SUSTAINABILITY OF ECOLOGICAL RESTORATION PROJECTS: A CASE STUDY OF FRUIT FARM CREEK MANGROVE RESTORATION

By

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“You are braver than you believe, stronger than you seem, smarter than you think.”
- Winnie the Pooh

Thank you to all those who gave me strength along the way. Thank you Jason for never letting me forget that I can conquer anything. And to my family, Kenleigh and Zac, thank you for helping me be brave in the toughest of times. I love you all.
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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>4</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>7</td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td>9</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>10</td>
</tr>
<tr>
<td>CHAPTER</td>
<td></td>
</tr>
<tr>
<td>1 INTRODUCTION</td>
<td>11</td>
</tr>
<tr>
<td>Current Situation</td>
<td>11</td>
</tr>
<tr>
<td>Mangrove Restoration</td>
<td>12</td>
</tr>
<tr>
<td>Thesis Outline</td>
<td>15</td>
</tr>
<tr>
<td>2 LITERATURE REVIEW</td>
<td>18</td>
</tr>
<tr>
<td>Examples of Sustainably Designed Ecological Restoration Projects</td>
<td>21</td>
</tr>
<tr>
<td>Major Themes of Overall Sustainability</td>
<td>21</td>
</tr>
<tr>
<td>Major Economic Sustainability Themes</td>
<td>23</td>
</tr>
<tr>
<td>Major Ecological Sustainability Themes</td>
<td>24</td>
</tr>
<tr>
<td>Major Social Sustainability Themes</td>
<td>26</td>
</tr>
<tr>
<td>Economic Sustainability</td>
<td>28</td>
</tr>
<tr>
<td>Cost of Mangrove Restoration</td>
<td>29</td>
</tr>
<tr>
<td>Improving Economic Sustainability</td>
<td>29</td>
</tr>
<tr>
<td>Ecological Sustainability</td>
<td>31</td>
</tr>
<tr>
<td>Setting Goals</td>
<td>32</td>
</tr>
<tr>
<td>Prioritizing Goals and Identifying Restoration Techniques</td>
<td>36</td>
</tr>
<tr>
<td>Monitoring Success and Sharing Results</td>
<td>37</td>
</tr>
<tr>
<td>Social Sustainability</td>
<td>41</td>
</tr>
<tr>
<td>Benefits of Participation</td>
<td>42</td>
</tr>
<tr>
<td>Framework for Participation</td>
<td>43</td>
</tr>
<tr>
<td>The Basics of Mangrove Restoration and Climate Change</td>
<td>50</td>
</tr>
<tr>
<td>Threats of Climate Changes</td>
<td>50</td>
</tr>
<tr>
<td>Potential Mitigation of Coastal Ecosystems</td>
<td>52</td>
</tr>
<tr>
<td>3 METHODOLOGY</td>
<td>56</td>
</tr>
<tr>
<td>Research Design and Techniques</td>
<td>56</td>
</tr>
<tr>
<td>Data Analysis and Tools</td>
<td>57</td>
</tr>
<tr>
<td>Limitations</td>
<td>60</td>
</tr>
<tr>
<td>4 DATA</td>
<td>62</td>
</tr>
</tbody>
</table>
5 DISCUSSION .............................................................................................................. 76

Project Benefits ........................................................................................................... 76
Current Progress ........................................................................................................... 77
Project Sustainability .................................................................................................... 80
  Economic ....................................................................................................................... 80
  Ecological ...................................................................................................................... 82
  Social ............................................................................................................................. 83
Applying the Sustainable Design Approach ................................................................. 84

6 CONCLUSION ............................................................................................................ 86

LIST OF REFERENCES ................................................................................................. 88

BIOGRAPHICAL SKETCH ........................................................................................... 92
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1</td>
<td>Reference Map showing the Fruit Farm Creek Site location</td>
</tr>
<tr>
<td>1-2</td>
<td>Supplemental research questions</td>
</tr>
<tr>
<td>2-1</td>
<td>Examples of terrestrial ecosystem goods and services</td>
</tr>
<tr>
<td>2-2</td>
<td>Example of testimony included in a project proposal</td>
</tr>
<tr>
<td>2-3</td>
<td>Conceptual model of possible mangrove restoration pathways depending on site conditions</td>
</tr>
<tr>
<td>2-4</td>
<td>A visual representation of the ecological restoration process</td>
</tr>
<tr>
<td>2-5</td>
<td>Framework for Stakeholder Participation</td>
</tr>
<tr>
<td>2-6</td>
<td>Categorization of participatory techniques</td>
</tr>
<tr>
<td>2-7</td>
<td>List of participatory techniques with their degree of involvement</td>
</tr>
<tr>
<td>2-8</td>
<td>Showing seagrass meadows capacity for climate change mitigation and adaptation</td>
</tr>
<tr>
<td>2-9</td>
<td>Showing salt marshes capacity for climate change mitigation and adaptation</td>
</tr>
<tr>
<td>2-10</td>
<td>Showing mangrove forests capacity for climate change mitigation and adaptation</td>
</tr>
<tr>
<td>3-1</td>
<td>Methodology Map</td>
</tr>
<tr>
<td>4-1</td>
<td>Reference Map showing the Fruit Farm Creek Site location along SR-92, RBNERR, surrounding cities, and Collier County</td>
</tr>
<tr>
<td>4-2</td>
<td>Image showing tidal creeks A-E, the three mangrove die-off areas and the one existing culvert</td>
</tr>
<tr>
<td>4-3</td>
<td>Die-off area #1; approximately 4 acres</td>
</tr>
<tr>
<td>4-4</td>
<td>Die-off area #3; approx. 50 acres</td>
</tr>
<tr>
<td>4-5</td>
<td>Die-off area #3; approx. 10 acres</td>
</tr>
<tr>
<td>4-6</td>
<td>Fruit Farm Creek Mangrove Restoration Information and Plan</td>
</tr>
<tr>
<td>4-7</td>
<td>Map showing the locations of the 15 study plots</td>
</tr>
</tbody>
</table>
5-1  Sampling locations in Phase 1a, 4-acre site...............................78

5-2  A-D) Phase 1a, 4-acre site restoration progression from September 2, 2012
to September 16, 2015 ........................................................................79
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMR</td>
<td>Ecological Mangrove Restoration</td>
</tr>
<tr>
<td>ER</td>
<td>Ecological Restoration</td>
</tr>
<tr>
<td>NERR</td>
<td>National Estuarine Research Reserve</td>
</tr>
<tr>
<td>NWR</td>
<td>National Wildlife Refuge</td>
</tr>
<tr>
<td>RBNERR</td>
<td>Rookery Bay National Estuarine Research Reserve</td>
</tr>
<tr>
<td>RSET</td>
<td>Rod Surface Elevation Table</td>
</tr>
<tr>
<td>SER</td>
<td>Society of Ecological Restoration</td>
</tr>
<tr>
<td>TEEB</td>
<td>The Economics of Ecosystems and Biodiversity</td>
</tr>
<tr>
<td>TIITF</td>
<td>Trustees of the Internal Improvement Trust Fund</td>
</tr>
<tr>
<td>USGS</td>
<td>United States Geological Survey</td>
</tr>
<tr>
<td>WARC</td>
<td>Wetland and Aquatic Research Center</td>
</tr>
</tbody>
</table>
Mangrove ecosystems benefit both the organisms that depend on the habitat and the humans that enjoy and affect them. Despite the benefits, mangroves are continually degraded and destroyed for short-term economic benefit. The field of restoration ecology is attempting to reverse that trend and restore precious natural landscapes, like mangrove ecosystems. This research is investigating how restoration projects can be designed in a sustainable way and why this is important for the long-term success of the efforts. Economic, ecological, and social aspects of restoration projects are explored to find best practices that can be applied to real projects. These concepts are used to analyze the Fruit Farm Creek Mangrove Restoration Project and identify successes and/or challenges. While the project has a sound, science-driven ecological restoration plan, the biggest challenge is funding. Based on the findings, recommendations are made to potentially increase the long-term sustainability of the restoration. Efforts that will have the biggest impact include increasing public involvement and stewardship, tapping into the partnership with Rookery Bay NERR, documenting the process, sharing the results, and exploring alternative funding resources.
CHAPTER 1
INTRODUCTION

In a world where the environment is so closely tied to the urban landscape, there is a constant struggle to protect the environment while allowing for human growth. Often we see that one may come at the expense of the other; the environment is degraded in the face of urban growth or human contact is ultimately restricted from the environment in order to protect it, with the former being the dominant trend. One environment being heavily degraded by human disturbance is mangrove forests.

Current Situation

There are currently roughly 181,000 km² of mangroves along various coastlines, with 9 orders, 20 families, 27 genera, and roughly 70 different species of mangroves (Alongi, 2002; Ellison, 2000). According to Lewis (2001), the larger coastal ecosystem typically includes mud flats, seagrass meadows, tidal marshes, salt barrens, coastal upland forests and freshwater wetlands, freshwater streams and rivers, and even coral reefs in some tropical climates. The benefits of these ecosystems are numerous to both the organisms found in the ecosystem and the humans that enjoy and affect them. Healthy mangrove habitat supports many species of fish and various wildlife including birds, reptiles, and other mammals (Alongi, 2002). Mangrove forests have the ability to trap sediment, contaminants, nutrients and carbon, which in turn helps to clarify the water (Alongi, 2002). Some ways that these forests directly benefit humans include food/resource production and commerce, community enjoyment and recreation, conservation of natural land, increasing water quality, and protection of coastal communities through soil stabilization and buffering against wind and storm surge.
Despite the many benefits, there has been a dramatic loss of global mangrove cover in the last half century. These lands are continually being destroyed or converted for short term economic gain. More specifically, there was a 2% loss per year of cover in the 1980s and 1% per year loss of cover in the following decade (Bosire, et al., 2008) (Lewis R. R., 2001). These losses are caused by both natural and anthropogenic stressors. Natural disturbances include destructive storms, lightning, tsunamis and other flooding (Alongi, 2002). Human impacts are numerous: using the materials for fuel and timber, conversion to aquaculture fisheries, development and coastal pressures, and pollution. The increase in population density and growth is positively related to mangrove destruction and exploitation (Alongi, 2002). In explaining the benefits and losses of these forests, it shows the need for action.

**Mangrove Restoration**

One method of action that has been utilized across the globe is ecological restoration projects to restore the damaged mangrove ecosystems. According to the Society of Ecological Restoration (SER), ecological restoration (ER) can be defined as “the process of assisting the recovery of an ecosystem that has been degraded or damaged or destroyed” (SER, 2002). Further analysis of ER will be discussed later in the paper. While a variety of techniques are used, the aim of each project is to successfully restore or rehabilitate the mangroves in the project area to a pre-defined state.

Being involved in a project in Southwest Florida, through the U.S. Geological Survey (USGS) Wetland and Aquatic Research Center (WARC) located in Gainesville, FL, provided insight into the process and challenges of a specific restoration effort. The Fruit Farm Creek Restoration project is a multi-phase project that is attempting to
restore 64 total acres of mangrove forest along SR-92 at the edge of Marco Island, within Rookery Bay National Estuarine Research Reserve (NERR). A map of the location is shown below in Figure 1-1. The construction of the road cut off the essential hydrological flow and created three dead zones: a 4-acre site, a 10-acre site, and a 50-acre site (Coastal Resources Group, Inc, n.d.). The engineers are using the Ecological Mangrove Restoration (EMR) approach to restore these sites, which aims to restore the hydrologic flow and allows for the natural regrowth of the mangroves (Coastal Resources Group, Inc, n.d.).

Figure 1-1. Reference Map showing the Fruit Farm Creek Site location (Created by: Kristin Buckingham)
As I collected samples in the field and completed work in the lab, I began to think critically about the project as a whole. My work with USGS exposed me to a small part of the restoration efforts and it left me wanting to know more about the social and economic implications of the project. For instance, I wondered how the public was involved in the project and if the community understood the importance of the restoration efforts. I also wondered where the funding came from and how the restoration team sought out stakeholders. It was these questions that inspired this research.

Along with wanting to learn more about the various components of the project, I learned that mangrove restoration is a long process. When measuring the functional equivalence of restored mangrove forests, compared to natural forests, the process can take decades. For example, a study done in the Tampa Bay region showed the restored mangroves reached functional equivalence in up to 20 years, based on soil carbon and nitrogen concentrations, and up to 55 years, based on tree diameter and density of adult trees (Osland, et al., 2012). To measure the growth after restoration and produce significant, replicable results, data must be collected for many years. This drives home the need for sustainably designed restoration projects that incorporate economic, ecological, and social best practices throughout the life of the project.

It is widely accepted that sustainability involves three pillars: economic, environmental and social. Based on the three pillars of sustainability, what makes an ecological restoration project sustainable? The practices may vary at different scales. This research for instance begins as a small-scale project (the Fruit Farm Creek project), which is located in the larger National Estuarine Research Reserve. There is
also the regional scale of SW Florida and at the largest scale is global restoration.

Different challenges and concerns of sustainability face each of these scales. For this research, I will be focusing on the project level specifically looking at the Fruit Farm Creek project. To answer the main question of project sustainability, it is necessary to further investigate each of the three components. The inspiration for these questions came from the gaps of knowledge identified while working in the field discussed earlier.

<table>
<thead>
<tr>
<th>For the economic component</th>
<th>Is the funding of the project sustainable?</th>
</tr>
</thead>
<tbody>
<tr>
<td>For the environmental component</td>
<td>To date, how successful is the Fruit Farm Creek restoration project based on success criteria found in the literature?</td>
</tr>
<tr>
<td></td>
<td>What can jeopardize the long-term ecological sustainability of mangrove restoration projects?</td>
</tr>
<tr>
<td>For the social component:</td>
<td>What stakeholders are involved in the Fruit Farm Creek Mangrove Restoration Project?</td>
</tr>
<tr>
<td></td>
<td>How is the public involved in the project?</td>
</tr>
</tbody>
</table>

Figure 1-2. Supplemental research questions

**Thesis Outline**

The introduction contains the problem, background information on the current situation and mangrove restoration, the research questions that are the basis of the project, and an overview of the methodology.

The literature review will cover information about restoration ecology and the various aspects of the emerging field, as they are related to the three pillars of sustainability. It will begin with an overview of ecological restoration and pertinent definitions. Then examples of sustainably designed ecological restoration projects are discussed, identifying major themes that contributed to the success of the projects.

Next, the discussion will center on the economic aspects including the cost of mangrove
restoration and ways to improve economic sustainability. The ecological portion will cover the widely accepted procedures of ecological restoration including setting goals, prioritizing goals and restoration techniques, establishing success criteria, and sharing successes and failures. The social aspects of ecological restoration will include the benefits of participation and a framework for successful participation in a project. Finally, there will be a brief overview of the threat of climate change to mangroves and the potential for coastal ecosystems to mitigate climate change.

The methodology contains the research design and techniques used in the study. This study will follow a qualitative research design with a case study approach. The case study will be the Fruit Farm Creek Mangrove Restoration Project. In addition, the data analysis and tools used will be discussed, along with the limitations of the methods. The primary source of data will be obtained from document collection. The information will follow the major themes of sustainability, as it pertains to the restoration project. Other possible types of data include on-site observations and interviews.

This chapter will contain an analysis of the Fruit Farm Creek Mangrove Restoration Project. It will begin with an overview of the project. More specifically, it will examine background information, the restoration plan, USGS involvement, funding, and partnerships.

This chapter will begin with a discussion about the benefits and current progress of the Fruit Farm Creek project. Then there will be a discussion about the analysis of the economic, ecological, and social aspects of the project. Finally, the chapter will include recommendations about how to increase the sustainability and overall success of the project.
The final chapter of the thesis will be the conclusion, which will summarize the findings, reiterate the suggestions for increasing the sustainability of the project, and outline possible areas of further research.
CHAPTER 2
LITERATURE REVIEW

The definition of ecological restoration has evolved over time, as lessons learned and undesirable outcomes have guided the re-evaluation of the ultimate goal of restoration. The gradual change over time displays an advancement in how restoration ecology is approached and it is important to identify the current practices of the field. Traditionally, the aim of ER has been to restore a landscape back to its historical vegetation (Wyant, Meganck, & Ham, 1995). Since then, ecologists have found that the historic state of the ecosystem is not necessarily desirable or achievable today (Wyant, Meganck, & Ham, 1995). Wyant, et al. (1995) combined multiple definitions to conclude that ER should include: “(1) the identification of ecologically and socially desirable ecosystem values, goods, and services, as determined through a number of scientific and public-input mechanisms; (2) identification of the functional and structural elements essential to a self-sustaining system that will provide those values; and finally, (3) facilitation of ecosystem recovery to a self-sustaining state by manipulation of the physical, biological, chemical, and even social or cultural elements of the system.”

Within this definition are important rationales used to guide this research. For instance, the mention of “public-input mechanisms” and “social or cultural elements of the system” emphasize the need for including social inputs in a project. It does however lack any mention of resilience and simply mentions the system should be self-sustaining. As threats to ecosystems become more prevalent, it is increasingly important to understand how ecosystems increase resilience and how land management can improve those odds.
The benefits of ER are numerous, including, but certainly not limited to, increasing biodiversity, reestablishing ecosystem services, sustaining livelihoods, and improving well-being both materially and culturally (Aronson, Clewell, Blignaut, & Milton, 2006). More detailed benefits are listed in Figure 2-1. Recognizing the benefits of ER provides a basis for gathering support for a project. To gather public and stakeholder support, as well as funding, people need to understand why the ecosystem is important and what can be lost if restoration does not occur. These concepts are discussed further in this chapter.

Throughout this literature review, the various aspects of the emerging field of restoration ecology will be examined, specifically as they relate to the three pillars of sustainability. This will involve searching the literature for best practices in gathering economic resources, designing ecological restoration plans, and increasing social involvement. This knowledge will guide the recommendations for increasing the sustainability and success of the Fruit Farm Creek project. But first, a number of ecological restoration projects are identified, which used a sustainable design approach. These cases were examined in order to get a sense of how sustainability was woven into the project and increased the success.
<table>
<thead>
<tr>
<th>Benefits of Mangroves</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Goods</strong></td>
</tr>
<tr>
<td>Human food</td>
</tr>
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<td>Live animals (nonfood)</td>
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<td>Animal materials (hides, feathers, etc.)</td>
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<tr>
<td>Livestock forage</td>
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<tr>
<td>Water (quality/quantity)</td>
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<tr>
<td>Fuels (biomass)</td>
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<tr>
<td>Plant materials (fertilizers, medicinals, fiber, etc.)</td>
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<tr>
<td><strong>Services</strong></td>
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<td>Pollination</td>
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<td>Wildlife/endangered species habitat</td>
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<td>Migratory corridor</td>
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<td>Disease and pest control/protection</td>
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<tr>
<td>Genetic diversity</td>
</tr>
<tr>
<td>Climate modification (micro, macro)</td>
</tr>
<tr>
<td>Biogeochemical cycling (nutrients, carbon sequestration)</td>
</tr>
<tr>
<td>Contaminant decomposition, transport, dilution and storage</td>
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<tr>
<td>Soil generation</td>
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<td>Erosion control and sediment trapping</td>
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<td>Floor control</td>
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<td>Recreation</td>
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<tr>
<td>Scientific research</td>
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<tr>
<td>Heritage value (historical, cultural, uniqueness)</td>
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</tbody>
</table>

Figure 2-1. Examples of terrestrial ecosystem goods and services (Wyant, Meganck, & Ham, 1995)
Examples of Sustainably Designed Ecological Restoration Projects

To get an understanding of the applicability of the sustainable design approach to ecological restoration projects, a number of cases were identified and examined. Themes seen across these cases will give an idea of what worked or did not work in a real world scenario. While the cases identified are not specifically geared toward mangrove restoration, the common themes should be relevant to many types of ecological restoration. A number of common themes will be presented throughout this section, along with specific examples from the literature.

Major Themes of Overall Sustainability

There are some themes that appeared in the literature that did not directly fit into one of the pillars of sustainability. These themes can be utilized to increase the overall sustainability of the project. It can be difficult to come up with overall themes in a field where the product, or landscape, differs so much. For instance, techniques used in stream restoration will likely not be applicable to mangrove restoration. But one important theme that emerged was the concept of replicable but contextual. One example of this can be seen in the Rebuild by Design: Living Breakwaters project, which aims to restore the coastal ecosystem and reduce future risk along the Staten Island and Raritan Bay coasts (Rebuild by Design, n.d.). The layered approach of configuring different designs along various coastlines using living shoreline techniques is applicable over many different conditions. But, the specific tools and techniques used greatly depend on the context of the site. Throughout the life of the project, from the design phase to the monitoring phase, the ideas and techniques should be replicable. This allows future projects to identify practices that have worked in the past, even though
some may need to be altered to fit within the context of the project. Alternatively, it allows for faulty practices to be avoided, which saves precious time and resources.

Collaboration with other projects and studies has also been shown to increase the sustainability of ecological restoration projects. An example is the Earth Partnership program at the University of Wisconsin – Madison. The program helps to get kids involved in restoration projects to help them “engage in the process of doing science that is relevant to their everyday lives” (Bauer-Armstrong, 2016). One project the program was involved with is the Kinnickinnic River restoration, the seventh most endangered river in the U.S. due to pollution and low water levels. Involving the students allows them to learn more about the process of restoration and the ecological issues while creating a bond with nature and other likeminded individuals. Another example is found in the Living Breakwaters project, where the team identified multiple programs, like the Billion Oyster Project, and other state and federal initiatives that could become partners (Rebuild by Design, n.d.). This extended the amount of resources for the project, increased awareness, and widened the impact of the project’s actions.

When looking at the implementation of a project, one way to increase the potential for success is to identify key elements of successful implementation. This was clearly evident in the Living Breakwaters project. The project identified four key elements including community and agency input, coalition building, a robust regulatory strategy, and strong funding justification (Rebuild by Design, n.d.). While the specific elements will vary for each project, the identification of the elements provides a path for identifying proper steps to take and accountability for completing each step or task.
Major Economic Sustainability Themes

As shown in later sections, it can be difficult to get long-term funding for ecological restoration projects. To combat this issue, projects must show a strong justification for funding. This is done by clearly identifying the need for restoration and the benefits that will follow to attract stakeholders and partners. Furthermore, the benefits expressed should identify the economic, ecological, and social outcomes of the project. An example of this is the ChonGae Canal Point Source Park in Seoul, South Korea. The park is located along a waterway that was once a great source of pride for the area because of its beauty and ability to transport goods (American Society of Landscape Architects – ChonGae Park, n.d.). After years of population growth, the waterway became polluted and a health hazard. This project was designed with sustainability in mind and had clear benefits across each of the pillars. Economically, the restoration brought people into an area where the business and commercial districts are located. Ecologically, the project restored a precious and historic waterway and used locally sourced materials to keep the culture intact. Socially, the urban park is now a central gathering place for the community. Families can enjoy the peaceful sound of the water or go to any of the special events, like festivals and rock concerts.

Another concept used to increase economic sustainability is to provide new economic opportunities through the project. In the Living Breakwaters project, the “water hubs” constructed at each of the restoration sites provided space for businesses designed for coastal recreation and tourism (Rebuild by Design, n.d.). For example, one hub provides space for kayak vendors and scuba rentals/lessons, while others provide space for small beachfront restaurants. Another example is found in the ChonGae Canal Point Source Park again. The restored waterway and constructed park connects
two neighborhoods of the central business district in the city. Project leaders also
developed a way to purify the water before it enters the canal, while designing the park
to withstand a 100-year flood. The economic benefits of the project may not be as
recognizable as the Living Waters example, but the features of the project help to purify
the water, protect surrounding areas from flooding, and bring people to an economically
driven area of town. Each of these results allow the government and/or citizens to save
money and also drives business in the area. Another side effect is the increasing real
estate values in the surrounding areas.

**Major Ecological Sustainability Themes**

To increase ecological sustainability, many projects followed the idea of working
with nature. This involves finding solutions that include the elements of the ecosystem
instead of fighting or excluding them. A great example of this is found in the Living
Breakwaters project. After Hurricane Sandy, the U.S. Department of Housing and Urban
Development’s Rebuild by Design Initiative held a global design contest for rebuilding
efforts (SCAPE, n.d.). The Living Waters proposal was one of six that won the contest.
The thing that sets the Living Waters proposal apart from other submissions was the
idea of embracing the water and designing a plan that restored the coastline without
building a seawall. In many cases, the latter is the desired form of protection where a
sea wall is built to try and keep the sea away from the surrounding built environment.
This project however, used the concept of “reef streets” and living shorelines to grow
ecological resiliency and allow people to interact with nature while reducing risk
(Rebuild by Design, n.d.).

Furthermore, successful projects identified restoration actions that benefit the
whole ecosystem. When this idea is ignored, projects often fail. This can be seen in the
Philippians, where despite large funding resources the long-term survival of mangrove restoration is 10-20% (Primavera & Esteban, 2008). The main cause of the low survival rates is the use of mass planting projects as the main technique for restoration. As shown in greater detail further on, this technique often fails because the initial cause of the degradation is not identified and remediated. By thinking more holistically and designing the projects with sustainability in mind, such losses can be avoided.

Successful, sustainably designed projects also increase access to areas previously unusable. The areas could be closed off to the public because of environmental and safety concerns. Two examples of this that stand out are the Quarry Garden project in the Shanghai Botanical Garden and the Transformative Water project in Pitkin County, Colorado. The Quarry Garden project took an abandoned quarry yard and transformed it into a new landmark in Shanghai (American Society of Landscape Architects – Quarry Garden, n.d.). The land was severely damaged, as well as dangerous and inaccessible, which provided challenges when designing the restoration plan. But now the gardens provide a peaceful scenic spot, while enhancing the ecology and culture of the area. Similarly, the Transformative Water project restored the polluted lands of an old asphalt plant into functioning wetlands that celebrate the cultural heritage of the historic ranch (American Society of Landscape Architects Inc., 2017). The lands were polluted and overgrown with invasive species. Following the restoration, the landscape acts as a storage wetland that purifies the water and increases the native biodiversity of the area. By restoring these areas and increasing access, these projects and others not discussed also increase the sense of place. Once restored, people can
begin to identify with the landscape in a positive manner and use the space to gather as a community.

**Major Social Sustainability Themes**

When thinking about the social sustainability of a project, it is imperative to realize that people are a critical component. A common error in mangrove restoration projects, especially in developing nations, is not adequately involving the local communities in the process (Blum & Herr, 2017). Involving the community in the project is often a key component in the long-term success of the restoration. Further, members of the community often times have knowledge that can assist the project. It is not only important to recognize people as a critical component but also identify ways in which the community can get involved in all aspects of the project. Projects in the Philippians that were successful (about 90% survival rate), were so because of the community-led nature of the initiatives (Primavera & Esteban, 2008). Surprisingly, it was the low budget projects that defied the low success track record because they contained features like regular maintenance by the nearby residents and co-management with local governments. These projects tended to be born out of a need for restoration (i.e. coastal protection), which incentivized the participation of the community and the long-term commitment of the upkeep. Successful projects allow the project to be shaped by the needs and aspirations of the community.

When developing a proposal for a restoration project, it is useful to include community and agency input, like testimony, in the product. In doing so, it gives investors and developers an idea of the support for the project. It also showcases the actions taken to involve the community in the early phases of the project. A great example of this is the Living Waters proposal. Throughout the proposal, the authors
included testimony from local residents (example shown in Figure 2-2), committee members, agency partners, and even included received letters of support.

![Figure 2-2. Example of testimony included in a project proposal (Rebuild by Design, n.d.)](image)

Finally, a theme present in all successful restoration projects was the use of expertise. In many cases, ecological restoration is highly technical and requires a certain level of expertise to properly restore the damaged ecosystem, whether it be restoring the hydrology of mangroves or remediating toxic pollution in a waterbody. One project that required a high level of expertise was the Quarry Garden in Shanghai. The complexity of the site conditions required the use of highly-difficult construction techniques (American Society of Landscape Architects – Quarry Garden, n.d.). It is also important to realize that when the site poses many challenges the design and construction may need to be altered as new problems are presented. When expertise is overlooked it will most likely result in project failure to some degree. In mangrove restoration specifically, the process is complex and should be founded on known principles of ecosystem restoration and management (Blum & Herr, 2017). “Often, fast-paced and large-scale ‘restoration events’ are not necessarily scientifically robust” (Blum & Herr, 2017), which leads to low long-term survival, as seen in the Philippians.
Economic Sustainability

Sustainability, in the economic context, is about choosing strategies that “meet the needs of the enterprise and stakeholders today while protecting, sustaining and enhancing the human and natural resources that will be needed in the future” (Silvius & Schipper, 2010). While this definition is geared more toward business and project management, the concepts presented can be applied to restoration projects. To achieve economic sustainability in a restoration project, the goals and restoration techniques of the project and the needs of the stakeholders must positively impact the ecosystem and the people in the area. The project should be financially responsible and must produce long-term benefits. The economic perspective tends to favor short-term thinking and quick actions, where social and environmental effects usually take longer to be seen. This short-term economic gain has seriously degraded our lands and drastically reduced the coastal mangrove ecosystem. A key concept of sustainability is to integrate the short-term and long-term aspects (Silvius & Schipper, 2010). Instead of reactively interpreting how sustainability fits into the context of the project, it should be integrated into the project from the beginning.

Opponents of ER cite expensive, long-term projects as a misuse of chronically small budgets (Aronson, Clewell, Blignaut, & Milton, 2006). The general perception is that these projects are an “expense with few tangible financial and economic benefits” (Blignaut, Aronson, & de Groot, 2013). In other countries, there must be a clear link to economic and/or social benefits, like jobs, for a project to gain support. Even if support for restoration does exist, the field has been riddled with failures across the globe. Some projects fail because of poor planning and unrealistic goals (Kamali & Hashim, 2011; Lewis, 2005). Others fail due to the use of techniques not suitable for the site and
poorly trained managers (Lewis R. R., 2001). Furthermore, limited funds and short-sighted efforts have led to a historic lack of documentation and shared knowledge of failures and successes (Lewis R. R., 2005). This allows for mistakes to be repeated and precious funds to be wasted. Again, this displays a need for the integration of short-term and long-term aspects into the project.

**Cost of Mangrove Restoration**

According to Lewis (2001), costs range from $225/ha to $216,000/ha to successfully restore mangrove forest vegetation cover and ecological functions, not including any purchasing of the land. These costs vary widely depending on the type of restoration used, labor costs, costs of permits, site conditions, and more. There are three techniques of restoration: (1) planting alone (2) hydrologic restoration (with and without planting) and (3) excavation or fill (with and without planting) (Lewis R. R., 2001). Planting alone is relatively inexpensive, $100-200/ha, but is not advised due to the low success rate. Hydrologic restoration can be executed at similar costs and can be very successful, if done correctly. Excavation or fill is the most expensive option because of the high costs of engineering the landscape. This option is likely not viable for developing countries (Lewis R. R., 2001).

**Improving Economic Sustainability**

There are some ways to increase the likelihood of success of a restoration undertaking, along with improving the economic sustainability of the project. First, there should be clear communication of the need for restoration. Without public and stakeholder support for the project, it will be difficult to acquire the necessary funding to carry out the manipulations and monitoring/analysis. It is vital to carefully plan and design each step of the restoration process for a project (Lewis III, 2009) (discussed in
detail in the next section). Careful planning should ensure the most cost effective restoration and monitoring techniques are utilized for the site. Continual “fine tuning” of practices and techniques is needed to find the most cost-effective way to restore ecosystems (Blignaut, Aronson, & de Groot, 2013) and those results should be shared. Possible collaboration opportunities should be explored to not only supply funding but also non-monetary goods like labor. One such example is using volunteers to collect and analyze data. Attempting to coordinate with graduate students and researchers will reduce costs, as well (Lewis III, 2009). These efforts would be more effective if projects utilized standardized methodologies of sampling and reporting.

Until now, there has been little evidence about the cost effectiveness of ER. Erroneous accounting practices and conventional cost-benefit analyses give the impression that little is to be gained financially from restoration (Blignaut, Aronson, & de Groot, 2013). These analyses use a short-term perspective and do not fully grasp the benefits of the ecosystem services provided by the natural systems being restored. A study of 225 case studies on benefits and 91 studies on costs, published in The Economics of Ecosystems and Biodiversity (TEEB) report, examines ER across a range of ecosystem types (Blignaut, Aronson, & de Groot, 2013). This is the most extensive economic analysis to date, which concludes that restoration provides a good return on investment, except in coral reefs and coastal systems (excluding coastal wetlands and mangroves) due to the high complexity and expensive nature of its restoration. The study found that restored coastal wetlands and inland wetlands (including mangroves) provided the most value for money in absolute terms (Blignaut, Aronson, & de Groot, 2013).
Another avenue to explore is to look at policy and advocate for the inclusion of successful methods of restoration in current laws. Ruiz-Jaen & Aide (2005) found in a review of all articles published in *Restoration Ecology* (Vols. 1[1]-11[4]), nearly 60% of the restoration efforts were done to comply with laws, like the U.S. Clean Water Act, and National Environmental Protection Measures Act (Australia). One successful method, not currently required by law, is the inclusion of reference sites in a project’s design. This idea is further explored in the next section, but reference sites are necessary for comparison and for tracking progress of the restoration effort. It is unlikely that future projects will incorporate this tactic because of the increased costs without the requirement by law (Ruiz-Jaen & Aide, 2005). This method and others, like standardized success criteria and means of reporting successes and failures, would be important additions to the current policy. Furthermore, as more evidence is published about the actual economic benefits of ER, policy makers should be informed that these efforts are worthwhile investments.

**Ecological Sustainability**

There are a number of steps to follow and questions to answer in the planning and execution of ER. These steps hold true to the wide array of ecosystems, including mangrove restoration. One step in the process is to identify the goals and objectives (if applicable) of the restoration project. These goals should consider the attributes of the ecosystem, the cause of the degradation and the actions needed to restore the site, as well as a clear picture of what the “restored” site should be (Hobbs & Harris, 2001). In other words, what should the outcome of the restoration look like? Another step is to identify the best restoration methods and technologies to use. Finally, the methods used
for monitoring the site and criteria used for measuring success should be identified, along with a schedule of when the monitoring will take place.

When looking at the success of mangrove restoration specifically, there are five critical steps first suggested by Lewis and Marshall’s (1997) Ecological Mangrove Restoration (EMR) approach. These steps follow the general principles discussed throughout this section, emphasizing the investigation of the ecosystem and disturbances, cautioning against planting when and if possible. Bosire, et al. (2008) created a conceptual framework, Figure 2-3, which takes these original principles and incorporates a human dimension. This is seen specifically in steps 4 and 10. Steps 4 includes surveying users and gaining an understanding of local traditions, perceptions, and needs. This knowledge can be used to understand historical patterns of the ecosystem but also can help to shape the project, a theme presented in the examples of sustainably designed restoration projects like the Living Waters project and successful mangrove restoration projects in the Philippians. Step 10 presents the need for giving recommendations for improved site management. This idea directly correlates with the intended outcome of this research.

**Setting Goals**

“The clear enunciation of goals is essential for [a project’s] success” (Hobbs & Harris, 2001). A criticism of the field of restoration ecology is that goals can often be idealistic, not taking the real social, economic, and political constraints into consideration (Choi, et al., 2008). Such goals can lead to the perception that these projects are expensive indulgences with little real world context. Realistic goals must be ecologically sound, economically feasible, and socially acceptable, and should be
Figure 2-3. Conceptual model of possible mangrove restoration pathways depending on site conditions (Bosire, et al., 2008)
spelled out in a very succinct way. To do this, there must be a consideration of the ecological potential of the site or larger ecosystem, matched against the societal desires and financial constraints (Hobbs & Harris, 2001). The primary goal of wetland restoration projects is to re-establish habitat and functions that have been lost and others include landscape enhancement, sustainable production of resources and protecting coastal areas (Kairo, Dahdouh-Guebas, Bosire, & Koedam, 2001). When assessing the ecological context of the site, the following attributes should be considered (Hobbs & Norton, 1996):

1. Composition: species present and abundance
2. Structure: vertical arrangements of vegetation and soil (living and dead)
3. Pattern: horizontal arrangement of system components
4. Heterogeneity: complex variable of #1-3
5. Function: performance of ecological processes
6. Dynamics and resilience: successional processes and recovery from disturbances

Other economic and social factors should be examined and are explained in each corresponding section of the literature review. Throughout the literature, the term “goals” is widely used with little mention of objectives. That being said, goals are the broad ideals of a project and objectives offer concrete measures taken to attain the corresponding goal (SER, 2002). Once goals have been decided through the various procedures discussed, it is also important to identify specific objectives that can be measured, to determine if progress is being made.

Identifying the cause of the degradation is as important as identifying the goals designed to remediate the damage. Historically, the “gardening approach” has been
used as the method of restoration, which focuses on planting without first identifying the cause of degradation (Lewis R. R., 2001). This can be seen as the most expensive method of restoration because the project is more likely to fail (Lewis R. R., 2001). Determining the ecological stressors responsible for the degradation of the ecosystem is necessary when trying to identify the appropriate technique of restoration (Gilman & Ellison, 2007). More broadly, stressors that are social and economic in nature can also have an effect on the ecosystem. This could include overuse and degradation from tourism or encroaching development, among other factors. While these stressors may not be relevant to the specific restoration technique chosen, they will need to be addressed when using a sustainable approach to restoration.

Also important to the process of setting goals is determining the desired outcome. Another major criticism of the field has been the impracticality of using a retrospective approach to determining the outcome of a project (Choi, et al., 2008). This approach focuses on using historic landscapes to guide the restoration. While historical information, like aerial photographs, is a valid and valuable resource to use, it should not be the only consideration. This is because the future landscape is likely going to be very different in the face of climate change (Choi, et al., 2008). Using climate change data, as well as considering other landscape changes like nitrogen enrichment and presence of invasive species, will increase the potential for sustainability. When considering characteristics of the system in the future, it is a good idea to develop alternative short-term and long-term scenarios (Hobbs & Harris, 2001). Another resource to use is nearby existing systems (Hobbs & Harris, 2001). These reference systems, or sites, offer measurement standards that can be studied and used as criteria.
for measuring success. The ultimate aim should be to weigh the various ecological attributes of the site, along with the social and financial constraints, in a future-thinking manner to identify goals and objectives that are clearly stated and defendable.

**Prioritizing Goals and Identifying Restoration Techniques**

Once the range of goals has been identified, the next step is to prioritize and possibly narrow down the list. Because objectives are specific measures of each goal, the following procedures do not need to be done for both goals and objectives. Objectives should be identified once the list of goals has been determined. Assessing risk is one way to assign priority. This includes an analysis of the anthropogenic stressors and how those stresses threaten critical resources in the ecosystem (Wyant, Meganck, & Ham, 1995). In addition, the normal instability of the site from natural disturbances should be determined in order to separate the human-caused disturbance from natural variation. Completing the context analysis and the risk analysis are two essential steps in prioritizing and finalizing goals.

Next, is the establishment of the intervention techniques. These actions should be guided by the goals. For instance, if the goal is to allow for natural generation of seedlings, physical planting will not be a restoration technique considered. The idea is to identify “ecological engineering methods that will initiate processes leading to establishment of naturally functioning and self-sustaining ecosystems that are integral parts of the landscape” (Wyant, Meganck, & Ham, 1995). Wyant, Meganck, & Ham (1995) suggest the most pragmatic techniques will mimic natural processes that establish the physical stability of the site, initiate soil development and facilitate invasion of native vegetation. In short, the technique must be site specific and take into account the underlying causes of degradation. While the type of restoration technique chosen
depends on stakeholder expectations and goals, the extent to which it is implemented depends on the financial and resource means available (Hobbs & Harris, 2001).

In mangrove restoration, there are two main techniques of restoration: natural generation and artificial regeneration (Kairo, Dahdouh-Guebas, Bosire, & Koedam, 2001). Natural generation uses propagules (seed pod that falls off mature trees) naturally produced in the area to restore the site, while artificial regeneration involves planting of the propagule by hand. Secondary succession will occur in the self-repair method in 15-30 years if normal hydrological patterns are in place and the availability of seeds is not blocked (Lewis R. R., 2001). In this case, restoration efforts will focus on restoring the hydrology, removing any blockages in the system by excavation or fill techniques, repairing or installing drainage pipes, and more. Active efforts include planting alone or excavation/fill techniques combined with planting. The techniques used will depend on the site, goals, and financial input.

Another criticism involves the often used ad-Hoc, site specific approach to ecological restoration (Choi, et al., 2008). In early times, a "gardening approach" was often used, which only served to treat the façade and not the underlying causes of the degradation or loss of resources. The premise of ecological restoration is to restore the site so it is self-sustaining. The fragmented approach of "gardening" does not accomplish this. To remedy this criticism, Choi, et al. (2008) suggests a multidisciplinary approach is needed. Each of the steps and ideas discussed thus far embody such an approach.

**Monitoring Success and Sharing Results**

Objectives are evaluated using a set of success criteria, also known as design criteria and performance standards (SER 2002). The success criteria and protocols for
monitoring and data assessment should be determined in the planning phase of the project, prior to physical manipulation of the site. Project objectives will be achieved when data interpretation shows the success criteria have been met. This does not automatically mean the goals have also been met, due to the possibility of inadequate objectives and success criteria.

Criteria are put in place to measure whether the ecosystem has “recovered” or not. This occurs when the ecosystem can sustain itself structurally and functionally, and can show resilience to normal stressors without further manipulation (SER, 2002). The SER has provided a guide for measuring restoration success, made up of nine attributes. Accomplishment of each attribute does not need to occur for restoration, but there should be an appropriate trajectory toward the goals and reference site(s) (SER, 2002). The measurements for each attribute will vary, some easily measured, others measured indirectly, and some may be out of reach financially for some projects. The following is a summary of each attribute (Ruiz-Jaen & Aide, 2005):

1. Similar diversity and community structure in comparison with reference sites
2. Presence of indigenous species
3. Presence of functional groups necessary for long-term stability
4. Capacity of the physical environment to sustain reproducing populations
5. Normal functioning
6. Integration with the landscape
7. Elimination of potential threats
8. Resilience to natural disturbances
9. Self-sustainability

As mentioned, it may be unrealistic for a project to measure each of the nine attributes listed above. Ruiz-Jaen & Aide (2005) suggest at least diversity, vegetation structure and ecological processes should be measured. Some other measurements in the literature include assessment of food-web complexity and development of symbiotic
relationships (Hobbs & Harris, 2001). Diversity is concerned with richness and abundance of organisms, along with the diversity of species within different functional groups, which can be used as an indirect measure of resilience (Ruiz-Jaen & Aide, 2005). Some measurements of vegetation structure include vegetation cover, woody plant density, biomass, and vegetation profiles. Measurements of ecological processes include nutrient cycling and biological interactions, which provide information on resilience of the ecosystem. While it increases the cost of the project, reference sites should be identified and measured to compare the progress of the restoration efforts (Ruiz-Jaen & Aide, 2005). That being said, the measurements used should have a purpose and should link to objectives of the project (Hobbs & Harris, 2001).

Once criteria are established, a monitoring schedule should be prepared. If funding allows, data should be collected before restoration manipulations occur to gather pre-restoration measurements. A typical monitoring schedule consisting of 10 reports, time zero being the first report directly following manipulations (Lewis III, 2009). The reports follow a general outline of Time Zero; Time Zero + 3 months; + 6 months; + 9 months; + 12 months; + 18 months; + 24 months; + 36 months; and + 48 months. The short span between the first few reports allows for corrective measures to take place quickly after any problems arise.

There are three strategies of evaluation: direct comparison, attribute analysis and trajectory analysis (SER, 2002). Direct comparison measures selected parameters in the restoration site against a reference site. A thorough comparison involves biotic and abiotic factors. There should be reason behind selecting parameters as too many can confuse the results. “The most satisfactory approach may be to carefully select a
coherent suite of traits that collectively describe an ecosystem fully yet succinctly” (SER, 2002). Attribute analysis uses the list of nine attributes, explained above, and evaluates parameters based on each of the nine goals. Trajectory analysis is still under development. This strategy interprets large sets of comparative data, which is collected periodically to establish trends. The restoration will follow its intended trajectory if the trends move toward the reference conditions. Each of these strategies is intended to assess the ecological progress of the project, but other tools will need to be identified in order to evaluate any cultural, economic or other societal goals and objectives.

Finally, across the literature, it shows there is a need for documentation of successes and failures, as well as generally accepted criteria for measuring success. This is especially true for mangrove restoration projects. When projects fail, there is little documentation as to why, increasing the opportunity for upcoming projects to make the same mistakes (Lewis R. R., 2001). A better way to disseminate this information is needed to act more effectively and increase cost-effectiveness of projects. Information should be spread to a larger audience, including international forums and politicians/policy makers (Lewis R. R., 2001). Each step listed in this section is summarized in Figure 2-4, which shows a flow of the ecological restoration process (Hobbs & Harris, 2001). Viewers can clearly visualize the process from data collection, to choosing techniques, to monitoring and evaluation. The figure also shows the importance of recognizing outside influences, like societal goals and policy instruments, and adaptation to close the system.
Interest in stakeholder and public participation in environmental projects and related fields like ecosystem management, integrated watershed management, and planning, has been increasing for decades (Luyet, Schlaepfer, Parlange, & Buttler, 2012). There have been many phases of participation that have resulted in vast resources of best practices today (Reed, 2008). The World Bank (1996) describes participation as “a process through which stakeholders influence and share control over development initiatives and the decision and resources which affect them.” Some projects or initiatives choose to differentiate between stakeholders and the public because stakeholders can be seen as organized, while the public can be seen as unstructured and unorganized (Luyet, Schlaepfer, Parlange, & Buttler, 2012). Whether this distinction is made will vary from project to project.
Reed (2008) shows many examples of stakeholder participation improving the quality of environmental decisions, but he also states that “the quality of a decision is strongly dependent on the quality of the process that leads to it.” When seeking to involve stakeholders in a project, it becomes a matter of who to involve, when to involve them, and how to involve them. Each of the questions will be explored throughout this section.

**Benefits of Participation**

There are many benefits of stakeholder participation, which can be broken down into two categories: normative and pragmatic. Benefits for democratic society, citizenship and equity all fall under normative claims (Reed, 2008). An example is the ability to include members of society that are normally marginalized to promote active citizenship and benefit the wider society. The equitable inclusion of stakeholders promotes decisions that are more holistic and fair. These actions may serve to increase public trust in the decisions that are made. Involving these stakeholders also provides the opportunity for social learning, in which relationships are developed to provide an avenue for co-learning, trust-building, and seeing others points of view (Reed, 2008).

Principles like the quality and durability of decisions make up the pragmatic claims (Reed, 2008). For instance, it has been argued that interventions and technology are more easily adopted in the local context through stakeholder participation. Also, the inclusion of stakeholders can increase the quality of research and other inputs. If applied in the early stages of the project, the likelihood of success is increased because each step is more informed from the project design, to the gathering of information, to the priorities set, and to the decisions made (Reed, 2008). Furthermore, inclusion may lead to a sense of ownership, which should influence more sustainable outcomes.
While there are many potential benefits of stakeholder participation, there is growing concern that actual implantation does not live up to the claims (Reed, 2008). One major concern is the failure to identify and include some stakeholders, which can introduce bias in the project (Luyet, Schlaepfer, Parlange, & Buttler, 2012). Additionally, if participatory processes are poorly run and techniques provide minimal outcomes, it can lead to fatigue and people can become disinterested in participating. The credibility of stakeholders has also been questioned if it is perceived that their expertise is not sufficient (Reed, 2008). All in all, there is little evidence of the validity of these claims because evaluations tend to focus on the process instead of the outcomes of increased stakeholder participation (Reed, 2008). This should not discourage the participation of stakeholders in a project, but instead should highlight potential problems so actions can be identified in order to eradicate them.

**Framework for Participation**

Recently, there has been a shift in the ideology of how to approach participation. The “toolkit” approach, which relies on selecting relevant tools, is being replaced with a process-based approach to participation (Reed, 2008). This method focuses on participation as a long-term collaboration of people who use the toolkit to negotiate potential decisions. This section explains a framework for stakeholder participation (Figure 2-5), developed by Luyet, Schlaepfer, Parlange & Buttler (2012), which explores each stage of the process.
Before identifying stakeholders, clear objectives should be defined (Reed, 2008). Having clearly articulated goals is an essential part of the process. Beierle (1998) completed an assessment of “systematic ailments” of the environmental regulatory system. For example, a lack of public basic knowledge of environmental issues and public mistrust can cause conflict. The study recognizes public participation as a part of the solution to these issues and identifies 6 goals. The goals include: educating and informing the public; incorporating public values into decision-making; improving the substantive quality of decisions; increasing trust in institutions; reducing conflict; and achieving cost-effectiveness (Beierle, 1998). While these goals may not specifically relate to every project, they provide a good reference when identifying goals of stakeholder participation. This process of goal setting may take place as a part of stakeholder analysis, which involves three parts, including (1) defining aspects affected
by the decision, (2) identifying individuals or groups affected by or that can affect those aspects and (3) prioritizing the involvement of the individuals or groups (Reed, 2008).

It is essential to identify a process that will allow for the equitable inclusion of stakeholders. The technique(s) used to identify stakeholders will depend on the project context, the project phase and the available resources (Luyet, Schlaepfer, Parlange, & Buttler, 2012). There are several techniques identified in the literature. It can be done based on proximity, social values, urgency, and legitimacy. Some choose to differentiate between stakeholders with an economic interest or those motivated by principles (Luyet, Schlaepfer, Parlange, & Buttler, 2012). The snowball technique includes a form of brainstorming to identify stakeholders. And there are many more. But, as mentioned, the technique used should result in a collection of all stakeholders. In doing so, the complexity and cost may become too much, so finding the balance is necessary.

Characterization of stakeholders can be done to understand the relationship of power and each stakeholder’s interest in the project (Luyet, Schlaepfer, Parlange, & Buttler, 2012). Identifying power structures can decrease the likelihood of weaker stakeholders being discriminated against. However, this step can be optional for small-scale projects or where the number of stakeholders is limited. Characterization includes criteria like attitudes, potential conflicts and coalitions, interest, access to resources, political influence, degree of implication, power, urgency, legitimacy, and scale of influence (Luyet, Schlaepfer, Parlange, & Buttler, 2012). Another useful tool is to draw stakeholder maps to show links and relationships.
The next step is to structure the stakeholders into groups and identify the level of involvement of each (Luyet, Schlaepfer, Parlange, & Buttler, 2012). Some projects choose to distinguish public participation from stakeholder participation, but it is useful to characterize public involvement, as well. Public participation can be contributory, collaborative, or co-created (Miller-Rushing, Primack, & Bonney, 2012). Determining the degree of involvement is important because it gives influence to stakeholders, which can affect the process. This is often a task for project leaders but involving other professionals can improve the outcome (Luyet, Schlaepfer, Parlange, & Buttler, 2012). An adaptation of Arstein’s ladder for citizen participation was developed by Luyet, Schlaepfer, Parlange, & Buttler (2012) and includes the following degrees of participation:

- **Information**: explanation of the project to the stakeholders
- **Consultation**: presentation of the project to stakeholders, collection of their suggestions, and then decision making with or without taking into account stakeholders input
- **Collaboration**: presentation of the project to stakeholders, collection of their suggestions, and then decision making, taking into account stakeholders input
- **Co-decision**: cooperation with stakeholders towards an agreement for solution and implementation
- **Empowerment**: delegation of decision-making over project development and implementation

Participatory techniques can be determined once the degree of involvement and objectives has been identified. The choice depends on factors like type of stakeholder, local norms, past events, timing, and experience of facilitator (Luyet, Schlaepfer, Parlange, & Buttler, 2012). Figure 2-6 shows a number of techniques, along with each techniques level of involvement. Other characteristics that will help to identify the
mechanism used include the desired direction of the flow of information, the degree of interaction, the type of representation and the decision making role (Beierle, 1998). Figure 2-7 captures some of these characteristics and group techniques based on direction of information flow and degree of interaction. Choosing an inadequate or misguided technique can affect the success of participation. That being said, Reed (2008) found that success was influenced more by facilitator ability, communication with participants, clarity of goals, and quality of planning than by the choice of technique.

![Figure 2-6. Categorization of participatory techniques. The techniques are distinguished based on the desired direction of information flow and degree of interaction between opposing interests (Beierle, 1998).](image-url)
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Figure 2-7. List of participatory techniques with their degree of involvement (Luyet, Schlaepfer, Parlange, & Buttler, 2012)
Next is the implementation of the chosen participatory technique. Practices that will increase success include a clear establishment of the rules and providing any necessary information to stakeholders. The wrong choice of technique can increase frustration, mistrust, and lead to failure (Luyet, Schlaepfer, Parlange, & Buttler, 2012). As mentioned, the use of highly skilled facilitation can contribute more to the success than the tools used (Reed, 2008). Successful facilitation requires the technical expertise to use the tools, remain impartial, navigate group dynamics, suppress negative or domineering individuals, draw out new conclusions, and achieve the intended goal. The level of participation, intended outcome, and degree of difficulty can determine the level of expertise needed but sometimes the simplest methods can require the most skilled facilitator (Reed, 2008).

Evaluation is the last step in the process and is important because it can provide useful information for future projects, such as successes and failures. Evaluation criteria can be broken up into three groups: those related to the process, those related to the outcomes, and those linked to different contexts (political, social, cultural, historical and environmental) (Luyet, Schlaepfer, Parlange, & Buttler, 2012). A good evaluation should contain criteria from all three groups. Criteria related to the process include concepts like organization, communication, conflict resolution, transparency, equity, and more. Criteria related to the outcomes include accountability, capacity building, impacts, emergent knowledge, and social learning. There is no standardized method but criteria should be chosen based on the goals of the project and the purpose and timing of the evaluation (Luyet, Schlaepfer, Parlange, & Buttler, 2012).
The Basics of Mangrove Restoration and Climate Change

Threats of Climate Changes

Some of the impacts of climate change that can threaten mangroves include rising sea levels, strong storms, and changes in precipitation and temperature. Sea levels can rise by expanding ocean water and melting of mountain glaciers and ice caps (NASA, 2017). While changes will vary by region, global sea levels are projected to rise 1 to 4 feet by 2100 (NASA, 2017). Climate change impacts are interwoven together, where a change in one will affect all others. Local changes in sea levels depend on many other variables like changes in wind, currents, salinity, and temperature. Mangroves are sensitive to changes in inundation duration and frequency, as well as changes in salinity. Local variations of land subsidence and lift will also affect mangroves adaptability to sea level rise. According to Ward, Friess, Day & MacKenzie (2016), mangroves in micro-tidal areas are located at lower elevations and therefore at a greater risk to sea level rise.

Changes in storminess are less certain than predictions of sea level rise and temperature, but changes will vary by season and region. Globally, the intensity of winds from tropical storms is likely to increase (NASA, 2017). North Atlantic hurricanes are likely to become more intense and frequent as the waters get warmer. Unlike sea level rise, intense storms can be both destructive and constructive to mangroves (Ward, Friess, Day, & MacKenzie, 2016). Storms can be destructive because of intense wave action and wind. Fringe mangroves will be most affected and in the worst case a large scale loss of mangroves can result in peat collapse and decrease in soil elevation. This would decrease resiliency against sea level rise and increase the chances of further erosion.
While global average precipitation is predicted to increase, changes may increase or decrease rainfall in some areas and not change at all in other areas (NASA, 2017). Overall, heavy rain events and intensity of precipitation is likely to increase, especially in tropical and high-latitude regions. In the United States, predictions show northern states experiencing more rain, but overall heavy precipitation events are also predicted to increase. According to Ward, Friess, Day & MacKenzie (2016), the U.S./Mexico border is “projected to be the most sensitive to change with increasing future rainfall patterns.” Changes in precipitation leads to changes in salinity levels within the mangrove ecosystems; less precipitation leads to more evaporation, which increases soil salinity levels (Ward, Friess, Day, & MacKenzie, 2016). This results in a decrease in seedling survival, productivity, growth rates, and ultimately mangrove loss.

Temperature changes have an effect on each of the climate change variables discussed so far. Rising temperatures cause land ice to melt and waters to expand and this leads to sea level rise. Changes in temperature have an effect on precipitation and where storms take place, which can be destructive or constructive to mangroves. Average global temperature is predicted to rise within a range of 0.5°F to 8.6°F by 2100 (EPA, n.d.). As with other climate change variables, changes in temperature will vary by region and some areas may experience temperatures above the expected global average temperature. U.S. projections show extreme heat events are likely to increase in the southeast, midwest, and southwest, with a high chance of increased wildfires and drought in the southwest (NASA, 2017). When temperatures increase, mangrove species composition, phenology, productivity and latitudinal range of distribution will all be disturbed (Ward, Friess, Day, & MacKenzie, 2016). Mangroves will be able to
migrate north and increase distribution as temperatures in the northern states rise and freezing events lessen. However, other constraints like development and urban growth, may limit the ability of mangroves to migrate. *R. mangal* has been found at its most northern point on the Atlantic coast of Florida. If temperatures become too hot (about 38-40°C), photosynthesis ceases and productivity will decrease (Ward, Friess, Day, & MacKenzie, 2016).

While mangroves are at risk from these effects of climate change, there are some mechanisms that increase resiliency. Mangroves can modify their environment by changing the surface elevation or by migrating inland, which can fight impacts of sea level rise (Ward, Friess, Day, & MacKenzie, 2016). To control the surface elevation, mangroves can trap inorganic material and woody debris, produce autochthonous peat, slow water velocity with aerial roots, and algal mats trap and bind sediment. This varies widely by site. Storms can be constructive by introducing rapid sediment input and nutrient pulses (Ward, Friess, Day, & MacKenzie, 2016). Sediment input would help to maintain soil elevation to combat sea level rise and nutrient pulses increase productivity and growth, which could speed up recovery following the event. Some of the traits that increase species resiliency to storms include large nutrient reserves, rapid nutrient turnover rates, and tolerance to inundation and salinity (Ward, Friess, Day, & MacKenzie, 2016). And where precipitation is concerned, more precipitation and riverine discharge will result in more productivity and sediment inputs, which increases resiliency.

**Potential Mitigation of Coastal Ecosystems**

While there are some ways in which mechanisms can increase resiliency of mangroves, these ecosystems can also act as a mitigation tool to protect development
and populations along coastlines. Figures 2-8, 2-9, and 2-10 show the different processes of seagrass, salt marsh, and mangrove habitats that mitigate climate change. Mangroves defend the coastline by protecting against flooding, decreasing erosion, and sequestrating carbon. Burial rates of salt marsh, mangrove, and seagrass systems exceed terrestrial forests by 30-50 fold and account for 46.9% of total carbon burial in ocean sediments (Duarte, Losada, Hendriks, Mazarrasa, & Marba, 2013). While sea walls and other protective structures can protect coastal communities, there is a greater return when natural vegetated systems are utilized. Submerged (seagrass, kelp, macroalgae) and partially-submerged (mangroves, salt marsh) canopies both reduce flow and speed of wave action (Duarte, Losada, Hendriks, Mazarrasa, & Marba, 2013). These ecosystems provide a sustainable approach to coastal protection and they offer a wide array of ecosystem services, like providing food or habitat and increasing biodiversity. This is not the case with artificial approaches; they serve one purpose, to protect against flooding, and can in turn cause other unforeseeable issues, like erosion and jellyfish blooms (Duarte, Losada, Hendriks, Mazarrasa, & Marba, 2013).
Figure 2-8. Showing seagrass meadows capacity for climate change mitigation and adaptation. Blue arrows show transport of atmospheric or dissolved material. Red arrows show transport of particulates. Purple arrows show vegetation growth (Duarte, Losada, Hendriks, Mazarrasa, & Marba, 2013)

Figure 2-9. Showing salt marshes capacity for climate change mitigation and adaptation.
Figure 2-10. Showing mangrove forests capacity for climate change mitigation and adaptation.
CHAPTER 3
METHODOLOGY

Research Design and Techniques

This research will follow a qualitative research design. Unlike qualitative research, a qualitative research design is more flexible and is often non-linear in its implementation (Kumar, 2011). In turn, this form of study design can be seen as less clear and less structured than others but also allows for the flexibility often needed for the research to evolve throughout the process. The data gathered often comes from multiple sources, like interviews, documents, observations and audiovisual information, which will be reviewed and organized into common themes or categories.

The purpose of this research is to develop a framework for using a sustainability approach to ecological restoration. This framework will then be applied using a case study approach. While the origins of case study research are not found from a specific social scientific tradition, the ability to be applicable in both qualitative and quantitative research, as well as across many disciplines and research traditions, makes it a useful approach (Cohen & Crabtree, 2006). In a case study approach, the goal of the researcher is to understand the complexity and boundaries of a specific case or cases. This approach is ideal when the aim is to answer “how” and “why” questions (Baxter & Jack, 2008). For this research, the unique nature of the Fruit Farm Creek Mangrove Restoration project provided a great opportunity to explore its complexities and increase understanding about inquiry found in the field. There are many types of case studies, but for this research, the most applicable is intrinsic case study. In an intrinsic approach, the researcher’s intent is to better understand the case (Baxter & Jack, 2008). The
interest is not to understand a generic phenomenon or build theory but instead to highlight the interest in the case itself.

**Data Analysis and Tools**

Data collection and analysis for this research consisted of collecting multiple forms of data related to the case, the mangrove restoration project, and content analysis of the qualitative documents. There are different types of data that can be collected, such as observations, interviews, documents, and audio-visual materials. Observations can be done with the researcher participating in differing levels (Creswell, 2013). Interviews are also a useful tool in understanding historic information or when the participants cannot be directly observed. This can be done through face-to-face interviews, or by telephone, e-mail, or group interviews. Document content analysis is a convenient way to learn about a case because it can be obtained at the researchers’ convenience and serves as a written record of what has occurred. Such documents include public documents, like meeting minutes or archived data, primary sources, like journals or biographies, and secondary sources, like peer-reviewed journal articles, and books. Finally, audio-visual materials are another creative type of data that can be analyzed, which includes photographs, tapes, art, sounds, and film (Creswell, 2013).

While document collection and analysis is vital to this research project, the first step was to gain access to the mangrove restoration project. As mentioned briefly in the introduction, Fruit Farm Creek Mangrove Restoration Project is a multi-phase restoration located in Rookery Bay NERR (RBNERR) in Southwest Florida. Many groups collaborated on the project, including RBNERR (manages the land), the City of Marco Island (responsible for SR-92), the Trustees of the Internal Improvement Trust Fund (TIITF) (own parcels of the project location), Coastal Resources Group (project
restoration), RBNERR, USGS (data collection and analysis), Ten Thousand Islands NWR, and the local community. My access to the project came through an internship followed by a contractor position with USGS, under the supervision of Amanda Demopoulos. The steps to gaining proper access at USGS included a background check and various steps necessary to becoming a contractor. There were two site visits during the time of employment, one in July 2016 and in January 2017. Making the site visits possible required collaboration with RBNERR, since the sites and lab are under their purview. Logistics included working with Rookery Bay to have physical access to the lab and various tools needed in the lab, a place to store the samples collected, housing for the team, volunteer help from Rookery Bay, and having access to the sites during the day. Funding for the site visits was acquired through the USGS Environments Program. More detailed information about the funding for the whole project will be described in the Data Chapter.

In collecting data, the documents were gathered with the purpose of answering the research questions and objectives listed in the introduction, following the major themes of social, economic, environmental, and overall sustainability. To increase understanding of social sustainability, visual or written records of public meetings were analyzed, along with reviewing the website(s) for any public outreach. For economic sustainability, information was gathered from project reports and relevant websites. Environmental sustainability content included project progress reports published by Coastal Resources Group and any relevant USGS reports detailing metrics used for evaluating success and current progress of the sites. Observations made while on site during the two visits provided some insight into social and environmental sustainability.
The analysis of these multiple sources of data was done in order to identify strengths and/or weaknesses of each of the major themes of sustainability. All of this was done in order to give recommendations with the hope to increase the longevity and overall success of the project. In the case of Fruit Farm Creek, this means achieving functional equivalency of the mangrove ecosystem.

When collecting mainly online sources of data, it is possible that a complete understanding will not be achieved. If this were to occur, holding interviews may be necessary. To do this, it is required to go through the proper IRB procedures. The procedures include completing training and completing the application. Possible candidates for interviews include Amanda Demopoulos, Jennifer McClain-Counts, and Jill Bourque (each involved with the project through USGS) and Roy Lewis, founder of Coastal Resources Group, mangrove restoration expert and principle investigator of the Fruit Farm Creek project. Interviewing Mrs. Demopoulos could give more insight into the environmental components, as well as the collaboration between USGS and Rookery Bay. She also may be able to give more complete information about the funding sources of the work done at USGS. Interviews with Mrs. Demopoulos, if needed, will take place in person. If unavailable, Mrs. McClain-Counts or Bourque will be contacted. An initial set of questions will be developed but the interview will be casual and may not strictly adhere to the prepared questions. Mr. Lewis has been involved in the project from the beginning, so he may be able to fill in any gaps of information from the early stages of the project. Possible gaps include initial funding sources, public involvement from the beginning and any information about the planning stage of the project. If an interview with Mr. Lewis is needed, the interviews will take place via e-mail or phone call.
because he is located out of town. A list of questions would be sent via e-mail for response but a phone call would be more casual to allow for the conversation to flow naturally. In the end, interviews were not needed for this research.

**Limitations**

As with all types of research designs, there are certain limitations found in a qualitative design. The nature of qualitative research is emergent so it is important for the researcher to explore how any biases or values may shape the direction of the study (Creswell, 2013). In this case, the biggest challenge will be to find enough data. The direction of the case study, such as construction phases and site visits, are set in advance and cannot be biased by this research project.

According to Creswell (2013), there are other limitations to be aware of when collecting data. In interviews, the information is likely gathered in a place other than the natural field setting and not all people are equally perceptive. Also, the presence of the research may bias the testimony of the interviewee. For this project, gaining access to the desired interviewees may be difficult as Amanda Demopoulos and Roy Lewis are both extremely busy. When gathering documents, some information may be protected and unavailable to the public. It can also be time consuming for the researcher to search out some documents, as well as transcribe the information for computer entry. Finally, some materials may be incomplete or inaccurate so it is important to have steps in place check the validity. For audio-visual materials, it also may be difficult to access the materials and/or interpret the material.
Figure 3-1. Methodology Map
CHAPTER 4
DATA

This chapter will contain an analysis of the Fruit Farm Creek Mangrove Restoration Project. The economic, ecological, and social aspects will be analyzed in order to assess the sustainability of the project. This information will include an overview of the project, discussing background information, the restoration plan and other information about USGS involvement, funding, and partnerships.

Figure 4-1. Reference Map showing the Fruit Farm Creek Site location along SR-92, RBNERR, surrounding cities, and Collier County (created by Kristin Buckingham).
Fruit Farm Creek Project Background Information

The Fruit Farm Creek Mangrove Restoration project area is located in Collier County along SR-92 between Marco Island and Goodland, shown in Figure 4-1 (Coastal Resources Group, Inc., 2011). The project area is located within the larger RBNERR, which is approximately 110,000 acres of mixed coastal uplands and wetlands located in Naples, Florida. Fruit Farm Creek makes up an area of approximately 250 acres of dead, dying, or severely stressed mangroves and is part of a much larger estuary. There are a number of stress indicators, including aerial roots growing on the trunks of large black mangroves, accumulations of elemental sulfur and sulfur-reducing bacteria, adventitious roots growing on black mangrove pneumatophores (an aerial root) (Coastal Resources Group, Inc., 2011). Within the project area there are three visible die-off areas, which total 64 acres of the total area (250 acres); die-off Area #1 is 4 acres to the north of SR-92, Area #2 is 50 acres and Area #3 is 10 acres, both to the south of the road (shown in Figures 4-3, 4-4, and 4-5). While these die-off areas are characterized by dead trees, the surrounding area, an additional 800 acres, is impaired due to a lack of connectivity and if left alone could result in an expansion of the dead zones. Altogether, this means a total area of 1,025 acres of impacted mangrove forest, including all the flora and fauna that exist there, can benefit from the hydrologic restoration project (Lewis III, 2013).

The cause of the degradation can be linked to the construction of SR-92 in 1938, which cut off the hydrologic connection and tidal flow to the mangrove system (Coastal Resources Group, Inc., 2011). Field investigations were conducted in 2010 by the Coastal Resources Group to determine the exact cause of the degradation, including topographic surveys, hydrologic data collection, and documentation of historic changes.
Through the field investigations, the researchers identified the lack of hydrologic flow from tidal creeks branching off of Fruit Farm Creek was due to inadequate culverts under SR-92 (shown in Figure 4-2). Original construction plans identify five culverts that were to be placed throughout the project area section of the road but only one was actually installed. The investigation also showed that the single existing culvert was being blocked by debris and not functioning adequately.

The mangroves began to show signs of stress in 1992 following Hurricane Andrew and started dying in 1995 following another major rain event (Coastal Resources Group, Inc., 2011). Too much rain puts stress on the trees because the water covers the part of the tree needed to deliver oxygen to the tree and stimulates the build-up of toxins in the soil; the trees essentially begin to drown (Coastal Resources Group, Inc, n.d.). Another byproduct of toxins in the soil is a rotten egg smell that can linger to surrounding residential areas. The culverts are intended to allow the water in and out and also allow for the dispersal of seedlings. An inadequate amount of culverts and blockages in the existing culvert is the cause of the degradation, but also provides a basis for designing a restoration plan.

**Restoration Plan**

Overall, the project has many components, including field investigations, permitting, educational components, construction, and monitoring, some of which has yet to be completed (Coastal Resources Group, Inc., 2011). A grant from the U.S. Fish and Wildlife Service (USFWS), as a part of the Coastal Program, prompted the start of the first phase of the project, which included the research and field investigations, educational components, and preparation and submittal of the permit applications,
Figure 4-2. Image showing tidal creeks A-E, the three mangrove die-off areas and the one existing culvert. The lack of flow from tributaries A-E, which branch off Fruit Farm Creek, resulted in the three die-off areas. The absence of adequate culverts along SR-92 has disrupted the historic flow of the tidal creeks (Coastal Resources Group, Inc., 2011).

Figure 4-3. Die-off area #1; approximately 4 acres (Coastal Resources Group, Inc., 2011)
Figure 4-4. Die-off area #3; approx. 50 acres (Coastal Resources Group, Inc., 2011)

Figure 4-5. Die-off area #3; approx. 10 acres (Coastal Resources Group, Inc., 2011)
among other steps. Field investigations took place from August to October of 2010. The full list of inventory and project design tasks is listed below (Lewis III, 2013):

1. “Facilitate a coordinated restoration effort among identified project stakeholders”

2. “Perform background characterization tasks, such as topographic surveys, hydrologic modeling, and historical change detection, and prepare maps and reports from these tasks”

3. “Prepare a cost effective restoration plan to restore the hydrology to the largest possible area of damaged mangroves and impaired estuarine habitat”

4. “Prepare and submit a Joint Environmental Resource Permit (ERP) and Federal Dredge and Fill permit application to the South Florida Water Management District (SFWMD) and the U.S. Army Corps of Engineers (USACOE)”

5. “Coordinate permitting with the City of Marco Island as needed”

6. “Coordinate permitting and review agency comments and respond to requests for additional information (RAIs) through the issuance of the ERP and Federal Dredge and Fill permits”

7. “Conduct a three-day workshop on “Mangrove Forest Ecology, Management and Restoration” on-site for interested stakeholders, agency personnel and RBNERR staff”

8. “Incorporate up to ten (10) “young professionals” from area schools, colleges and/or universities in an on-going program to develop hands-on capabilities in restoration project design, implementation and monitoring for the life of the project”

9. “Prepare construction drawings for the permitted project”

10. “Assist with bidding and contractor selection for the actual restoration work”

11. “Supervise construction work and compliance reporting”

12. “Conduct monitoring of the project in conjunction with the “young professionals” team (underway with the Conservancy)”

13. “Make adjustments to the restoration plan as data on the success of vegetation establishment and faunal use are collected and analyzed”

14. “Prepare and circulate regular reports on the progress of the project”
There are three phases of construction outlined in the restoration plan (Lewis III, 2013). The phases correspond with the three die-off areas: Phase 1a with die-off Area #1 (4 acres), Phase 1b with Area #3 (10 acres), and Phase 2 with Area #2 (50 acres) (Zysko, Evans, & Lewis III, n.d.). As a part of the initial USFWS grant, plus an additional grant and other donations of money and services, steps 1-8 were completed as a part of Phase 1a, which was completed in September 2012 (Lewis III, 2013). This phase involved the construction of 360 linear feet of tidal channel. Before construction, the Restoration Team had to identify stakeholders, acquire multiple permits, complete background research, and prepare a complete restoration plan. As a part of gathering background information, topographic and bathymetric surveys were used. To get initial data about hydrology and tidal flow, hydrologic monitor devices (HOBO Meters) were placed throughout the project area. Monitoring of the 4-acre site began following construction.

To date, Phases 1b and 2 have not been completed due to a lack of funding. To complete these phases, steps 9-14 will be followed again. The proposed restoration plan, listed in step 3, is the guide for Phases 1b and 2. The plan outlines nine elements ranging from installation of culverts, removal/trimming of mangroves, excavation, and more (shown in figure 4-6). It follows the principles of EMR, where the actions taken are designed to allow the natural system to restore itself through restoring the tidal flow. By using this method, no physical planting would be necessary on any of the sites. The plan also includes a full restoration monitoring program with the following ten reports: Time Zero, and Time Zero + 3, 6, 9, 12, 18, 24, 36, 48, and 60 months (Lewis III, 2013).
The final report to be completed for Phase 1a (4-acre site) is the Time Zero + 60 Months Report to be done in October 2017.

To fulfill the education requirement of the USFWS Coastal Program grant, the project held a three-day workshop and set up a “young professionals” program (Lewis III, 2013). The workshop “Mangrove Forest Ecology, Management and Restoration” was conducted in January 2011 at RBNERR. The workshop was intended to engage and educate interested stakeholders, agency personnel, and NBNERR staff about mangrove restoration and the Fruit Farm Creek project. To engage local, young professionals, the project gave students from local schools and universities the opportunity to “develop hands-on capabilities in restoration project design, implementation and monitoring for the life of the project” (Coastal Resources Group, Inc., 2011). One such instance is the continued monitoring of the project after construction was completed, in conjunction with the Conservancy of SW Florida, such as the upcoming Time Zero + 60 Months Report.

**USGS Involvement**

Following the completion of Phase 1a, the project’s lead contact Roy R. Lewis III and founder of Coastal Resources Group, Inc. requested the assistance of USGS. The principle investigators from the USGS Wetland and Aquatic Research Center (WARC) are Amanda Demopoulos, in the Gainesville, Florida location, and Ken Krauss, in the Lafayette, Louisiana location. USGS efforts are split between the two locations and are completed in coordination with RBNERR (Krauss, Cormier, & Demopoulos, 2013). Mr. Lewis specifically wanted to collaborate with USGS to install Rod Surface Elevation Tables (RSETs). The purpose of the RSET is provide highly-accurate measurements of
Figure 4-6. Fruit Farm Creek Mangrove Restoration Information and Plan. Figure used to briefly explain the project and its elements, as well as give some visual reference of some of the issues.
the relative elevation change of wetland sediments (Cahoon & Lynch, 2010). This
information can inform about the ability of a wetland to adapt to sea level rise. Amanda
Demopoulos and her team are responsible for setting up the plots and conducting field
collections and isotope analyses. Ken Krauss and his team are responsible for SET
work, mangrove forest measurements, and water level recordings.

A total of 15 study plots were set up as a part of USGS involvement, shown in
Figure 4-7 (Demopoulos & Krauss, 2016). Four plots were installed within the
hydrological restoration area and three control plots were installed at a reference site,
located outside of the restoration area (Horrs Island reference site). Within each site,
plots were placed in the dead mangrove zones, transition zones where mangroves had
begun to degrade, and reference zones where the mangroves were not visibly
impacted. RSETs were also installed in each of the zones, at each of the sites. A
number of collections were taken from each plot to track changes in forest structure,
benthic community trajectories, and surface elevation (through RSET measurements);
ultimately the overall progress of the restoration effort. These include forest structure
attributes (basal area, tree height, stem density by species), soil attributes (bulk density,
total carbon, total nitrogen, total phosphorus, and pore water Eh and salinity) and light
attenuation by the mangrove canopy using a irradiance meter (Krauss, Cormier, &
Demopoulos, 2013). Furthermore, flora and fauna are collected at each plot to examine
the benthic community and food-web structure using isotope analysis. Funding for
USGS involvement is separate from the FFC Restoration Project’s funding.
Figure 4-7. Map showing the locations of the 15 study plots. The blue dots correspond with the 4 acre restoration site and are referred to as Sites 1 and 2. The dark green dots correspond with the 50 acre die-off area and is referred to as Site 3. The yellow dots correspond with the 10 acre die-off area and is referred to as Site 4. The red dots correspond with the Horrs Island reference site and is referred to as Site 5A,B,C. The red star among the red dots shows the water level recorder. The green polygons depict land and the light blue polygons depict mangrove habitat. (Source: USGS)
Funding

The total project cost of all phases, including planning and research, is $1.94 million (Lewis III, 2013). This number could change as time goes on because of the need to reapply for permits. Of the total cost, $539,000 was received from in-kind cash donations and services. Phase 1a, including the inventory, project design, permitting, and construction, was completed using USFWS Coastal Program grant of $75,875 and $10,000 in local donations and $90,000 in locally donated materials and labor. A RESTORE funding application requesting the remaining $1.4 million was completed in 2013 but the project did not receive the funds. The RESTORE Act was established in July 2012 to providing funding, which can be utilized “to restore and protect the natural resources, ecosystems, fisheries, marine and wildlife habitats, beaches, coastal wetlands, and economy of the Gulf Coast region” (Gulf Coast Ecosystem Restoration Council, n.d.). The requested RESTORE funding was to be used to carry out the Proposed Restoration Plan (Figure 4-6) and complete the construction of Phases 1b and 2.

Funding for USGS contribution was awarded from the USGS Environments Program and amounted to roughly $495,000. These funds covered a four-year period, from October 2013 to September 2017, in which the investigators established the pre-restoration condition of the project and continued to monitor the restoration. The funds were distributed to each of the principles investigators, Demopoulos and Krauss, each performing different analyses. Additional funding has been requested to continue tracking the post-creation and restoration response, but has not yet been received (Demopoulos & Krauss, 2016).
In January 2016, a Chinese billionaire, Wenliang Wang, promised to donate $5 million to the project. An article in the Naples Daily News explains that even though Wang had never been to the site, he wanted to restore the mangroves (Staats, 2016). Though the donation was initially promised to the project, the funding fell through leaving the restoration project currently unfunded and uncompleted.

**Contributing Partners**

The principle investigator of the project is Roy R. Lewis III from Coastal Resources Group, Inc. (Lewis III, 2013). The co-investigator, Dorothea Zysko, is from The Ecology Group. Another lead partner in the project is RBNERR, which manages the site, along with the much larger reserve. Rookery Bay’s staff has contributed time and technical support throughout the project, including coordinating with USGS in planning, site selection, and fieldwork for the long-term assessment project (Krauss, Cormier, & Demopoulos, 2013). The project area is located within parcels owned by the Trustees of the Internal Improvement Trust Fund (TIITF) (Zysko, Evans, & Lewis III, Fruit Farm Creek Mangrove Restoration, n.d.). Also, the City of Marco Island is responsible for SR-92. Identifying each entity involved in the many aspects of the project, points to possible partners or stakeholders.

In the early stages of the project, the Restoration Team consisting of the project investigators formed a Steering Committee of project partners and stakeholders. The committee includes RBNERR staff, representatives from USFWS South Florida Ecological Services Office, the Conservancy for Southwest Florida, the Florida Fish and Wildlife Conservation Commission, the City of Marco Island, and representatives from the adjacent residential developments, Key Marco, and Steven’s Landing (Lewis III,
2013). The Restoration Team and Steering Committee worked together to confirm the project goals and outline the roles of each partner/stakeholder.
CHAPTER 5
DISCUSSION

This purpose of this chapter is to discuss the sustainability of the Fruit Farm Creek project in more detail and identify possible ways to increase sustainability. It will begin by describing the project benefits and current progress documented in the latest progress reports. Again, understanding the benefits of the project is an essential step in gaining support for the project. Then the economic, ecological, and social challenges and strategies for improvement are identified.

Project Benefits

Several benefits are outlined in various articles, funding applications, and reports about the project. General information about the positive impacts of mangrove restoration has been outlined in the literature review and is applicable to this project as well. This habitat provides a crucial nursery for a number of species that have commercial and recreational importance (Lewis III, 2013). Some such species include the endangered smalltooth sawfish, and others like snook, mangrove snapper, stone crab, oysters, and more, which all have commercial value. Mangroves also provide important foraging and roosting areas for many bird species that draw tourists to Florida every year, like the roseate spoonbill, great blue heron, snowy egret, and more. Furthermore, it is presented that mangrove restoration will enhance the resiliency of the community (Lewis III, n.d.). By improving the hydrology, the estuary has a better ability to adapt to rising water and sea level rise. Once the hydrology of the area is restored and the health of the mangroves improves, this allows for natural increases in soil and plant elevations over time.
Economically this project is creating a minimal amount of jobs, as long as funding is available, and positively impacting the local economy. If funded, the project expects to employ 10 people, both full time and part time (Lewis III, n.d.). Also the economic impact to the local economy, if completed, is expected to be $5,000 per acre per year restored or preserved, which could total more than $5 million (these figures include the ecosystem services) (Lewis III, n.d.). Collier County and Marco Island both have seasonal economies, which rely on tourism and “snow bird” residents that spend the winter months in the warmer weather. Real estate is one of the top four industries in Marco Island, along with retail, accommodation and food services, and health care (GIS Planning Inc, 2017). Healthy, thriving natural resources positively affect real estate values and help drive tourists and recreationalists to the area.

**Current Progress**

The most current published report of progress is the Time Zero + 36 Months Monitoring Report. The report is focused on the completed Phase 1a (4-acre site) and is separate from USGS analyses and reporting. There are four sampling locations on the site, shown in Figure 5-1, 1D and 2D in the die-off area and 3A and 4A in a nearby reference area (Zysko, Worley, Lewis III, & Flynn, 2015). Figure 5-2 shows a progression of the restoration from 2012 to 2015, the photos taken near the constructed tidal channel. The growth occurred from natural colonization of primarily black and white mangroves, among other vegetation, and shows a significant increase in ground cover and height of the mangroves.

As seen in the literature review, restoration of mangroves can take many years to reach functional equivalency of a healthy mangrove system. The approach of natural regeneration through fixing the hydrology is not commonly used, but this research aims
to analyze the cost-effectiveness of the hydrology-only approach. As the figures below show, the restoration of Phase 1a is showing results. No tree canopy cover is currently present in the die-off sites, but ground cover is increasing (Zysko, Worley, Lewis III, & Flynn, 2015). There has also been an increase in the numbers of observed individual invertebrate species, which is a major change from previous samplings. In the reference sites, there has been an increase in ground cover with no major changes in species composition or canopy cover (from the Time Zero + 24 Months Report to the 36 month report). Initial findings from the USGS study also show signs of recovery. According to the findings, the restored hydrology regime may be facilitating recovery in the ecosystem. The maturing of the mangroves and development of detritus is “allowing for the trophic pathways in the degraded and transition zones to be more similar to reference areas” (Demopoulos, Bourque, McClain-Counts, Cormier, & Krauss). Recovery of the infaunal communities has been documented and is likely linked to the restoration efforts.

Figure 5-1. Sampling locations in Phase 1a, 4-acre site (Zysko, Worley, Lewis III, & Flynn, 2015)
Figure 5-2. A-D) Phase 1a, 4-acre site restoration progression from September 2, 2012 to September 16, 2015 (Zysko, Worley, Lewis III, & Flynn, 2015)
Project Sustainability

Economic

The lack of funding to complete the next phases of construction is the largest obstacle of the project. The initial funding acquired to complete Phase 1a construction is a fraction of what is needed when looking at the whole project. When the RESTORE funding was not awarded and the promised $5 million donation from Mr. Wang fell through, it left the project at a standstill. From the beginning, the project had a large presence of willingness to donate time and services from the Restoration Team and Steering Committee members, with some interest from the public to gather cash donations. Much of the initial planning sessions and Steering Committee meetings were accomplished through donated time, which is why there is little documentation of the planning process.

A possible solution is to collaborate with the local universities and colleges to develop more than hands-on capabilities in restoration. This could involve sponsoring an internship program where the students seek out grants and funding opportunities, either through the “young professionals” program or otherwise. Grant writing is a marketable skill for students to have when entering the workforce, especially for urban planners. The students would have the time to seek out-of-the-ordinary connections, which could produce a “blessing from heaven” as was the case with the Chinese billionaire, Mr. Wang (Staats, 2016). It would be wise to seek students from multiple disciplines that could truly benefit from such experiences.

Another avenue of funding to be further explored is the Marco Island community. Marco Island is a wealth community that takes pride in its beaches and natural landscapes. These resources provide recreation opportunities, like kayaking through the
mangroves, and tourist destinations. Driving by dead mangroves on the trip into this beautiful community can be seen as an eye sore. It would take some marketing to reach the larger Marco Island community. The marketing should make the citizen aware of the issue and the benefits of the ecosystem, inform about the cost of restoration, and push them to get involved by donating. An example of this would be to explain how their money would be used and what affect it would have. These ideas relate back to the idea of providing a strong justification for funding.

Since the USGS work and funding are essentially separate from the restoration project, the future of the monitoring and analysis work has a more positive position. The team currently uses volunteers and paid student contractors, along with volunteers from Rookery Bay, to assist with field work and analysis of the samples collected. The study has put itself in a good position to establish the pre-restoration condition of the sites. Even if Phases 1b and 2 are not completed, USGS is in a good position to track the long-term changes of the sites. In the future, it would be a good idea to collaborate with other studies to provide the long-term data. The data, especially the RSET data, would be useful to understand how climate change and particularly sea level rise might affect mangroves, as well as how mangroves and wetlands have the potential to increase community resilience. The information will become more and more sought out as cities and counties seek alternative measures to fortify their communities. Also, it is important to remember that degradation in the Fruit Farm Creek mangroves began to show following two major rain events, one being Hurricane Donna. It is predicted that storm intensity and duration is going to increase due to climate change, so this could become a serious factor in the future health of the mangroves. Climate science, resilience, and
adaptation initiatives and programs may also provide a great funding opportunity for the project, especially following the recent Hurricane Irma.

**Ecological**

The outlook from the ecological point of view is a more positive one. This project does a great job of identifying actions that benefit the whole ecosystem, not just the degraded mangrove trees. The progress reports from Zysko, Worley, and Lewis, as well as the USGS findings, show that even though the project is at a standstill, the restoration efforts completed are working. The project has the unique opportunity to report about the effectiveness of hydrology-only restoration and the EMR approach. As shown in the literature review, historically there has been a misconception that planting seedlings is necessary in mangrove restoration projects. But recent literature has shown that method is often most costly due to the low level of success.

The ability of the project to remain relevant relies on funding and the continual assessment and adjustment when necessary. Looking back at Figures 2 and 3, both models include monitoring/evaluation and adaptation in the ecological restoration process. It is essential to monitor the progress and make changes when progress is slowing or reversing. Another step presented Figure 2, the model by Bosire, et al. (2008), is to give recommendations for improved site management. Relaying the findings to RBNERR would help to increase the ecological sustainability of the Fruit Farm Creek site but also the entire reserve. The ability of the reserve to make well-informed decisions, moves beyond the science and results in actions that enhance the management of a large and important natural area.
Social

It is difficult to fully analyze the social aspect of the Fruit Farm Creek project. This is mainly due to the lack of documentation of the social process: how the stakeholders were identified and characterized; the identification of roles for each stakeholder; record of the meetings where project decisions were made; and the record of public involvement. The project involved collaboration between many entities, including federal, state, and local agencies and representatives. Inclusion of many disciplines, as well as the public, has been shown to increase the success of ecological projects. In this case, there is a strong presence of expertise with a wide array of disciplines. This has contributed to the success of the restoration plan, even though the project is only partially completed.

Public awareness of the project came from the visibility of the dead mangrove areas. Marco Island is a wealthy area and dead vegetation does not provide a peaceful, sightly landscape. Also the “rotten egg” smell creates an issue for the surrounding residential developments. It is these reasons that urged representatives of the community to get involved with the project and raise some funds, a total of $10,000. While some documents say these representatives will “directly assist in the public education outreach component of residents living in their communities” there is no documentation of how this was to be done (Lewis III, 2013).

Engaging the community, those directly affected and in surrounding areas, is a crucial step in gaining support for the project. The initial excitement of the project has worn off, and therefore support is dwindling. The project could do a better job of identifying and documenting how the public could be involved in every phase of the project. One way to increase support is to boost online engagement. The project’s
website could be more inviting and robust. While some of the information is clear, other information is out of data and missing. This is especially prevalent in the News! tab where many of the links do not work. The realm of social media could also be explored to keep people informed and interested in the project. For instance, creating a space, through Instagram, Facebook, or Twitter, where people can post pictures or testimony would drive interest for the project. Using the RBNERR connection through social media would also broaden exposure. Changing and updating the website does require time and money, therefore different opportunities should be explored. For example, maintaining the online presence could be tasked to an intern adept in computer skills.

The partnership with RBNERR is also a tool that can be used to increase awareness and support. Rookery Bay has a learning center, offers nature tours, provides learning opportunities for kids, hosts lectures and special events, and more. This provides a great opportunity for people to learn about the project, see what is being done, and become invested in the success of the project. Site visits could be arranged to give people first hand experiences of the degradation and restoration progress. If the remaining phases of the project are not funded and completed, there could be a shift in the goal. One option would be to search for ways to take the science and expertise available and use it to change perceptions about mangrove habitats and restoration efforts to create a lasting impact within the local community and surrounding areas.

**Applying the Sustainable Design Approach**

Findings from this research have shown the need for a sustainable approach to ecological restoration and resulted in a framework for analyzing the sustainability of projects. Through analyzing the Fruit Farm Creek project, a number of recommendations were made. But when increasing the scale, these concepts can have
a great impact on the management of Rookery Bay NERR. These concepts are applicable to the management plan and accompanying initiatives, as well as various projects located within the reserve. Rookery Bay has a great opportunity to partner with projects that apply sustainable design, which can only contribute the long-term health of the natural resources within the reserve. In the case of the Fruit Farm Creek project, the resources of Rookery Bay vastly increase the chances of success for the project, if fully utilized. This will take interest and willingness of the reserve to identify opportunities that can benefit the project, some of which were discussed above.
The urban landscape is continually encroaching on the natural landscape and there is a constant struggle between environmental protection and urban growth. Natural ecosystems are constantly degrading because of human impacts. While it has been well documented than mangroves provide many benefits, both to humans and the organisms found in the ecosystem, there has been a dramatic loss of global mangrove cover in the last half century. Ecological restoration projects around the world are attempting to remedy the situation.

The focus of this research has been to assess the sustainability of one such project. The Fruit Farm Creek Mangrove Restoration Project is located in Southwestern Florida, at the edge of Marco Island, within the Rookery Bay NERR. The project is using the Ecological Mangrove Restoration approach to restore 64 acres of dead mangroves and halt the potential degradation of a total of 1,025 acres of mangrove ecosystem.

In analyzing the sustainability of the project, the economic, ecological, and social aspects were examined. Ecologically, the project is showing signs of progress. Both the Fruit Farm Creek and USGS projects have documented beginning stages of recovery. This is especially evident in the 4-acre site. The lack of funding is the most substantial barrier to the completion of the project, as it is currently unfunded and unfinished. Attaining funding takes time and resources so out-of-the-box solutions should be explored, which could result in a “blessing from heaven” outcome. Documentation of the progression of the project, from start to finish, is necessary. As time goes by, monitoring and analyzing progress is important to determine if adjustments need to be made. Documentation also informs future projects so the continual implementation of bad
practices is not repeated, which has historically been the case. Collaboration across disciplines and expertise, and involving the public plays a role in the success of the project. Exploring different opportunities with stakeholders and the public contributes to the awareness and interest of the project. The concepts discovered in this research offer exciting opportunities for management of Rookery Bay NERR.

There is much to learn from the Fruit Farm Creek project, as well as other ecological restoration projects, especially when concerned about climate change and adapting to sea level rise. This study, along with the USGS study, can inform future research about how healthy mangrove ecosystems can adapt to sea level rise and increase community resiliency.
LIST OF REFERENCES


BIOGRAPHICAL SKETCH

As a transfer student, Kristin started her schooling at the University of Florida in the College of Design, Construction and Planning by receiving her Bachelor of Science in Sustainability and the Built Environment. Following that, she graduated as a Master of Urban and Regional Planning. While attending school, she worked at the U.S. Geological Survey, which inspired the topic for this thesis. Working at USGS provided Kristin with an invaluable experience learning about mangrove restoration and the planning it takes to successfully complete an ecological restoration project.

Throughout her master’s schooling Kristin was involved in a number of emergency management projects. She was a part of a team of UF students tasked with auditing Manatee County’s Post-Disaster Redevelopment Plan (PDRP). She is also participating in a project developed to document the informal emergency management processes for the City of Cedar Key. For this project, she presented preliminary findings at the Sierra Club’s Cedar Key Climate Conference.