually also consist of pruning island plants to help with growth, and taking photos/observing the wildlife (ArcGIS Story Maps. (n.d.).)
iNaturalist (Boston Harbor Islands National Recreation Area, US, MA, (n.d.).).	An app to track biodiversity. Users can take and upload photos of plants and animals they see along with the date and location so scientists can track wildlife species and their movement throughout the islands.	It's easy for anyone to engage, and can produce a large quantity of data.

These programs are important to BOHA because they each contribute to tracking biodiversity in the park, which in turn can track aspects of coastal change effects. The design of the programs to allow data to be collected on a continuous or frequent basis gives researchers/park management a larger database of information. The programs are also important to our team because they show that there are several different program designs which attract volunteers and produce data, indicating that visitors will participate on varying degrees of engagement, time commitment and education levels. However, the park lacks a program to track the effects of coastal change on the land of the islands, independent from the flora and fauna. Implementing programs focused on this will not only benefit the islands themselves by giving the park management information they need to enact island protection methods, but will also benefit flora and fauna by protecting the land it sits on.

§3: Research Methods

The goal of our project was to recommend community science programs related to coastal change in BOHA. To come to these recommendations, we completed a literature review on community science and conducted several interviews which led us to creating the Key Design Aspects of Community Science (KDACS) chart which we then used to assess the quality of our program recommendations. To achieve this goal we:

- Identified key aspects of community science program design as it relates to BOHA,
- Identified the questions CS can help answer about coastal change,
- Developed Key Design Aspects of Community Science (KDACS),
- Conceptualized and evaluated community science program ideas with KDACS.

This chapter presents the research methods we used to gather information for each objective, and how this information led to the development of materials and recommendations for BOHA.

§3.1: Identify key aspects of community science program design as it relates to BOHA

Our team used the NPS areas of concern (scientific validity, relevance to park decision making, and education/involvement of participants) as a baseline for researching specific features relating to CS program design.

To identify key aspects of community science program design, we researched existing community science programs that focus on coastal change such as the Volunteer Beach Profile Monitoring program in Southern Maine, the Fluker Post program, and the Heritage Monitoring Scouts in Florida. To identify considerations specific to BOHA, we also researched a science program that doesn't focus on coastal change but does run in BOHA: the Coastal Breeding Bird Monitoring program. We analyzed the methodology of those programs to identify features that would work in BOHA and fulfill our sponsor's goals (or not), we also paid careful attention to the advantages/challenges of these programs.

We also read peer-reviewed papers that address CS programs, specifically their benefits and challenges compared to traditional research processes which don't involve the community. We looked into university studies who survey their participants to gather feedback on programs they were running. To gather more information on design aspects, our team interviewed eight professionals and professors with experience running these types of programs. Finally, to better understand important aspects of a community science program for those actually taking part in it, we conducted interviews with community members who have participated in these programs. Interview questions can be found in Appendices D and E. The specific interviewees will be mentioned in the next section.

§3.1.1: Interviews

The following table contains the names of community scientists who we interviewed as well as the intentions of the interviews. The interviewees' last names have been excluded for confidentiality.

Table 5: List of Community Scientists

Interviewee	Interview intentions
Betsy	To learn about their experiences participating in CS, and identify aspects they liked and disliked about the projects they participate in
Judy	
George	

The following table contains the names of community science organizers we interviewed as well as the intentions of each interview.

Table 6: List of Community Science Organizers

Interviewee & organization	Interview intentions
Matthew Liebman, Environmental Protection Agency	To learn about the basics of organizing a CS project; why people participate, tips for how to organize a CS project/areas to focus on, and how to ensure good data
Emily Greene, Volunteer Beach Profile Monitoring program/Maine SeaGrant	To gather insight on advantages/challenges of managing a CS program as well as any recommendations she has towards running a successful program.
Carol Trocki, Coastal Breeding Bird Monitoring	To gather insight on advantages/challenges of managing a CS program specifically in BOHA.

The following table contains the names of outside professionals we interviewed and the intentions of each interview.

Table 7: List of Outside Professionals

Interviewee & organization	Interview intentions
Joe Bagley, City of Boston Archaeologist	To discuss feasibility of implementing an archeological aspect to our recommendations
Elizabeth Solomon, Massachusett Tribe	To understand the precautions that must be taken to protect the many important artifacts left behind by Native Americans
Zoe Hughes, Boston University	To understand specifics about the uniqueness of BHI as well as how coastal change affects the area.
Colleen Hitchcock, Brandeis University	To gather knowledge about community science.

§3.2: Identify the questions CS can help answer about coastal change

Interviews with coastal change experts such as Zoe Hughes led us to generate questions which can be solved fully or partially with data collected by community scientists. Additionally, we met with participants and leaders of citizen science projects listed in Tables five and six to interview them about their experiences with citizen science such as data collection methods, seasonal/meteorological impacts on data, the effect of coastal change on native wildlife, and how events such as storms can reveal evidence of past coastal change. An example of this is how Elizabeth discussed how it is possible to find tree stumps on the beach after a storm moves a lot of sand around as evidence of how that area was once more vegetative, and there was one time when, after a big storm, her group discovered about 60 tree stumps aged about 2,000 years. Also, our interviews with Carol Trocki and Matt Liebman gave us some ideas for subjects community scientists could look into. Carol discussed the relationship between erosion and loss of animal habitats, like the birds' nests on Sheep Island; and Matt suggested that a beach's wrack line, piles of organic materials like seaweed deposited on the beach by storm waves (University of California Santa Barbara, n.d.), could be used as evidence of biological changes caused by erosion, where many studies focus on the physical changes.

§3.3: Road to Recommendations

After finalizing our data collection, we used a qualitative approach to analyze information from our literature review and interviews to identify key aspects of community science programs. We used these design aspects as well as interview notes from both organizers and participants of community science programs and notes we took on relevant literature to generate ideas for community science program topics. To further develop these ideas, we used the design features our team outlined to add detail and justify the programs. We then presented our ideas to our sponsor and advisors for initial feedback to then rework and refine into our final recommendations.

§3.3.1: Challenges we faced

As a result of COVID-19, we were unable to spend any time in Boston or on the islands. We had planned one trip to see the islands safely, but we had to cancel it due to unexpected bad weather, and couldn't reschedule it in time for it to be meaningful. This also made it more challenging to communicate with our sponsor the same way that we would have been able to, had we actually met in person. However, twice a week through the course of our project, we met via online meetings with Marc Albert, who represented the National Parks of Boston, to update him on our progress and get feedback on preliminary charts and deliverables. Throughout the term, Marc also gave us suggestions of people to talk to for interviews to help us inform our research on community science specifics and to generate project ideas.

§4: Developing KDACS

The research we did led us to creating preliminary summaries of our results, such as Table 8, a summary of the important features we identified as important to BOHA and community scientists.

Table 8: Important Features of Community Science Projects

Important Features of CS projects	Why
Engagement	Keeps people interested and coming back, repeated involvement is important
Usefulness of data	No point in doing the project if the data is useless to those that are supposed to use it
Cost effectiveness	Not feasible if the NPS can't afford to run it
Logistical possibility	If it requires a lot of infrastructure that doesn't exist, it might not be possible to implement
Easy for participants	Overly challenging or unclear data collection procedures can make a project uninteresting and result in inaccurate data
Cheap for participants	If they must foot a lot of expenses, some won't participate
Accessible for participants	A project that is hours from someone's home has much less of a draw than a closer project
Participants' connection to the place	Matt said that one of the larger draws to a project is a personal connection and feeling of protection
Connection to results	Seeing the results of their effort helps make participants want to participate again

We then created KDACS from these results, which our team used to develop and evaluate our final recommendations for CS programs. BOHA originally gave our team a citizen science rubric, which can be found in Appendix C. This rubric shows the three main areas of concern for the park regarding CS programs, gives a definition for each concern, and finally provides qualifiers for each concern which can be used to rate each aspect of a program on a scale of 1-3. However, to develop recommendations for the park using a rubric more closely connected to BOHA specifically and designed with coastal change in mind, our team needed to gain a deeper understanding of the crucial elements for a successful CS program. We kept the three main concerns for the park in mind, but we specifically focused on participant experience, management of the programs, and program design. This chapter will describe KDACS in detail.

§4.1: KDACS

The final draft of KDACS is split into two main sections, “Important factors for community scientists” and “Important factors for BOHA.” We also identified several aspects that were important to both participants and BOHA, which we listed under both sections and colored in a color scheme designed to be accessible to a color-blind audience. Each shared factor has been given a specific color to match it to the same factor on the other section.

A simplified overview of KDACS can be seen in Figure 10, and the full chart is included as supplemental information.

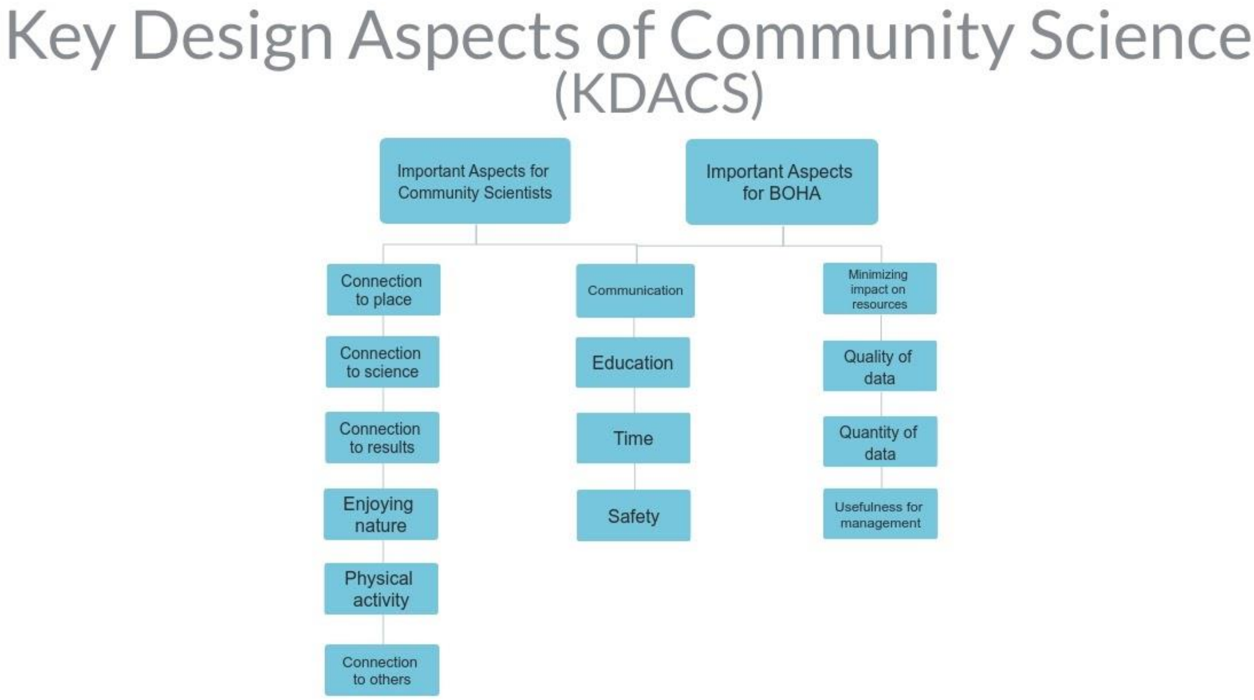

Figure 10: Key Design Aspects of Community Science (KDACS)

§4.1.1: Important factors for community scientists

The “Important Factors for Community Scientists” section compiles the factors which our team gathered from doing interviews of actual community scientists. Figure 11 shows this branch, and this section will explain why each aspect is included.

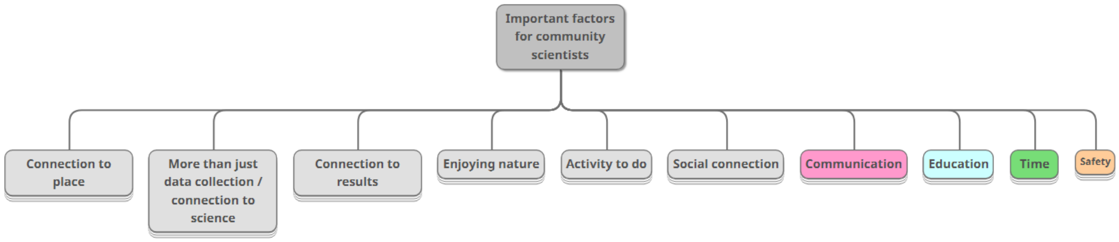

Figure 11: Important factors for community scientists

Connection to place: All of the community members that we interviewed had a personal connection to the areas which they were participating in programs for. Many of the interviewees were also involved in town committees or voting members of their town board. They felt that being engaged in community science was another way that they could be directly involved in the betterment of their town.

Connection to science: One of the volunteers was a retired professor, and another was a retired researcher, both in varying scientific fields, but they joined to projects to regain their connection to science. One volunteer we spoke with is still working, but currently working in a job unrelated to his scientific background. He joined the program because it reconnected him to his scientific background. Each volunteer also stated that the more hands-on programs allowed for more of a connection to the science.

Connection to results: All the volunteers stated that one aspect that brought them back to projects was being able to be connected to the data in some way. This is confirmed by our literature review, with one study stating that many participants felt dissatisfied with a community science program when they felt unsure of how scientists were using their data (Evans et al., 2005). For example, in the Beach Profiling project we mentioned earlier, the data collected from this project all goes to public databases that all of the participants have access to as well as being published yearly. The volunteers enjoy being recognizing the data that they collected and seeing how it is being used.

Enjoying nature: A simpler reason, yet still very important to the volunteers, is getting to be outside. For the retired volunteers, it is because they love where they live, and they want to be connected to nature and the environment around them. This also rings true for the volunteers who are still working, but for these volunteers it gives them a break from having to be inside because of their jobs. Especially due to the COVID-19 pandemic, the volunteers who are still working said that it is a change of scenery from the online meetings they are in all day.

Activity to do: Similar to both enjoying nature and connection to science, the volunteers explained that participating in these programs gave them something to do and look forward to outside of their daily routine.

Social connection: The volunteers we talked to also mentioned how participating in these programs allowed them to feel more connected to other members of their community whom they had shared interests with.

Communication: This is a shared factor for both participants and BOHA, however all the volunteers mentioned in their interviews that they greatly valued good communication from management of the programs. This goes for keeping in touch as far as results/findings of the project, as well as being able to be in contact with the project manager while they are in the field so they are easily able to ask questions or convey any issues they may be having.

Education: This is another shared factor, and on the participant side, they value learning from what they are doing. They enjoy learning why the data they are collecting matters, as well as learning about coastal issues.

Time: This is also a shared factor. The participants appreciate as much flexibility in scheduling as the park management can give because. although they may be busy, they still enjoy being able to fit participating in these programs into their schedule.

Safety: Many of the volunteers that we spoke to mentioned that because of the harsher weather conditions that can arise when working on a project or even just the terrain of a project site, personal safety is also an important aspect of these projects. Many said that some adventure is fun, however too much risk can be dangerous.

§4.1.2: Important factors for BOHA

The "Important factors for BOHA" section, seen in Figure 12, addresses the factors we've determined to be the most meaningful to organizers of a community science project and to BOHA specifically. We identified these through our literature review, weekly meetings with Marc, and interviews with other organizers of community science project.

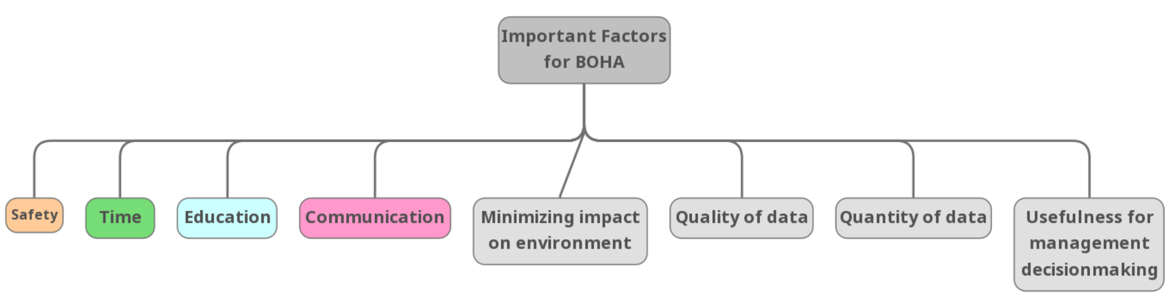

Figure 12: Important Factors for BOHA

Safety: Throughout all of our interviews and meetings, safety rose to the top as one of the most important considerations for everyone involved, from participants to organizers. Due to the widespread importance, we chose to include safety as one of the shared factors in KDACS for both BOHA and participants. In many of our meetings with Marc, he stressed that the top priority of the NPS is the health and safety of staff and volunteers. Additionally, Carol Trocki brought up safety as a key concern in general, but especially when out on the Boston Harbor Islands as certain areas are rocky and can be slippery when wet. With this in mind, every project must be deliberately designed to keep participants and staff safe. In addition to environmental considerations such as the risks introduced by rain, storms, and wind, the physical capabilities of volunteers and staff must also be considered. A final consideration right now is the COVID-19 pandemic, any programs running in the near future must ensure volunteers and staff follow physical distancing guidelines to stay as safe as possible while participating in the program.

Time: The community science organizers we interviewed brought up the amount of time required to organize a community science program. Emily Greene, from the Maine SeaGrant, stated that she originally worked 5 hours per week organizing over 100 volunteers, which simply wasn't enough. She now works 10 hours per week, but still feels that more is needed. Matt Liebman from the EPA estimated that some projects could require a part time or even full-time staff member to organize. While BOHA's actual budgetary restrictions are well beyond the scope of this IQP, the amount of time required to organize a community science program is an important consideration when designing or evaluating a program.

Education: In the NPS' Management Policies, they mention education of participants as one of the main objectives for any research study (National Park Service, 2006), so any community science program organized by BOHA must be effective in educating its participants about the Boston Harbor Islands and their history.

Communication: Through our interviews, we determined that clear and efficient communication is crucial to ensure a community science program runs smoothly and with as few unforeseen issues as possible, leading us to list this as an important factor for both BOHA and for participants. Communication between BOHA management and the participants would need to be clear for both the organization and scheduling of participants and other moving parts as well as when relaying the methodology the participants are to follow when conducting the project. In their interviews, both Emily Greene and Matt Liebman stressed the importance of leaving as little room for interpretation as possible in the directions for participants; any unclear directions could result in errors in data collection or data storage, leading to inaccurate or unusable data. Additionally, all community scientists we interviewed mentioned that good communication was part of the reason they enjoyed participating in community science projects and were so invested, with some even leaving projects because of a lack of communication and support. Participants who are invested in the project and enjoy the process will be more likely to participate repeatedly, leading to less turnover and allowing BOHA to spend less time recruiting volunteers and more time focusing on the many other aspects of organizing a successful community science project.

Minimizing impact on environment: A large part of BOHA's mission is to preserve island resources, so any program they run must not have a significant harmful impact on the environment. This can be accomplished by avoiding travelling on the more fragile parts of the islands and by minimizing the number of participants.

Quality of data: For the data generated by a community science program to be meaningful, it must be of a high quality. The quality of data is primarily determined by the accuracy of data collected, which depends on the calibration of the data collection instrument(s) and the methodology used to collect data. This can be described in two aspects: credibility and legitimacy. Credibility is the authoritativeness or believability of methods of the assessment process, while legitimacy is the fairness of the assessment process to those involved (Cash, D., Clark, W. C., 2001). Credibility is largely determined by the data collection procedures and is closely connected to accuracy. Methods with more precise instruments and more thorough procedures for using those instruments will result in more credible data, especially if the methodology is established and accepted as accurate and reliable. Legitimacy is less of a concern for community science programs and more of a concern for professional research, as there are few reasons for a community scientist to skew data one way or the other due to a bias. The quality of data can also be raised by implementing data validation measures, which would reject obviously inaccurate data and would vary from project to project.

Quantity of data: While less important than quality of data, the quantity of data produced by a community science program can still be very important. A community science program depends on having enough participants, and if the program fails to attract that many, it may simply produce too little data to be meaningful. With too small of a sample size, it could be hard or impossible for BOHA to draw a well-supported conclusion from the data. While the number of participants can't be predicted exactly during the evaluation of a potential program, research into past programs can determine what has been successful and what hasn't. Additionally, the number of participants required to produce enough data will vary depending on the design of the program; some programs rely on attracting large numbers of participants that produce relatively small amounts of data each, while others have less participants that produce more data each.

Usefulness for management decision making: One of the most important factors for BOHA is the usefulness of the data produced by a community science project, which is primarily determined by how well the data answers the questions BOHA has. This can also be described as saliency, the relevance or value of the assessment to those who will use the results (Cash, D., Clark, W. C., 2001). Through the methods described in section 3.2, we've determined those questions to be:

- Which areas of the Boston Harbor Islands are threatened the most by coastal change?
    - Which landmarks or resources need attention due to their vulnerability?
- What patterns does coastal change follow in the Boston Harbor Islands?
- How can the impact of coastal change be predicted and anticipated before it damages important resources?

§5: Recommendation for Community Science Programs

After developing KDACS and using it to evaluate potential suggestions, we have assembled a list of three recommendations for community science programs which BOHA can implement to monitor the effects of coastal change. While each project is separate, they all share a common overarching goal: to reveal coastal change effects on a park scale that can allow for action and engage park participants. This section will address each recommendation including the Coastal Change Photo Hunt, Mapping Island Change Risk, and Beach Profiling, with an overview of the purpose of the recommendation, scientific objectives, management objectives, and education/engagement objectives as well as a review of how the program aligns with KDACS.

§5.1: Coastal Change Photo Hunt

Our goal for the first recommendation, named Coastal Change Photo Hunt, is to document the effects of coastal change on important features of BOHA. As shown in Figure 13, the other objectives of this program are to gather visual data over time showing the impact of coastal change in specific areas that park management can use to make decisions regarding protecting the park. Lastly, this program will take participants on a journey around the park while learning simultaneously about coastal change and park landmarks.

Recommendation 1	Coastal Change Photo Hunt
Goal	To document effects of coastal change on important park features
Scientific Objectives	Obtain visual data of the impact of coastal change in specific areas of the islands
Management Objectives	Track the impact of coastal change on resources and landmarks across BOHA
Education/engagement objectives	Take visitors on an educational journey, learning about landmarks on the islands as well as coastal change

Figure 13: Coastal Change Photo Hunt

Methodology

For this program, we recommend two ways that this program could be implemented. The common theme for the projects is to have several posts, placed through the publicly accessible islands, where visitors can stop and take a photo of important landmarks which they will then upload to a database of photos for that particular post. This program has a similar design to the SciStarter Picture Post project, as it involves taking pictures at designated places to monitor the environment. Additionally, NPS.gov has a list of community science projects related to photography over time to show changes in landscapes.

The individual posts in BOHA will be aimed at spots of the landmark which are at risk of coastal change. The posts will also have educational materials about the importance of the landmark and the coastal change effects that would impact the landmark. Some landmarks which could be featured as photo spots are the Deer Island Light, a few of the historical forts from the Civil War, and any of the lighthouses on the bluffs of Great Brewster's Island.

The first design recommendation for this program is a self-guided tour. Participants will get a handout of some kind (a brochure for example), with information about individual photo spots they could visit. This method could include just one of the islands where participants only go to one photo post, or participants can come back several times to visit each post and after taking a photo at each they could earn some form of 'badge' to show that they have completed the photo hunt. The concept of volunteers earning a badge for participating in this project is based on the BOHA junior ranger badge that our sponsor discussed.

The second design is a guided tour of the photo spots led by a park staff member who can discuss key facts about each location and how it is being affected by coastal change. Aside from the guide informing the tour group about the photo spots, it would be very similar to the self-guided version. Participants will take photos and submit them to a database for park management to use. One option for the guided tour would be to have time slots that people can sign up for.

Feasibility Considerations

The feasibility considerations largely depend on how the program is organized; if it follows the self-guided tour design there are almost no feasibility considerations to keep in mind, while there would be a few following the guided tour design.

For the self-guided tour, the program relies solely on posts in the ground and brochures scattered across the park which inform visitors of the program. This is almost entirely passive, once the posts and brochures are designed and the posts are put into the ground. The only upkeep would be restocking brochures or fixing a post if it gets damaged. A staff member would be required to vet and interpret the data collected, but that could be done as needed instead of a mandatory weekly commitment.

For a guided tour, there are more considerations involved. These include the scheduling of a guide and attraction of participants. Per the Boston Harbor Islands website, park staff already host guided tours of Fort Warren on George's Island, so this aspect could potentially be added to that tour as a few additional stops where people can take part in the community science program. If it didn't work to add this to the Fort Tour, the Guided Photo Hunt could be designed to follow the preexisting methodology of the Fort Tours. Additionally, Park management would have to figure out how to get a tour group to and from multiple islands in the winter when the ferry no longer runs and would have to schedule tours based on community scientists' availability.

KDACS evaluation

This program has several positive considerations for each design. First, the self-guided tour would be a very minimal time commitment for BOHA, as there is no scheduling that needs to be set up, and it is also a smaller time commitment as far as communication because participants would be able to access the results via public database themselves.

Second, on the participant side, there is no training necessary for this program, and the time commitment is also not an issue because the participants are already taking the time to come to the park. However, if this program is designed as a guided tour, it would be more time consuming for park management, as they would be dealing with scheduling appropriate times to conduct the tours.

Third, either program design would be giving participants a connection to nature and education as they would actively be on the islands learning about important landmarks and coastal change considerations. Additionally, the photo database will be public so the participants can access previous photos from each location. This program also aims to generate a large amount of high-quality data, which would also be beneficial to park management in the long term. Lastly, this program prioritizes safety and minimizing risk to the islands themselves as the photo spots would be predetermined as safe areas.

There are several aspects to this program that still must be considered. Many community scientists that we spoke with mentioned that they enjoyed the social connection of working with a team on these programs; this would be missed with a self–guided tour. Additionally, quality of data might be an issue as people will be using personal devices to take these photos; park management would have to assess the data collected to ensure that photos of the highest quality are kept. Quantity of data is also a potential issue. If there is not a high interest and participation rate in the program, it would not benefit the park. Going off of this, if there are large gaps in data, it also would not be useful to park management. Participants may also feel disconnected/uninvolved in the program because it is less demanding than other recommendations. Lastly, participants may gain less scientific/educational value from the self-guided approach compared to a guided tour, if they don't pay attention to the signs.

§5.2: Mapping Island Change Risk

Our second recommendation is named Mapping Island Risk, and the specific goals and objectives can be seen in Figure 14. The larger goal for this program is to create a detailed map of areas of erosion on the islands; this program will help create a reliable way to track these effects of coastal change, and reveal park areas that need greater attention to protect the features or resources which are being affected. This section will cover the methodology, feasibility considerations, a KDACS evaluation, as well as further program considerations for the program.

Recommendation 2	Mapping Island Change Risk
Goal	To generate a detailed and dynamic map of the parts of the islands that are at highest risk of damage due to coastal change
Scientific Objectives	Establish a regular and reliable process for tracking coastal change across vulnerable park lands
Management Objectives	Identify which resources and landmarks on the islands need greater attention due to vulnerability
Education/engagement objectives	Educate participants in how to spot erosion/accretion & its effects Can also include helping people understand the human history of interaction with the islands

Figure 14: Mapping Island Risk

Methodology

For this program we are recommending the methodology be similar to that of the Coastal Breeding Bird CS program (National Park Service, 2019a), as mentioned previously in section 2.3.2. This program aims to create a detailed, dynamic map of all of the islands, and this required transportation to these islands. Like the Coastal Breeding Bird program, we recommend that an open-faced landing boat is chartered to take a small group of participants are taken around the islands. The participants will land on certain islands to survey the effects of erosion, or lack thereof, on that island. They will receive training prior to completing their first survey, and the first couple boat trips will be accompanied by a guide. However, creating hierarchy of the participants where there can be a team leader, who is a participant who receives extra training, would be ideal so that the teams can just go survey without a guide, which is less time consuming on park management side and allows for more room for participants. This survey would ultimately be a simple form that the participants fill out where they identify spots which are eroding, spots which are at risk of eroding, and spots that are not eroding/have a low risk of eroding. After every boat trip, we recommend that there is some form of communication to all of the participants of the program updating them on new findings from the day.

Feasibility Considerations

This program is highly dependent on two factors: the weather and boat scheduling. Harsh weather in the harbor can make it unsafe for the participants to be out on the boat, and on the islands themselves. Secondly, there would need to be a boat chartered to take the participants out to the islands, as many are not accessible by public ferry. This means that the schedule for the program would be based around the boat availability.

KDACS Evaluation

This program is fairly well catered towards all the important aspects we have found for CS programs. Often with chartered boat trips, the participants are brought to islands that are not necessarily open to the public. Because people tend to be drawn to the programs when they are connected to the place, getting more of an inside look at the park gives participants a stronger connection to BOHA and will encourage repeated participation. Since this program allows participates to directly be collecting the data, the participants will have a direct connection to the science as well as a better educational experience due to being trained to look for signs of erosion. Additionally, with sending some form of communication after the boat trips, the participants will feel more connected to the results if they are being updated even when they did not collect the data. This communication aspect may be somewhat time consuming for the organizers, but it will benefit the program in the long term. Ensuring clear and frequent communication in both conveying results as well as allowing participants to reach out to organizers is vital to running a smooth program with high participant retention.

This program also satisfies many of the key aspects for park management, however the program design will trade quantity of data for quality of data. This is due to boat restrictions only allowing a small amount of people gathering data at a time. However, with the trinary set up of the erosion scale (signs of erosion, spots at risk of eroding, and spots that are not eroding/have a low risk of eroding), the data will be useful and of higher quality. Lastly, the smaller group design will minimize risk of detrimental impacts to the islands and the habitats on them.

There are several challenges to this program that still must be considered. One of them being scheduling difficulties; again, with the program times being centered around boat availability participants may be limited in the times that they can come out to the islands to participate. Additionally, safety may be a concern with the terrain on the islands as well as some weather conditions which may make the islands trickier to maneuver or may make the boat trip more trying on the participants.

§5.2.1: Further Archeological Considerations

Throughout the course of our project, we spoke with the Boston City Archeologist, Joe Bagley, and our sponsor about integrating archeological aspects to one of our program recommendations. Due to archeological knowledge not being open to the public, as mentioned before, we spoke about how creating more of a detailed erosion map would be of great help to archeologists as the goals of the program align with the goals of archeology. Bagley said that the map itself would be applicable to archeologists without any modifications at all, but an easy aspect to add on to the erosion mapping is shell midden identification. While many archeological sites are underground and not visible to the public, shell middens simply can’t be hidden once they’re exposed, as they stand out from surrounding soil by being much darker soil with white flecks, shells and bones. Anyone who wanted to find the shell middens and dig around for artifacts would already be doing it. With necessary approval from the appropriate tribes, it would be easy to combine erosion mapping with shell midden identification in this recommendation. It wouldn't add any meaningful risk of archeological sites being discovered by those that would harm them, but it could help archeologists identify previously unknown sites so they can work to protect them, allowing this community science program to further satisfy BOHA's goals of helping park management protect resources.

§5.3: Revealing Island Profiles

The third recommendation is not one we designed, but rather the implementation of preexisting beach profiling methods which would fulfill BOHA's needs as well as providing the benefit of following methodology that has been tested and improved by other researchers over the years that this method has been in use. Figure 15 outlines the goal and broad objectives of this recommendation. This section will cover the methodology, feasibility considerations, as well as a KDACS evaluation for this program.

Recommendation 3	Revealing Island Profiles
Goal	To reveal the cyclical and seasonal patterns of change in the profile of shorelines
Scientific Objectives	To observe and monitor the changes in shoreline profiles due to coastal change
Management Objectives	To characterize change in coastal areas of islands accessible by public ferry
Education/engagement objectives	Providing participants with experience engaging in a common scientific field sampling protocol

Figure 15: Revealing Island Profiles

Methodology

This program will follow preexisting methods, specifically the Emery Method used by countless other beach profiling projects. Beach profiling is a survey technique which measures the contour of a beach. By tracking this over time, the patterns of change in the beach contour can be revealed, indicating rates and locations of erosion or accretion.

Groups of volunteers will take a public ferry out to the Boston Harbor Islands where they will conduct the data collection. Measuring the profile of a beach at low tide is preferable because it exposes as much of the beach as possible, allowing volunteers to create the most complete beach profile they can without having to deal with the ocean. The data collection itself is quite simple, requiring only two vertical stakes, a rope or tape measure, and a view of the horizon. As can be seen in figure 16, the change in elevation of the beach over a known distance is determined by moving the viewer's head vertically to align the top of the seaward stake with the horizon. The distance from the top of the landward stake to the viewer's eye ("a" in the diagram) is then measured. This is the same distance as "b" in the diagram, the change in elevation of the beach in the interval measured. The full procedure, from the Maine SeaGrant, can be seen in Appendix F.

In our interviews with Emily Greene from the Maine SeaGrant program, she said that the beach profile they obtained by this method was within 1cm of the profile obtained by the state of Maine using incredibly accurate real-time kinematic (RTK) satellite positioning systems.

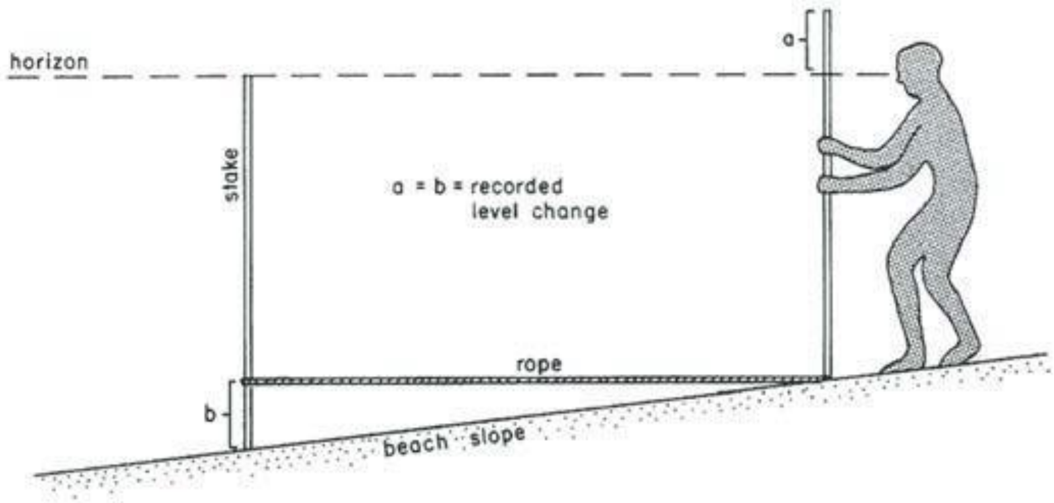

Figure 16: Beach Profiling Diagram

Note: by D. M. Bush and R. Young, 2009

Feasibility Considerations

The main feasibility consideration for this recommendation is the dependency on public ferries for transportation to the islands. This challenge presents itself in two main ways: identifying low tides that line up with the ferry's schedule, and the fact that the ferry doesn't run year round. During the months the ferry is running, organizers must identify low tide cycles that occur between ferry trips and on days that the volunteers are available. Additionally, the public ferries typically only run from late May through early October. A significant amount of damage to the Boston Harbor Islands occurs during the winter, when the ferry isn't running, due to storms called nor'easters. These storms would likely result in relatively dramatic changes to the profile of the shoreline, so profiles taken before and after the storm would be valuable as they would reveal the changes to specific islands due to the storm. Getting volunteers out onto the islands would require the chartering of a different boat as well as braving the cold temperatures. The feasibility of each trip like that would need to be carefully considered.

Other considerations

Since this program would be following the methodology of the many SeaGrants nearby, there's a possibility for BOHA and one of the SeaGrants to work together, with the SeaGrant handling the data storage and organization and both of them benefiting from the data collected on the Boston Harbor Islands.

KDACS evaluation

This program scores well in KDACS, satisfying many of the key aspects for BOHA and participants alike, although it has the possibility to be somewhat demanding to organize depending on the scale of implementation.

For community scientists, this program fulfills all the key aspects as an active group project out in nature that provides a connection to science as well as the islands. Ensuring a connection to results is also quite easy; with a portal that allows participants to see each profile they've collected as well as regular emails, participants can be kept in the loop and feel that their effort is meaningful and appreciated. In addition to the regular newsletter-type emails, the communication aspect for participants can be satisfied by simply responding promptly and being available for the participants.

This recommendation also does well in many of the aspects that are relevant to BOHA. For a community scientist to measure the profile of a beach, they must understand the basics of coastal change, requiring a prerequisite basic level of education and allowing for many opportunities for further education. Additionally, safety is not a significant concern for BOHA since this program is limited to rather flat sandy beaches, incurring no notable risks. This program also has a very minimal impact on the environment as volunteers avoid the more fragile parts of the islands, such as bluffs, easily damaged plants, or animal habitats. Following established methods would not only remove some of the trial and error involved in starting a community science project, but would also allow the data produced by this program to easily integrate with other SeaGrant type programs in other areas. Due to the regular monitoring of beach profiles, the amount of data produced by this program would remain rather constant, avoiding large gaps in data or too much data to handle. Finally, the results from this program can be directly used by park management to answer their key questions mentioned in section 4.2.2.

There are also several challenges to this recommendation though, all connected to time. As mentioned in the Feasibility Considerations, it could be challenging to align low tides with the ferry schedules. Additionally, this program could demand a large time commitment from BOHA to organize and ensure clear and constant communication. Emily Greene organizes over 100 volunteers in her SeaGrant program on 10 hours per week, but said in our interview that she feels more time is needed. With fewer volunteers involved though, the time commitment could be less

§6: Conclusion

The National Parks of Boston makes education a priority in their parks, as well as preservation of cultural, historical, and natural resources. Community science can integrate both of these priorities, working towards a larger objective of helping inform park management's efforts to protect the islands with scientifically valid information. Our project goal was to recommend community science programs focused on monitoring coastal change in the Boston Harbor Islands.

The primary threats focused on in this project are the impacts of climate change and coastal change, such as rising sea levels, coastal erosion, and storm surges. Rising sea levels bring the possibility of submersion, and coastal erosion and storm surges threaten the island with irreversible changes in morphology which can lead to loss of resources and features in BOHA.

Despite the limitations that our team faced throughout the course of our project, mainly due to the COVID-19 pandemic, we quickly adapted to work as effectively as possible. Communication was one of the largest adaptions that we needed to make, again because of pandemic restrictions. All our project work was done online, including meetings and interviews. This was a bit trying at first, but as our team got used to the online meeting format it was very useful because we were easily able to connect with a wider array of people.

We proposed three programs which share a common goal to reveal coastal change effects in BHI which can allow for action and engage park participants. Each of these recommendations meet BOHA's three main goals relating to community science (scientific validity, relevance to park management, and providing an educational/enjoyable experience for participants) as well as meeting several of the Key Design Aspects of Community Science.

- Our first recommendation accomplishes this by utilizing a photo hunt where participants take and submit photos of established landmarks. This program will reveal effects of coastal change on these landmarks over time.
- Our second recommendation aims to create a detailed map of areas of erosion on the islands. This map will also change over time as new information is uncovered, but its implications will stretch further than just the park management of BOHA as it can also be used for archeological purposes.
- Our third recommendation focuses on profiling the islands with sandy beaches in BOHA. This program shows erosion/accretion in the form of sediment movement over time.

Each recommended program offers additional opportunities to integrate in each program to elevate the overall value for both BOHA and program participants. Our team believes that integration of these programs will have a lasting positive impact on the Boston Harbor Islands and those who enjoy them.

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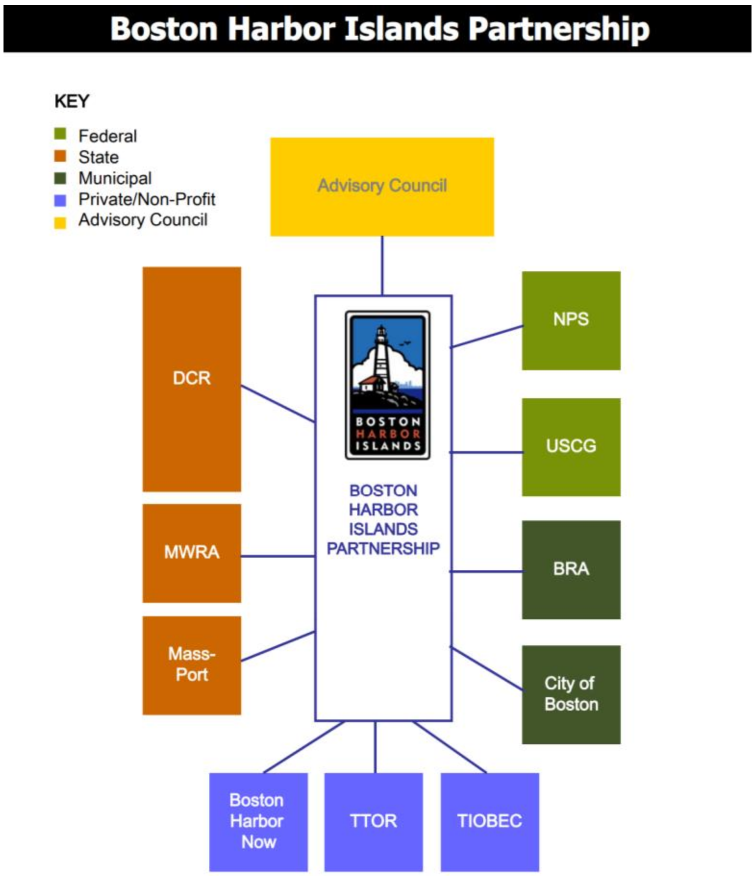
Appendices

Appendix A: Boston Harbor Islands Partnership Entities

The chart below shows the entities who make up the Advisory Council of Boston Harbor Islands, as well as the governmental or nongovernmental affiliation.



Appendix B: Island by Island Accessibility

This specific list was provided to our team by our sponsor, it shows the different accessibility of several of the islands apart of BHI.

Mainland areas of the park that are accessible year-round by vehicle:

- Worlds End
- Webb Memorial
- Deer Island
- Nut Island

Islands that are available by public ferry from late May - early Oct:

- Georges
- Spectacle
- Thompson

"Camping Islands" that are available by more limited public ferries from July-August:

- Peddocks (may be in the first group in the future)
- Lovells
- Grape
- Bumpkin

Other islands with erosion challenges / scientific / archeological interest:

Private boaters allowed

- Rainsford
- Sheep

Private boaters not currently allowed

- Gallops
- Long

Appendix C: Citizen Science Rubric

Below is an existing rubric for assessing citizen science projects which was provided to us by our sponsor. We plan on refining these parameters once we begin our project in August.

Citizen Science Rubric

Categories		Definition	1	2	3
Scientific Quality		*The quality of scientific data that results in a citizen science activity.*	The activity was scientifically faulty, and data cannot be trusted or used in the future.	Activity produces quality scientific data but not reliable enough for scientific papers.	Scientific papers and further research can use data produced during the citizen science activity. Data is trustworthy and could be duplicated.
		The amount of time citizens participated in scientific research.	Participants can only participate in a single stage of the activity once.	Participants have the ability to participate in activity more than once, but in only one stage.	Participants have the opportunity to participate in multiple stages of the activity and can participate multiple times.
		The participants have access to the final results of the project and the ability to understand the outcome.	They have no greater knowledge of the outcome of the project.	Access is available to the outcome of the research, but the outcome is not intelligible to all learning levels.	Access is available for the outcome of the research, and the impact the research had inside and outside the park. The outcome is made accessible to diverse audiences. Participants are acknowledged in results and publications.
Management Relevance	Long Term	*Long term management is when results from the research require additional park management for longer than one season.*	There is no long term management decision.	There are possibilities for relevant long term management decision if the correct personnel is contacted and if finances are available.	There are possibilities for a specific long term management decision for the park along with needed personnel and finances. i.e. Adaptive Management Plan
	Short Term	*Short term management is when results from the research require additional park management for less than one season.*	There is no short term management decision.	There are possibilities for relevant short term management decision if the correct personnel is contacted and if finances are available.	There are possibilities for a specific short term management decision for the park along with needed personnel and finances. i.e. Adaptive Management Plan
Participant Experience	*Number of People*	*Amount of people who participated in the activity.*	4 or less	5-9	10 or more
	Quality	*The amount of enjoyment citizens express during and after the activity.*	Participants disliked the activity and the subject of the activity.	Participants enjoyed parts of the activity. They found the subject of the activity semi enjoyable.	Participants enjoyed the activity and found the work rewarding. They would be willing to continue the activity alone or with others in the future. They wish to gain a better understanding of the subject, the park, or the National Park Service.
		The level of understanding of the Boston Harbor Islands National and State Park, and the National Park Service	They left with no new knowledge of the Boston Harbor Islands National and State Park, and the National Park Service and are unlikely to visit again.	They understand that Boston Harbor Islands is a National and State Park but does not fully understand the purpose and goals of the National Park Service. They might revisit Boston Harbor Island.	They have a better understanding of the park service and are likely to tell friends and family about the Boston Harbor Islands National and State Park and the National Park Service. They are very interested in revisiting the Boston Harbor Islands National and State Park.
		Understanding of resources and stories of the Boston Harbor Islands and the park generally.	They left with no new knowledge or understanding of the Boston Harbor Islands National and State Park.	They have a general understanding of the resources and stories of the Boston Harbor Islands.	They have a strong understanding of the resources and stories of the Boston Harbor Islands.
		The amount of knowledge and understanding the citizens express during and after the experiment.	They would not be able to do the activity alone or lead others. Did not retain any information about the activity.	The participant can generalize what the activity was about and its purpose other. The participant has some new knowledge and understanding of the activities subject.	Participants can lead and communicate the activity to a diverse audience. The participant has new knowledge and understanding of the activities subject and wishes to learn more outside of this activity.

Appendix D: Interview Questions for Organizers of Community Science Projects

Introduction:

Hello, thank you for taking the time to meet with our team. We would first like to start by introducing ourselves and the project. [we each said our name and major]. Our project is working with the National Parks of Boston to recommend community science programs for them to eventually implement in their park. We are meeting with you today to ask you questions about your experience with managing community science programs.

- Are you okay with this interview being recorded and for us to use the answers to these questions in our final report?
- What challenges have you faced with the organization and management of the project?
- How often do citizen scientists participate repeatedly?
- What are some advantages and challenges of citizen science that you've seen?
- What have you seen that draws people in to participate in citizen science?
- What methods do you use to collect data?
- How are participants connected to the results?
- How much effort does it take to organize a citizen science project?
- How has coronavirus impacted your project?
- Who is your general demographic for volunteers?

Appendix E: Interview Questions for Participants in Community Science Projects

Introduction:

Hello, thank you for taking the time to meet with our team. We would first like to start by introducing ourselves and the project. [We each said our name and major]. Our project is working with the National Parks of Boston to recommend community science programs for them to eventually implement in their park. We are meeting with you today to ask you questions about your experience participating in community science programs.

- Are you okay with this interview being recorded and for us to use the answers to these questions in our final report?
- What drew you to participating in the project?
- How long have you been participating?
- What do you like & dislike about it?
- Have you participated in other projects?
- Would you be interested in an archeological aspect?

Appendix F: Full Methodology for Beach Profiling

Step-by-Step Instructions for the Emery Method of Beach Profiling [PDF]. (2019). Augusta, Maine: Maine Geological Survey, Deparment of Conservation.

Step-by-Step Instructions for the Emery Method of Beach Profiling

1. Find the Starting Point. Set a control point (a reference stake or pin) in the ground. This is done once before the first profile is taken. The same control point is reused for each subsequent profile and is the starting point of all measurements. A second control point (stake or pin) or object (sometimes a utility pole, tree, chimney, etc.) is used also. These two reference points define a line to follow to measure a beach profile. Often it helps to place a temporary marker post at these control points that rises up from the dune or above a seawall so the line-of-sight can still be seen down on the beach.

2. Begin Notes. Fill in the top part of the log sheet. Include names of people in the team, the date, time, profile name or number, beach location, etc.

3. Record Stake Height. Measure the height of the ground in relation to the top of the control point with the numbers (scale)up. The person holding this rod should stand off the profile line for the next step.

4. Set Rod 1. Stand the end of one profile rod (Rod 1) on the ground next to the control point with the numbers (scale) up. The person holding this rod should stand off the profile line for the next step.

5. Set Rod 2. The second person takes Rod 2 toward the ocean. Looking back toward land and Rod 1, this lead person places Rod 2 (with scale up) on the profile line using the control points as a guide. Pick a horizontal distance of a meter (or other suitable distance if obstacles are in the way) as a spacing between the two poles. Use a graduated chain or pole to do this and be careful to hold both poles straight up and down while setting Rod 2 in place.

6. Measure and Record. From the landward pole, the first person sights the horizon and the top of the lower of the two rods. This line-ofsight will intersect part way up the other rod. Read the elevation number marked on the other rod that is in line with the pole top and the horizon. Keep both poles vertical when reading! Note that sometimes the reading will come from Rod 1 and sometimes from Rod 2. This is because the ground may slope down or up and may change which pole is higher at different places on the beach profile line. When the ground slopes down toward the ocean, the forward rod

(Rod @) will be lower, and a negative [-] number is assigned to the vertical reading off of Rod 1. when the ground slopes up looking toward the ocean, the forward rod will be higher, and a positive [+] number is assigned to the reading. IN this case, the number is read off the forward rod)Rod 2). So moving forward on the profile, uphill is [+] and downhill is [-]. Always use either a = or – before the number. It takes careful attention to get this right on each measurement. A single error will make the rest of the data plot incorrectly on a graph. Record the elevation change and horizontal distance between poles on the log sheet. Also note any features at the forward rod (such as edge of dune, slope change, water line, etc.) in the Notes column on the log Sheet.

7. Move Ahead. After the notes are taken, move Rod 1 to the same “footprint” occupied by Rod 2. The person at Rod 2 should wait for Rod 1 to come up alongside Rode 2 in order to be certain of getting the position correct. After Rod 1 is in the place of Rod 2, the forward rod can be moved ahead another meter or two and place o n the ground in line with Rod 1 and the original control point(s). The job of the lead person is to be sure each forward move stays on the line. Rod 2 must be set down on the ground keeping the chain (or other tape measure) level.

8. Repeat Steps 6 and 7. Measure, Record, & Move. Continue to move ahead, repeat these steps all the way to the water. As you go, everyone on the team should look ahead for features to stop on and measure. If some feature, perhaps the edge of the dune, does not occur at a horizontal interval of one meter, then make the horizontal distance smaller. For example, if the dune edge is only 0.6m from the least measurement, move the forward pole ahead only that far. ON the next measurement move ahead only 0.4 (or 1.4) m in order to get back on a spacing of 1 m intervals. Keeping a set interval in whole meters will help with data analysis later.

9. Stop at the Water. Make a measurement that includes the water line. IN the notes column of the log sheet abbreviate it W.L. and record the TIME it was measured. Because the height of the tide is changing, the time of the reading is important. Estimate the place on the beach where the water level would be without the waves, the still water level. There is no need to measure how far up the beach the swash is going at the time of the measurement.

10. Continue On (Optional). The process can be continued into the water if teams want to. This is optional and not necessary. In cold water there is a risk of hypothermia. In rough seas there is a risk of getting hit by breaking waves. Do not take chances. Always keep your

personal safety and that of your team members in mind. A few extra points on a graph are not work the risk of personal injury.

11. Final Reading. At the last measurement, record the TIME finished in the Notes column on the log sheet.

12. Photograph the Beach. Take three photographs of the beach. It helps to place the profile rods down on the profile line part way up the beach, near the high-tide line. Stepping back from the rods, take a picture looking up to the dune)or seawall) from a spot near the water line. Move up about halfway on the profile and take two more pictures: one looking each way along the beach (parallel to the water line). For these shots try and include the profile rods in the foreground. Frame the picture to include the beach from dune (seawall) to the water.

13. Pack Up. Gather up all the gear, including any posts back at the control points, notes, and field gear. The profile is done!