Climate Change in Acadia National Park

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WPI

Abstract

The problem addressed in this project is climate change in Acadia National Park and how the park can implement strategies to help mitigate and adapt to climate change. These strategies were presented in the form of five recommendations. These recommendations were made on the basis of research conducted as to what other National Parks are doing to mitigate and adapt to climate change. These suggestions cover the rising sea level, transportation in the park, the lack of educational programs, and plants and animals in the park.

Authorship

The entire paper was edited and reviewed by each member of the team. The primary authors for each section are listed below according to their initials.

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Executive Summary

This project examined Acadia National Park and the area surrounding it with the intent of making recommendations directed at addressing the effects of climate change. Acadia National Park is located primarily on Mount Desert Island in Maine, southwest of Bar Harbor. It is along the Atlantic coastline of the United States. This park is visited by over 3.3 million people a year and includes many hiking trails as well as provides activities for kids to learn more about the area and the importance of nature ("Acadia National Park" n.d.).

Acadia is attempting to mitigate and adapt to the harmful effects of climate change in a variety of ways. They have had to implement a transportation plan to lessen the effects of higher visitor volume and their cars. Further, they have to anticipate the outcomes of heavy rainfall and observe how the current species of vegetation respond to the weather. The greatest difficulty for park ecologists is determining how they should manage the changing flora of the region—for example, would it be better to attempt to preserve the current species, anticipate what species will dominate in the future and prepare for that, or plant species that existed in the park in the past? The dominant species of plants will likely change as the temperatures increase and precipitation patterns change (Tocci, 2014).

The goal of this project was to provide suggestions to Acadia National Park to allow them to better prepare for the effects of climate change. The suggestions were based on how other National Parks are responding to current climate change research.

Although there are already efforts to mitigate the effects of climate change, this project will be useful since it is coming from an outside source. It also could help many other national parks because although the recommendations are specifically for Acadia, they may still be applicable to many other national parks. The Friends of Acadia, a nonprofit organization that organizes volunteer efforts and private philanthropy for the benefit of Acadia National Park, may be able to use these suggestions to add to their work related to climate change.

Along with National Parks, these suggestions could benefit many locations and even people in general since they are ways to mitigate and adapt to the effects of a global problem. Each person will be affected by climate change and these are ways to deal with and adjust to these changes. Since Bar Harbor and many other locations near Acadia will be affected in similar ways, they could use some of the suggestions provided to adapt and prepare.

The three terms commonly associated with climate change and the discussion around it are mitigation, resilience, and adaptation. These terms represent three distinct approaches to the issue. Mitigation refers to a solution related to adjustment and management. An example of this is slowing the rate of global warming or lessening the effects of climate change. Resilience is finding ways to be more prepared in the future. An example of this is planning to ensure that natural resources can last in the future. Adaptation is different in that it focuses on adjusting to what is happening, but not changing what is actually happening. An example of adaptation is building walls to prevent the oceans from moving inland. This does not solve the issue, but instead adapts to the problem and finds a temporary solution. This project focused on mitigation and adaptation when providing suggestions to Acadia National Park.("Mitigation," n.d.).

The project had four main objectives. The objectives of this project are listed below:

1. Adjust to the rising sea levels.
2. Limit the loss of plant and animal species in the park.
3. Reduce carbon emission from park vehicles.
4. Develop an education plan.

By researching what other national parks have been doing, we have been able to compare this information to the current practices of Acadia National Park in order to find areas where Acadia could improve their practices. This comparison also allowed us to see what other parks are doing and figure out if Acadia could benefit from doing the same things. These comparisons are explained below and are categorized by the objectives of the methods section. Since these objectives break down the major issues related to climate change, they easily lead to suggestions for the park. These efforts were examined to determine if they helped resolve the issues we looked at. Some of the main parks that were examined were Climate Friendly Parks. These parks have been benchmarks to gain this title and are supported by the Climate Friendly Parks Program, which provides resources to all national parks to help them adjust to climate change ("Climate Friendly Parks," 2019). Since Acadia has not yet met these benchmarks, it will be beneficial for them to use suggestions based on other parks who have.

The general findings of this project relate to each individual objective and include a brief summary of the ways that Acadia could meet the objectives. These findings were created by looking at other National Parks as well as general areas where similar issues are being found.

Objective 1: Adjust to the Rising Sea Levels:

One of the findings for this objective was that roads are preventing the migration of marshes, which could prevent them from being preserved. This inland migration is how marshes naturally adapt to changing sea levels as they are generally quite resistant to change. A second finding was that the roads could also be impacted by the sea level rise, but they are not the main focus. The marshes are more important to the ecosystem and will be the first to flood.

Objective 2: Limit the Loss of Plant and Animal Species:

One of the findings related to this objective was that the parks should utilize other resources such as the Exotic Plant Management Team, a team that works with the National Park Service to support National Parks in combating invasive plants, to help them mitigate the effects of climate change on the ecosystem ("Of Salmon," n.d.). Another finding was that although limiting invasive plants and introducing native plants are both important, invasive plants should be removed or controlled before native plants can be introduced. This would allow the native plants to grow more easily and without competition from the remaining invasive species.

Objective 3: Reduce Carbon Emission from Park Vehicles:

One finding related to this objective was that shuttles are used by many parks in order to reduce the usage of personal vehicles as well as to make viewing the park easier for many visitors. Another finding was that a main way to reduce carbon emissions would be to switch to more efficient fuel sources. A third finding was that by eliminating access to vehicles other than shuttles, overall carbon emissions would be reduced.

Objective 4: Develop an Education Plan:

One of the two findings related to this objective is that climate change efforts that are carried out by the parks or that are going to be carried out by the parks should be posted on their websites. This allows the general public as well as other parks to be made aware of what efforts

are being made. The second finding is that visitors should be educated on climate change and both its impact on the park and its future impacts. This would be an opportunity for the park to teach visitors about how they can make a difference.

Figure 1 shows the final recommendations made by our group in order to help Acadia mitigate and adapt to the effects of climate change in the park.

When making suggestions to Acadia National Park, the overall goals were to improve the environmental impact of the park and ultimately, ensure that the park would be qualified to be included in the list of Climate Friendly Parks in the future. By following the suggestions shown in Table 1, Acadia will be able to do not only that, but also to educate the community and help visitors become more sustainable.

Table 1: Final Recommendations

Objectives	Recommendations
1. Adjust to the rising sea levels.	● Allow for marsh migration by improving culverts and removing barriers
2. Limit the loss of plant and animal species in the park.	● Introduce native plants in smaller areas of the park and monitor closely. ● Partner with organizations such as other National Parks or the Exotic Plant Management Team to control the invasive plant species.
3. Reduce carbon emission from park vehicles.	● Limit traffic flow by restricting entry of private vehicles and encouraging the use of the shuttle system. ● The shuttles should be switched to hybrid vehicles where possible.
4. Develop an education plan.	● Increase employee education regarding climate change. ● Add more information about climate change to the park website. This information should be targeted at both children and adults, and should feature activities for both age groups.

1.Introduction

This project examined Acadia National Park and the area surrounding it with the intent of making recommendations directed at addressing climate change effects. Acadia National Park is located primarily on Mount Desert Island in Maine, southwest of Bar Harbor, along the Atlantic coastline of the United States. The park is visited by over 3.3 million people a year and includes many hiking trails as well as provides activities for kids to learn more about the area and the importance of nature ("Acadia National Park," n.d.).

Acadia is attempting to mitigate and adapt to the harmful effects of climate change in a variety of ways. They have had to implement a transportation plan to lessen the effects of higher visitor volume and traffic congestion. Further, they have to anticipate the outcomes of heavy rainfall and observe how the current species of vegetation respond to the weather. The greatest difficulty for park ecologists is determining how they should manage the changing flora of the region—for example, would it be better to attempt to preserve the current species, anticipate what species will dominate in the future and prepare for that, or plant species that existed in the park in the past? The dominant species of plants will likely change as the temperatures increase and precipitation patterns change (Tocci, 2014).

The goal of this project was to provide suggestions to Acadia National Park to allow them to better prepare for the effects of climate change. The suggestions were based on how other National Parks are responding to current climate change research.

Although there are already efforts to mitigate and adapt to the effects of climate change, this project will be useful since it is coming from an outside source. It could also help many other national parks because although the recommendations are specifically for Acadia, they may still be applicable to many other national parks. The Friends of Acadia, a nonprofit organization that organizes volunteer efforts and private philanthropy for the benefit of Acadia National Park, may be able to use these suggestions to add to their work related to climate change.

Along with National Parks, these suggestions could benefit many locations and even people in general since they are ways to address the effects of a global problem. Each person will be affected by climate change and these are suggestions to deal with and adjust to these changes. Since Bar Harbor and many other locations near Acadia will be affected in similar ways, they could use some of the suggestions provided to adapt and prepare.

This project followed four main objectives that were used to make suggestions to Acadia National Park. These objectives are listed below:

1. Adjust to the rising sea levels.
2. Limit the loss of plant and animal species in the park.
3. Reduce carbon emission from park vehicles.
4. Develop an education plan.

In conducting research for this project, the overarching goal of the team was not only to help Acadia mitigate and adapt to the effects of climate change, but also provide suggestions that would allow Acadia to become a Climate Friendly Park in the near future ("Climate Friendly Parks," 2019). This would allow them to reach a status that would prove that they are contributing to climate change in a positive way.

2. Background

2.1 Discussion of Climate Change

Climate change is the general term for the changes that are happening to the planet that include rising sea levels, more severe storms, and shifts in seasons ("The Causes of Climate Change," 2019). It is attributed to the burning of fossil fuels such as coal and oil, which results in the release of large amounts of carbon dioxide into the atmosphere. Fossil fuels are resources such as coal or oil that are burned and in the process, allow carbon to be combined with oxygen that is present in the air. This further contributes to the increased carbon footprint on the planet. Carbon footprint is the amount of carbon dioxide released by a particular person or group; this value can be used to evaluate contribution to climate change and to see the changes that people or organizations have made to lessen their negative environmental impact. Since the start of the Industrial Revolution in the eighteenth century, the levels of carbon dioxide in the atmosphere have vastly increased. This unnaturally high release of carbon dioxide has altered the ability of the atmosphere to reflect energy away from Earth, as the heat is absorbed and trapped by the gases, also known as greenhouse gasses; this generally results in the warming of Earth, which can all be seen in Figure 1 ("The Causes of Climate Change," 2019).

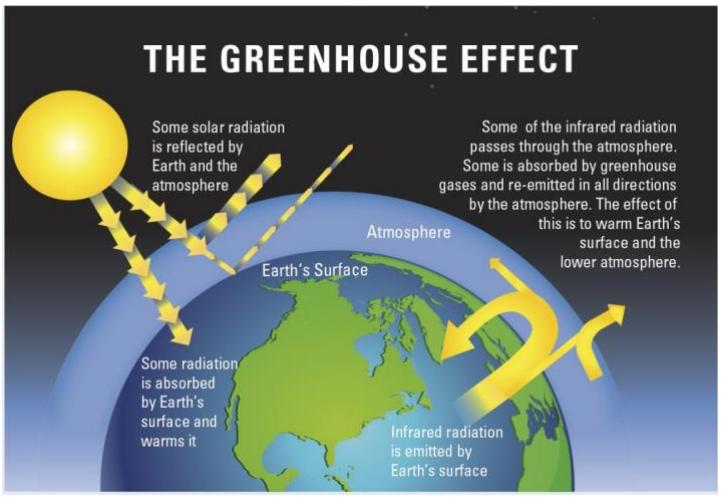

Figure 1.The Greenhouse Effect. From *The Basics of Climate Change*, by The Royal Society, 2014, https://royalsociety.org/topics-policy/projects/climate-change-evidence-causes/basics-of-climate-change/. Copyright 2014 by The Royal Society.

Another term commonly used when describing climate change is global warming. This term is encompassed within climate change, but refers specifically to the long term warming of the planet ("The Causes of Climate Change," 2019).

The potential effects of climate change include polar ice caps melting causing sea levels to rise and flood areas of lower elevation; the warming of large bodies of water, affecting the marine ecosystems; and an increase in severity and occurrences of natural disasters such as hurricanes, droughts, and wildfires. Currently, the planet's global temperature has been raised by about 1.62 degrees Fahrenheit since the late 19th century and global sea levels have risen about 8 inches in the last 100 years ("The Causes of Climate Change," 2019). These effects differ by location as, for example, the coastal climate of Acadia makes wildfires less common than in parks in dryer, warmer areas ("Environmental Factors," n.d.). Acadia is likely to see heavier rainfall and flooding, erosion of the coastline, changes in the composition of the ecosystem as the climate is unable to accommodate existing vegetation and different species begin to dominate, and droughts. Furthermore, warmer temperatures yield longer visitation seasons as the cold seasons get shorter, resulting in a higher volume of visitors to the park (Fisichelli & Ziesler, 2015; Trotter, 2018).

This project relies on the current predictions and scope of climate change that will be explained below. The goal is not to eliminate or stop climate change, but rather help the park adjust to the changes that will come as climate changes progress. This smaller goal will help allow this team to make educated and practical suggestions that can be implemented.

Most of this project relied on the points of consensus present. These involved the changes that are happening in the park and the need for something to be done. The suggestions given provide ways for the park to further preserve the land and avoid changes in the future.

One area of debate is if climate change is a real problem. This does not directly affect this project since the effects are, in fact, being seen, but it will be addressed regardless. The Intergovernmental Panel on Climate Change has shown that there is evidence that humans have made an impact on the global climate. As of 2008, 71% of people believed that climate change was real. These facts alone prove that it is real and something needs to be done, but many people still don't believe it. Their lack of belief comes from many sources, one being a scandal in 2009 called "Climategate" which involved a group of scientists who withheld data that disproved the severity of climate change. This event alone caused the percentage of people who believed in

climate change to drop from 71% in 2008 to 57% in 2009 (Hoffman, 2011). There are more than just two categories of people when it comes to the climate change debate. There are also people who are skeptical about climate change and those who believe that it exists, but that it is not as serious as it seems.

This debate is a large issue when it comes to dealing with climate change. However, the current project will focus on the effects that are being seen today. These effects are evident and cannot be debated. They include a larger number of visitors to the parks in later months due to extended periods of moderate temperature, as well as more severe weather. Since the fall has become warmer in recent years, tourists have been able to visit Acadia National Park later in the year (Trotter, 2018). This has resulted in increased traffic congestion and has necessitated the development of a Transportation Plan by Acadia National Park. In addition, severe storms are causing erosion and an increase in the amount of maintenance needed for the park (Trotter, 2018).

2.2 Mitigation, Resilience, and Adaptation

The three terms commonly associated with climate change and the discussion around it are mitigation, resilience, and adaptation. These terms represent three distinct approaches to the issue. Mitigation refers to a solution related to adjustment and management; an example of this is slowing the rate of global warming or lessening the effects of climate change. Resilience is finding ways to be more prepared in the future; an example of this is planning to ensure that natural resources can last in the future. Adaptation focuses on adjusting to what is happening, but not changing what is actually happening; an example of adaptation is building walls to prevent the oceans from moving inland ("Mitigation," n.d.). This does not solve the issue, but instead adapts to the problem and finds a temporary solution. This project focused on mitigation and adaptation when providing suggestions to Acadia National Park.

2.3 Climate Change and the National Parks

National parks need to be protected from climate change in order to protect their resources. When the National Park Service was created in 1916, it was stated that the parks should remain "unimpaired for the enjoyment of future generations."(Ladzinski & Nijhuis, 2016). Although the definition of unimpaired is not clear, allowing the national parks to

experience the effects of climate change without trying to stop them does not follow this goal. Despite the lack of definition for the term unimpaired, the general understanding of the term means that the park should not be damaged or destroyed in any way. This could happen through vandalism, resource depletion, or natural changes. Either way, it should be avoided so that future generations can visit the parks and they remain as similar to the condition that they can be found in today. The quote above also indicates that the purpose of national parks is for the enjoyment of the people. This puts pressure on the government to maintain and preserve these locations despite changes that are out of their control. Even if the cause of the changes is not fully known or understood, action has to be taken to avoid major alterations to the national parks.

This project examined Acadia National Park and the area surrounding it with the intent of making recommendations directed at addressing climate change effects. Acadia National Park is located primarily on Mount Desert Island in Maine, southwest of Bar Harbor. Acadia National Park is along the Atlantic coastline of the United States and is shown on the map in Figure 2.

Figure 2. Map of Maine. From *A Practical Guide to Acadia*, by J. Braun, 2019, https://www.citrusmilo.com/acadiaguide/gettingtoacadia.cfm. Copyright 2019 by J. Braun.

Acadia was originally named Sieur de Monts National Monument in 1916. In 1919 it was renamed Lafayette National Park by the Congress as the first national park east of Mississippi. In 1929 it was officially named as Acadia National Park for the first time ("History of Acadia,"

2017). The name of "Acadia" came from historical descriptions by French and Greek fishermen and traders. Some believe that it is derived from the term of native Mi'kmaq "akadie" or " cadie" which means " piece of land". It was then expressed as "*I'Acaide*" by French explorers ("What is the origin of 'Acadia'?" 2019).

Acadia National Park is visited by over 3.3 million people a year and includes many hiking trails as well as provides activities for kids to learn more about the area and the importance of nature. In order to access the park one must purchase a parking pass for $30, which is valid for one week; however, if they would rather enter on foot, the fee is $15 per person and also lasts for one week. In the park itself there are options to canoe, kayak, swim, spend time on the beach, hike, or explore the area, which includes 49,075 acres ("Acadia National Park," n.d.).

Acadia is attempting to mitigate the harmful effects of climate change in different ways. They have had to implement a transportation plan to lessen the effects of higher visitor volume and their cars. Further, they have to anticipate the outcomes of heavy rainfall and observe how the current species of vegetation respond to the weather. The greatest difficulty for park ecologists is determining how they should manage the changing flora of the region—for example, would it be better to attempt to preserve the current species, anticipate what species will dominate in the future and prepare for that, or plant species that existed in the park in the past? The dominant species of plants will likely change as the temperatures increase and precipitation patterns change (Tocci, 2014).

The diverse landscape and ecological zones of Acadia provide habitats for a variety of plant and animal species. There are more than 400 kinds of deciduous and coniferous trees, bog plants, vascular plants, meadow and roadside plants, freshwater marsh and pond plants as well as many algal and fungal species within the park ("The Wild Gardens of Acadia Visitor Information: History of the Gardens," 2017; "Common Native Plants," 2019). Acadia is also home to 37 mammalian species, 215 bird species, 7 reptilian species, 11 amphibian species, 28 fish species and many different types of insects ("Animals," 2019). Protection of its abundance of habitats and its high level of biodiversity was one of the reasons the park was created ("Foundation Document Acadia National Park," 2016).

Since there is such a large number of bird species in the park, Acadia has become known for birdwatching. These birdwatchers are observing changing species as the general temperature

of the park has begun to increase. Not only is this an example of animals adapting to climate change, but it also can be used as an educational tool in the park. Luckily, birds are fairly resistant to climate change meaning that they can easily migrate to areas that represent the climate they are used to. For example, birds that are typically found in Acadia may move further north where temperatures may have changed to be comparable to the original temperatures of Acadia. Unlike other species of animals, birds can easily move which prevents them from going extinct as easily. The current evidence shows that birds will migrate to climates that better fit their specific species even if these climates were not originally suitable for them. Figure 3 shows the number of species that are predicted to migrate to climates by 2100 that were not suitable for habitation during the baseline period. This baseline period refers to 1990 (Fisichelli, 2014). It is shown that Neotropical species will be most likely to migrate to these new climates, but resident and short distance species also will migrate. This table shows a definitive trend to migrate to more suitable climates, which is on trend with research that has been conducted by both The National Park Service and individual researchers.

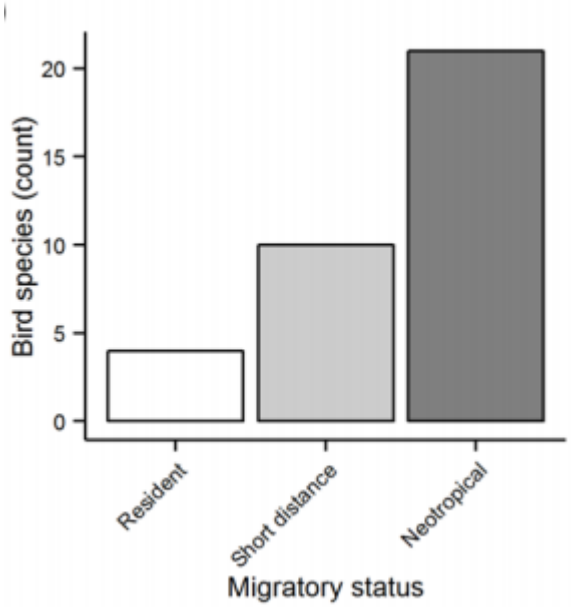

Figure 3. Changes in Migratory Status of Bird Species. From *Climate Change and Birds of the Acadia National Park Region*, by N. Fisichelli, 2014, https://irma.nps.gov/DataStore/DownloadFile/501461. Copyright 2014 by N. Fisichelli

Changing species of birds is a major effect of climate change, but is also is impacting the forests and plants present. As a National Park, Acadia is tasked with maintaining the original

species that were present when the park was created. This is proving to be a difficult task for Acadia since species that can easily adapt to the warmer temperatures are taking over; these species are being referred to as invasive species due to their superior growth. Since it would be extremely difficult for Acadia to completely remove these species, they are instead focusing on restoring as many of the native species as possible. This is being done through two vegetation restoration programs which will focus on the summit and Sieur de Monts Spring and will also introduce only the native species that are predicted to be able to survive in the warmer temperatures (Trotter, 2014).

There have been many action plans published by Acadia as well as a number of ideas generated, but no clear action. It is evident that they want to avoid the effects of climate change and are trying to do so, but the park itself has yet to publish a clear plan as to how they wish to do this. This is part of the reason why this project will be beneficial to the park. Even if they are already working on a plan, it will offer more suggestions as to how they may improve it.

The Climate Friendly Parks (CFP) Program, a program initiated by the National Parks Service, provides resources to all national parks to help them adjust to climate change. These resources can be in the form of information or suggestions like those provided in this project. The purpose of the CFP is to ensure that the parks are both able to withstand climate change, but also to ensure that they are operating sustainably. There are currently around 120 parks, which includes both National Parks and State Parks, that have qualified as climate friendly parks. The qualifications include submitting an application, developing baseline emissions inventory, educating staff, and developing an action plan to address sustainability. Acadia is not currently listed as a climate friendly park, which means they need to continue making progress in addressing climate change issues ("Climate Friendly Parks," 2019).

The major stakeholders for this project include not only the people who work at Acadia National Park, but also the many people who visit Acadia throughout the year, and the Friends of Acadia. Friends of Acadia is a nonprofit organization that organizes volunteer work and manages philanthropy gifts for Acadia National Park. This organization also allows people in the area to get involved and help take care of the park. One of their main concerns is climate change, so they are already working on possible changes that can be made. Their recent focus has been on transportation and they have been asking themselves, "How can we enable more people to enjoy more of the park, while putting fewer cars on Acadia's scenic roads and less pollution into

Acadia's air?" ("What We Do", n.d.). The suggestions provided in this project can help them answer these questions and further protect the park.

In addition to supporting research to mitigate the effects of climate change, The Friends of Acadia also publishes a journal three times a year. The journal includes information about the park including its history, activities, current research, and ways to get involved. By publishing the journal, the Friends of Acadia are sharing information about the park and inviting volunteers to join in their efforts to ensure that the park remains a place for everyone to visit ("Friends of Acadia Journal," n.d.).

The Friends of Acadia have already started discussing potential changes to the way that Acadia is run. In order to adjust to the changes and make themselves a more sustainable park, there has been a transportation plan discussed that involves four possible plans. These four plans are labeled A through D and cover a range of options such as eliminating parking in certain areas of the park and managing traffic levels throughout the park. A major concern when making changes to Acadia both in regards to traffic control and general changes is the preservation of the historical value of the park (NPS PEPC, n.d.). This is something that was taken into consideration when making suggestions.

Alternative A would not require the park to make any changes as it would act as a comparison to the other options. This would mean that the park would still allow private and commercial vehicles as well as their Island Explorer bus. Alternative B addresses parking concerns and would require the park to adapt a reservation system for parking. Alternative C, which is the preferred option according to the written transportation plan, involves a timed entry system for several roads and parking lots throughout the park. This would allow the park to limit congestion and traffic that both contributes to increasing the carbon footprint of the park and detracts from the overall enjoyment of the people visiting the park. The final option, Alternative D, involves the addition of automated gates and additional entrances to control manage vehicle volumes in the park (NPS PEPC, n.d.). All of these alternatives could be beneficial to the park and apply especially during the peak season as this is when traffic is the biggest issue.

Additional stakeholders for this project include the other businesses and people living around the park. These people experience the same effects of climate change that the park does, and may benefit from suggestions on how to mitigate these effects. These stakeholders could use the suggestions produced in this report and adapt them to their operations as well.

Although national parks deal with many issues every day such as management and financial concerns, climate change is a problem facing all of the national parks. Some of the parks have begun making changes to help protect themselves from the effects of climate change such as switching to more sustainable methods of transportation as seen in Mount Rainier Park, but others, like Acadia National Park, are still focusing on figuring out how to deal with this problem ("Preparing Acadia National Park," 2015). Climate change will affect Acadia in many ways such as through rising sea levels and erosion.

Due to its location along the coast, Acadia may experience more serious effects related to the rising sea levels. Sea level rise is one of the most obvious consequences of climate change. Along with sea level rise, heightened storm surge and heavier rainfalls are also problematic for Acadia National Park, which may wash away the historic carriage roads and hiking trails. Rising temperatures increase the risk of disease outbreaks and invasive species and habitat suitability change. Moreover, the longer warm seasons may augment the number of visitors and the demand for longer hours ("Preparing Acadia National Park," 2015). Therefore, it is important to prioritize this aspect of climate change. Shown below is the comparison between the changes in global land temperatures and the changes in land temperature at Acadia National Park. Figures 4 and 5 show that since Acadia is by the coast, it has experienced smaller changes in the past, but the last two decades did show a large increase in land temperatures at Acadia National Park as well as global land temperatures.

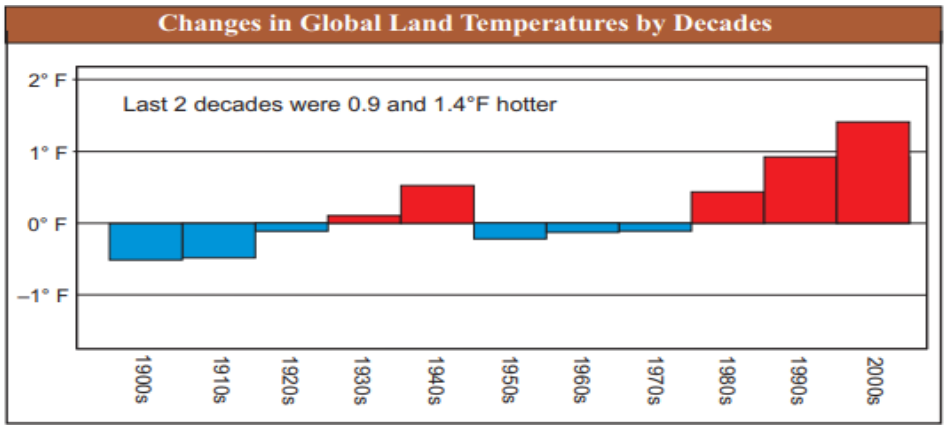

Figure 4. Changes in Global Land Temperatures by Decades. From *Acadia National Park in Peril the Threats of Climate Disruption*, by T. Easley and S. Saunders, 2010, http://www.rockymountainclimate.org/images/AcadiaInPeril-1.pdf. Copyright 2010 by T. Easley and S. Saunders

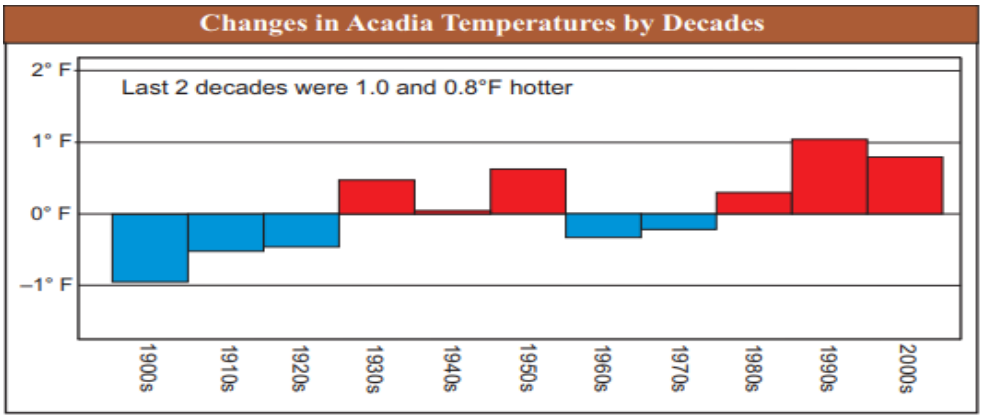

Figure 5. Changes in Acadia Temperatures by Decades. From *Acadia National Park in Peril the Threats of Climate Disruption*, by T. Easley and S. Saunders, 2010, http://www.rockymountainclimate.org/images/AcadiaInPeril-1.pdf. Copyright 2010 by T. Easley and S. Saunders

One way that the parks are adapting to this issue of climate change is by preparing the parks to withstand the effects rather than ignore the problem. This could mean moving structures such as the lighthouse that was moved inland half of a mile at Cape Hatteras National Seashore (Ladzinski & Nijhuis, 2016). The main general issue is climate change, but this project focuses on how the parks can deal with the effects of climate change and allow themselves to maintain their titles as national parks. Their purpose is for the enjoyment of the visitors, so this should be maintained even if minor changes need to be made to the processes or to the actual park itself.

3. Methodology

3.1 Purpose

The goal of this project was to provide suggestions to Acadia National Park to allow them to better prepare for the effects of climate change. The suggestions were based on how the National Parks are responding to current climate change research. In making these suggestions, the following factors were considered:

1. Cost
2. Feasibility
3. Impact
4. Time

This project addressed climate change through adaptation and mitigation strategies, which are described below.

3.2 Climate Change Mitigation

Mitigation refers to an adjustment in practices to positively impact climate change. This could range from recycling to switching from gasoline powered vehicles to electric vehicles. Mitigation includes a switch from one practice to another that would impact the planet in a positive way and help lessen the effects of climate change. Mitigation will not eliminate climate change, but it will reduce the speed at which it is affecting the planet ("Mitigation," n.d.). The mitigation strategies explored in this project cover two out of the four objectives. They include solutions to the problems related to carbon emissions related to transportation in the park and education about climate change that is offered in the park.

3.3 Climate Change Adaptation

Adaptation refers to a change in practice to account for previous changes caused by climate change. An example of this is collecting rainwater to prepare for a future drought, or changing building codes so that buildings can withstand more severe weather ("Mitigation," n.d.). Adaptation prepares for the effects of climate change without solving the actual problem.

The adaptation strategies included in this project cover the issues of rising sea level and the loss of plant and animal species in the park.

3.4 Objectives

The project had four main objectives. The objectives of this project are listed below:

1. Adjust to the rising sea levels.
2. Limit the loss of plant and animal species in the park.
3. Reduce carbon emission from park vehicles.
4. Develop an education plan.

Each section below contains an explanation of what other parks are doing to tackle each issue related to climate change. These sections also address what Acadia National Park is currently doing to mitigate the effects of climate change related to each objective.

3.5 Sea Level Rise

Caffrey, Beavers, and Hoffman (2018) contend that Acadia National Park has the lowest risk for sea level rise within the Northeast region, which ranges from Baltimore, Maryland, to Maine. There is still cause for concern because there is the potential for flooding of roads that allow access to park attractions and the damaging of fresh and saltwater marsh ecosystems (Saunders, Easley, & Spencer, 2010). Marsh ecosystems are very important as they "buffer the coast from storms, sequester carbon, improve water quality and provide important habitat for commercial fisheries" (Kirwan et al., 2016). Generally marshes are capable of adapting to sea level rise, but if not allowed to migrate inland will be unable to survive. This damage could not only affect the ecosystems of the park, but also the visitation of the park as people will be less likely to visit if the most popular attractions are flooded, destroyed, or unable to be accessed by road. It is important to look at what other parks are doing to adjust to the sea level rise for comparison. However, it must also be considered that Acadia may have differences from other parks that may affect how those adjustments would help, as not all solutions are universally suitable.

There are generally two methods for responding to sea level rise: shore protection and retreat. Shore protection focuses on protecting coastal communities from flooding and shore erosion through the use of dikes or bulkheads. Retreat is more suited to less populated or undeveloped areas as it requires the removal of structures that may inhibit the migration of ecosystems inland (Titus et al., 2009). The latter is likely more effective for national parks as it would allow protection of the ecosystem by allowing its migration; shore protection prevents inland migration which could be extremely harmful to coastal species.

As seen in Figure 6, sea level rise is not only an issue for Acadia, but it is an issue all along the coast. In order to better evaluate the best option for Acadia, this group looked at other locations along the east coast to see what methods they are using to prepare for the changes in sea level. A prominent example of coastal response to sea level rise in the United States is the shift inland of the Cape Hatteras lighthouse in North Carolina. When the light station was built in 1870, it was 1500 feet from the ocean; by 1970, it was only 120 feet away. In 1999, it was moved 1600 feet from the ocean, protecting it from shore erosion and storm surges for at least the next century (National Park Service, 2015).

Ibáñez, Day, and Reyes (2014) describe the adaptation of three deltas to rising sea levels: the Rhine Delta in The Netherlands, the Ebro Delta in Catalonia, Spain along the Mediterranean Sea, and the Mississippi Delta in the United States. The Rhine Delta is an example of shore protection; the intention is to protect the infrastructure of the city from flooding, as the area is densely populated. Rice farmers around the Ebro Delta utilize the sediment that flows from the river to the salt marshes where rice paddies thrive. The farmers raise the elevation of the delta with sediment to improve rice production, which eliminates the need to invest in coastal defense from flooding. Further, the Ebro Delta does not receive heavy tropical storms so it is less affected by climate change. The Mississippi Delta utilizes the methods of "rising grounds" and building dikes for minimizing land loss and coastal protection. The rising grounds strategy requires movement of sediment to parts of the river and delta that are being submerged so that the ground may be effectively raised. Dikes are important to be built in more populated regions along the delta, especially in the New Orleans region which is far below sea level and is extremely vulnerable to damage from flooding. The most effective method of protection for New Orleans would likely be the combination of rising delta grounds and rising dikes. Between New

Brunswick and Prince Edward Island in Canada, the Northumberland Bridge was built to account for an increase in sea level (Tol, Klein, & Nicholls, 2008).

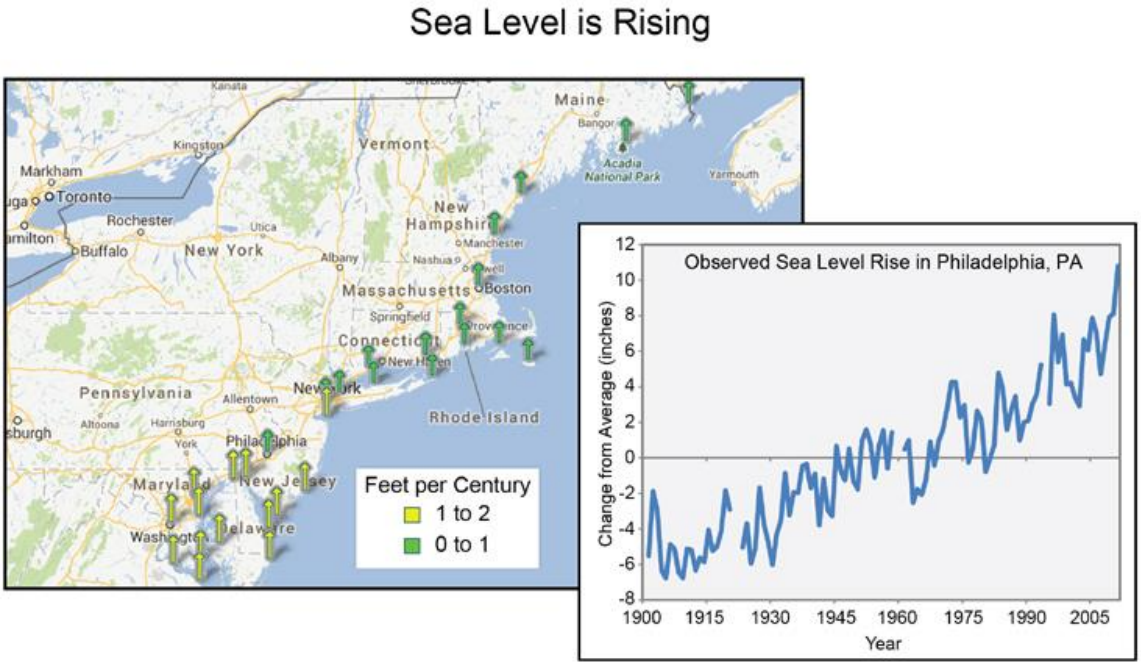

Figure 6. Sea Level is Rising. From *Climate Impacts in the Northeast*, https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-northeast_.html. Copyright 2016

3.6 Plants and Animals in the Park

National Parks are in a position to preserve land and animal species located in that area ("What We Do," n.d.). Due to climate change, there has been increased efforts to ensure that National Parks are able to maintain these native species (Trotter, 2014). Acadia currently has a team dedicated to restoring the native plants and limiting the invasive species in the park. Not only are they using the staff of Acadia and hiring new staff to help treat these invasive plants, but they are also welcoming new staff to help revive the native plants (Tocci, 2014). Based on the focus of the team, it is clear that Acadia is focusing on removing invasive plants in an effort to allow the native plants to recover. By allowing the native plants to return to the area, the native species will also be able to continue to live in the area. The rising temperature may force them out of the area, but since the park can control the plants and not the temperature, this is an effort they can take to preserve the park.

Yellowstone National Park is one of the parks that Acadia can look towards when finalizing their plan on dealing with plants and animals in the park. One of the ways that Yellowstone is controlling the invasive plants is by fencing in 4 pilot plots that are 50 acres each where they are treating the nonnative plants with herbicides. This method is allowing them to limit the invasive species while still keeping the soil suited for future growth. After four years, Yellowstone intends to fill this space with native plants, which will be protected by fencing for about 10 years. Once the native plants are well established, the fencing will be removed. The monitoring of these plants is going to continue for many years and adjustments will be made to allow the native plants to survive given the changes in climate ("Restoring Native Plants," n.d.).

Another park that is making efforts to limit the loss of native plants is Olympic National Park. Olympic National Park has been working for years to get rid of knotweed, which is an invasive species that has been changing the ecosystem by layering the ground with its leaves and causing the warming and removal of nutrients from the streams and rivers in the area. This directly caused the salmon species to decrease since the warmer water and lack of nutrients negatively impact the eggs present. In order to get rid of this invasive species, the Exotic Plant Management Team, a team that works with the National Park Service to support National Parks in combating invasive plants, partnered with the National Park staff and worked to focus on only this species. By treating the species they were able to reduce its presence by 93%. This change allowed the salmon population to be restored in the area ("Of Salmon," n.d.).

Acadia can look to these two parks as well as many others in terms of what they can do to restore native plant species with the purpose of preserving the land and animals in the park.

3.7 Carbon Emissions

Currently, Acadia National Park is visited by over 3.3 million people a year. Transportation to access the park, therefore, has become a big issue, so reducing the stress of traffic jams and limited parking has become one major concern in Acadia. In order to limit the number of private vehicles, one must purchase a parking pass for $30, which is valid for one week, but if the visitors would rather enter on foot, the fee is $15 per person and also lasts for one week ("Acadia National Park" n.d.). Moreover, advice on how to avoid traffic is listed as the first information page on the official website of Acadia. It gives notifications on the most congested areas and suggestions such as alternative transportation and times. Also, the detailed

plan of 6 different bus lines is provided ("Traffic & Congestion," 2019). Currently, the Island Explorer Shuttle Bus is operating 10 routes from June 23 to early October. The shuttle routes can be seen in Figure 7. However, it is not efficient enough to reduce the number of private vehicles in the park. The greenhouse gas (GHG) emissions of the park is 300.72 metric tons of carbon dioxide equivalent (MTCE) per 1,000 acres, which is much higher than most of the Climate Friendly Parks (CFP) such as Mount Rainier National Park and Zion National Park (Fields et al., 2016).

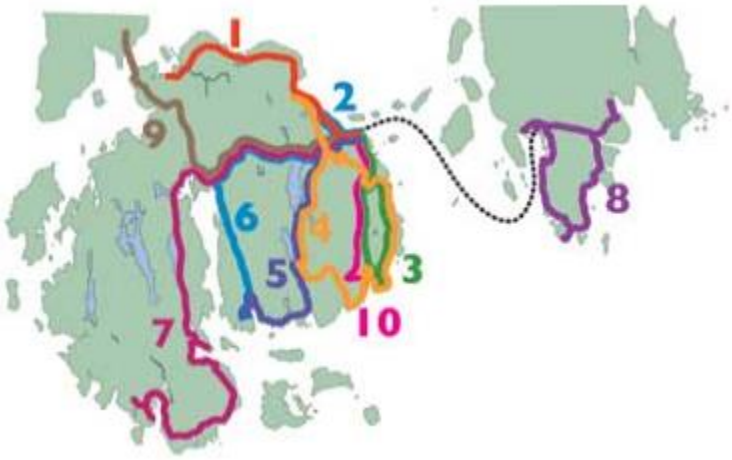

Figure 7. Bus Routes in Acadia National Park. From *Acacia Free Shuttles*, http://www.exploreacadia.com/routefinder.htm. Copyright 2019

Mount Rainier Park is one of the CFPs that is located in southeast Pierce County and northeast Lewis County in Washington. It was established in 1899 as the fifth National Park in America ("History & Culture," 2017). The GHG emission of the park is 53.94 MTCE per 1,000 acres (Fields et al., 2016), which is 3100.0 MTCE in total. The transportation management plan for Mount Rainier National Park is generally divided into park operations and visitor management. Reducing the vehicle miles traveled, improving vehicle efficiency, and using alternative are three major measures for the park operations ("Mount Rainier National Park Action Plan," n.d.). For example, all of the diesel vehicles in this park run on special emissions-reducing fuel made with soybean-based, low-sulfur fuel. They also use hybrid vehicles with a combustion engine and electric motor to reduce GHG emissions ("Sustainable Park Practices," 2017). For visitor transportation, shuttles are used to try to achieve a 15% reduction of private vehicles ("Mount Rainier National Park Action Plan," n.d.). Shuttles run during weekends from

9:15 a.m to 5 p.m for free (Repanshek, 2008). Moreover, the park is looking for the opportunity for research funding for community transportation plans from Federal Transit Administration funds and scenic byway funds ("Mount Rainier National Park Action Plan," n.d.).

Zion National Park is one of the CFPs that is located in southwestern Utah. It is the first National Park in Utah ("Plan Your Visit," 2019). The management plan for Zion National Park is quite similar to Mount Rainier Park. However, no private vehicles are allowed on the Zion Canyon Scenic Drive when the shuttle is running. Free shuttles are the only access other than walking. There are two shuttle routes in the park, with both shuttles running throughout the day, as frequently as every 7 to 10 minutes ("Shuttle System," 2019). The shuttle bus map is shown in Figure 8. In 2002, the total GHG emissions were 2839.0 MTCE ("Greenhouse Gas Emissions Inventory," 2004). Due to the Green Transit plan, 5,000 cars were replaced by 21 buses, and each propane-powered bus can reduce 12 tons of CO_2 emissions per day ("Sustainability," 2017). The access for large vehicles is controlled due to the Zion-Mount Carmel Tunnel. In 2019, large vehicles only have access during daytime based on the date, and an extra $15 is charged for large vehicles for two trips for the same vehicles within 7 days. Vehicles that are over 13 feet 1 inch tall and/or over 50,000 pounds are prohibited ("The Zion-Mount Carmel Tunnel," 2019). Furthermore, all off-highway vehicles (OHVs) and all-terrain vehicles (ATVs) are not permitted in the park ("Off-road Vehicles," 2019).

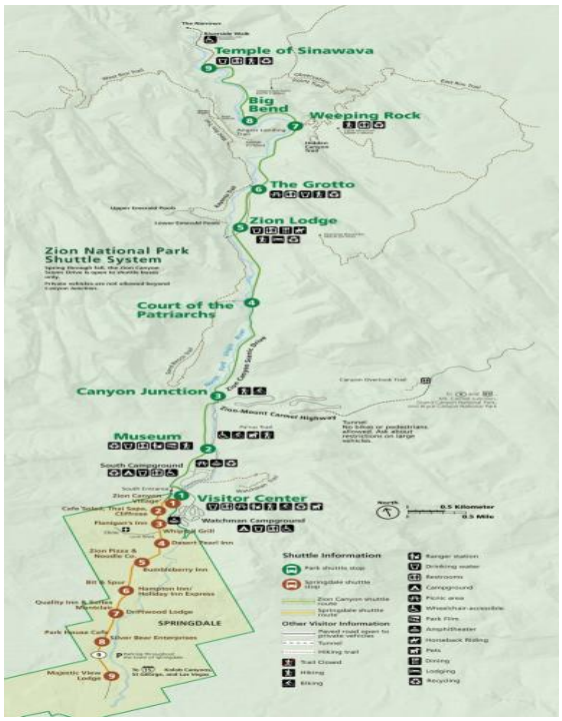

Figure 8. Shuttle Bus Map in Zion National Park. From National Park Service ,*https://www.nps.gov/zion/planyourvisit/upload/Shuttle_Map_7_7_17_ADA_5-2-19.pdf*. Copyright 2019

3.8 Education plan

According to the website of Acadia National Park, there are various educational programs available. For example, there are in-school outreach programs involving field trips in the park, overnight student trips, internships, and volunteer opportunities for youth ("Acadia: Your Outdoor Classroom," 2019). For this study, research was conducted on other National Parks to investigate their educational plans and potential improvements for Acadia, with Yellowstone National Park investigated in detail.

Yellowstone National Park is located in Wyoming, Montana, and Idaho. It was the first National Park in America. It is known for wildlife such as bears, wolves, bison and elk ("Basic Information," 2019). On the website of Yellowstone National Park, the "Climate Change" is particularly listed, which is not present on every park website. A six minute video about watershed down is on top of the Climate Change page. Statistics on the rise in average temperature in the park, lengthening of the growing season, shortening of the snow days are also

shown on the same page, as well as the consequences of climate change on the ecosystems of Yellowstone. On the bottom of this page, links to "Changes in Yellowstone Climate," "Climate Change Explorer," and "Examining the Evidence" are shown ("Climate Change," 2019). The page of Changes in Yellowstone Climate compares the historic and current temperature and precipitation in the park and predicts the future temperatures and precipitation. It also discusses the influence of climate change on the future snowpack, stream flow, insect activity, and fire activity ("Changes in Yellowstone Climate," 2019). The Climate Change Explorer is a project to examine the climate change data and compare them with the historic data. All together the information provides a clear vision of the consequences of climate change to the visitors ("Climate Change Explorer V1.0," 2019). The page of Examining the Evidence: Climate Change discusses the effects of climate on each fraction of Yellowstone's ecosystem, such as plants, wetlands, and wildlife. It also states the current management and monitoring of the park as a solution for facing climate change ("Examining the Evidence: Climate Change," 2019). Moreover, various education and youth programs are provided by Yellowstone where young people can participate in the junior ranger or young scientist programs (Resource Education and Youth Programs, 2019).

3.9 Problems, Limitations, and Flaws

Even though this group conducted a large amount of research to ensure that the suggestions provided were practical and could be implemented by Acadia National Park, there are some limitations and flaws of this study. One major limitation is the lack of insight that this team had in terms of what the park is already doing. This is not due to a lack of research, but rather a lack of published information. This team found all of the available information regarding this matter, but the park may be doing more than they publish. Since the park will only post changes after they have decided on them and worked through any issues, they could already be working on the action items listed in these suggestions. This means that some suggestions may not help the park at all, but rather would restate ideas that they have already talked over. At the same time, these suggestions could have been ones that have already been made and ruled out. Since we are an outside group, we do not know all of the details behind Acadia National Park. There could be specific reasons why they have chosen not to implement these changes.

Not being directly involved with the National Park is the main limitation that we have faced. It has prevented us from receiving current information and has created a larger need for research. Another flaw of this study is that is has been conducted in a way that compares Acadia National Park to other parks. This could have allowed us to make more accurate suggestions, but it may have also created suggestions that are not personalized enough for Acadia specifically. Since we did not have many specifics for Acadia, it was a good method to learn some information, but it could only be relevant to the other parks. Another limitation is that the effects of climate change may change in the future and may affect the park in different ways than research has previously indicated.

Other than limitations and flaws, there were also some problems with this study. The problems that impacted the suggestions the most included a lack of specific information and a lack of updated information. It was easy to find general information about climate change and what can be done to help prevent it, but since the goal of the project is to deal with the effects and lessen their impact, there was not as much information regarding this. The issue with updated information stems from the amount of research that is being conducted on climate change. It is a large global issue and there are constant updates about the effects and impact. While conducting this project, our group tried to use the most updated information, but there is some information that was used when it was the most updated information, but that has changed since it was used. This is mainly due to the fact that this project was carried out throughout the course of seven weeks.

4. Findings

Before suggestions could be made to Acadia National Park, a variety of parks were researched in terms of what issues they were having and what they were doing to help mitigate the effects of climate change and adapt to the changes caused by global warming. Most parks are combining mitigation and adaptation strategies and using resilience strategies to help prepare themselves for the future. This project focuses on mitigation and adaptation because these are strategies that the parks can take that will directly impact the park and visitors. The parks are practicing resilience strategies by doing their own private research ("Mitigation," n.d.).

By researching what other national parks have been doing, we have been able to compare this information to the current practices of Acadia National Park in order to find areas where Acadia could improve their practices. This comparison also allowed us to see what other parks are doing and figure out if Acadia could benefit from doing the same things. These comparisons are explained below and are categorized by the objectives of the methods section. Since these objectives break down the major issues related to climate change, they easily lead to suggestions for the park. These efforts were examined to determine if they helped resolve the issues we looked at. Some of the main parks that were examined were Climate Friendly Parks. These parks met benchmarks to gain this title and are supported by the Climate Friendly Parks Program, which provides resources to all national parks to help them adjust to climate change ("Climate Friendly Parks," 2019). Since Acadia has not yet met these benchmarks, it will be beneficial for them to use suggestions based on other parks that have.

Table 2 shows a summary of the goals that our team had going into this section. Each objective that we created was broken down into a specific goal that we wanted to meet with each suggestion. This helped specify what we were looking for when researching other parks.

Table 2: Goals for this Project

Objectives:	Goals:
1. Adjust to the rising sea levels.	Protect the marshes.
2. Limit the loss of plant and animal species in the park.	Reduce invasive species.
3. Reduce carbon emission from park vehicles.	Switch to energy efficient vehicles.
4. Develop an education plan.	Educate staff and visitors about climate change.

4.1 Adaptation

The general goals that this team was looking to meet in terms of adaptation were to lessen the effects of the rising sea level on the marshes in Acadia and to find a way to help the plants and animal species adapt to the rising temperatures and climate changes in the area. These goals are linked since they are both focusing on preserving the wildlife in the park, but they require completely different strategies. In researching rising sea levels, the areas that were experiencing the most problems were not national parks, but rather general sections of land that are near the coast. Acadia can benefit from strategies that these other areas of land are using since it is also on the coast. The areas of land looked at were the Mississippi Delta in the United States, the Rhine Delta in The Netherlands, and the Ebro Delta in Catalonia, Spain. Looking specifically at other National Parks was more beneficial when creating suggestions for preserving plant and animal species. The National Parks that were examined were Yellowstone National Park and Olympic National Park.

4.2 Sea Level Rise

While shore protection would be an effective method for protecting coastal communities and roads in Acadia that may be flooded due to sea level rise, protection of marshes is also very important and would require methods of retreat. However, the inland migration of marshes is

barred by many roads throughout the park and outside of it. According to the study by Nielsen and Dudley (2012), there are 41 potential barriers within the regions they studied that would prevent the migration of marshes, all save two of which are roads. Within the park itself, there are about ten potential barriers. Many of these identified barriers have some kind of bridge or culvert to allow for water and sediment flow, but they still restrict movement enough to affect the migration of the marshes. This is being addressed by Acadia in that they are improving the culverts to allow for better passage of fish, water, and sediment ("Acadia Watersheds", n.d.).

Wigand et al. (2017) describe what they call "climate adaptive actions" as methods that allow marshes to survive sea level rise and other climate change-related effects. These actions include the improvement of resistance of marshes to shoreline erosion, resilience to allow for marshes to bounce back from altered conditions, and transformation of ecosystems, for example woodlands, into marshes when their migration inland occurs. These actions were used to adapt the Narrow River Estuary (NRE) in southern Rhode Island to climate change. Climate adaptive actions are chosen based on the specifics of the ecosystem so as to cause little damage to the wildlife that inhabits the marsh. The actions that were proposed "included shoreline protection, raising the elevation of the marsh, increasing marsh drainage, facilitating marsh upland migration, and dam removal." Marsh elevation requires a process known as sediment dredging, which is the transferring of sediment from one part of the marsh to another; however, it can affect species that are sensitive to the sediment movement. The shoreline was stabilized using coconut fiber and oyster shells, with the intention of preventing further shoreline erosion and improving sediment deposition. It was also planned to dig shallow creeks to promote drainage and help marsh flora grow (Wigand et al., 2017). Thus, there are extensive methods that could be used to adapt marshes to sea level rise, but they very much depend on the dynamics of the ecosystem, including how different species respond to the proposed actions.

It is important that park management examine each marsh carefully, as not all of them will necessarily be able to respond effectively to rising sea level. Some marshes will require more human intervention than others to be able to migrate, especially if there are barriers (i.e. roads) or steep grades. The climate adaptive actions, as described previously, are all viable methods for assisting marsh migration inland, depending on the dynamics of each individual marsh within the park. There are many marshes within Acadia National Park, as seen in Figure 9, each with their own circumstances (i.e. surroundings). In some cases, it may be necessary to

either remove or shift impeding roadways, improve or rebuild inefficient culverts, and manually assist in the salt marsh migration (Alizad et al., 2018).

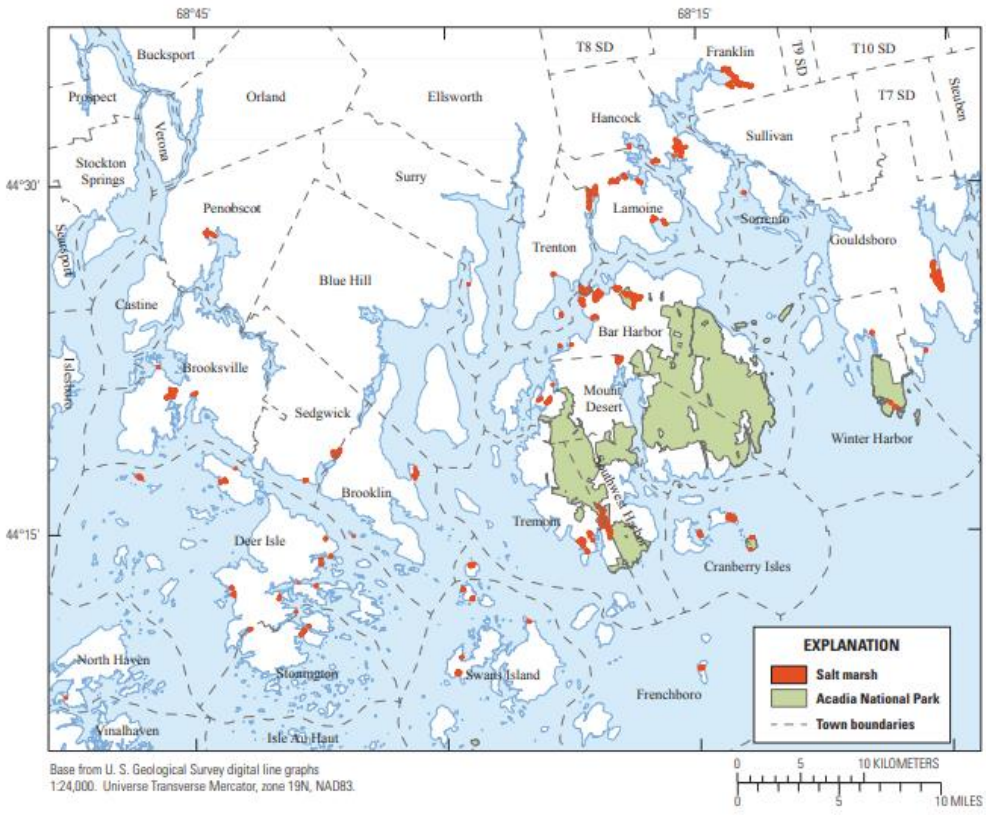

Figure 9: Marshes Around Acadia. From *Estimates of Future Inundation of Salt Marshes in Response to Sea-Level Rise in and Around Acadia National Park, Maine*, by Martha G. Nielsen and Robert W. Dudley, 2012.

4.3 Plants and Animals in the Park

Acadia National Park can be benefited by following the strategies being used by both Yellowstone National Park and Olympic National Park. All three of these parks are experiencing similar issues regarding the increase in invasive plant species which is causing native species of both plants and animals to suffer. Yellowstone National Park has seen an increase in invasive plants, which is why they sectioned off 200 acres of land to be treated and replaced with native plants ("Restoring Native Plants," n.d.). Olympic National Park has had issues with the knotweed that is growing in the park. It is preventing the salmon population from living in the bodies of water in the park, which is why the park partnered with the Exotic Plant Management Team to reduce the presence of knotweed ("Of Salmon," n.d.).

Both of these parks were successful, which is why they are being used to create suggestions for Acadia National Park. Acadia National Park is having a similar issue to Yellowstone in that they are having problems controlling the invasive species. Although they have plans in place and teams working to reduce these species, they can use more suggestions on how to better approach the situation (Tocci, 2014). They are not having the same issues as Olympic National Park, but they could use similar strategies as they used.

A main strategy that Olympic National Park used was that they looked to other resources for help. They not only looked to other resources in their area, but they also looked within Pennsylvania and beyond state lines for help. By doing this, they were able to ensure that they had the best approach and the maximum input in their efforts to get rid of the invasive species ("Of Salmon," n.d.).

The strategies used by each of these parts are useful to Acadia, but there are parts of their approaches that would not work. Yellowstone National Park dedicated large open areas of land to restoring native plants, which would not work for Acadia because the park is not one large open area, but rather many smaller non-consistent areas of land ("Restoring Native Plants," n.d.). This approach could be adapted to include the larger areas of land that are present in Acadia, or it could be broken up into many smaller portions of land. Another way that this difference can be accounted for is by focusing on a few main areas of Acadia National Park such as the summit and Sieur de Monts Spring. Olympic National Park focused on only one species since it was dominating the area, which would not work for Acadia ("Of Salmon," n.d.). This is because Acadia is having similar issues with invasive plants, but is struggling with several species of plants and not just one. The difference can be accounted for by instead using the strategy of finding help from other resources that Olympic National Park used. This was one of the main reasons they were successful, so it could help Acadia as well.

The main strategies collected from these two parks that could be useful are the focus on finding help from outside resources and the introduction technique for native species. Protection of its abundance of habitats and its high level of biodiversity was one of the reasons this park was created, so it should be a main focus when preserving the park ("Foundation Document Acadia National Park," 2016). Another thing that could benefit Acadia is seeking help from outside resources.

The bird species at Acadia are one of the only species that are not threatened by climate change. They are able to move quickly from one place to the next, which allows them to move when a climate no longer suits their species (Fisichelli, 2014). This will benefit the park and may allow them to create an educational program related to watching the bird species change over time. It would show the visitors that they can see the direct impact of climate change.

4.4 Mitigation

The goals that this group established for mitigation in Acadia National Park were to reduce carbon emissions in the park by switching to more energy efficient vehicles and to establish and education plan to educate both the park staff and visitors. This would allow the park to serve as a teaching space. These are mitigation strategies since they are focusing on looking at the effects of climate change and using the current knowledge on why they are happening to reduce them in the future. By lessening the carbon emissions of the park, it will reduce the contribution that Acadia is making to the greenhouse gases in the atmosphere. An education plan is helpful because it will teach everyone in the park ways that they can help contribute to reducing the impact of climate change in their personal lives. The parks looked at to find suggestions for Acadia relating to reducing carbon emissions were Mount Rainier National Park and Zion National Park. Both of these parks are listed as Climate Friendly Parks, so it was beneficial to look at what they are doing to ensure that they are not impacting the climate in a negative way ("Climate Friendly Parks," 2019). The park that was examined in terms of developing an education plan for Acadia was Yellowstone National Park.

4.5 Carbon Emissions

Over 3.3 million visitors come to Acadia National Park every year and bring problems such as traffic jams, limited parking, and high vehicle combustions ("Acadia National Park," n.d.). However, no effective carbon emission plan is available for the park. Over 300.72 metric tons of MTCE per 1,000 acres has been produced in the park (Fields et al, 2016).

As a climate friendly park, Mount Rainier National Park proposed transportation management plan involves park operations and visitor management ("Mount Rainier National Park Action Plan," n. d.). In order to reduce vehicle miles traveled and improve vehicle efficiency, all of the diesel vehicles of the park operation team use special emissions-reducing

fuel made with soybean-based, low-sulfur fuel. Hybrid vehicles with a combustion engine and electric motor are also used to reduce GHG emissions ("Sustainable Park Practices," 2017). On the other hand, shuttles are used to replace private vehicles ("Mount Rainier National Park Action Plan," n. d.). Moreover, the roads in the park are divided into different categories based on the accessibility. On the road status webpage, name, condition, and status of the road are provided. For example, the Carbon River Road is open, but only to pedestrian and bicycle traffic. It helps the visitors to plan their trip better and the park to control the traffic and carbon emissions in a more efficient way.

For Zion National Park, the transportation management plan is similar to Mount Rainier Park. However, no private vehicles are allowed on the Zion Canyon Scenic Drive when the shuttle is running, and walking is the only alternative of taking shuttles. ("Shuttle System," 2019). Furthermore, access of large vehicles is controlled due to the Zion-Mount Carmel Tunnel. But it is a good way to reduce the carbon emission, as the larger and oversized vehicles usually produce more combustion than normal size cars. In 2019, large vehicles only have access during day time based on the date with an extra $15 is charged for large vehicles for two trips for the same vehicles within 7 days. Further, all the off-highway vehicles (OHVs) and all-terrain vehicles (ATVs) are not allowed in the park ("Off-road Vehicles," 2019). The park controls the damages of soil erosion and protects the habitat of many animal and plant species.

4.6 Education plan

There are various educational programs available on the website of Acadia National Park. For example, there are field trips in Acadia National Park, overnight student trips, internships and volunteer opportunities for youth, etc ("Acadia: Your Outdoor Classroom," 2019). However, no information related to the climate change program is provided on the official website. As examples, Yellowstone and Zion National Park effectively designed different educational programs to educate the effects of climate change for visitors and employees.

Yellowstone National Park uses the advantage of their large visitor number and powerful internal guiding tools to provide ample educational programs in facing climate change. For example, In the "Learn About the Park," "Climate Change" is particularly listed as an important section. Comparison of historic and current temperature and precipitation in the park are revealed with statistics and case studies. Visitors can vividly experience the changing caused by climate

change. Prediction of the future temperature and precipitation are also list to help the visitors to understand the potential negative consequences on the ecosystem and wildlife of climate change ("Climate Change," 2019). Programs such as "Climate Change Explorer" and "Examining the Evidence" are also provided. They allow visitors to experience the influence of climate change on the future snowpack, stream flow, insect activity, and fire activity, as well as the effects of climate on each fraction of Yellowstone's ecosystem, such as plants, wetlands, and wildlife. ("Climate Change Explorer V1.0," 2019; "Examining the Evidence: Climate Change," 2019). As a park with around six million visitors annually, the influences of the online climate change education plans are unpredictable ("Yellowstone National Park Sets May Visitation Record," 2018).

On the other hand, as a Climate Friendly Park, Zion National Park not only provides educational programs for visitors, but for park employees, park partners, and the community. In Zion National Park, both full-time and seasonal employees are required to learn the effects of greenhouse gases and encouraged to pass the knowledge on to the visitors ("Zion National Park Environmental Management System (EMS)," 2005). Zion National Park is also working on developing a Memorandum of Understanding with its partners to reduce greenhouse gas by sharing technical information. For the visitors and community, Zion National Park offers plenty of programs, such as recycling programs and Green Transit. Visitors and residents are encouraged to recycle waste disposals and walk, bike, and use fuel-efficient vehicles in the park ("Sustainability," 2017). Moreover, residents are highly welcomed to join the park's gateway community to help on recycling and using renewable energy ("Green Springdale," n.d.).

4.7 Summary

The findings observed in this project can be found in Table 3. These findings cover the four objectives that are also restated in Table 3.

The general findings of this project relate to each individual objective and include a brief summary of the ways that Acadia could meet the objectives. These findings were created by looking at other National Parks as well as general areas where similar issues are being found.

Table 3: Findings

Objectives	Findings
1. Adjust to the rising sea levels.	● The migration of marshes is being prevented by roads in the park. ● Roads could be impacted by sea level rise, but the marshes will be impacted first.
2. Limit the loss of plant and animal species in the park.	● National Parks need to utilize other resources to help mitigate the effects of climate change related to plants and animals. ● Removing invasive species should be a priority. ● Introducing native plant species can help native animal species survive in the park.
3. Reduce carbon emission from park vehicles.	● Shuttles are often used with the intention of reducing personal vehicle usage. ● Switching to a more efficient fuel source would reduce carbon emissions. ● Eliminating access for vehicles other than the shuttle would reduce overall carbon emissions.
4. Develop an education plan.	● Climate change efforts should be posted on park websites and be easy to access. ● National Parks should be educating visitors on the future of climate change.

Objective 1: Adjust to the Rising Sea Levels:

One of the findings for this objective was that roads are preventing the migration of marshes, which could prevent them from being preserved. This inland migration is how marshes

naturally adapt to changing sea levels as they are generally quite resistant to change. A second finding was that the roads could also be impacted by the sea level rise, but they are not the main focus. The marshes are more important to the ecosystem and will be the first to flood.

Objective 2: Limit the Loss of Plant and Animal Species:

One of the findings related to this objective was that the parks should utilize other resources such as the Exotic Plant Management Team to help them mitigate the effects of climate change on the ecosystem. Another finding was that although limiting invasive plants and introducing native plants are both important, invasive plants should be removed or controlled before native plants can be introduced. This would allow the native plants to grow more easily and without competition from the remaining invasive species.

Objective 3: Reduce Carbon Emission from Park Vehicles:

One finding related to this objective was that shuttles are used by many parks in order to reduce the usage of personal vehicles as well as to make viewing the park easier for many visitors. Another finding was that a main way to reduce carbon emissions would be to switch to more efficient fuel sources. A third finding was that by eliminating access to vehicles other than shuttles, overall carbon emissions would be reduced.

Objective 4: Develop and Education Plan:

One of the two findings related to this objective is that climate change efforts that are carried out by the parks or that are going to be carried out by the parks should be posted on their websites. This allows the general public as well as other parks to be made aware of what efforts are being made. The second finding is that visitors should be educated on climate change regarding both its impact on the park and its future impacts. This would be an opportunity for the park to teach visitors how they can make a difference.

These findings are in regards to what Acadia is currently doing in comparison to other parks. These findings were examined for efficiency and practicality in terms of Acadia National Park. Acadia is mainly supported by the federal government and the Friends of Acadia. The Friends of Acadia have already started recruiting additional staff as well as volunteers to help increase efforts to mitigate the effects of climate change and adapt to the impacts that are being

seen in the park. A large portion of their efforts has been focused on developing a traffic plan, which has been used towards Objective 3 (NPS PEPC, n.d.). Despite these efforts, it is clear that they cannot conduct all of the research necessary on their own, which is why these findings will be beneficial to the park.

5. Conclusions and Recommendations

5.1 Conclusion

Before this project began, it was evident that many suggestions could be made, but there had to be limitations in order to narrow the suggestions to between five and ten. These suggestions needed to cover areas such as transportation in the parks, protecting the integrity of the park, preserving the land and animals, and adjusting to rising sea levels. Although there are many things that the park can do, the best suggestions are those that can be done in a timely manner and have the greatest effects. This being said, suggestions that would need a very large amount of money or time were ruled out since it is not likely that the park could do these along with making other changes. Instead, they were broken down into smaller, more practical parts.

5.2 Recommendations

Conducting research as to what other parks were doing to solve similar issues helped introduce new potential solutions and ultimately helped us come up with the following recommendations shown in Table 4.

Table 4: Recommendations for Acadia National Park

Objectives	Recommendations
1. Adjust to the rising sea levels.	● Allow for marsh migration by improving culverts and removing barriers
2. Limit the loss of plant and animal species in the park.	● Introduce native plants in smaller areas of the park and monitor closely. ● Partner with organizations such as other National Parks or the Exotic Plant Management Team to control the invasive plant species.
3. Reduce carbon emission from park vehicles.	● Limit traffic flow by restricting entry to private vehicles and encouraging the use of the shuttle system. ● The shuttles should be switched to hybrid vehicles where possible.
4. Develop an education plan.	● Increase employee education regarding climate change. ● Add more information about climate change to both the website and the park. This information should be targeted at both children and adults, and should feature activities for both age groups.

5.3 Adjust to the rising sea levels.

While Acadia is already taking steps to improve or replace existing culverts with the aim of facilitating better movement of fish, water, and sediment, it should be taken into account how to allow for the possibility of better marsh migration. Further, depending on the prioritization of the protection of marshes over the preservation of roads, it may be necessary to remove or shift

the roads that prevent healthy expansion of marshes. Though marshes are quite resilient on their own, if there is restricted water and sediment flow then the marshes will likely not be able to survive the effects of climate change, especially sea level rise. Depending on the needs of each marsh, different processes such as marsh elevation, shoreline stabilization, and increase in drainage may be necessary.

5.4 Limit the loss of plant and animal species in the park.

The first suggestion made to limit the loss of plant and animal species in the park was to introduce native plants in smaller areas of the park. This is an important suggestion because native plant species are vital to maintaining the same animal species in the park. National parks are in place is to preserve the land and species within them (Ladzinski & Nijhuis, 2016). In order to introduce native species, Acadia must first eliminate invasive species. They are currently in the process of doing this through teams that they have set up (Tocci, 2014). Acadia already has shown interest in reviving native plants, but they should do so by focusing on smaller areas and fencing in these areas to preserve the plants. This will allow them to grow freely and avoid damage caused by both animals and people visiting the park.

The second suggestion made to limit the loss of plants animals in the park is to partner with other organizations and parks. The National Park Service has many available resources to all parks such as the Exotic Plant Management Team. The Climate Friendly Parks Program is also a resource that parks can utilize in order to reduce their negative impacts on the climate. These resources, along with the Friends of Acadia and the suggestions provided in this report can help Acadia National Park improve their environmental impact and become a Climate Friendly Park.

5.5 Reduce carbon emission from park vehicles.

The first suggestion made to reduce carbon emissions from park vehicles was to limit traffic flow by restricting entry to private vehicles and encouraging the use of the shuttle system. Currently, 10 different shuttle bus lines are running in the great Acadia area. It is essential to limit the access of private vehicles, and especially the non-resident vehicles. As the park is comprised of numerous residential areas, limiting access of all private vehicles, as Zion National Park, is impossible. But, there could be restraining on out-of-state vehicles or permits for local

vehicles only in the range of the park. If the number of out-of-state vehicles is not controlled, there could be situations in which lower numbers of people take the shuttle bus. The traffic could become even worse with both a high number of private cars and additional shuttle buses. Hence, controlling the entry of private vehicles in the park is necessary.

The second suggestion made to reduce carbon emissions from park vehicles was to switch to hybrid vehicles where possible. It means not only the shuttle bus should be on hybrid power, but all vehicles traveling in Acadia should try to switch to lower carbon emissions. The green community of Zion National Park is a great example. All the residents are encouraged to participate in renewable energy choices. In this case, the greenhouse emission from the vehicles traveling through the park would be reduced significantly.

5.6 Develop an education plan.

The first suggestion made to develop an education plan was to increase employee education regarding climate change. It is important that the employees of the park have ample knowledge on the effects and consequences of climate change to the park they are working for. It can both help the employee to understand why the park is using energy-saving vehicles and renewable energy and encourage them to make climate friendly choices. Further, the employees can pass the knowledge to the visitors they meet while working.

The second suggestion made to develop an education plan was to design a website and programs in the visitor center to provide more information about climate change. Currently, there is no information about the effects and consequences of climate change on the Acadia National Park website. The lack of educational information is a critical element that could prevent Acadia from becoming a climate friendly park. Moreover, educational programs should be designed for both children and adults.

When making suggestions to Acadia National Park, the overall goals were to improve the positive environmental impact of the park and ultimately ensure that the park would be qualified to be included in the list of Climate Friendly Parks in the future. As a National Park, Acadia should be helping protect the environment and not doing unnecessary harm. By following the suggestions shown in Figure 4, Acadia will be able to do not only that, but also will be able to

educate the community and help visitors become more sustainable both while they are visiting the park and in their daily lives.

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