The Political Ecology of Community-Based Management of Coral Reefs in the Caribbean

by

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Foreword

Having entered the MES degree program with a BES in the environmental management stream, my approach to the plan of study and major paper has been fundamentally informed by an interdisciplinary approach to conservation management. For this reason, this major paper is an amalgamation of both academic literature and primary qualitative research. This paper identifies and discusses challenges and opportunities for community-based coastal resource management in the Caribbean. During the development stage of my plan of study (POS), I sought to understand the factors that affect coral reef restoration projects using political ecology as a framework. The components of the area of concentration and learning objectives in my POS are listed as: political ecology of reefs, reef ecosystems, protected area management, and community outreach and education. Now that I have reached the culmination of my program, it is clear that I remained focus on these components as each have served as a section in my major paper. While elements of my learning strategies evolved from what was laid out in the POS, my research remained well within the area of concentration and the contours of the currents of thought and practice. Throughout my courses during the MES I and II, as well as my field terms during the MES III, certain aspects of my education resonated strongly with the objectives of my research, resulting in a slight shift in focus toward community-based management of coastal resources as the central theme of my major paper.

Abstract

Coral reefs provide numerous benefits to coastal ecosystems and communities in the Caribbean as a source of food and subsistence, as well as shoreline protection against extreme weather events and land erosion. In recent decades, corals of the Caribbean have suffered vast declines due to the increased prevalence of natural disasters and human-induced pressures. Coral cover loss has severe implications for coastal and rural communities of small island developing states (SIDS) in the Caribbean. The rapid decline of coral may be mitigated if effective management strategies are employed. The majority of the literature that informs coral reef restoration tends to focus on the ecological rather than human dimensions of reefs, creating a 'nature-culture' split. Restoration projects need to be approached using a framework that links social system structural traits, human activities, ecosystem services and human well-being. This paper uses political ecology as a theoretical framework through which to understand the current social, cultural, political and economic factors impacting community-based management of coral reefs in the Caribbean region, taking a specific look at Grenada's Coastal Ecosystem-based Adaptation (EbA) program for SIDS. This project is explored and evaluated using theories in political ecology, specifically Tighe Geoghegan and Yves Renard's four key lessons of direct relevance to the relationship between protected areas and local communities in the Caribbean. Understanding how these factors affect the success of conservation management is crucial, not only during the project design and planning stages, but also during the implementation and evaluation phases, and will ensure that coral reef conservation is sustainable in the long-term.

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Introduction:

The Caribbean Sea is home to about 9% of the world's reefs, but only around one-sixth of the coral cover remains. The biographic region that contains Caribbean coral reefs is commonly known as the 'tropical Western Atlantic' and extends from the Bahamas in the north through the Caribbean Sea proper and the North-East coast of South America. The region also includes the waters of the greater and lesser Antilles. Caribbean coral reefs consist of a unique collection of stony coral species which are home to variety of other indigenous species. These reefs provide numerous benefits to nearby human communities, especially as a measure of shoreline protection from hurricanes and extreme weather events that frequent these waters. While the majority of Caribbean coral reefs are the fringing type, the Caribbean Sea is also home to 20 atolls and two "true" barrier reefs. The largest is the Mesoamerican reef, stretching 220 kilometres in length and runs along the coasts of Belize and Guatemala. The second barrier reef is located to the east of Nicaragua.

The Greater Caribbean is home to unique endemic coral reef biota, which is a direct result of the closing of the Isthmus of Panama approximately 3-4 million years ago, isolating the Caribbean from the Pacific Ocean. Consequentially, the diversity of Caribbean reef life is far less extensive than that of the Indo-Pacific. The Caribbean reefs are still far richer in biodiversity than any other marine habitat in the Atlantic Ocean, with about 65 species or hard corals and an estimated 500 to 700 reef associated fish species (Humann & Deloach, 2002).

Over the last 50 years, Caribbean coral reefs have suffered vast declines in live coral cover from 50-60% (in its baseline state) to less than 15% (Alevizon, 2015). The vacant space is increasingly occupied by a mixture of sponges, algae and bare substrate. The cause of wide spread declines in reef health can not be attributed to a specific cause, however it is widely suspected to be coral disease resulting from human impacts. Corals of the Caribbean have been severely impacted by disease outbreaks, which appear to be more prevalent after coral bleaching events associated with warmer waters and in locations exposed to local human pressures such as

decreasing water quality, extensive coastal development, overfishing, as well as direct and indirect impacts from tourism. (Reigl et al., 2009). These stresses combined with disease in sea urchins have driven a sustained, nation-wide decline in health of the Caribbean coral reefs over the last several decades (Gardener et al., 2003).

The rapid loss of coral has stark implications for human health and well-being in coastal communities (Adger et al, 2005) as some estimate coral reefs provide $30 billion USD annually in net benefits in goods and services to world economies (Cesar et al, 2003). Declines in coral reefs may be mitigated with proper restoration techniques (Precht, 2006), but a lack of funding and stakeholder cooperation, as well as ineffective project implementation (Rinkevich, 2008; Jones, 2014) pose significant challenges. While recognizing the intrinsic value and vulnerability of coral reefs, many Island states of the Caribbean have begun to develop Marine Protected Areas (MPAs) as well as increasingly tightened regulations in order to protect valuable marine resources. Unfortunately, current managers of many marine protected areas (MPA) and restoration projects have not given adequate consideration to local ecology, socio-economic realities or how to implement effective long-term management strategies (Rinkevich, 2008; Lundquist & Granek, 2005). Conservation objectives will continue to fall short if new, 'active' techniques of restoration and long-term management are not applied (Rinkevich, 2008; Kidd et al, 2011). Despite acknowledgement of the human role in coral reef deterioration, the majority of research focuses on ecological rather than human dimensions of coral reefs (Kittinger et al, 2012). This limits our understanding of social relationships with the environment and how they impact potential solutions for reef recovery (Kittinger et al, 2012).

In this paper I will discuss the social, political, cultural and economic determinants of success in reef restoration projects and MPA management. I will argue that in order to implement such projects as outlined in the planning phase, managers and governing agencies need to anticipate how these determinants will fit into the application of conservation efforts, either as an aid or a hindrance. In order to understand these relationships, project planning requires open

communication and feedback from stakeholders, and also requires public outreach and the flexibility to revise expectations as essential components of the planning phase. I will introduce the various aspects of coastal ecosystem management that need to be considered during the project design stage, starting with an overview of coral reefs. Understanding of the biological processes that are taking place on coral reefs and how various perturbations may compound to cause rapid degradation is crucial to selecting the appropriate measures to apply in conservation. I will move into the various reef restoration techniques currently practiced, and how current environmental needs, the availability of manpower and materials, and associated implementation costs may determine which techniques are applied to a project. I will then discuss the role of invasive species in Caribbean reef health and how community-based management can be used to mitigate impacts and empower communities. In the fourth chapter I will consider the role of environmental education and understanding our position within nature as it relates to the long-term success of community-based management of natural resources. In chapter five I will discuss at depth the political ecology of community-based coastal resource management and how the co-production of knowledge is often overlooked, leading to a lack of foresight in the application of successful conservation practices. Lastly, I will present my field work results in the form of a case study focusing on Grenada's coastal ecosystem-based adaption project. The project is an example of how community-based coastal resource management in the Caribbean is often carried out, and will discuss the various determinants that led to the eventual outcome of the project. I will then make recommendations based on interview feedback with community members that can provide insight to future project planning.

Chapter 1: Coral Reefs: An Overview

Introduction:

Coral reefs are vital ecosystems in tropical seas. Reefs provide a habitat, as well as nursing and breeding grounds for the majority of marine life. Reefs are highly productive and provide a major source of protein for humans living in tropical regions. Coral reefs support terrestrial life by providing shoreline protection and preventing land erosion. Reefs were first observed by humans in the late 1700s, although the inability to explore beneath the surface meant that they were not well understood until recent decades (Sheppard et al, 2009). Charles Darwin was the first naturalist to understand these geological features as impermanent structures because they evolve, grow and become reduced again through weathering over centuries rather than millennia (Rohwer, 2010). The development of scuba equipment has permitted the close examination of reefs and its species interactions over the last 60 years. Reefs have existed for eons, many built by other, now extinct groups of species (Sheppard et al, 2009). Reefs are biogenic in nature, meaning that they are formed by biological processes (Sheppard et al, 2009). They are a unique ecosystem in that they create their own substrate (Jones, 1994). The substrate are molecules that are acted upon by an enzyme, which means that reefs are able to catalyze their own formation (Jones, 1994). Reefs are made of limestone, mostly derived from the skeletons of corals themselves but some limestone is also derived from other marine life forms that have died and eroded into rubble and sand (Jones, 1994).

Corals belong to the phylum Cnidaria, which they share with jellyfish and sea anemones (Rohwer, 2010). Existing for at least 540 million years, Cnidarians have survived many environmental changes, including previous mass extinctions that (collectively) wiped out 99% of Earth's earlier species (Sheppard et al, 2009). This survival through the eons displays how corals are in fact extremely tough and adaptable creatures, despite common belief that they are fragile and highly sensitive to their surroundings. Rapid changes to marine ecosystems as a result of intense overfishing, climate warming, nutrient loading, and acidification have resulted in sudden coral mortality in recent decades. Despite their adaptability, these changes to marine

ecosystems have occurred more rapidly than corals are able to adapt to in such a short time span. This chapter will cover a brief natural history of the development of coral reefs, as well as provide an introduction to the types of corals that play an integral role in reef building. The paper will conclude with an explanation of how environmental stressors impact coral reef health and provide recommendations for improving reef resilience and protecting the various dynamic interactions that take place on coral reefs.

Ancient Reefs:

Over time, several different groups of organisms have developed reefs, all of which are able to extract calcium carbonate from water and deposit it in solid, skeletal form (Jones, 1994). In Precambrian times, which extended from 4.6 billion years ago to about 550 million years ago, stromatolites formed abundant reefs consisting entirely of bacteria-like microbes and can still be seen in calm, shallow waters with high salinity and temperatures, like off the coast of Western Australia (Sheppard et al., 2009). These structures trap and deposit sediments, some of which are now preserved as fossilized reefs (Sheppard et al., 2009), the oldest being about 3.5 billion years of age. Modern coral reefs consisting of assemblages of sponge-like invertebrates and eukaryotic 'stony' algae first appeared in the fossil record during the Cambrian period that began 550 million years ago (Sheppard et al., 2009). Brachiopods were the next to build reefs, these being closely related to the shelled animals that still exist today. Between the Ordovician and Permian periods (500 to 225 million years ago), bryozoans (primitive colonial animals of a tiny size), stromatoporoids (primitive sponges), tabulate corals and rugose corals all formed reefs (Sheppard et al., 2009). These extinct corals were cnidarians, but were not closely related to common corals seen today.

All of these species disappeared in the great extinction at the end of the Permian period, although the causes of ancient coral extinctions are not well understood (Sheppard et al., 2009). Most of these now extinct reefs can be seen in the form of geological structures inland, commonly making up low hills, cliffs and limestone structures (Sheppard et al., 2009). The

growth and erosion of reefs took place at different elevations, at different times. According to Daly's 'Glacial Control' theory, huge volumes of water periodically became removed from the global ocean, becoming locked up into ice caps (Daly, 1915). This left the reefs in shallow waters exposed above sea level. Reefs have also been elevated by violent tectonic forces (Daly, 1915). Exposure of corals to the elements, such as rain, would ultimately result in etching and erosion due to its acidic pH (Sheppard et al, 2009). While it was difficult to measure past sea levels accurately, it is increasingly realized that understanding past sea levels is critical to the explanation of coral reef formation and erosion.

Areas and Distribution of Reefs:

Reefs are tropical, bounded by the Tropics of Cancer and Capricorn (23.4^{o} N and S), requiring warm water and are limited to shallow water due to their reliance on sunlight for energy. Other controls on their distribution such as temperature and salinity will be further described later on.

Mapping of reefs and exact calculations of total areas have produced different estimates, partly because of differing methods of measurement, though rough estimates are available. Survey methods commonly used for estimating reef boundaries are satellite imagery and depth sounding (Spalding & Grenfell, 1997), both of which may not convey the full ecological extent of coral communities. Estimates of coral cover vary from 284,300 square kilometres (Spalding et. al., 2001), with 91% of this in the Indo-Pacific region, to 920,000 square kilometres (Costanza et al., 1997). Many reef biologists posit that due to limitations in data collection, it is plausible to suggest that anywhere from half a million to nearly one million squared kilometres is a reasonable estimate of the ecological extent of reefs (Sheppar et al, 2009). Indonesia is estimated to hold the largest coral cover on the planet, at 17.95% of the total world cover (51,020 sq. kms.). This is followed by Australia, holding 17.22% (48,960 sq. kms.) and the Philippines with 8% (25,060sq. kms.) of the total world coral cover (Spalding et al., 2001).

The most northerly reefs of the Indian Ocean and those peripheral to it are near Suez, at nearly 30 degrees north in the Red Sea (Sheppard et al, 2009). In the Pacific, the northern extent lies in the southern Japanese islands at 31 degrees north (Sheppard et al, 2009). In the Atlantic, Bermuda is home to the most northerly reefs at nearly 32 degrees north (Sheppard et al, 2009). These northerly extremes are only inhabitable due to local conditions such as warm northerly flowing currents. In the southern hemisphere, warm southward flowing currents allow for reefs to flourish as far south as South Africa at 28 degrees south and Australia, home to the southern most reefs in the world at 31 degrees south (Sheppard et al, 2009).

Types of Reefs:

The basic types of coral reefs are generally defined by their overall structure and the geological conditions under which they evolved (Ladd, 2012). These distinctions are often unclear because of the overlapping stages of their development (Ladd, 2012). There are predominantly three different types of reefs: fringing, barrier, and atoll, although marine scientists have argued that there may be up to five different types of reefs, including bank and patch reefs (Humann and Deloach, 2013).

Fringing reefs grow out from the shore or are separated by a shallow lagoon (Humann & Deloach, 2013). They generally parallel the coastline and at their shallowest often break or nearly reach the water’s surface. They are common around most Caribbean and Bahamian islands, but are virtually absent along both Florida coasts and the Florida Keys. Geologically, they are considered to be the youngest type of reef (Humann and Deloach, 2013). This means that most reefs develop first as a fringing reef and then evolve into either a barrier reef or an atoll when the land mass sinks or submerges.

Barrier reefs generally grow parallel to a coastline, but are separated by extensive distance and a relatively deep lagoon. The distance may vary from about one mile to 25 miles or more and

the lagoon may exceed 60 feet in depth (Humann and Deloach, 2013). At their shallowest, barriers reefs often break or nearly reach the waters surface, forming a 'barrier' (Humann and Deloach, 2013). The outer edge of a barrier reef drops from the island platform or continental shelf into very deep water (Humann and Deloach, 2013). The two largest barrier reefs on the planet are the Great Barrier Reef off the coast of Australia, and the Mesoamerican Barrier reef off the coast of Belize in the Caribbean Sea. Typically, fringing reefs turn into barrier reefs when their associated land mass and lagoon undergoes a slow geological sinking (Humann and Deloach, 2013).

Atolls are open sea reefs that form rings, ovals or horseshoe-shapes around a shallow lagoon (Humann and Deloach, 2013). Occasionally, small coral islands that support vegetation form as a part of the ring. On the outside the fore reef drops into deep water. Atolls are generally found in the tropical Pacific where large geological plates supporting volcanic peaks gradually sink (Humann and Deloach, 2013). Fringing reefs first form around volcanic islands. As the plate sinks, the reefs become more distant from the land and grow upward, forming barrier reefs. The final stage of an atoll's development occurs when the volcanic island is completely submerged, leaving the lagoon in its place (Humann and Deloach, 2013).

Bank reefs are open sea reefs, without a central lagoon, surrounded by deep water and are located miles from any land mass (Ladd, 2012). Patch reefs are small, isolated reef areas that grow up from the open bottom of the island platform or continental shelf (Ladd, 2012). They generally occur between the fringing reefs and barrier reefs (if present). A patch reef may vary in size from a small house to an area that could cover several city blocks. Depths also vary greatly, although the reefs crest rarely ever breaks the surface (Ladd, 2012).

Profiles and Zones of Reefs:

Despite the varying features of reefs, they tend to share a general cross-sectional profile. Almost all reefs which reach the surface today have a reef flat, a crest, and a slope (Gourlay, 1994, p.20). The reef flat typically extends out from the beach to where the reef begins to slope off into deeper water (Gourlay, 1994). Reef flats may become exposed at low tide and are rarely deeper than one or two metres (Gourlay, 1994). The flat also makes up the largest expanse of reefs and tends to receive the most sunlight. As a result, reef flats may also be vulnerable to dramatic increases in water temperature and decreases in salinity from rainwater. At the seaward edge of the reef flat is the reef crest. The reef builds and grows very actively in the crest as this is where the reef begins to plunge downwards (Gourlay, 1994). The reef crest is the area separating the flat and the slope. The crest is also the section of the reef that is most exposed to waves and is characterized by very few species of fast growing corals tolerant of wave action (Sheppard et al. 2009). Beyond the crest, the reef plunges steeply down. This section of the reef is referred to as the slope. Depending on water visibility, the slope can support corals to a depth of 50 metres or greater (Sheppard et al, 2009). The reef slope is considered to be the heart of the reef as this tends to be the region with highest diversity, growth and activity. Several factors define the zones of a reef slope. These factors include wave energy (which declines with increasing depth); light (also declines with increasing depth); sedimentation (increases with depth); and temperature (which may decrease gradually or suddenly in the presence of a thermocline) (Sheppard et al, 2009).

Reef Builders:

The main types of biota on coral reefs are corals, soft corals, sponges and algae (Rohwer, 2010). The ratios in which these groups appear on a reef vary depending on the ocean, water quality and the exposure to light of each region. Corals grow over a long period of time, beginning with a single coral polyp (Hatcher, 1997). While corals appear to be one whole entity, a single coral structure is actually made up of thousands of tiny, genetically identical coral polyps that band together to create a colony (Hatcher, 1997). Together the colony of thousands of polyps creates

the massive coral reef structures over a long period of time. A polyp shares a similar body plan to that of a jellyfish or anemones, which are members of the phylum Cnidaria (Hatcher, 1997). Cnidarians, like sponges, are considered to be the oldest animals on earth, however they have evolved very differently in comparison to sponges and contain numerous unique features such as two organized tissue layers, specialized cell types and a nervous system (Rohwer, 2010).

In order to picture what a single coral polyp looks like, imagine a small, inverted version of a jellyfish. A soft sac, only a few millimetres in diameter with a cylindrical shape characterized by a round bulb with tiny little tentacles. These sacs are made up of two layers: the inner layer (the endoderm) lines the internal cavity and functions in the digestion and absorption of food (Rohwer, 2010), and the outer layer (the ectoderm) which interacts with the environment (Rohwer, 2010). The ectoderm is also responsible for building the external skeleton around the polyp as protection. Each polyp attaches to the base of a reef skeleton with the tentacles facing outwards so that they can extend to capture prey for food such as zooplankton. Nematocysts, or poisonous barbs extend out from the polyp that sting or stun prey temporarily making it easier for the polyp to catch its prey (Rohwer, 2010). The coral's tentacles and surface cilia sweep the food into the sac where it is digested. There is a system of canals connecting the sacs within the coral colony so that neighbouring polyps can share the resources (Rohwer, 2010).

In order to produce large reef structures, corals consume large amounts of fuel in the form of sugar and carbohydrates. In order to meet this demand for food, corals partner up with single celled algae call zooxanthellae. Zooxanthellae share a symbiotic relationship with coral, living within the cells of its endoderm acting as the coral's internal farm (Rohwer, 2010). Like other algae, zooxanthellae carry out photosynthesis. Through photosynthesis, the zooxanthellae convert CO_2 and water into carbohydrates and energy rich sugars. Zooxanthellae also lend their vibrant colour to coral, which is the colour one sees when looking at a coral structure. Without the presence of zooxanthellae within, the coral would remain white in colour as can be seen in coral bleaching events which kill the algae (Rohwer, 2010). It is estimated that the

zooxanthellae transfer approximately 90-99% of their produced sugars to the coral (Rohwer, 2010). This amount of energy is necessary in order for the coral to grow and deposit its calcium carbonate skeleton fast enough to stay ahead of erosion (Rohwer, 2010). Certain types of corals grow faster than others, with the fast-growing varieties often referred to as reef-building corals. The most commonly found reef building corals are blue coral, organ pipe coral, soft coral and fire coral, although the actual species tend to vary between the different oceans.

Symbiotic Relationship Between Reef Builders, Protectors, and Cleaners:

Coral reefs are complex ecosystems composed of many interacting variables. While the coral polyps and their symbionts, the zooxanthellae have been already introduced, there are other important elements to coral growth and function. One important contributor to coral health is the microbes that live on the coral structure's exterior. Most of the biodiversity on a reef resides in the microbes, including one hundred or more species living with any one particular coral (Rohwer, 2010). The microbes that live on the calcium carbonate exterior of the coral act as a protective coating, shielding the structure from viruses and diseases. This is why scuba divers are strongly discouraged from touching corals, as even the swipe of a hand can remove some of this protective microbe-like coating, leaving small areas of the coral exposed and susceptible to illnesses like white band and black band disease (Humann & Deloach, 2013).

The term "coral holobiont" is used to encompass the coral animal itself and all of its associates: the microbes, algae, viruses and fungi (Bourne et al, 2009). Together they function as an entity, improving metabolism and the coral's ability to adapt to changing environments (Bourne et al, 2009). When one member of this holistic team is suffering, it impacts the productivity of the rest of the holobiont (Bourne et al, 2009). For example, if the coral loses its protective microbe coating, it can cause algae to attach itself to the coral structure. If the algae continue to grow and thicken, it will decrease the amount of sunlight that can reach the coral polyps. If the zooxanthellae are unable to receive sunlight they cannot carry out photosynthesis (Bourne et al, 2009). If photosynthesis is not taking place then there is a dramatic reduction in nutrients provided to the coral, thus limiting reef growth and production. This can also cause the coral to

become stressed and 'expel' the zooxanthellae from within the cell endoderm (Bourne et al, 2009). Once expelled, the zooxanthellae float away in the current and the coral structure begins to bleach (Bourne et al, 2009). If the coral is unable to attain a new group of zooxanthellae soon enough, this will result in death. Luckily all components of the holobiont work together to reduce the likeliness of this occurring (Bourne et al, 2009). Despite its efforts, the holobiont is not always able to adapt quickly enough to a rapidly changing environment.

In the next section, I will discuss common risks to coral reef health and main contributors to recent mass coral mortality.

Risks to Coral Health:

In the 1980s, the reefs around Jamaica quickly changed from teeming with colourful corals to an algae-dominated ecosystem (Rohwer, 2010). Since then, similar shifts have been seen on reefs around the world. This shift to algae domination has been correlated with local overfishing, nutrient loading, and unethical boating, fishing and diving practices.

Overfishing:

Most small fish that live on the reef act as reef cleaners, meaning that they feed off of the algae that grows on coral (Hughes et al, 2003). With this, the fish receive sustenance from the reef while keeping the algae population in check, which in turn allows sunlight to reach the coral and maintain the health of the coral. Species such as parrot fish (*Scaridae)*, cleaning wrasse (*Labridae*), and sea urchins *(Diadema*),among other herbivores, graze the larger, leafy algae that are predominately responsible for overgrowing the reef if otherwise left unchecked (Rohwer, 2010). These herbivores are eaten by larger predators, that are themselves eaten by yet larger predators. This relationship makes up the food web. All organisms on one level eat those on the level below them, and are eaten by those in the level above them. At the top of the food chain is the apex predator of the community. On coral reefs, sharks are the top apex predator, as well as the keystone species, meaning that their population is vital in maintaining

the balance of the ecosystem. Keystone species are good indicators of overall ecosystem health (Rohwer, 2010).

Overfishing has only become apparent in recent decades but fishing has likely been conducted at an unsustainable rate for last few centuries (Rohwer, 2010). Most drastically reduced are the populations of sharks (*Selachimorpha)*, snappers (*Lutjanus campechanus*), groupers (*Epinaphelinae*) and other large fish predators (Hughes et al, 2003). Populations of large vertebrates like turtles (*Chelonioidea)*, manatees (*Serenia)* and monk seals (*Monachus)* have also declined dramatically during this time (Hughes et al, 2003). By the 1960s, these larger species had become scarce forcing fishermen to start catching the smaller fish, including the reef cleaners (Hughes et al, 2003). With fewer cleaners to graze the algae off of the reef, populations of fleshy algae started to grow out of control. Algae produce energy-rich photosynthates (sugars and carbohydrates) that are released into the water as dissolved organic carbon (DOC) (Rohwer, 2010). DOC fuels the production of microbes on the reef, which when overpopulated, will kill corals through suffocation (Rohwer, 2010). This suffocation makes room for more algae growth, thus creating a positive feedback loop of algae and microbe overgrowth. This mechanism suffocated much of the coral reefs that are now barren, like those off the coast of Jamaica, and has been directly linked to overfishing (Rohwer, 2010). Even the reefs that did not face immediate threat of mortality experienced reduced resiliency, leaving them vulnerable to disease and mortality when other factors such as nutrient loading were compounded with reduced fish stocks.

Nutrient Loading:

Human activities add large quantities of nutrients like phosphate and nitrogen compounds to marine environments. Extensive field observations have linked nutrient enrichment to coral death. While short term adding of nutrients may not kill corals, it tends to have subtle, long term negative effects on coral health (Lapointe, 1997). Added nutrients stimulate increased algae growth, thus contributing to the positive feedback loop mentioned above. Excessive

nutrients in marine ecosystems typically come from industrial production, agricultural run off (chemical fertilizers) and sewage discharge (Lapointe, 1997). Even treated sewage stimulates growth of cyanobacteria and fleshy algal blooms (Lapointe, 1997). These added nutrients increase the amount of usable nitrogen in the world's oceans. Anthropogenic nitrogen is exported to coastal waters as ammonia (NH_3), nitrate (NO_3) and organic nitrogen. When these forms become exhausted, certain bacteria and cyanobacteria begin to 'fix' nitrogen, i.e., they convert N_2 into NH_3. Since the atmosphere is 78% N_2, surface waters have lots of dissolved N_2 available for fixation but the fixation rate may, however, be limited by low levels of other nutrients like iron which is a critical component of the N-fixing enzyme, nitrogenase. This usable nitrogen (N_2), contains two nitrogen atoms which are strongly joined together by triple bonds, making it impossible to use as a nitrogen source for organisms lacking the nitrogenase (Rohwer, 2010). There are only a few specialized bacteria which can 'fix' nitrogen, or in other words, break the bonds so that the nitrogen atoms can be combined with other elements. When sufficient iron is available, N fixation can supply additional N in the form of ammonia to an N-limited reef.

While increased nutrients may not directly kill corals, they produce more algal biomass. This produces more excess photosynthate that is released into water as DOC, which supports faster microbial growth (Rohwer, 2010). Overgrowth of microbes leads to suffocation of corals as they consume all the local oxygen. This leads to increased risk for coral disease and ultimately coral death. The increased algal growth from nutrient enrichment can be reduced through grazing by reef cleaners, and therefore nutrient loading would have a lesser impact on corals if the reefs were supporting abundant fish populations (Rohwer, 2010). This is how both overfishing, compounded with nutrient loading can be implicated in increased reef mortality. Both of these factors are further compounded by extreme weather events, unethical or unsafe fishing and boating practices, as well as increased recreational interactions between humans and corals (Rohwer, 2010).

Other Contributors to Reef Damage:

Extreme weather events such as hurricanes and tsunamis cannot be prevented, and sometimes cannot be predicted. Unfortunately, many of the planet's beautiful reef systems which took hundreds of years to grow have been permanently destroyed during a single hurricane (Bythell et al, 2000). Irresponsible boating practices such as dropping an anchor onto a reef patch or not adhering to in water traffic protocols have frequently resulted in boat on reef collisions, thus breaking and destroying century old coral structures (Barker & Roberts, 2004). This has become increasingly problematic with the rise of tourism in tropical regions with abundant shallow reef systems. Unethical fishing practices like dynamite fishing, in which fishermen intentionally blow up large reef structures or use harsh chemicals to temporarily stun fish have directly caused severe coral mortality (Hodgeson, 1999). These practices are frequently used in order to catch live fish for the aquarium industry. Even scuba divers have been implicated in disturbing reef productivity through touching and breaking corals or chasing away reef dwellers by coming too close to the coral (Barker & Roberts, 2004). As previously stated, these factors act together on an increasingly vulnerable reef, resulting in coral mortality (Rohwer, 2010).

Reef Resilience and the Role of Conservation:

Resilience refers to the capacity of an ecosystem to recover from disturbance without a shift in community structure (Knowlton, 2004). In the case of coral reefs, loss of resilience refers to reduced coral coverage, spatial heterogeneity, biodiversity, and connectivity (Nystrom et al, 2008). Subtle but cumulative changes in the environment, or severe conditions including recurrent disturbances from hurricanes, predator outbreaks or coral bleaching and disease events may cause a loss of resilience and large-scale, relatively rapid change from coral-dominated communities to less desirable ones (Goldberg, 2013). Such alterations in a community's composition is called a phase shift, which may lead to self-perpetuating algal dominated environments. Experimental evidence suggests that anthropogenic factors including overfishing, nitrification, and increased sedimentation exacerbate this change through positive feedback, causing coral recruitment failure.

The number of reefs that are being driven from a coral dominated state is increasing, for example, Caribbean reefs with a baseline of 2% algal cover in the 1970s are now 40% covered (Goldberg, 2013). Not only is algal cover increasing, but the disappearance of structure building corals like *Acropora* are resulting in reef flattening. There are only two frame-building species of *Acropora* in the Caribbean, which once composed 30-50% of coral cover at a depth of 20 metres; however, a series of diseases have placed them both on the endangered species list (Vollmer & Kline, 2008). This is the reason *Acropora* is so commonly used in reef restoration projects in the Caribbean region. Reef cleaners such as parrotfish play a prominent role in maintaining the stability of a reef ecosystem and are divided into three functional groups: excavators, scrapers and browsers (Goldberg, 2013). The first two clear algae from the substratum allowing recruitment by corals and are therefore especially significant in the Caribbean Sea where species richness and diversity of grazers is much lower (Goldberg, 2013).

One-third of all reef corals are now facing extinction, and coral coverage across the tropics has declined to less than half of what it was before 1980 (Goldberg, 2013). This trend of rapid decline has prompted government agencies and environmental managers to look towards the creation of sanctuaries, reserves, and marine protected areas (MPA). Setting aside areas where reef species can enjoy protection from direct human influence is a widely recognized objective for conservation of biological resources. Areas that restrict recreational activities or fishing may be called reserves, sanctuaries, marine protected areas (MPA) or “no-take zones.”

Marine protected areas are a key element in the protection of coral reefs, unfortunately many are protected in name only (Goldberg, 2013). MPAs can be vital to maximize management and conservation goals and many have been notably successful, especially when adequately staffed. This can only happen when local economies support conservation efforts (Goldberg, 2013). MPAs cover only 1.6% of the worlds coral reefs, with “no-take zones” only accounting for less than 0.1% of coral reefs (Mora et al, 2006). Many MPAs are in areas where regulations may be

poorly conceived, or may be clearly articulated without proper structure for implementation. Such conservation areas are often referred to as ‘paper parks’ (Goldberg, 2013). This concept will be revisited in later chapters.

While no-take marine reserves are widely used as tools for sustaining biodiversity as well as the conservation and management of exploited fisheries, they are nonetheless controversial. Critics worry that reserves do not work with highly mobile species, and that they will decrease catch, increase pressure on surrounding areas, or increase travel time to get around them. Despite this, long term studies have shown that targeted species inside of reserves often increase in size, live longer, and develop an increase in fecundity (Goldberg, 2013). More specifically, community diversity and the average size of organisms within a reserve are between 20-30% higher relative to unprotected areas; like-wise population density is roughly double in reserves, and fish biomass is nearly triple (Halpern, 2003). Fish diversity is positively correlated with increased grazing by herbivores, especially parrotfish, whose activities lead to increased recruitment and growth of stony coral populations (Mumby et al, 2006.). Reserves that emphasize protection of fish appear to produce a trophic cascade effect that enhance the preservation or recovery of coral structure and function (Mumby et al, 2006).

Structural complexity (three-dimensionality) and habitat diversity are associated with high species richness of both corals and coral reef fish. Thus, as branching corals like *Acropora* decline, so does the abundance of coral-feeding and coral-associated species (Alvarez-Filip et al, 2009). Likewise, reefs protect shorelines from waves, which became clear after coral mining greatly increased damage in coastal Sri Lanka after the 2004 tsunami that devastated the region. This would suggest that the maintenance of structural integrity becomes yet another function of reserves (Goldberg, 2013). Marine reserves are a good start, but alone will not curtail the rapid decline of coral cover. In order to increase resilience and connectivity, coral reefs must function more effectively both inside and outside of reserves.

Conclusion:

Coral reefs in the Caribbean are dying from the local impacts of overfishing and nutrient enrichment. In the future, they will also be facing intensification of the current global stressors: rising temperature and increased ocean acidification. Both short term and long-term survival of the reefs requires immediate and dramatic reduction of fishing and nutrient enrichment, as well as increased establishment of protected areas around large reef systems (Rohwer, 2010, p.151). Our need for food in an ever increasingly populated world is often cited as a justification for overfishing. Coral reefs have the potential to serve as productive, long term food sources and the concept of over-fishing was long seen as impossible (Rohwer, 2010, p.152). Unfortunately, with the introduction of new fishing technologies, the rate of over fishing has increased in recent decades with no apparent plans to curtail it in the future. According to Sumaila et al.’s 2007 fisheries report, it is estimated that there are twice as many fishing boats worldwide as would be required to meet the maximum sustainable yield of harvesting (2007, p.2). People tend to view ocean resources as common property and that everyone should have open access to them without considering the very stark reality of overfishing and its implications for future fish stocks. The fishing industries world wide tend to avoid this reality by hiding the origin of fish caught in areas where fishing is restricted or mislabelling of fish that have been deemed endangered and therefore have restrictions on their harvesting (Logan et al., 2008).

The growth of fleshy algae on coral reefs can be regulated through top-down control (ie. grazing) and bottom-up control (i.e., limiting nutrient additions). Extra nutrients reach coral reefs due to poorly managed human activities, particularly in the form of agriculture, deforestation, land clearing and sewage discharges. Economics tend to influence where our sewage goes and how it is treated and decisions on how to get rid of sewage and industry waste often ignores the environmental impacts of discharges (Rohwer, 2010). The ongoing economic value of a healthy reef is far greater than the cost of building and operating proper

treatment and waste facilities and therefore these need to be taken into serious consideration when calculating long-term costs of development (Rohwer, 2010).

Habitat fragmentation through interference has decreased the resilience of coral reefs around the world. Decreased resilience of an ecosystem makes it easier for perturbations to shift reef systems from a stable state to unstable. The obvious plan of action is to establish more protected areas of reefs in order to reduce overfishing, nutrient enrichment and general damage to reefs. This may also serve as the only hope to strengthen coral's immunity against inevitable environmental perturbations projected for the near future. In order to do so, reefs need to be protected from local stressors so as to maintain their ability to defend itself against unforeseen impacts.

Chapter 2: Coral Reef Restoration in the Caribbean:

Coral reefs have always been subject to damage and disturbances throughout geologic time. Storm events, temperature variations and ultraviolet light exposure have been and remain threats to coral health. These factors are exacerbated by current anthropogenic disturbances such as vessel groundings, anchor damage, blast fishing, coral mining, dredging, coastal development, water quality degradation through nutrient loading and pollution, as well as recreation and tourism. Due to alarming rates of reef degradation in recent decades, it has become apparent to researchers that natural recovery will not suffice after a severe reef disturbance. For this reason, intentional reef restoration has become increasingly popular, with projects being implemented across the globe. In the Caribbean region, coral transplantation, specifically the creation of coral gardens, has been used as a cost-effective, viable technique for rebuilding a damaged reef. In this chapter, I will discuss the different methods used to build coral nurseries as well as the various restoration techniques including reef repair and the use of artificial reef structures. I will also discuss the costs associated with restoration projects and the future of coral restoration in the Caribbean.

Restoration Techniques:

A variety of techniques have been used for restoration in recent decades including indirect action, reef repair, transplantation and the installation of artificial reefs (Zimmer, 2006). These techniques vary depending on the focus of scale by either restoring lost or dead coral and its associated biota (transplantation, artificial reefs) or on a broader scale by restoring reef structure and natural recruitment (indirect action, reef repair). Although information is limited on long term impacts of restoration, these techniques, especially when combined and implemented through community based management have proven to be cost-effective methods to improve reef health.

Indirect Action:

Indirect action refers to eliminating the source of external anthropogenic disturbances causing damaging impacts to a reef. These anthropogenic factors include nutrient loading, runoff and sedimentation, water discharges, and vessel groundings on reefs (Zimmer, 2006, p.2). Combining indirect action with other restoration techniques is important for project success as reefs that face chronic disturbances are a lot less likely to recover naturally, and failure to remove said disturbances will hinder the ability of other techniques, like transplantation, to be effective (Zimmer, 2006). The following are examples of indirect actions that have been used in reef restoration projects:

1. Diverting sewage outfalls to reduce nutrient loading in Hawaii (Hunter & Evans, 1995)
2. Discontinuing activities that cause land based erosion in order to reduce sedimentation in Hawaii (Jokiel & Crosby, 1993)
3. Diverting of effluent from a thermal power plant from shallow inshore to deep offshore waters in Hawaii (Coles, 1984)
4. Coastal discharges of silt-laden water and bagasse (a fibrous residue from pressing sugar cane) were terminated in Hawaii (Grigg, 1985; Grigg, 1991)
5. Installation of vessel deterrent devices (radar response transmitters) on navigational aids in the Florida Keys as mitigation following the *Containership Houston* grounding (Jaap, 2000)

These approaches are critical to the long-term success of coral reef restoration efforts. They would be particularly effective on coral reefs with high recruitment rates, such as those in central and western South Pacific and the Great Barrier Reef (Bowden-Kirby, 2001). Unfortunately, indirect actions alone will not result in complete restoration of an already damaged reef, and therefore work best when combined with more direct techniques such as transplantation or use of artificial reefs (Precht & Robbart, 2006). Indirect actions are also limited by costs and lack of cooperation from other government or industry actors.

Reef Repair:

Reef repair attempts to minimize additional damage following a disturbance, and to enhance natural recruitment. Repair may consist of emergency triage, restoring the structural integrity of the reef framework, or restoring topographic complexity (Zimmer, 2006).

Triage:

Triage techniques are used for restoration when an event has occurred in which acute damage has been applied to a reef and needs to be repaired. Triage, as it applies to coral reefs, can be defined as restoring the structural integrity of the reef framework. Careful vessel salvage following a grounding event would require triage (NOAA, 2004).

After a vessel grounding, the vessel must be carefully removed from the site as botched vessel salvaging can lead to additional reef damage (Hernandez-Delgado et al, 1997). Methods used in order to prevent further reef damage include off-loading of cargo or fuel before removal in order for the vessel to gain neutral or positive buoyancy, or utilizing floating lines to tow the vessel (Jaap, 1998).

Coral rubble and sediment produced during a disturbance event can cause damage to the reef (Fox et al, 1999). This can also happen during storms and extreme weather events. Additionally, the presence of unstable substrate or a layer of fine sediment can delay reef recovery by inhibiting the settlement and growth of corals (Endean & Stablum, 1973; Miller et al, 1993). Triage techniques may include removal or stabilization of the loose rubble because it reduces secondary damage, increases substrate stability, enhances recruitment, and increases habitat complexity (Endean & Stablum, 1973; Gittings et al, 1988). Rubble and debris such as vessel fragments or other foreign objects may be removed from the damage site using lift bags, lift vacuums, clam dredges or suction dredges (Jaap, 1998; Miller et al, 1993). Rubble can be stabilized or re-fastened to a reef using epoxy, limestone boulders, concrete mats or other adhesive materials (Zimmer, 2006). Sea sponges can also aid in rubble consolidation by

temporarily stabilizing rubble until carbonate secreting organisms permanently bind the rubble back onto the reef structure (Wulf, 1984).

After disturbance events such as vessel groundings, and anchor or dredging damage, triage may include recovering dislodged corals or surviving coral fragments for re-fastening. Typically, dislodged corals in shallow, high wave-action areas may be subject to increased mortality due to inversion, burial or displacement (Graham & Fitzgerald, 1999). Dislodged corals that are recovered can be immediately re-attached or stored in a safe, contained environment until it can be reattached (Jaap, 1998). Reattachment can be done using epoxy, cement, expansion anchors and threaded rod, wire and nails, bamboo skewers (Nishihira, 1994), or plastic zip ties (Iliff et al, 1999; Bruckner & Bruckner, 2001; NOAA, 2004). Methods for transplanting and coral nursing will be discussed further in the transplantation section. Reef repair, or reattaching surviving, dislodged colonies is particularly important in areas where coral recruitment is limited, such as the Caribbean and Western Atlantic (Zimmer, 2006).

Restoring Structural Integrity:

Restoration of the structural integrity of a reef may be required after a catastrophic disturbance has damaged the reef's framework (Zimmer, 2006). Destructive practices such as blast fishing or large vessel groundings can create fractures, fissures, gouges or craters in the reef limestone, damaging not only the corals, but the foundational structure on which they grow (Miller et al, 1993; Alcala & Gomez, 1987). Repairing structural framework damage can prevent further structural deterioration and can minimize or ideally avoid the potential of secondary damage produced by rubble and sand (Miller et al, 1993). It is important to carefully consider the substrate material being used for restoration of structural integrity. It is also important to consider the complexity of a damaged reef, as the function of an artificial substrate depends on structural characteristics such as composition, surface type, design and stability (Spieler et al, 2001). Artificial substrate is also sensitive to environmental characteristics such as temperature,

light, sediment, surrounding biota, hydrodynamics, depth and temporal effects (Spieler et al, 2001).

Restoring Topographic Complexity:

The loss of topographic (i.e., 3 dimensional) complexity is common in the event of large vessel groundings, coral mining, blast fishing, and major dredging accidents (Miller et al, 1993). Re-establishing topographic complexity and appropriate substrate on a reef is crucial to coral recruitment and fish abundance, and therefore plays a major role in restoration projects (Szmant, 1997). According to Peterson and Tollrian, coral larvae require specific substrate and environmental conditions in order to settle (2001). Surfaces with more spatial complexity and rugosity are better for the recruitment and survival of biota (Peterson & Tollrian, 2001; Miller & Barimo, 2001).

There is a positive correlation between coral cover and fish abundance, as well as a correlation between topographic complexity and reef fish diversity and abundance, and therefore re-establishing a complex topography on a reef is crucial for the success of other restoration processes or techniques (Spieler et al, 2001). This relationship occurs because topographic complexity and the presence of epifauna such as coral columns and sponges provide can provide shelter and food sources for reef fish (Spieler et al, 2001). Reef fish, particularly herbivorous reef cleaners, aid in the recovery of a reef as coral recruits depend on them to reduce algae cover (Hughes, 1994; Szmant, 1997). Failure to restore topographic complexity on a damaged reef could lead to exacerbation of damages caused by other disturbances, and ultimately lead to large shifts in community structure (Precht et al, 2001).

Using materials that promote coral recruitment are crucial to rebuilding a reef (Jaap, 1998; Miller et al, 1993). The most common materials used to rebuild three-dimensional reef structures are limestone and concrete, as they both aid in coral recruitment by providing substrates for attachment. Rebuilding a reef structure is often combined with adding larval

attractants such as calcium carbonate (Quinn et al, 2004), coralline algae (Morse et al, 1994), bacteria from coralline algae (Negri et al, 2001), red algae (Iwao, 1997) and neuropeptides from cnidarians (Hatta & Iwao, 2003). Unfortunately, while this combination of methods is proven highly effective, it is also difficult to apply to a restoration project due to the intense labour required and the high cost of materials and equipment (Zimmer, 2006).

Transplantation:

Coral transplantation, which gained popularity in the 1990s, is now one of the most widely researched and used technique for coral restoration. The goal behind transplantation is to speed up the natural recovery rate of a damaged reef by rapidly improving the affected reef's coral cover, biodiversity, and structural complexity (Clark & Edwards, 1995). If left to recover alone, damaged reefs are at risk of dying before they can recover. This is a result of the coral's slow growth rate and high-mortality of some life cycle stage (Bowden-Kirby, 2001). Enhancement of coral recruitment to the reef may be achieved by introducing reproductive adult corals or asexual reproduction through fragmentation (Edwards & Clark, 1998). Transplantation has the benefits of enhancing the survival of locally rare or endemic coral species, as well as enhancing the aesthetic value of a damaged reef, which is crucial for tourism (Edwards & Clark, 1998). Adding corals to areas where recruitment may be limited due to poor larvae supply or high larval mortality post-damage will help to build a stronger reef, and consequentially provide an enhanced habitat for reef-dwelling organisms (Edwards & Clark, 1998).

Coral transplantation has been used in a variety of reef disturbance scenarios such as:

- To avoid or minimize impacts from coastal development projects by transplanting individual corals or entire portions of reefs in Hawaii, Mexico, Guam, Saipan, Singapore, Japan, Tutuila, American Samoa and Palau
- Minimize coral loss from outfall pipe repairs in Florida

- Minimize coral loss from pollution in Guam
- Rehabilitate reefs following dynamite fishing and coral mining in the Maldives, Philippines, Indonesia and the Solomon Islands
- Accelerate reef recovery following the grounding of the USS Memphis submarine in Florida, as well as other groundings in the Cayman Islands
- Rehabilitate reefs damaged through diving and tourism in Eilat, Israel
- Rehabilitate reefs damaged by thermal stress and algal blooms in Costa Rica, Panama and Colombia

The above examples are a few of the many listed in Beth Zimmer's "Coral Reef Restoration: An Overview" (p.44, 2006)

Transplanting is typically done using coral branches, colony fragments, entire colonies or settled planulae (Zimmer, 2006). Various techniques are used to fasten fragments to the reef including using epoxy, Portland cement and molding plaster, terracotta tiles, plastic zip ties, rubber coated wire, steel stakes or other corrosion resistant hardware (Kaley, 1995; Neeley, 1998). While transplanting, often referred to as coral gardening, has proven to be an effective method for restoration, it also has disadvantages. Some disadvantages of transplanting corals are the intense labour and costs required, especially since all work has to be done underwater (Edwards & Clark, 1998). There is also potential for increased mortality and decreased growth rates in transplanted individuals, dislodging after attachment due to wave action, and reduced fecundity of transplants due to the stress of removal and transport (Rinkevich & Loya, 1989). In terms of site selection, transplants are more likely to survive when transplanted into low-energy, sheltered environments with good water quality (Rinkevich and Loya, 1989).

Alternative Transplanting Techniques:

Transplantation without Attachment:

Typical methods of transplantation, characterized by fixing coral transplants to the substrate, require extensive labour and other expenses. Unfortunately, most of the countries with the greatest need for coral restoration do not necessarily have the resources needed to fund large transplantation projects, and therefore transplantation without attachment may provide an alternative to the traditional methods of restoration (Zimmer, 2006). This method mimics asexual fragmentation and the advantage is that it does not require SCUBA diving or subsequent equipment (Lindahl, 1998). This disadvantage of this method is that unattached fragments could be displaced or subject to damage from weather events or wave action. This also means that transplantation without attachment should not be used in high-energy environments (Lindahl, 1998).

Coral Gardening:

Coral gardening is the mariculture of corals for use in coral restoration. The concept of coral gardening is similar to silviculture, in which coral recruits or fragments are raised in either an in situ (on site) or ex situ (off site) nursery, and are then transplanted to an established restoration site (Rinkevich, 1995). Propagating coral in a nursery can minimize impacts to donor corals and populations. Possible donor sources include collecting juveniles from high-risk, extremely shallow reef environments with a lot of wave action, and the use of fast growing corals that may be outcompeting larger coral colonies in its original habitat (Ortiz-Prosper & Bowdent-Kirby, 1999).

The advantage of this technique is that it eliminates potential harm or adverse impacts to the donor populations that can occur in direct coral transplanting (Rinkevich, 1995). Another advantage to the gardening concept is that the introduced corals can provide increased genetic diversity to a damaged reef (Borneman & Lowrie, 2001). The disadvantages of the gardening

technique are that it requires a lengthy time frame in order to establish a viable nursery capable of supplying transplants, and the high risk of potential damage by environmental disturbances (more common with in situ transplantation) such as storms, temperature changes, disease or wave action (Rinkevich, 2000).

There are a few different methods of employing a coral garden. One is to fasten coral fragments to a table that has been harnessed to the ocean floor. This would be an ideal method for relatively shallow regions (eight meters maximum depth) with high visibility. Coral tables are easiest to install and maintain, but can be less effective in the event that visibility decreases, making it harder for sunlight to reach the coral recruits. Another common method is the use of a coral “ladder” or tree-like structure, suspended in midwater. This technique is best used in regions where the floor is deeper than ten meters or the visibility is moderate. These structures are more difficult to install but the midwater positioning decreases the chances of predation on the coral fragments. This method also decreases the chances of the donor corals threatening or harming the existing reef structures below.

Coral seeding can be an effective method for enhancing recruitment for restoration and involves the collection of coral larvae or spawn in the field, which is then cultured in a laboratory. The larvae are then placed on the reef substrate (Szmant, 1999; Sammarco et al, 1999). The advantage to this method is that it avoids the removal and potential damage of healthy donor corals, however a successful and efficient methodology has not been developed yet (Szmant, 1999).

Questions and Research Needs:

Coral transplantation is one of the most widely researched restoration techniques, however researchers have not yet determined which coral strategies are most appropriate for specific transplantation scenarios. Many researchers suggest that using branching coral species is ideal

for use in transplantation in low energy areas due to its rapid growth rate and ability to increase coral cover over a shorter span of time (Rinkevich, 2000). Branching corals also increase architectural complexity of a reef and can provide habitat for a diverse array of reef dwelling organisms (Precht, 2006). Branching corals, particularly *Acropora*, are commonly used for restoration in the Caribbean, a scenario that will be discussed further in the case study chapter. Other researchers argue that growing mounding corals are more appropriate for transplanting because while they are slower to recruit, they have longer life spans and are more likely to endure storm events (Edwards & Clarke, 1998).

Other researchers have theorized that the best corals for transplantation are missive broadcasters because of their high survival rate (Gittings et al, 1990), while others suggest the use of hermaphroditic brooding corals as the most appropriate for transplantation techniques (Rinkevich, 2000; Gleason et al, 2001). Moving forward, additional research is needed to determine suitability of a particular species for transplanting while taking into consideration certain environmental factors such as depth, wave action, visibility, water quality, season and the role of the substrate (Lindahl, 1998). Further research also needs to be done to determine the long-term impacts of donor corals on the current habitat conditions (Lindahl, 1998).

Artificial Reefs:

Installation of artificial reefs is considered to be a viable option where reef restoration via indirect action, reef repair or transplantation are not viable or feasible. A variety of items may be used to construct an artificial reef structure such as tires, metal, steel, wood, PVC, or boulders, however cement and limestone are most commonly used (Spieler et al, 2001). The role of an artificial reef structure is to create a stable, wave-resistant, fixed substrate for corals to recruit. Artificial reef structures may also be used to mitigate damage caused by anthropogenic activities, alter currents, restrain rubble, restore habitat for reef organisms, conserve biodiversity and restore damaged reef structures for tourism (Spieler et al, 2001). The benefits of using artificial structures is that the materials can be relatively inexpensive, and

most structures can be built on land, reducing the amount of time necessary for work to be done underwater. The disadvantage is that artificial reef materials may not be as resistant to salt water and weathering or as successful at recruitment in reef habitats as a natural reef structure would be.

The Cost of Coral Reef Restoration:

The cost of reef restoration varies dramatically, depending primarily on materials and labour. Factors affecting restoration costs include site location, chosen restoration technique, site conditions and funding (Spurgeon, 2001). Spurgeon and Lindahl's essay on the economics of coral reefs compared the costs of five different coral restoration projects which varied in technique (reef repair, transplantation and artificial reefs) and were located in different countries (United States, Maldives, Australia, and Tanzania). Their findings showed that costs varied dramatically, ranging from $13,000 USD per hectare when using low-tech methods and local labour, to $100 million USD per hectare for high-tech, extensive restoration work (2001). According to the authors, previous restoration projects may have been more cost-effective if the focus was on prevention, preservation and protection of resources (Spurgeon & Lindahl, 2001). Cost is often the major factor in selecting an appropriate restoration method as the country's economic resources determine which restoration options are available. This would explain why most high-tech, comprehensive restoration projects and research have been conducted in developed countries such as the United States and Japan (Zimmer, 2006).

Coral Gardening in the Caribbean:

Coral restoration is increasingly recognized as a promising strategy for ecosystem-based adaption (EbA) to climate change in Caribbean. Projects in the region have been under way for 20 plus years but only recently have studies demonstrated significant progress with propagation and out-planting of several thermally resistant coral genotypes or Acropora species (Bowden-Kirby & Carne, 2013). Coral propagation refers to the reproduction of coral,

commonly accomplished in an aquarium or coral nursery using fragments of existing corals. Out-planting refers to the process of transplanting the propagated coral fragments out onto a reef structure. Restoration activities have largely focused on re-growth of two major shallow water reef building species in the Caribbean: Elkhorn coral (*Acropora palmata*) and staghorn (*Acropora cervicornis*) in part because they provide major ecological services. A review by Ferrario et al. found that corals dissipate 80% of wave energy impacts on coastal zones (2014). They also found that the most important zone of the reef for wave attenuation was the shallow reef crest dominated by *Acropora* corals (Ferrario et al, 2014). *Acropora* also provides habitat for many reef dwelling species of fish (parrotfish, snappers) and shellfish (lobsters), which are important for maintaining ecosystem resilience. Regionally, populations of elkhorn and staghorn corals were greatly reduced (95-98%) by hurricanes, disease and ecosystem breakdowns through the 1980s and are now so rare they were recently added to IUCN red list in 2006 as critically threatened with extinction (Hall, 2006; IUCN; Aaronson et al, 2008).

In recent years, methodologies and techniques for large-scale restoration of *Acropora* species have been greatly improved, with nurseries established all over the Caribbean region (Puerto Rico, Dominican Republic, Florida, Belize and Jamaica). Nurseries in the Caribbean are most commonly built on solid steel frames, suspended ropes or using tree-like structures (Young et al, 2012). Procedures are typically cost effective for out-planting large numbers of coral from these nurseries, with several hundreds of thousands of corals out-planted by volunteers in Florida in the last few years (Herlan, 2008). Low mortality rate and high growth rate achieved with *Acropora* species in nursery culture projects is highly encouraging and strengthens justification for larger restoration programs (Young et al, 2012). Increasing evidence indicates that thermal tolerance is associated with genes of the coral host rather than the algal symbiosis (zooxanthellae) (Bowden-Kirby & Carne, 2013). Restoration projects that select and propagate resilient genotypes could help increase long term resilience of Caribbean coral reefs against climate change.

Conclusion:

Coral reef restoration projects are becoming increasingly common in the Caribbean region as attempts to mitigate reef damage and remove the factors that are negatively impacting reefs' ability to recover from destruction. The restoration techniques that have been employed thus far include indirect action, reef repair, transplantation and artificial reefs. Each method has benefits and limitations, and depend on factors such as cause of initial damage, external factors influencing the state of the reef, and available funding and materials. Most restoration projects conducted to date have been designed based on a cost-benefit analysis and then carried out as pilot projects using trial and error. When designing a coral restoration project, managers need to consider engineering, geological, biological, aesthetic and socioeconomic factors. While there has been an increasing amount of research done on restoration methods over the past decade, more long-term research is needed in order to develop the most efficient, cost-effective method for applying restoration techniques.

Chapter 3: Community Based Management of the Lionfish Invasion in the Caribbean Region

The first sighting of invasive lionfish in the Western Atlantic was off the southeast coast of Florida in the mid-1980s (Arias-Gonzalez et al., 2011). Since then, populations have spread rapidly along the southwest US Atlantic coast, and across the Caribbean and the Gulf of Mexico at unparalleled speed and magnitude (Green et al, 2012). While successful invasion of a marine ecosystem by a vertebrate predator is rare, lionfish have managed to dominate the coral reefs of the Caribbean in less than three decades. Without any known predators in the Caribbean Sea, along with the invasion came many negative impacts such as rapid decreases in native fish populations and increased algae cover, both of which result in an unhealthy reef and the potential collapse of the ecosystem (Green et al, 2012). A collapse in the coral reefs would ultimately lead to a reduction in ecosystem services for coastal communities in the Caribbean region who rely on coral reefs for food and income (Pejchar & Mooney, 2009). Although the effects of invasive alien species on native species is well documented, it is often difficult to quantify the impacts on ecosystem services and human well-being. This knowledge gap may be responsible for a lack of a policy framework for restoring life-support services for the Caribbean coral reefs. Policy responses to date have been based on rough estimates of ecological, social and economic damages which may not encapsulate the full picture and magnitude of the damage (Pejchar & Mooney, 2009).

In order to avoid further negative impacts from invasive lionfish, managers will need to find solutions that curtail their population growth while continuing to protect the reefs against further damage. One form of management that has been proven successful in marine protected areas is community-based management (Pomeroy & Carlos, 1997). Community-based coastal resource management (CBCRM) has been well documented in marine protected areas of Malaysia and the Philippines, proving that it protects ecosystem services while informing, educating and empowering local community members in maintenance of governance over their own resources (Gjertsen, 2005). In this chapter I will argue that a viable strategy for managing the current lionfish invasion in the Caribbean region should be community-based management

practices which empower local communities by educating them on the impacts of alien species invasions as well as fostering environmental citizenship over land through the management and protection of local resources, goods and services. CBCRM practices such as predator control programs and reef restoration projects led and operated by community members have proven to successfully accomplish environmental protection as well as community empowerment while yielding long term benefits that can be passed down to future generations.

Spatial Analysis of the Lionfish Invasion:

A few theories have been proposed regarding the initial introduction of the Indo-Pacific lionfish to the Western Atlantic. One obvious method is through ballast water discharge, a very common introduction for marine invertebrates (Hare & Whitfield, 2003). This happens when large ships sail over from the Pacific carrying exported goods. Upon arrival in the State of Florida, the ballast tank that was filled with Pacific sea water prior to departure was likely emptied in an inshore region of the Caribbean upon arrival, releasing any organisms that were caught in the ballast during fill-up. It is predicted that some lionfish may have arrived in the western Atlantic via this method. Another theory is that lionfish were introduced via unintentional or intentional aquarium releases. The introduction of lionfish into United States waters should lead to an assessment of the threat posed by the aquarium trade as a vector for fish introductions (Hare & Whitfield, 2003). One unintentional release often cited as the initial cause of the lionfish introduction is due to the event of Hurricane Andrew in 1992, which led to the supposed flood and release of six lionfish from an aquarium located in Biscayne Bay, Florida (Morris & Whitfield, 2009). Intentional releases of lionfish into the Western Atlantic have also been cited as a main cause for the rapid invasion (Hare & Whitfield, 2003).

Due to their intricate colours and ornamental design, lionfish are considered to be an important commodity for aquarium owners who are often willing to pay steep prices to attain one for their personal fish tanks. With a voracious, piscivorous appetite, lionfish often consume all of the other fish and bottom feeders within a fish tank upon introduction. It is predicted that aquarium owners on the east coast of the United States, upon coming to this realization,

released the lionfish from their tanks off of piers and into the bays in southern Florida without considering the fact that this species of fish would eventually take over the surrounding reef ecosystems (Hines et al, 2011). This process, of course, went unnoticed for decades until about ten years ago at which point the abundant presence of lionfish on an otherwise barren reef began to gain attention.

Once released, the lionfish population began to spread southward throughout the Caribbean Sea (Hines et al, 2011). As a highly productive species of fish, lionfish are extremely opportunistic in nature and reach fecundity at a very early age making their invasion extremely successful. Lionfish possess a broad suite of traits that make them particularly successful invaders and strong negative interactors with native fauna, including defensive venomous spines, cryptic form, colour and behaviour, habitat generality, high competitive ability, low parasite load, efficient predation, rapid growth and high reproductive rates (Albins & Hixon, 2011, p.1151). Lionfish can release up to 30,000 eggs every four days. With these eggs travelling through the Gulf Stream for optimal dispersal it is no surprise that they were able to overpopulate the entire Caribbean Sea in a matter of a few decades (Johnston & Purkis, 2011). Lionfish sightings have been reported as far north as the state of Massachusetts in cold, brackish water and recently as far south as Colombia and Brazil. Six individuals were collected in Tayrona National Park, Santa Marta and two more observed off of San Andres Island in Colombia in 2009, the first reported sighting of lionfish in South America (Gonzalez et al, 2009). Populations have since grown in the region and continue to disperse farther southward threatening local fish stocks and human livelihoods (Gonzalez et al., 2009).

Impacts of the Lionfish Invasion on the Native Reef Community:

While the first lionfish sightings were reported in 1995, their population began to increase rapidly between 2004 and 2010 (Green et al, 2012). From 2008 and onward, the abundance of lionfish coincided with significant declines in native fish species according to data from reef surveys (Green et al, 2012, p.2). During this time, lionfish populations in the Bahamas were recorded as increasing to approximately 40% of the total biomass of predators on the reef

(Green et al, 2012, p.2). In the Bahamas, multiple reef surveys and studies have been carried out in attempts to monitor and understand the lionfish invasion and its impacts on native fish species. Using stomach content analysis, studies indicate that approximately 90% of the prey consumed by lionfish in the Bahamas region were small bodied reef fish from 42 different species. According to Green et al., by 2010 the combined biomass of these 42 species had declined by 65%, strongly suggesting that the increasing presence of lionfish is adversely impacting fish stocks on the Caribbean reefs (p.2). Supporting evidence for this theory came from observations that the populations of smaller bodied fish species not considered to be lionfish prey, had remained relatively stable (Green et al, 2012, p.4).

A study conducted in the Bahamas region by Arias-Gonzalez et al. (2011) showed that lionfish predation reduced native fish recruitment by 79% on the coral reefs (2011, p.917). Similar to the findings of Green et al., the authors found significant declines in 41 species of teleost fish, with approximately ten different species making up the majority of the lionfish diet (2011, p.918). According to a third study conducted by Lesser and Slattery (2011, p.1855), mesophotic coral reefs (depth of 30 - 150m) in the Bahamian region have undergone a phase shift from a coral dominated ocean floor cover to an algal dominated cover throughout the benthic regions (benthic area refers to the ocean floor). This phase shift into the overgrowth and domination of algae over benthic cover can be attributed to the absence of smaller bodied, herbivorous fish that typically clean and maintain the coral reefs, keeping algae cover under control (Lesser & Slattery, 2011). Algae dominated reefs have a reduced resilience capacity, causing them to collapse because of minor local disturbances such as nutrient loading and overfishing (Lesser & Slattery, 2011, p.1856).

With a diverse array of fish prey and high consumption rates, the presence of lionfish is proving to have extensive trophic impacts on Caribbean food webs (Arias-Gonzalez et al., 2011). Lionfish populations are projected to increase exponentially over the next few years, raising grave concerns over impending disturbances to reef communities and food web structure in the Caribbean. Not only does this threaten the health of the coral reefs through algae dominance

and decreasing presence of native fish, but an ecosystem collapse will inevitably impact food and income sources for humans across the Caribbean.

Community-Based Coastal Resource Management (CBCRM) to Mitigate Impacts of the Lionfish Invasion:

Community-based management of natural resources has been gaining popularity over the last decade as environmental managers rush to find solutions to a rapidly degrading reef system. Managers and conservationists alone are unable to handle the magnitude of work required to mitigate environmental degradation, calling for active participation on the part of local communities and stake holders. Various long-term community based management programs have been successfully implemented and studied in marine protected areas of the Philippines (Pomeroy & Carlos, 1997). These programs have been evaluated based on their ability to positively affect marine protected areas as well as how participation in the program has educated and empowered community members and whether or not communities are capable of carrying out and maintaining daily project operations without aid or management from an external source (Pomeroy & Carlos, 1997, p.448).

According to Pollnac et al. (2001, p.683) in the same region, important predictors of project success include human population size (of the affected community), perceived understanding of crisis or environmental problem (reduced fish populations), successful alternative income projects, high levels of community participation in decision making processes, and continuing advice and inputs of implementing organizations and local governments. Pollnac et al. argue that these factors are crucial to determining long term success of environmental protection and that these factors can all be linked to the importance of community education and empowerment. Community empowerment is best achieved through programs that inform and engage community members in active participation of daily program operations (Pollnac et al, 2001). Another review of community-based management projects conducted by Pomeroy et al. in the Philippines concluded that early and continuous participation in community-based programs is related to positive evaluations of success and positive cultural attitudes toward

collective action, job satisfaction and perceptions of positive changes among community members (1997, p.97).

Selecting the best method for reef restoration requires planners and managers to consider the long-term practicality of a project and whether or not it will keep local community members active and involved long after implementation. According to Cleland & Wyborn (2010, p.414) article on applying critical systems thinking in an engaging way, the use of visual methods such as constructing rich pictures is a successful method for bridging knowledge gaps and identifying differences in views and opinions between different stakeholders. In their case study on coral reef management in the Philippines, researchers developed a visual game for the local fishermen to help them understand fish stocks and the importance of sustainable fishing for coral health (Cleland & Wyborn 2010, p.422).

Various invasive predator control programs have been implemented throughout the Western Atlantic region as a means to manage the lionfish invasion. One technique that has proven to be particularly successful is the implementation of lionfish culling programs, or in other words, lionfish hunting. According to Frazer et al., targeted removals of lionfish can yield highly beneficial effects on the ecosystem as fewer lionfish and decreased predation on threatened grouper, herbivores and other economically and ecologically important fish represent key steps toward protecting Caribbean reefs (2012, p.185). Frazer et al. showed that removal at sites off of the Cayman Islands shifted the size frequency distribution of remaining lionfish toward smaller individuals whose stomachs contained less prey and fewer fish (2012, p.187). While targeted removals have proven to be successful, it is a method that needs to be carried out frequently and requires significant manpower. For this reason, community-based management is crucial to the success of invasive predator control programs.

Unfortunately, since lionfish tend to hide in crevices and underneath rocks and coral on the reef, traditional fishing methods using a line have proven unsuccessful at reducing the lionfish population. The most effective method of removal is through spear fishing, usually conducted

by either free diving or scuba diving. For many members of coastal communities in the Caribbean, scuba diving is an activity seldom practiced since it requires rigorous certification, training and expensive equipment. A few experimental programs have been implemented over the last decade in the Caribbean in which local fishermen and community members are given the opportunity to become scuba certified and trained in spear fishing in order to meet the demands of targeted removals of lionfish. Not only do these programs provide alternative food sources and economic incentive through consumption and sales of caught lionfish, it also encourages fishermen to shift priorities from hunting native fish species to hunting an invasive species, allowing for native fish populations to replenish.

An important feature of community based management programs is the community outreach and education component, in which local communities can learn and understand about this new invasive species, its impacts on their resources and ways to mitigate these impacts. Community empowerment is also achieved through local communities feeling like they are in control of their own resources, rather than having experts and researchers coming into a region to conduct their own management practices. According to Gjertsen, poverty often causes environmental degradation, and this degradation in turn fuels further poverty (2005, p.199). For this reason, it is crucial that governing authorities invest in resource management that protects the environment while informing the community members. Through CBCRM, coastal communities are able to benefit economically while improving human well-being and empowerment through active participation.

Conclusion:

The lionfish invasion throughout the Western Atlantic has been well documented and has proven to be one of the largest contributing factors to the rapid degradation of the reef ecosystems in the Caribbean. The presence of lionfish has resulted in a decrease in overall biomass of native reef fish, which has implications for both the reef and for coastal communities in the region. Researchers have observed a phase shift from coral domination over to algae dominated reefs in benthic regions of the Caribbean, threatening coral reefs with

ecosystem collapse. This will have social and economic implications for coastal communities that rely on coral reefs for their ecosystem services and also for the tourism industry which will suffer dramatically from the disappearance of the Caribbean reefs.

Targeted removals and implementation of invasive predator control programs is necessary to keep lionfish populations low in the region, and the community-based management approach (CBCRM) has proven to be the most effective method of management in order to ensure long-term active participation by community members and stakeholders. Community-based lionfish culling programs can provide an alternate food and income source for local fishermen and could even potentially open new doors for generating income through the use of lionfish fins for jewellery making. These programs would also empower the local community to obtain scuba certification and technical training that local community members would not otherwise have the opportunity to acquire. CBCRM can also have positive effective on cultural attitudes towards resource management programs and their perception of positive change. Lastly, CBCRM can aid in developing supplementary employment opportunities and increase job satisfaction for local fishermen and active participants.

Chapter 4: The Role of Biophilia in Community Based Resource Management

Modern society has entered a time of both serious environmental despair and great opportunity. Concerns about species protection, water, land use, global warming and pollution have been growing, yet the number of individuals who are actively engaged in protecting nature continue to be small. How will environmentalists encourage society to expand and deepen their concerns for the environment enough to turn those concerns into ongoing committed action? In Mishka Lysack's "Defending and Protecting What We Love," the author discusses the need to move from passive consumers and bystanders to active environmental citizens engaged with protecting nature (2009). Lysack explains that fostering environmental citizenship lies in cultivating the growth of biophilia. Biophilia is defined by Harvard biologist E. O. Wilson (2007) as the innate urge to affiliate with other forms of life and by Bai et al., (2010) as the love for life and nature. According to Lysack, human beings are naturally attracted to life and its processes, and that this is displayed in the way children are drawn to and curious of animals.

In this chapter I will discuss the ways in which environmental conservation is co-produced along with environmental education, and the role this may play in the overall success of conservation projects. Introducing the importance environmental citizenship through environmental education at an early age is crucial to developing feelings of stewardship over the land and will positively impact resource management strategies in the future.

Environmental Education for Successful Community-Based Management:

Environmental Citizenship:

Environmental Citizenship is the idea that we are all an integral part of our surrounding ecosystem, and also a part of an even larger, global ecosystem. The term suggests that each one of us must embrace environmental challenges and act responsibly and positively towards our environment because our futures depend on it. It is about making changes in our daily lives to be environmental citizens all day, every day (Berkowitz et al, 2005). This concept is very

similar to Aldo Leopold's *Land Ethic*, "a land ethic changes the role of Homo sapiens from conqueror of the land-community to plain member and citizen of it. It implies respect for his fellow-members, and also respect for the community as such" (p. 240).

According to Greg Misiaszek, ecopedagogy is a critical approach to the teaching and learning of connections between environmental and social problems (2015, p.280). Although these aspects are often inseparable, the connections are nevertheless often avoided or intentionally taught incorrectly (2015, p.280). Some scholars argue that this is because of the power relations that are embedded both inside and outside educational systems. For small island nations such as that of the Caribbean region, maximizing community involvement in environmental protection is crucial to ensuring natural resources will be available for generations to come.

In order to ensure that communities hold a sense of environmental citizenship, it is important to expose them to these concepts in early childhood. Introducing biophilia and encouraging environmental and social consciousness in children will encourage environmental citizenship later in life (Bai et. al., 2010, p.352). According to Lysack, the foundation of a deep conservation ethic can not be found by understanding nature for its economic gain, or the promise of personal health, or our enthusiasm for outdoor activities, but rather in the powerful biophilic attraction and impulse to affiliate ourselves with other forms of life (2009).

An effective method for conveying environmental thought is through education programs and school curriculum. Lysack developed an educational pathway that can assist people to re-connect with their desire to protect the environment, involving engaging with questions that lead people into their own inner awareness of their connections with living beings and the biosphere (2009). Lysack also argues that these questions can be easily embedded within the education system. According to Bai et al.'s (2010) article, there is often a push back on the aptly coined "greening" of the education system as many educators argue that there simply is not

enough space in the curriculum to fit environmental education in. Bai et al. argue that this is an oversimplification of a much larger issue, that as people who live in, thrive on, and are impacted by our environment, our curriculum should reflect the need for this information. Lysack (2010) provides examples of ways that the environment can be understood by using elements of our surroundings in mathematical problems, or mentioned as crucial pieces of history and in geography lessons.

Ecopedagogy for Community-Based Management:

Technology has often been seen as the perpetrator in the disconnection between humans and nature; however, it is more important to consider how socio-economic and political factors influence this relationship. It is arguable that promoting the use of technological devices is in itself political, since increased sales of devices and gadgets are beneficial to any nation's economy. While it may not always be obvious, information promoting increased consumption patterns have been ingrained in people at a very early age with a very clear place in the elementary curriculum (Lysack, 2010).

For Island nations in the Caribbean, the disconnection between humans and nature is much smaller than most Western nations due to the close proximity between humans and the land and sea which they use for sustenance. The majority of environmental learning tends to happen outdoors or in nature, as most island dwellers not only use natural resources for food and sustenance, but also as a form of transportation and sometimes even as shelter. Since environmental conservation and environmental education must be learned simultaneously, it is alarming to think that environmental education has very little space in the classroom.

Available strategy for managing the degradation of coral reefs in the Caribbean region is using community-based management practices to empower local communities by educating them on the impacts of alien species invasions and overfishing, as well as fostering environmental

citizenship over land through management and protection of local resources, goods and services. CBCRM practices such as predator control programs and reef restoration projects led and operated by community members have proven to successfully accomplish environmental protection as well as community empowerment while yielding long term benefits that can be passed down to future generations. Unfortunately, facilitating conservation projects alone will not ensure that local communities will continue to practise protection over marine resources after the project has been terminated. For this reason, environmental education and outreach programs are a crucial component for community-based management initiatives.

We can use the example of the lionfish invasion in the Caribbean. Teaching youth how to identify invasive species, the impacts that they have on the native reef community and how it can translate into increased environmental degradation and a decrease in resources is crucial to ensuring that the community as a whole will do their part in managing lionfish populations long after the government funded management projects have ended. Environmental education is not only important for the youth, but also for the adult community members. Outreach programs need to focus on teaching both practical and biophilic aspects of conservation. According the Lysack, it is not enough to expose people to the reality of environmental degradation, rather to position themselves within environmental issues and how they may be personally affected by changes (2009). A part of Lysacks' educational pathway is to connect a person with their own experiences in nature, and to ask themselves how that particular part of the natural world became so important to them. According to Lysack, questions like this remind people of positive connections in nature that are most often also embedded in emotional connections to other people in their lives. Creating an emotional context for experiences in nature will conjure feelings of environmental responsibility and stewardship. Programs that engage community members at every age are crucial for catalyzing a large-scale movement in environmental protection.

Conclusion:

It is helpful if we can envision or picture the impact of our actions of protecting the planet's ecological communities. It is easy to fall back into feelings that our personal actions will not account for much and therefore making a conscious effort to act in a way that protects life communities and species seems pointless. Being empowered to engage in sustained and committed action relies on our continued cultivation of a growing awareness of how our actions contribute to the current state of our surroundings, both locally and globally. Conservation management strategies tend to fall short of the expectations in most cases because they have failed to engage community in their desire to protect the natural world. Environmental citizenship and a love for nature can not be solely derived from acknowledging the economic values associated with conservation, or from our desire to seek adventure in nature. Rather it must come from our innate desire to protect the places and life forms in nature that are attached to powerful, emotional experiences in connections that we share with our community. Environmental conservation and environmental education are coproduced and therefore must be applied equally to conservation projects during the developmental stages in order to ensure long term success and shift towards a more sustainable future.

Chapter 5: Political Ecology of Community Based Management of Coral Reefs

Introduction:

The rapid loss of coral cover in the Caribbean region has stark implications for human health and well-being (Adger et al, 2005) as coral reefs provide food and subsistence to coastal communities as well as goods and services to world economies (Cesar et al, 2003). Declines in coral reefs may be mitigated with proper restoration techniques (Precht, 2006), but a lack of funding and stakeholder cooperation, as well as ineffective project planning and implementation (Rinkevich, 2008; Jones, 2014) pose significant challenges. Current managers of many marine protected areas (MPA) have not given adequate consideration to local ecology, socio-economic realities or how to implement effective long-term management strategies (Rinkevich, 2008; Lundquist & Granek, 2005). Despite acknowledgement of the human role in coral reef destruction, the majority of research focuses on ecological rather than human dimensions of coral reefs (Kittinger et al, 2012). This limits our understanding of social relationships with the environment and how they affect implementation of potential solutions for reef recovery (Kittinger et al, 2012). General frameworks for social-ecological systems have been advanced but have failed to provide a system-specific approach to management.

According to Kittinger et al.'s article on the human dimensions of coral reefs, system-specific approaches are necessary to develop a more nuanced view of human-environmental interactions for a specific context or resource system at a specific scale (2012). In this chapter I will argue that most research and literature on coral reef restoration has largely focused on ecology, not humans, thus reproducing a 'nature-culture' split. This has led to an incomplete understanding of how social change and the structure of social systems mediate ecological outcomes. The literature that does incorporate human dimensions tends to place blame on local communities and governing authorities for a lack of stewardship over their land which is not helpful from a restoration perspective. Restoration projects need to be approached using a human dimension framework that acknowledges and explores linkages between social system structural traits, human activities, ecosystem services and human well-being (Kittinger et al., 2012).

Coral reefs and their associated human systems are complex and while global patterns of decline in coral cover have been documented, evidence of recovery from sustainable restoration efforts are also emerging (Kittinger et al., 2012). The need to understand the complexity of human relationships with oceans, including their cultural, social, and economic dimensions is largely hindered by a lack of a comprehensive framework or approach to management (Kittinger et al., 2012). This is especially the case in community based coastal resource management (CBCRM), in which project execution relies heavily on co-management by local workers, governing authorities and marine biologists (Brown & Pomeroy, 1999). There is a need to develop a conceptual framework that links the different research fields and their knowledge systems, methodologies and approaches to find a model that addresses the totality of ecological along with social, political and economic dimensions, or in other words, the human dimensions.

According to Kittinger et al., human dimensions can be defined as the ways in which individuals, communities, and societies interact with, affect, or are affected by natural ecosystems and environmental change through time (2012). While analysis of social data is practiced in some instances, there is still no substantive approach or framework for linking this social information to ecological conditions or outcomes. Linking social and ecological relationships in a way that informs and benefits management plans will require linking both social and ecological data in order to understand the dynamics between the two factors.

The politics of management over marine ecosystems serve as an inhibitor of success and a source of tension in reef conservation. The discourse surrounding coral reef degradation typically suggests that marine biologists maintain the role of the expert while being faced with resistance by local community members and stakeholders to commit to a management strategy (Lave, 2015). The majority of the academic literature that does acknowledge the social, political and economic factors frame the issue as one of local community members and politicians ignoring the scientific evidence provided by the experts. In reality, the effectiveness of

community based restoration projects is threatened by the fact that not enough attention has been paid to the social and political dynamics of a particular place and people during the planning phase of the project (Kidd et al. 2011).

Political ecology can help us to understand and identify the political circumstances that force people into activities which cause environmental degradation, while having little or no access to alternative options (Robbins, 2011; Stott & Sullivan, 2000). Acknowledging these circumstances will allow marine planners and managers to create programs that can be successfully implemented despite apparent barriers that may or may not be caused by a lack of cooperation on the part of governing authorities and institutions (Kidd et al., 2011). In this chapter I will discuss aspects of the academic literature that are often used to inform coral reef restoration and management while attempting to explain the barriers to successful restoration. I will look specifically at the ways in which our understanding of nature is co-produced, the role of expertise in project planning and the issues with using a 'one size fits all' approach to reef restoration projects. To conclude, I will consider the role of co-management in avoiding barriers to marine conservation.

The role of expertise:

In the field of conservation management, restoration projects require a high level of planning and consultation with experts. While expertise based on empirical research and quantitative data collection is necessary to establish specific targets for ecological restoration, local and traditional ecological knowledge can inform project design and methodology to best meet the needs and expectations of local community members involved with and directly impacted by the project (Lave, 2015). For this reason, the community-based approach to natural resource management (CBNRM) has gained popularity in recent years as it aims to achieve not only conservation goals but also strives to empower community members and stakeholders by putting their needs first (Lave, 2015).

There is a growing literature that addresses the absence of local knowledge in conservation and questions experts as not just academics or scientists (Lave, 2015). According to Lave's article "the future of environmental expertise," a new regime of knowledge production is emerging in which academia carries significantly less merit than it previously had, and that questionably sourced knowledge is increasingly being developed outside of academic institutions (2015, p.244). Lave argues that these changes have obvious implications for the future of academic legitimacy in institutions and less obvious implications for environmental and social justice. These consequences are equally if not more important to consider as relaxed standards for knowledge production could lead to discrepancies in how questions are investigated or potentially ignored (Lave, 2015).

While Lave's argument is a legitimate one, it forces me to question whether or not, and to what degree this already takes place in academic research. Much of the literature used to inform conservation management projects are based on scientific research that frames the issue of degradation as one which has been poorly managed by local people and therefore requires experts, namely researchers who practise western science, to come in and save them. In this way the researcher, perhaps inadvertently, assigns specific roles and responsibilities to actors as either the cause or the solution to the problem. Marine biologists, marine protected area (MPA) officials, and policy makers are commonly listed as the main actors in reef conservation (Rinkevich, 2008; Sale, 2008; Precht, 2006). While local community members and fishermen are frequently listed as stakeholders that should be consulted prior to project implementation, they are seldom grouped in with environmental managers as actors who could use or benefit from the published study nor are they often considered as sources of relevant knowledge.

Even the role of governing authorities and local experts appear questionable through the framing of management issues as one in which despite the presence of scientific evidence and urgency for action on the part of marine scientists, governing authorities are slow to allocate necessary resources for the mitigation of such issues (Kidd et al, 2011; Rinkevich, 2008; Sale, 2008). Tania Li refers to this as an oversimplification of the role of communities in management

(2002). Li advocates for integrated, community-based natural resource management (CBNRM) and argues that "people who live close to a resource and whose livelihoods directly depend upon it have more interest in sustainable use and management than state authorities or distant corporations" and that rural people are strategic, rational actors rather than "ecologically noble savages" (Li, 2002, p.2; Lynch & Talbott, 1995). Li explains that framing conservation issues as one in which rural people need to be saved is especially appealing in the policy arena and is therefore often done strategically to gain support for the CBNRM platform (2002, p.2). While project support is crucial to successful implementation, this oversimplification can result in project targets and outcomes that do not actually address the main concerns or objectives of the local community, and ultimately leads to certain actors being ignored.

The question of who maintains the role of the expert and whether or not local ecological knowledge is essential to planning is further complicated when applied to marine ecosystem management. While it seems redundant to point out that humans are a terrestrial, as opposed to aquatic species, this fact plays a huge role in evaluating the validity of local or traditional ecological knowledge in coastal regions. Marine ecosystems are incredibly complex chemical and physical systems that cannot be understood only through visual observation (Rohwer, 2010). Until recent decades, very few people had ever seen what lies beneath the surface of the ocean, and visual observations alone can not provide an observer with an understanding of the processes taking place underwater (Rohwer, 2010). Some of the first naturalists to ever observe benthic and pelagic ecosystems described them as perplexing, highly abundant ecosystems bursting with a unique array life and biodiversity (Rohwer, 2010, p.21). Due to a lack of technology, most accounts of early observations are more descriptive than empirical, as data collection was not made possible until the last few decades (Rohwer, 2010). Even then, shifting baselines make it almost impossible to assess the level and rate of degradation in reef ecosystems (Rohwer, 2010).

Studying coral reefs requires a lot of training and equipment that are both expensive and difficult to attain in rural, small island states. For this reason, much of the expertise in coral reef

conservation does in fact lie with scholars and scientific researchers who have both the time and resources to collect the necessary data to determine adequate conservation objectives. This is not to say that rural people do not have any insight to offer during the project planning phase, but that understanding the magnitude of the problem and the urgency to take action may be subject to scrutiny or debate by local stakeholders who do not have a scientific understanding of the problem. For example, local fishermen may not acknowledge the severity of depleted fish stocks because they are still able to catch a large enough yield of fish to meet their subsistence needs on a daily basis; but just because one can see fish swimming at the surface does not mean that their populations have not been depleted to the point of endangerment. Nevertheless, traditional knowledge of local marine systems and how these systems may have changed over periods of time that are much longer than the typical three year length of a scientific study should not necessarily be discounted.

The same circumstance can be applied to selecting which fish are sustainable to catch, which are not, and at what volume. Sharks have long been fished for consumption in the Caribbean (and more so elsewhere) and are frequently used in dishes such as shark and bake, a meal that is strongly tied to Caribbean culture and identity. Advancements in marine research have concluded that consumption of shark meat has negative health implications due to high levels of mercury in the meat (Hightower & Moore, 2003), and more importantly overfishing of sharks has been speculated to be the number one cause for dramatic declines in native fish species and may be responsible for the impending collapse of coral reefs (Rohwer, 2010). Without coral reefs, which support majority of both benthic and pelagic life forms in the oceans, photosynthesis cannot take place underwater thereby threatening the existence of all marine life (Rohwer, 2010).

The point that needs to be stressed here is that traditional ecological knowledge as expertise plays a less significant role in marine conservation planning than it does in terrestrial ecosystems because visual observation is limited, and therefore further complicates the power dynamics of CBNRM that are often criticized in political ecology. This raises the question of how

to design a project that can successfully improve coral reef health as well and incorporate public participation in order to educate and empower local community members based specifically on their needs and capabilities. One particularly large barrier to attaining active community involvement and empowerment in conservation projects is creating programs based on a standardized 'one size fits all' design (Kittinger et al, 2012). In the next section I will discuss the prevalence of fitting reef restoration projects into standardized packages that are meant to accommodate the needs and objectives of all small island states in the Caribbean region collectively, and the implications that this has for management.

Restoration projects as standardized packages:

According to Joan Fujimura there are many kinds of worlds that are involved in constructing scientific knowledge which are achieved in numerous and diverse ways (1992, p.168). In "Crafting science: standardized packages, boundary objects and translation," Fujimura questions how these different worlds with different methodological and substantive concerns succeed in cooperating to produce new knowledge (1992, p.168). Fujimura uses the concept of standardized packages to analyze how collective action is managed across social worlds to achieve enough agreement at various times to get work done and to establish new "facts" (1992, p.169). Standardized packages are described as scientific theory and a standardized set of technologies which is adopted by many members of multiple social worlds to construct a new and at least temporally stable set of facts (Fujimura, 1992, p.169). While creating a standard may be helpful for sharing and transferring knowledge across languages and cultures, there is a risk of placing certain issues and tasks inside of a binary that may not accommodate discrepancies.

Scholars have cited this as a significant problem with coral reef restoration projects, as not all degradation is caused by the same factors or at the same level of intensity. Environmental problems are also not perceived the same way across different cultures and therefore may be ranked differently in terms of importance or urgency for action. According to Geoghegan and Renard's "Beyond community involvement: lessons from the insular Caribbean," road blocks to

successful community involvement in protected area planning and management can be attributed to the common misconceptions about the homogeneity of local communities (2002, p.16). The authors argue that managers need to understand and reconcile the interests and expectations of a wide range of stakeholders (p.17). Their case study identified four key lessons learned from past failed projects: the first being that effective management requires the integration of the full diversity of stakeholders and takes into account the differing ways they are impacted by and impact upon protected areas (2002, p.22).

In order to achieve this, planners need to consider that while communities may have a coherence and unity in wanting what is best for their people, interests of the different stakeholders within the communities can be very diverse (2002, p.22). Geoghegan and Renard also point out that resource use patterns, institutions and power relations are in constant evolution which presents additional challenges to planners and managers who have to account for stakeholder's ever evolving attitudes and relationships with the project and with each other (2002, p.22). Another important fact that managers need to be conscious of is that they themselves are not a neutral party, but also a stakeholder. It is therefore important to understand one's own role of intervention in a project as neutral facilitation is crucial to ensure planning and objectives are not skewed towards any one particular interest (Geoghegan & Renard, 2002, p.22).

The second key lesson identified in the study is that long-term success of participatory management depends on the suitability of the institutional arrangements (2002, p.23). The authors offer some principles to guide the design of institutional arrangements such as: focusing on being democratic and contributing to the empowerment of disadvantaged groups (2002, p.23). They must also include structure and mechanisms that allow stakeholders to influence management decisions, and must be flexible and capable of responding and adapting to change or the event of an unforeseen circumstance (2002, p.23). Structures and mechanisms must also be put in place that promote and sustain linkages between sectors and the involvement of non-traditional actors in management (2002, p.23).

The third lesson that Geoghegan and Renard provide stresses the importance of transparency. Given the limited resources available for protected area management, transparent processes of negotiation are required to determine how much participation is possible and what objectives are given priority (2002, p.24). The authors explain that protected areas in the Caribbean are typically lacking management and financial resources, and therefore conservation and social objectives must be approached incrementally so as to not compromise the integrity of the entire initiative (2002, p.24). The fourth and final lesson identified in the study is that participatory management of protected areas must yield appreciable benefits for local communities (Geoghegan & Renard, 2002, p.24). If the project does not yield real benefits for local people, community involvement cannot be meaningful (2002, p.24). The authors provide some observations that may assist managers in addressing issues of stakeholder benefits such as acknowledging that not all potential benefits from protected areas are economic, but may also be recreational, cultural or educational in nature (2002, p.24). The authors also urge managers to be aware that inequitable participation is likely to be reflected in the objectives that are defined (2002, p.24).

An example of this is the way in which the tourism industry tends to drive the establishment of marine protected areas, and therefore objectives are skewed towards benefitting aspects of the protected area that supports the tourism activities, often at the expense of the fisheries or other less powerful sectors. The fourth lesson proves to be a recurring argument in literature related to CBNRM. The fate of community-based management projects lies in the degree to which communities feel they are experiencing positive results or empowerment from the project. There is a notion that a community will experience empowerment as a result of the established intended outcomes listed in a project plan; however, the actual outcome of a project does not always match the objectives. Unfortunately, this is also a difficult vector to measure, since feelings of empowerment are for the most part subjective and may be experienced differently across time.

Other scholars in the field have taken issue with the standardization of conservation management models such as Fikret Berkes, whose essay “From community-based resource management to complex systems” highlights issues related to scale and the over simplification of community-based resource management in order to develop theory in a convenient way (2006, p.43). Berkes argues that researchers are often so intent to develop a theory that will help to explain overarching themes and issues related to management that they end up generalizing the characteristics of regional and global commons (2006, p.44) to the point where the generalizations are not useful for a specific restoration project. Berkes explains that this is done to provide a relative ease to observing processes of self-governance; however, it becomes an issue related to scale (2006, p.45). Managers often try to make sense of the findings of small-scale, community-based commons and assume that lessons can be applied to larger-scale commons or to other small-scale projects spread across a large area within a complex adaptive system (2006, p.46). Berkes suggests that managers can avoid this frame of thought by developing a plan that acknowledges how the multiple levels of governance and external drivers of change are vastly different according to spatial characteristics and the scale of a project (2006, p.48).

Similar to Berkes article, Kittinger et al.’s essay on the “Human dimensions of coral reef social-ecological systems” stresses the importance of establishing system-specific and site-specific solutions for reef degradation (2012, p.1). According to the authors, general frameworks for social-ecological systems have been advanced, but system-specific approaches are needed to develop a more nuanced view of human-environmental interactions for specific contexts and resource systems, and at specific scales (2012, p.9). In order to achieve this, managers need to apply a human dimensions framework that considers linkages between social system structural traits, human activities, ecosystem services and human well being as they relate to coral reefs (2012, p.9). The authors point out that although these direct linkages between social factors and ecosystem conditions have been identified in coral reef studies, they tend to focus on single factors at a time, such as population or economic markets (2012, p.2). In order to develop a system or site-specific plan, managers need to contextualize conservation problems

as they narrate a broad array of inter-related human dimensions necessary for characterizing social-ecological systems (2012, p.2).

Neoliberal conservation and the co-production of nature:

Breaking away from this social ecological split may be difficult to accomplish while operating under the current neoliberal paradigm of modern society. Neoliberal conservation is a conjunct of methods, as well as a managerial style of governing environmental problems (Fletcher, 2010, p.171). It is characterized by the creation of a capitalist market for natural resources (or in other words the commodification of nature), the privatization of resource control and the withdrawal of direct intervention by governments (Fletcher, 2010). Instead, authority to intervene is passed on to NGO's and international corporations (Fletcher, 2010). Attempting to place value on coral reefs based strictly on its monetary worth is problematic for reef conservation as it produces a central argument for conserving coral reefs as one that only holds financial benefits. In this way, coral reef restoration projects are valued only for their ability to improve payments from ecosystem services. Referring to Geoghegan and Renard's article on lessons for community involvement (2002), one of the biggest hindrances for effective community-based management is that governing authorities fail to see that not all potential benefits from these projects are economic (p.24). Payments from ecosystem services need to be seen as inherently linked to the recreational, cultural and educational benefits that also arise through community-based programs.

Sheila Jasanoff's chapters on "the idiom of co-production" and "ordering knowledge, ordering society" discuss the notion that while science and culture are perceived as separate entities, they are in fact co-produced and that understanding this will allow us to appreciate and understand cultural and political formations (2004, p.2). According to Jasanoff, we gain explanatory power by considering natural and social orders as being produced together, or co-produced. Co-production can help us to understand and identify connections between scientific knowledge and technology, and how it embeds and is embedded in social practices and discourses (Jasanoff, 2004, p.3). Jasanoff explains that people tend to separate the domains of

nature, facts, objectivity, reason and policy from those of culture, values, subjectivity, emotion and politics when in reality these domains are produced simultaneously (2004, p.3). This way of thinking further perpetuates the nature-culture split that is evidently displayed through implementation failures in coral reef management.

The future of coral reef restoration lies in the ability of managers to design projects using a framework that acknowledges the intertwined relationship between the cultural and political factors that influence environmental degradation, and the economic implications of it. Over the last couple of decades, literature has begun to emerge (albeit few and far between) introducing co-management as a viable option for coastal resource management in the Caribbean that pays close attention to the needs of community members, as well as the institutional constraints that hinder collective action (Brown & Pomeroy, 1999; Noble, 2000; Pomeroy, McConney & Mahon, 2004).

Coastal Resource Co-management:

Co-management brings together the use of research-based scientific knowledge to train and educate rural people and relevant institutions on their roles in community-based management of fisheries (Armitage, 2005). In Brown and Pomeroy's "Co-management of Caribbean community (CARICOM) fisheries," they argue that countries of the Caribbean have statistically had poor records of fisheries management and need to reconsider the way fisheries are governed (1999, p.549). Promoting good governance requires fishermen and other stakeholders to become involved in the management process, thereby bringing forth a vested interest in strengthening capacity-building for governing authorities and fisheries departments (Brown & Pomeroy, 1999, p.552). Bram Noble's "Institutional criteria for co-management" posits that while co-management is generally accepted as an effective means of minimizing conflict in fisheries management and recirculating the benefits of effective management back into the local communities, its development and implementation has been slowed by institutional constraints (2000, p.69).

Similarly, a report by Pomeroy, McConney and Mahon (2004) highlights the results of a comparative analysis of coastal resource co-management in three small island states in the Caribbean (p.429). Co-management projects on the islands of Barbados, Belize and Grenada were evaluated and compared for overall success rate and lessons learned for future projects. The authors cited clearly defined membership, effective communication, support from external agents and enforceable rules as the most crucial conditions for success (Pomeroy, McConney & Mahon, 2004, p.443). The findings of the analysis were that conventional, top-down, command-and-control approaches to fisheries and coastal resource management do not work well in the Caribbean region (2004, p.444).

The authors also stress that the people whose livelihoods depend on these resources need to be involved in carrying out management, and that governments in the region are realizing that they cannot manage the resources without input from stakeholders (2004, p.444). This was apparent in the way that the projects were co-managed differently in the three different sites, with the project in Grenada being the least successful. This was due to little or no interest from the fishermen to collaborate with scientists and governing authorities (2004, p.442). In a more positive light, while some co-management projects fail to reach successful implementation, every failed project provides insight for managers and community members alike on what aspects of management are working and which aspects need to be revised.

Conclusion:

Coral reef restoration projects in the Caribbean region have gain popularity in recent decades, but are slow to reach the implementation phase due to structural and institutional barriers. The rapid destruction of coral reef systems threatens the livelihoods of local communities as they provide ecosystem services that support the majority of the subsistence and economic income in the region. The need to understand the complexity of human relationships with oceans, including their cultural, social, and economic dimensions is crucial to the effective implementation of community based restoration projects but is largely complicated by a lack of a comprehensive framework or approach to management. Policy and project failures result

from a misrepresentation of rural people in the role of expertise and participation, as well as the development of programs that are designed to suit a ‘one size fits all’ package. These standardized packages do not take into account localized political and economic agendas, as well as the social and cultural factors that narrate human interactions with nature and conservation.

Reef restoration managers and planners need to be aware of the risk in framing natural resources strictly as a commodity, or expressing its value in relation to what payments can be derived from ecosystem services. This neoliberal attitude inevitably leads to the commodification of nature and the neglect of significant non-monetary benefits to local communities. In order to account for all areas of expertise, full and comprehensive stakeholder involvement (including managers and researchers themselves), community empowerment and improved coral reef health in restoration projects, managers should adopt a co-management model for conservation. This will ensure that project targets are informed by legitimate scientific data and scholarly research and ensure that local needs are met, increasing the likelihood of a successful outcome. Co-management also promotes environmental education and empowerment for community members, resulting in an increase in active participation on the parts of all stakeholders. Framing environmental issues as a co-production of relevant and useful knowledge by all stakeholders will better inform policy and project development, ensuring that the needs of local people are not being ignored.

Field Work Case Study: "Building for Coastal Ecosystem-based Adaptation (EbA) in Small Island Developing States (SIDS)"

Field Work Overview:

In this chapter, the results of my field work are presented and discussed using various theories presented in chapter five. The objective of my field research was to determine which social, cultural, political and economic factors affected the overall success of Grenada's Ecosystem-based Adaptation (EbA) project at the Carriacou site. Within this research, I wanted to firstly determine how these factors affect the ways in which local people use, rely on, protect and degrade their environment. I then wanted to understand how (if at all) these actions changed with the development of marine protected areas and localized conservation initiatives. My research focused on the community based management aspect of these projects, to what extent local communities and stakeholders were included in the planning and implementation phases, and whether or not planners incorporated the goals of the community into the overall objectives of the program.

Methods:

My field term in Carriacou, Grenada ran from June to September 2016. The two main conservation initiatives I chose to focus on for my field research were Carriacou's Sandy Island / Oyster Bed marine protected area (SIOBMPA), which is employed solely by locals; and the EbA project. Within the EbA project, I looked at two community-based management programs: the coral reef restoration project and the lionfish containment project. My data collection methods consisted primarily of conducting semi-structured interviews with community members, as well as to attend various outreach events and educational workshops. I chose to use semi-structured interviews as opposed to structured interviews because my research is intended to provide insight into the thoughts, feelings, opinions and stories of the local community members. These narratives could not be conveyed through answering a series of generic questions.

I conducted a total of 20 interviews; eight of which were with MPA stakeholders, including marine park employees and local fishermen. The rest of the interviews were with EbA projects

coral gardeners, lionfish hunters, the dive shop owners and employees, as well as local business owners. During my field term, I also completed my certification and internship as a dive master at Deefer Diving, the dive shop through which the EbA projects were facilitated. The intention behind this internship was to be able to participate in the daily operations of the EbA projects coral garden, however in the weeks before I arrived in Carriacou a new regulation had been passed in the MPA denying coral nursery access to any non-local directly employed by the project. Despite multiple attempts to attain permission to enter the site, I was never granted official approval by Grenada's Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment. Fortunately, through my internship I was still able to observe the coral gardeners without actually "entering" the site and was therefore able to form relationships, and eventually interview each gardener. Collecting qualitative data for the lionfish containment program was much simpler. I participated in weekly lionfish culls for the duration of my field term, and attended two lionfish jewelry making workshops and a lionfish derby hosted by Deefer Diving for the local community members. I also attended a lionfish information session at the L'Esterre elementary school facilitated by NGO Caribbean Reef Buddy.

Grenada's Coral Reefs:

Tourism is the main driving force behind Grenada's economy, and the majority of tourism-related financial investments are concentrated in hazard-prone coastal environments. The tourism sector generates more than 50 percent of the country's foreign exchange earnings and stimulates activity in construction and ancillary services. Grenada has the second largest coastal shelf areas in the Organization of Eastern Caribbean States (OECS) (CCCCC, 2014). Reef systems off Grenada and Carriacou range from heavily stressed to pristine, with the majority classified as moderately stressed. Most of the reefs are located in the northeast and south-east coasts of Grenada, and relatively large banks of barrier reef can also be found on the east coast of Carriacou. Coral abundance, referring to the relative representation of coral cover in a particular ecosystem or region, ranged from 13-35% for Grenada's bank reefs and 16-40% of Carriacou's fringing reefs. Grenada's overall mean coral abundance was 27%, slightly higher than Carriacou's 22%. Carriacou's reefs were drastically affected by Hurricane Lenny (1999) which destroyed large areas of live coral, leaving barren substrates and increasing susceptibility

to other environmental and anthropogenic impacts. The main coral stressors in Grenada include land-based sources of pollution (sediment, pesticides, and inadequately treated sewage), over-fishing, anchor damage from boats, coral harvesting and coastal development.

Significance of Acropora in Grenada:

The branching corals Staghorn (*Acropora cervicornis*) and Elkhorn (*Acropora palmata*) were once the dominant reef building corals in most shallow reefs (<6m depth) surrounding Grenada, Carriacou and Petite Martinique (PM). Due to a regional disease affecting both these Acroporids in the 1980s and early 1990s, these branching corals suffered significant declines with estimated population losses of up to 95% (Bruckner, 2002). Mortality was so significant that these Acropora species were added to the IUCN Red List in 2008. Despite fast declines, Acroporids exhibit particularly high growth rates relative to other corals which enabled sustained reef growth during periods of rapid sea level changes. Both species have large branches, providing essential habitat for other reef organisms, particularly fish and lobster, making it critical in the Caribbean for reef growth, island formation, fisheries habitats and coastal protection.

A recent review (Farrario et al, 2014) provided the first quantitative meta-analysis of the role of coral reefs in reducing wave energy across reefs in the Indian, Pacific and Atlantic Oceans. Combined results across studies showed that reefs reduce 97% of wave energy that would otherwise impact shorelines (86% of wave energy is dissipate by the shallow reef crest) because the branching structure of Acroporids makes them particularly effective at dissipating wave energy although the branching structure makes them susceptible to damage during extreme turbulence. The loss of Acroporids around Grenada and across the Caribbean has decreased both the height and roughness of reefs, particularly reef crests and hence their ability to dissipate wave energy and reduce coastal erosion. Coral restoration projects designed for coastal protection and hazard mitigation, and not just for tourism and fisheries, are now recommended as an adaptation strategy (Ferrario et al., 2014)

EbA Project Introduction:

Ecosystem-based adaptation (EbA), as defined by the Convention on Biological Diversity's technical expert group, uses the range of opportunities for the sustainable management, conservation, and restoration of ecosystems to provide services that enable people to adapt to the impacts of climate change.

Grenada is particularly vulnerable to impacts of climate change due to its location in the southern extremity of the Windward Islands. The vulnerability is compounded by high population density, limited land, scarce fresh water supplies, and dependence on tourism (mainisland only). Grenada's low lying coastal communities are at particular risk from sea level rise and intensifying storms – exacerbated by degraded conditions of Grenada's coastal ecosystems, particularly mangroves and coral reefs which in a healthy state could provide effective barriers and therefore reduce the risk of disasters.

These ecosystems have been exposed to a combination of stressors from anthropogenic activities that have reduced their natural ability to recover and adapt to climate change. Increased levels of land-based pollution, sedimentation and over-fishing have shifted many of Grenada's fringing coral reefs towards an algae-dominated state. This has led to losing much of their value for coastal protection, tourism and fisheries. In a healthy coral-dominated state, fringing reefs can absorb over 80% of wave energy, and provide services worth an estimated $350,000USD per hectare per year (value based on 94 studies w/ median value of $198k per HA per year).

Grenada's coastal EbA project is a United Nations Environmental Program (UNEP) initiative, funded by the European Commission. The overall goal of the project is to increase the resilience and adaptive capacity of small island developing states (SIDS), which have a high dependence on coastal ecosystems, against the impacts of climate change. The goals of the project were determined based on a report examining the social and ecological vulnerability of Grenada (Day et al., 2015). The report also assessed various adaptation options, focusing on opportunities for coastal ecosystem based adaptation.

Day et al. (2015) assessed the vulnerability of three sites – two in Carriacou (Lauriston Beach and Windward) and one in Grenada (Grand Anse) – which are affected by significant coastal erosion. The recommendation for all three sites is to focus on the preservation and enhancement of existing ecosystems (coastal vegetation, dune, mangrove and coral) and to reduce/remove local stressors. Community-based mangrove and coral restoration is also recommended as an EbA strategy. Coral restoration recommendations focused on branching staghorn (*Acropora cervicornis*) and elkhorn (*Acropora palmata*) corals, which were once dominant in the shallow reef (< 6 m) around Carriacou and Grenada.

A Community-Based Approach to EbA:

The report (Day et al., 2015) recommends that Grenada's marine protection area (MPA) goals be re-aligned to optimize their value for the EbA project – protecting and restoring populations of herbivorous fish has been found to be particularly important for the ecological resilience of coral reefs and their ability to recover after bleaching events, storms or sedimentation.

When developing potential adaptation options, the following factors were considered: The existing status of the ecosystems; how intervention would affect ecosystem services; the influence of intervention on ecosystem resilience; how the intervention reduces local stressors; whether the local planning context is supportive; whether the intervention will address climate change hazard; willingness of community to participate; and the ability to overcome social barriers. EbA measures should be assessed, planned and implemented with the local community, as this is essential to increase participation, engagement and education. Adopting greater focus on EbA is highly consistent with Grenada's national policy to move towards a green economic model.

EbA Program Details:

Grenada was chosen as one of two pilot countries, with the other being Seychelles. The pilot in Grenada was implemented by the Ministry of Agriculture, Land, Forestry, Fisheries and the Environment in partnership with the UNEP. The time frame for project was two years: May 2014-June 2016 and is comprised of six outputs:

A) social-ecological climate change vulnerability scenarios and cost benefit analysis developed using existing data in two locations

A social-ecological (SE) vulnerability assessment was done at the national level using available information obtained from published and grey literature. This included a review of proposed and projected impacts for the island, an assessment of the social sensitivity and adaptive capacity to the impacts of climate change, the compilation of a geographical information system (GIS) database containing all geo-referenced data layers relevant to the SE vulnerability and associated ecosystems services and values (and assessment of this).

B) EbA demonstrations developed and implementation initiated in two project countries

C) EbA coastal decision support framework developed and tested in two regions

D) Regional trainings delivered in SIDS in Eastern Caribbean to government officials

E) SIDS relevant adaptation network initiated and knowledge products on adaptation in SIDS developed and disseminated

F) Global knowledge products on adaptation in SIDS developed

Specific tasks undertaken for the project include the following:

A) A review of initiatives addressing coastal vulnerability and climate change

B) Vulnerability assessments and analysis of scenarios for study areas – entailed modelling inundation scenarios and using best available topography to explore the impact of sea level rise (SLR) and storm surges at study areas

C) Analysis of adaptation options for study areas – this included identifying and assessing EbA and hard engineering options (example: Breakwaters, beach nourishment, artificial reefs) and see how they would reduce vulnerabilities.

D) Initial cost-benefit analysis of options for study areas.

The scope of output A included developing a GIS database that contains all available geo-referenced data layers relevant to the social-ecological vulnerability of Grenada. The database

includes habitat maps that describe the nature and extent of each coastal ecosystem, including more detailed maps. This was done between September and November 2014.

Results of UNEP Surveys for Carriacou:

Two contrasting sites were surveyed in Carriacou: Lauriston Bay (4 km) on the western side and Windward (2.5km) on the eastern side (see figure A). The Lauriston site is characteristic of a typical sandy tropical beach system with fronting coral reef and sea grass habitat and mangroves in the backshore. This system is generally more protected from wave energy than Windward due to being in a bay. Windward has a much lower gradient foreshore slope, higher wave energy and chronic erosion, therefore coastal protection methods are much more haphazard at this site and constructed to protect individual properties or reclaim land that was previously eroded. The Windward field assessment clearly illustrated the vulnerability of the residents in the area to flooding that would affect their dwellings, livelihoods (ie. boatbuilding and fishing) and water quality.

Adaptation Options for the Pilot Sites:

Ecosystem based adaptation (EbA) options were considered in relation to existing status of the surrounding ecosystems with special consideration given to how intervention would actually affect related ecosystem services. In other words, would it strengthen the resilience of the ecosystem, making it more likely to survive or adapt to climate change?

An emphasis was placed on how the selected EbA strategy could help reduce local stressors, thus help to restore ecosystem function. For this the planning context is important: it is essential that intervention integrates fisheries and tourism policies and development plans with a strong commitment to improving the blue economy in Grenada. With this, it is also important to understand the willingness of the community to participate in the EbA process. It was hoped that the intervention would provide long-term benefits, accompanied by some short-term sacrifices that the community would be required to make. For this reason, public salience and approval from community members is crucial to the implementation phase. This means that social interactions between stakeholders and their environment must be understood to

develop successful EbA options, and similarly cultural and social barriers to implementation must be weighed against the likely short-term rewards that will benefit the local community.

Suggested Adaptations for Windward, Carriacou:

The east coast of Carriacou was once dominated by thickets of elkhorn coral until the 1980s. These shallow extensive reefs gave Carriacou its name (from 'kayryouacou' meaning island of reefs). The elkhorn colonies are now very rare in the area, with only a few remaining. As a result, the reef crest lost its 3D structure and therefore no longer dissipates wave energy leading to more coastline erosion. Coral restoration was recommended as an ecosystem based adaptation approach for the windward region and community as a means of increasing coral cover on the barrier reef and thus helping to increase its value as a coastal defence. Since elkhorn coral was once the dominating coral species at the Windward site, restoration activities focused on elkhorn (*Acropora palmata*) and used local colonies as source material. It was also recommended that a coral nursery be established just inside the barrier reef, on areas of sand where steel nursery tables could be built and secured. For Lauriston Bay, coral restoration was proposed as an EbA option with the primary aim to propagate and out-plant the remaining population of elkhorn (i.e., planting coral fragments).

Cost Benefit Analysis:

The monetary value of the ecosystem services provided by coral reefs used in this study were taken from international statistics recently reviewed by Degroot et al, 2012. These values are based on 94 independent studies, have a mean value of $353,000USD per hectare per year, with a median value of $198,000USD (min was $37,000 and max $2,129,000).

The estimated budget required for the Windward restoration project in Carriacou is $500,000-1,000,000USD.

Benefits: fisheries, tourism sand production and coastal protection – when comparing USD$350,000 value of reef per 1 hectare per year to restoration value of USD$1,000,000 per hectare based on commercial restoration rates, this would result in a three-year return on investment. A community based coral restoration project would not cost as much as a

commercial project and would provide livelihood for stakeholders. That being said, the cost depends on the approach and amount of community support. The project should provide community livelihood and education opportunities for schools.

The estimated budget required for the Lauriston Bay restoration site in Carriacou is $200,000–350,000USD.

Benefits: contribute to beach protection and sand production and increase the value of fisheries and tourism. The project would also provide community livelihood and potential outreach projects for schools.

The Role of the Marine Protected Area:

Day et al. (2015) highlighted that this project could be combined with a wider coral restoration program for other reefs inside the sandy island oyster bed MPA (see figure A). This would offer opportunities for co-funding and synergies with the MPA management team. Unfortunately, the goals and actions of the MPA to move towards conservation are not clearly defined in Carriacou's Sandy Island / Oyster Bed MPA.

Sandy Island / Oyster Bed Marine Protected Area (SIOBMPA) and Results of the Survey

The SIOBMPA was officially established July 31, 2010. The key features of the MPA are the mangroves and oysters bed, sandy beaches including the sandy island sand bar, and the fringing coral reefs. The goals and objectives of the MPA are to conserve coastal and marine ecosystems, to engage all stakeholders and improve communication with MPA management and stakeholders, and to ensure the reputation of the SIOBMPA on a regional, national and international scale. Activities that take place within the MPA include SCUBA diving, snorkeling, sailing, kayaking, and beach recreation (picnics, swimming, weddings and parties). The MPA receives a lot of negative feedback from locals, particularly those from the fishing community as they feel that tourists and in particular recreational scuba divers get to utilize the MPA for activities while the locals have been pushed out to accommodate them. These feelings are further heightened with the tensions that have arisen on the island between the locals and the dive shop operators who are all foreigners of European or North American origin. Tensions

began to arise when dive shop operators started to dismantle lobster traps and on one occasion, move a boat out of the MPA borders. MPA representatives have commented that although they were there illegally, removal of these items by non-MPA workers is unethical and only increases tensions within the community and reinforces a negative attitude towards the MPA.

The MPA was originally 787 hectares and included an area that extended beyond the MPA's proposed borders so as to avoid fishermen parking their boats just beyond the MPA borders where the reef fish populations were recovering. The MPA was resized after launching to a smaller 659 hectares, which was a result of push back from the local fishing community and developers who wanted to use the region for fishing purposes. One specific area of mangrove forest that was eliminated from the MPA was later cleared and used for the construction of a large-scale marina, with development still currently underway in 2017. MPA establishment took 18 years from the planning stages to come into fruition, after organizations like the Lighthouse Foundation and the Nature Conservancy started visiting Carriacou and discovered the need to protect its fringing reefs which are some of the few pristine reefs left in the Caribbean region. The positioning of the MPA to surround Sandy Island, a sand bar located just off the south-western shores of Carriacou, was carefully chosen using community-based planning strategies combined with consultation with marine biologists. This means the local stakeholders and fishermen were able to contribute to the decision making during the planning stages. Since establishing the MPA, locals have proposed various projects such as a beach erosion initiative by the name of 'Save Sandy Island,' however such initiatives were not received well by the government when first introduced.

It was not until natural disasters hit that governing agencies were forced to consider restoration options. In 2004, hurricane Ivan hit Carriacou and Grenada, devastating coastline vegetation and consequentially further increasing rates of erosion. In 2005, hurricane Emily swept through and destroyed almost all that was left on Carriacou's coastlines. Since then, marine policy has been developed, however existing laws and governance practices have not necessarily ensured that the policy is being applied. According to Davon Baker, a SIOBMPA supervisor, this is a result of the fact that there are no laws binding commitment to policy or regulation enforcement, and

also that there is not enough man power or initiative to monitor the MPA properly. These issues are exacerbated by the fact that Carriacou and its marine protected area are often left out of funding and management by its larger sister island of Grenada. Carriacou and the third sister island of Grenada, Petite Martinique, are both listed in funding proposals in order to maximize funding opportunities for Grenada, however both sister islands rarely receive any of the money for its own projects. This creates a vicious cycle in which a lack of funding results in a lack of training, management and monitoring, as well as an increase in both smuggling and fishing within the region to generate income.

In 2010, The Nature Conservancy (TNC) partnered with Grenada's Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment to reinstall broken moorings and provide funding for daily operations within the SIOBMPA; however according to one MPA employee, the funding was misused and incorrectly allocated resulting in little change being made. During this same year, the continuous push back from the local fishing community resulted in further contracting of the MPA borders. Fishing is permitted within the MPA, however only traditional seines are allowed. A seine is a large net with sinkers on one edge and floats on the other that hangs vertically in the water and is used to enclose and catch fish when its ends are pulled together or are drawn ashore (Merriam-Webster, 2017). While net fishing can be considered as more detrimental than line fishing due to the sheer volume of fish than can be caught at once, it allows for the fishermen to be more selective of their catch and provides the ability for fishermen to remove unwanted bycatch. The fish that the MPA aims to ultimately protect are the reef fish, and therefore the use of a seine is the most ethical fishing technique for the SIOBMPA.

According to Davon Baker, the relationship between the MPA and fisheries tends to fluctuate due to inconsistent engagement and misalignment of interests. The fisheries include the Fishermen Folk, a local organization created by fishermen in the villages of L'Esterre and Hillsborough, which are surrounded by the MPA. Baker posits that the fishermen, particularly those that are more active as stakeholders like the Fishermen Folk know the benefits offered by the MPA but often do not feel that they are valued as crucial stakeholders in the decision making and management processes. This results in a lot of the fishermen deviating from the

proposed and agreed upon plans for action within the MPA borders. This lack of cooperation is further complicated by the fact that the Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment which oversees the MPA operations are located on the main island of Grenada, with visits back and forth being few and far between. Despite the distance barriers, Grenada's Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment decided to focus efforts on Carriacou's MPA because governance on Grenada's main island is poor, and splitting funding for the MPA projects between the two islands would likely result in failure.

While progress within the SOIBMPA has been slow, there have been a few initiatives that have taken off in recent years. To start off with, the MPA launched a new patrol boat in 2014 that is used daily. The primary function of the patrols is to ensure that visiting yachts are paying the park fees and mooring to the MPA's lines, and penalizing those that drop anchor in the park (monetary penalty). Another function of the patrols is to make sure all mooring lines are still intact, and that the fishermen adhere to fishing regulations within the park boundaries. Lastly, the patrols provide an additional safety measure as their presence can provide for assistance to distressed persons, particularly divers. MPA managers have attempted to provide outreach to the local community by means of a monthly newsletter, however issue releases are few and far between. Using park funding, the government of Grenada has provided equipment and training for the local fishermen to subsidize for the extra effort required for many fishermen to now travel outside of the MPA's borders for fish.

The Fishermen Folk expressed concerns over the increased distances they would have to travel in order to fish (the fish finders are located 15 miles off shore), and whether or not their modest boats and fishing equipment would withstand the trips back and forth. As a result, the MPA sent two local fishermen from the L'Esterre community to Belize for a monitoring, training and learning exchange work shop in which they learned about fish trackers, and how to build and deploy them. Both fishermen, who were active members of the Fishermen Folk, were able to come back and share this knowledge with their fellow community members. In 2016, four fish finders were deployed 15 miles off shore of Carriacou, making for an easier transition for the fishermen into pelagic fishing. They were also provided with subsidies to purchase new and improved fishing equipment, as well as funds towards larger engines or supplies to build larger

boats for the extended commute. The MPA also now provides two-way radios to any fishermen who plan to fish by the fish trackers to ensure that if anything were to go wrong along the way, help could be sent in a timely manner. In 2016, six new moorings were installed in L'Esterre bay after the fishermen folk had expressed concerns over foreign yachts taking up all the spaces on the mooring lines, forcing the fishermen to either drop anchor or in some cases move their boats to neighbouring bays overnight. Unfortunately conflict still arose from this accomplishment, as competition over the newly installed moorings between community members resulted in the illegal removal of the lines. According to Davon Baker, some of the moorings have since been replaced. I conducted interviews with three SIOBMPA workers, two of which were MPA wardens, the other was Davon Baker, a supervisor. Two of the three interview participants requested to remain anonymous and therefore their names will not be mentioned. Throughout the interviews there were common views and opinions of the problems that plague the SIOBMPA, however the varying levels in breadth and depth of knowledge of marine ecosystems and their subsequent environmental issues were very apparent. According to Baker, the biggest challenges that the SIOBMPA faces are issues in governance and expert management. Baker believes that there is a lack of consistency in expert management and site monitoring, which is often the result of a lack of experience working within a marine park setting, as well as a lack of adequate resources. "The most important resource that the MPA is lacking is man power," Baker went on to say that a lack of manpower makes it difficult for managers to focus on other efforts that improve community support and participation, such as outreach programs. Mangrove and beach clean ups and maintenance were also among the list of projects that the SIOBMPA hoped to tackle however Baker said that the MPA workers expressed a lack of interest or passion in improving the conditions of the MPA, and therefore any associated work would have to be compensated financially, which is difficult when funding is limited.

I asked Baker why they did not look towards volunteer clean up initiatives, "Those initiatives require hard work and are expensive, money isn't everything but it is important," he replied. He believes that passion and consistency of engagement with community is severely lacking with MPA workers. I asked Baker to discuss why he thinks there may be push back or a lack of

interest in the MPA on the parts of the local community, if any. Baker replied that the community knows that something needs to change, while they may not be well versed in the science behind it, they have observed changes to the landscape and the fish stocks but they are not sure how to go about it, and may not necessarily be ready to give anything up. Baker then continued to discuss the misconceptions of how the MPA is run, and how this may impact cooperation between the MPA and the community. “There is a big misconception that the dive operators are the people dictating the goals of the MPA, which is simply not true,” Baker said this notion first began when some of the fishermen’s fish pots (or traps) were moved from within the MPA and dropped outside of the borders. Allegations were mostly directed at the foreign dive operators, and Baker says this contention has led to rumours and accusations that the MPA managers are paid off by dive operators to run the marine park as they see fit.

This growing tension will be revisited later in the chapter as it relates to the success of the coral reef restoration project that operates within the MPA. I asked Baker about disciplinary measures, and whether financial penalties could be used as a policy tool to increase community and public salience about MPA regulations. Baker confirmed that there are established fines for illegal actions within the MPA borders (to a maximum of $10,000USD) however he believes they are not very effective because everything must be enforced through the court system, which is characterized by lengthy processing times and therefore does not hold visitors and passersby accountable for their misdemeanors. Baker also commented that this usually leads to MPA workers doing a lot of paperwork with little results, resulting in leniency on the part of the wardens.

I asked Baker what his recommendations would be moving forward, to which is responded that the most important thing to do is to focus more on integration of community members in the day to day operations of the park, with an emphasis on stakeholder participation with increased input and representation on the board. Baker believes that incentives for participation would be effective, and provided the example of offering free moorings within the park to locals only, so that they would feel like they belong in the park as well. Secondly Baker recommended promoting youth participation and education through outreach, “environmental consciousness

starts at a young age, and on an island like this, education about our water should be the main priority."

The Fishermen Folk:

After my interviews with the MPA workers, I sought out interviews with members of the Fishermen Folk in order to get a better understanding of how their feelings towards the SIOBMPA have changed since increasing their stakeholder involvement with the park. The Fishermen Folk is a 15-member board that was organized by community members Cobra (president) and Joshua Clement (Vice President), both of which are prominent fishermen in the L'Esterre community. The board meets every Tuesday to raise issues and concerns, as well as to discuss further production of fish finders (locally named 'fads'). I interviewed five members, including the committee president, who goes by the name of Cobra. Cobra founded the Fishermen Folk non-government organization (NGO) in 2012 in response to community concerns that fishermen were not being valued as crucial stakeholders in the planning process for the SIOBMPA. The committee members believed that their livelihoods were impacted the most with the establishment of a marine park in their village, but were never consulted during the decision-making process. I asked Cobra why he thinks the fishermen did not have adequate representation during the planning stages, to which he replied "we fishermen are the number one stakeholder, but we are seen as not educated enough to make informed decisions, so input from us is minimal."

Cobra, as well as other members expressed feelings that the dive shops and other stakeholders are given higher esteem and therefore more input. The Fishermen Folk were often invited to SIOBMPA meetings but did not feel that there was a space for them to voice their opinions. Some fishermen discussed tensions between themselves and the Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment in Grenada as they feel that the government tends to forget about the two sister islands (Carriacou and Petite Martinique). I asked Cobra to describe how the SIOBMPA area was used prior to park establishment. He explained that the region was used mostly for bait fishing by all local and Grenadian fishermen, and that now they have resorted to boating up to Canouan and Bequia, two of the Grenadine islands (St. Vincent and

the Grenadines) to catch bait fish. Unfortunately, this means that the problem of overfishing is not being addressed locally, and instead has been shifted to another region. Cobra added that many fishermen also changed their techniques to long line fishing to compensate for the lack of bait fish availability. “I would say that this MPA is pretty much a paper park though, because fishing is still happening here and a lot of the workers turn a blind eye” says Cobra. I was unable to verify this when I interviewed the MPA workers, but the park wardens did express feelings of being conflicted when it came to reprimanding their fellow community members for illegal activity in the park. “This island is very small, and so when you come across a fisherman in the park doing something wrong, there is a great chance that he is your uncle or neighbour” said one MPA employee.

I asked Cobra to discuss his thoughts on people still fishing in the park borders. He said that fishing techniques are spread through generations of fishermen and the older ones are not as educated because a long time ago boys would drop out of school early to become fishermen, sometimes at 12 years of age. He went on to say that the new generation of fishermen are more informed and therefore make more informed fishing decisions. For this reason, he feels the resistance against the SIOBMPA and moving towards sustainable fishing practices has declined. While the new generation of fishermen are more welcoming to changes to their traditional ways of fishing, many are still frustrated that the government took a long time to offer any sort of compensation. “There is not a proper balance in terms of displacement of the fishermen and alternate livelihood options. The alternatives were not offered until years later, after many fishermen were put out” said Keron Wtais (known as Robot), one of the youngest members of the Fishermen Folk.

All committee members interviewed mentioned that the rules of the MPA tend to change and bend depending on personal interests. One major example is the large-scale development of the Tyrell Bay Marina that is located inside the Oyster Bed, which is a part of the SIOBMPA. Many fishermen agree that development is necessary, but needs to be community based. “In the last 15 years there has been plans to build businesses like banks, hotels and strip malls for the tourists that the new marina will bring in, however there is has been no talks of training or opportunities for locals. Who will do these jobs, locals or ex-pats? And what is in it for the

locals?" said another committee member. The fishermen claim to have been penalized for spear fishing within the park borders, and yet the government approved the dredging of the Oyster Bed within the MPA in order to build the marina. I asked the members if they were aware of the Coral Reef Restoration Project taking place in the MPA or whether they were interested in participating, many replied that they think it is a good project, but did not even know about it until they noticed the marker buoys located within the park, just off of Mabouya Island. Some felt that they were probably not told about the project sooner or offered involvement because the dive shops do not have respect for local fishermen.

When asked what they would like to see change for the future of the SIOBMPA and the fishing community, the fishermen unanimously agreed that Carriacou needs to be preserved for and used by Kayaks (the local term for a person from Carriacou). Cobra said that the park needs proper zoning and a clear outline of rules, and that this needs to be clear to the fishermen. "Some spot needs to be fishable, and others not. Certain species of fish should have restrictions, like parrot fish and doctor fish, the reef fish" said Cobra, who believes that the fishermen should be allowed to catch the larger, pelagic fish like barracuda because they do not live on the reef. The Fishermen Folk board members have also proposed a downsizing of the MPA area. I asked them how they thought decreasing the MPA size may impact reef recovery efforts. Many said that this was already done for the development of a marina, in which dredging had grave impacts on the mangroves and oyster bed, and felt that the fishermen's livelihoods should also be a priority since it is the main form of employment on the island.

Through the interviews, I got an overall sense that above all else, the Fishermen Folk strive for inclusivity, and want to be informed of what is expected of them, and how they fit into the changing landscape of their villages. "Overfishing is not necessarily killing the reefs in Carriacou; fishing methods are the bigger issue, like net fishing that lands directly on the reef. The government needs to allocate funds towards preventing that damage by working with local fishermen and keeping us informed" says Cobra, who vows to continue to facilitate a healthier working relationship between the SIOBMPA and the fishermen of Carriacou. Not only does proper communication between the MPA and the fishermen need to be a priority, so does the communication between the SIOBMPA and its workers. While employees like Davon Baker

exhibit a clear understanding of the issues facing Carriacou's marine ecosystems and the the MPA as a whole, other employees were unable to describe or even name the title of their position with the SIOBMPA.

While legislation has been enacted, the facilitation of the various projects introduced through the MPA has fallen by the wayside. The MPA's list of stakeholders includes: The Grenadian government (Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment), the MPA and its employees, the funding agencies, the dive operators, the fishermen and the local communities in the surrounding areas, including those that are pushing development inside of the MPA. It is clear that proper jurisdiction for each party needs to be clearly established and conveyed. Subsequent environmental education and outreach needs to be provided in order to ensure that stakeholders understand their role within the MPA, as well as the role of the MPA in empowering the community as a whole. This includes basic education on marine ecosystems and the importance of not only reef fish, but also pelagic fish and larger predators to reef health. Marine conservation and community empowerment need to be seen as one goal, the main goal of the SIOBMPA.

Overall EbA Project Implementation and Outcomes - Results:

Coral Reef Restoration Program:

On July 2, 2015, The Nature Conservancy (TNC) along with volunteers through Deefer Diving, the on-island dive resort that was contracted to facilitate the project, installed 15 coral nursery tables on the south side of Mabouya Island within the SIOBMPA. The tables were installed at a depth of eight metres and contained 25 fragments of *Acropora* per table. The tables were constructed using PVC piping for the structure. Coral fragments were attached to terracotta tiles using an epoxy putty. The tiles were then fastened to the table using plastic zip ties. There were ten Community Coral Gardeners (CCG) hired, nine of which were locals and one Canadian permanent resident and PADI Scuba Instructor contracted through the dive shop to work as the on-site divemaster, CCG trainer and acting head gardener until the position could be filled by a local. At the time of installation, the coral gardeners began to undergo training, receiving their PADI Open Water Diver certifications and training on coral, fish, algae and seagrass

identification. Once training was complete, the gardeners were split into groups of five, each group were assigned one weekday afternoon each week to clean and maintain the coral tables.

These paid sessions took place on Tuesday and Thursday afternoons, commencing at around 13:00 and ending at 15:00. The cleaning dives, due to the shallow depth and immobility of the divers were timed based on air-consumption, but lasted for an average dive time of 90 minutes. During each dive, the gardeners would use a soft bristle tooth brush to clean any algae that had attached to the fragment itself; a firm bristle brush to clean algae off of the tiles; and a steel wool pad to clean any algae that had grown on the PVC piping (see appendix figure C). This process is important to reduce algal domination and eliminate the risk of algae growing from the table onto the fragments.

Approximately six months into the project, Lyle Bullens, a local community member and certified diver was hired as the head coral gardener. The fragments were ready for the first transplantation cycle in May 2016. During the project planning phase, the transplanting schedule was based on six-month cycles, and therefore the project was slightly behind schedule, however most fragments had grown large enough for transplant and therefore the project methods were proving effective. Fragments from the first cycle were transplanted to one of two sites: a pilot site established off the windward shore of Carriacou (see appendix figure A); and a pilot site off the main island of Grenada's Grande Anse beach (see appendix figure B). The fragments have since successfully attached and integrated into the existing reefs at both sites. All transplants were monitored periodically through visits to the pilot sites. New fragments were recruited in-situ (close to the nursery site) and fastened to the tables for the second transplantation cycle. During the second cycle, the fragments were not as productive for various reasons. Some of the fragments became diseased and had to be transferred to quarantine tables. During my field term in the summer of 2016, participation from the gardeners began to suffer. Two gardeners from the Carriacou site had quit, one of which had found a new job that would not permit them to participate in weekday dives; the other had quit for an unknown reason. Some of the other gardeners began showing up late or not at all, siting other job opportunities as their reason for absence. On some days, the dive shop would cancel the boat ride out to the site altogether because they did not think it was worth heading out

with only one or two gardeners. The lack of attendance and numerous boat cancellations caused tensions to rise between the gardeners and the dive shop owners.

In order to understand what caused the shift in both attendance and morale, I conducted interviews with all remaining coral gardeners at the Carriacou site, as well as one gardener from the Grand Anse pilot site on Grenada. I also conducted interviews with Gary Ward, the dive shop owner, and Katlynd Treiber-Vajda, the on-site divemaster and previous senior coral gardener. Treiber-Vajda, a wildlife biologist, had originally travelled to Carriacou to work with nesting sea turtles but quickly found her passion in diving and marine conservation. She loved the role of the senior coral gardener and was really excited about the project when it had first begun. Although Treiber-Vajda was sad to give up her role, she was equally happy that a local community member was able to fill the position as she was also a full-time employee at Deefer diving, and acknowledged that this was the end goal of the local initiative.

The role of the senior coral gardener is to write reports, communicate with gardeners as a liaison with the EBA project managers in Grenada, maintenance of equipment and ordering of supplies. Treiber-Vajda expressed feeling disassociated from the other gardeners at times because she is not a local, but said that overall, she got along well with the gardeners and felt that they were all hard-working individuals. I asked her about the sudden change in attendance, to which she replied “I cannot say for sure what the root cause of it is, but everyone has been a bit frustrated because of the disjointed nature of the project.” She went on to say that the gardeners had complained that they were not receiving their pay cheques, and that they had been waiting for a month for the project managers to send over a new container of epoxy putty, as some fragments had broken loose from the tiles. After a while the fragments began to die as they had not been re-attached quickly enough. The container arrived over a month later, but had hardened and was unusable. The dive shop decided to order a new batch of epoxy out of pocket rather than wait for the project managers to do it. Deefer Diving holds a contract with the EbA project to provide their boat twice a week for trips to the nursery site and to store the dive equipment at their shop. Beyond this, Deefer has no other known role in the project and therefore should not have been responsible for the purchasing of supplies or monitoring attendance of the employees.

Treiber-Vajda believes that an Island like Carriacou can benefit from a small-scale project like this but there are issues in policy versus practice, as is common in conservation projects. I asked her if she had any recommendations for the project. “The managers need to be more actively involved in communication with the Carriacou site. When the Grenada chapter has issues, they are physically closer to the managers to be able to better express their concerns.” Katlynd added that she felt the project could benefit from reducing the employee roster and focusing on a smaller group of gardeners that could commit two days per week. This would likely make the project more streamlined and may actually do more to empower those individuals. She also mentioned that the out-planting thus far has been successful, and that ensuring the fragments grow healthily for transplanting should be the number one goal of the project.

At this point the lack of cleaning and maintenance of the coral nursery tables lead to algal growth and the health of the fragments began to suffer. The lack of enthusiasm in the project made it difficult to convince the gardeners to sit down for an interview, but one month into my field term I was finally getting answers to the questions I had been asking myself. I first sat down for an interview with the gardener who had quit for an unknown reason. I had met this individual (who requested anonymity) during the summer of 2015 when I was helping to set up and maintain the coral tables at the start of the project. At that time, the gardeners were going through training and were all very enthusiastic about their roles. Most of the gardeners are of the new generation of fishermen (traditional or spearfishing) and were aware that the reefs are in trouble and wanted to get involved in a conservation project. When I asked this individual why they had decided to resign, they responded by saying they had developed a bad relationship with the dive shop owners and did not want to work with them anymore. They felt the project would work best if it were run by a locally owned dive shop. Unfortunately, there are no locally owned dive shops on the island. This however, was a sentiment that all of the gardeners shared, with every one mentioning it as a recommendation. “This is a community-based project being facilitated by foreigners, it doesn’t seem like the right way to empower locals” said another gardener, who also asked to remain anonymous.

All of the gardeners expressed concerns over tensions between the local employees and the dive shop owners, feeling as though the owners did not trust them, and some even claimed

that the tensions were race related. When I interviewed the dive shop owner, Gary Ward said that he as well could not say for sure why the gardeners' attendance began to suffer, but that he felt like they lost their motivation and were not putting in enough effort. Ward also acknowledged that their pay was being withheld, which is a big problem, but that the employees also need to understand the goals of the project. "In order for the project to be successful, the fragments must be cleaned consistently, if the workers stop showing up, the fragments will die and then all of this will have been for nothing." A few of the gardeners that did continue to show up consistently despite withheld pay agreed with this sentiment, and were disappointed that the others stopped showing up so quickly.

While this may be true, just showing up while not getting paid is not always easy. One coral gardener, Shevon Wells, told me that he had to ask special permission from his employer to come to the dive shop once a week. For Wells it was a worth the trouble for such a worthy cause and according to Treiber-Vajda, he was also one of the most productive gardeners. The added benefit of learning how to dive, as well as getting to participate in something meaningful for his community were the driving factors for him. Unfortunately, between maintaining his farm, taking a slight pay cut for missing one afternoon a week of work, and having to pay child support, Wells was unable to afford being withheld his pay and decided to quit his position as a coral gardener when he was offered a promotion at his full-time job. At the time of the interview, the gardeners had not received pay for almost six months.

According to the former senior coral gardener at the Grand Anse pilot site in Grenada, many of the gardeners stopped wanting to participate due to issues with their pay being held as well. This individual went on to say that there is a lot of disconnect and a lack of clear communication even coming from the United Nations Environmental Program (UNEP), and that it has unfortunately trickled down to all the other levels. Another concern that was highlighted was that everyone in the government tends to want to keep pertinent information to themselves, which makes collaboration difficult, "there is definitely a competition for success in the government and in the community." Their decision to stop participation in the project however was not related to project politics but rather was ultimately due to having interests in wildlife ecology, and therefore wanting to explore other genres of work. This former employee

offered similar recommendations to those of Treiber-Vajda, stating that the project could benefit from shrinking the groups from eight gardeners to four, siting consistency as the most important quality of the gardener role.

By September 2016, the end of my field term, 1100 fragments had been successfully out planted to three sites (two sites in Grenada, one site in Carriacou). Unfortunately, during that same month a coral bleaching event took place at the out-planting site off of Grand Anse (see appendix figure D). The bleaching was due to increased temperatures, with thermal stress levels reaching category four, the highest level characterized by the likeliness of mortality (NOAA, 2017). Despite this, most of the fragments survived and were recorded in November 2016, five months after transplant, in a healthy and stable state (see appendix figure E). The out planting had proven so successful that it attracted a lot of media attention. The project sites even received a visit from Prince Harry, with whom the gardeners were able to use their knowledge and presenting skills to teach about the project and discuss how their involvement has affected their livelihood (see appendix figure F). Unfortunately, the coral nursery off of Mabouya garden is no longer operating, with all efforts ceased once the UNEP program and funding stopped. I recently contacted one of Deefer Diving’s employees to follow up on the nursery progress, who confirmed that the nursery is now abandoned with the majority of the fragments completely bleached or engulfed in algae.

While the project was successful at reaching the desired out-planting goals, it failed to empower the community due to a lack of communication and various other management issues. The number one problem with the project is that the governing agency is severely understaffed. I interviewed the project manager, Kerricia Hobson, who informed me there were only two staff members running the project from the head office in Grenada, which made it difficult to stay on top of everything. She was unable to respond to questions regarding the employees’ pay being withheld, and claimed to visit Carriacou’s site at least once a month. This claim was, however, disputed by the gardeners and dive operators who said representatives from Grenada visited the site maybe once every three months, if that much.

I myself was faced with this issue when attempting to apply for a permit to conduct research within the SIOBMPA. From September 2015 until the start date of my field term in May 2016, I sent numerous requests via e-mail to Roland Baldeo and Justin Rennie at the Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment, whom I was advised to contact regarding permission to conduct research. I received one response from Baldeo who said he was very interested in my research topic, but failed to respond ever again regarding approval to collect quantitative data. Upon arrival I attempted to contact the office via phone on various occasions, to which I was always told I would receive a phone call but never did. One month into my field term I was forced to change the nature of my research as it was clear I would never receive written approval. When this issue was raised during my interview with Hobson, she said she was not surprised, as even a task as seemingly simple as stamping a piece of paper offering me approval was too much to ask because the offices were so disorganized and far behind on paper work.

Despite the fact that I had been one of the volunteers who helped set up the coral tables for the pilot site in Carriacou, as well as clean and monitor the fragments in July 2015, I was no longer granted access to the coral nursery in 2016. A new regulation had been passed that banned non-locals from working in the nursery. This issue of politics became even more problematic when the gardeners stopped showing up for the dives, resulting in the boat trips being cancelled entirely. I offered on numerous occasions to help (unpaid) with cleaning of the fragments when there were not enough gardeners present, to which I was told I could do so only if I got permission from the Ministry of Agriculture, Lands, Forestry, Fisheries and the Environment. This not only made my ability to collect data difficult, it also meant I was unable to publish any official quantitative data in my major paper. This does not pose a serious problem to me as a researcher, as I was able to change the direction and methods of my research to focus on the social side of the project, and how it affected locals and their feelings of empowerment. The bigger concern is that issues with paperwork and written approvals were getting in the way of having extra available hands on site to help maintain the health and resilience of the coral fragments, which were quickly becoming engrossed in algal growths.

The fact that getting anything approved or reviewed is nearly impossible no matter how small or important, is more concerning because it is telling of how disorganized the governing agencies are, which sets up projects like this for failure. Had the gardeners been paid on time, they would have continued to show up to work for every shift. This would have reduced tensions and a lack of communication between the dive operators and the gardeners, and would have increased coral fragment productivity. The gardeners started their training motivated and informed, and were able to learn and grow throughout the course of their careers as coral gardeners. Every gardener that was interviewed stated feeling very proud and accomplished to learn how to dive, and to learn more about species identification. They also mentioned how proud their families and community leaders were for them when they received their Community Coral Gardener Certificates. The project had the potential to empower its community members if implemented properly; however, the disorganization and subsequent lack of communication resulted in feelings of disrespect towards the workers, and ultimately led to some of them dropping out of the program. This could have been avoided if project planners and managers had kept the needs of the community in mind, and prioritized making sure that they felt comfortable in their role and empowered through their affiliation with the program.

No official documents or government reports have been published to date on whether the project met all the goals highlighted in the project proposal, or whether the out-planted corals have improved the ecosystem resilience. Unfortunately, this is a very difficult value to measure and may take years to determine. I was recently contacted by a group of researchers regarding the findings of my own research, which would lead me to believe that no one else to date has collected any sort of qualitative data regarding impacts of the MPA and project on community-building and empowerment.

Lionfish Containment Program:

Funded by the Global Environment Facility (GEF) Small Grants Programme, the Lionfish Containment Project was carried out by the NGO Caribbean Reef Buddy, to whom a grant of $50,000USD was awarded. The project start date was April 2015, and ended June 2017. The

goals of the project were to improve capacity building, policy impact, promote public awareness of the global environment, and emphasized a push towards a sustainable livelihood and community participation. The project also focused on active participation by both males and females and encompassed all community members from fishermen to local business and restaurant owners. Eight local community members were trained to Open Water Diver certification to form the nucleus of the Lionfish culls. Local women and business owners were trained in how to produce jewelry using the fins from the Lionfish caught during the culls. A comprehensive presentation was also designed and delivered to local primary and secondary schools focusing on educating children about the detrimental effects of Lionfish on the marine ecosystem, the edible nature of the meat, and the importance of species removal through fishing. A workshop was also held for local restaurants providing techniques in the preparation of Lionfish dishes.

Weekly Lionfish culls took place on Saturday afternoons, and drew impressive crowds of divers. At first many of the coral gardeners who were now certified were showing up for the Lionfish culls. Participants were allowed to keep whatever they caught, although the catch was often divided equally between who ever wanted to take them home. Some of the local fishermen who participated would sell their catch at the market or process the meat into saltfish, a staple food on the island. Other participants would donate their catch to local restaurant owners, who would typically offer it as a daily special on Saturdays. The fins from the catch would be cleaned and dried out, then given to local women who turned them into jewelry. The weekly cull dives provided a fun outing for locals and promoted comradery between participants. This was heightened through quarterly Lionfish derby's organized by Caribbean Reef Buddy, boasting an overwhelming turn out at each event. Each derby was characterized by a lionfish hunt competition, followed by a Lionfish cook off between all of the local restaurants with cash prizes for both the largest catch and the best dish. The event always culminated in a big community barbecue to which hundreds of community members would attend.

The Lionfish containment program was a huge success overall and although funding was not renewed, the legacy of the project has lived on with Lionfish now being a commonly caught and eaten species on the island. Not only is Lionfish sold in the local fish market at a premium price,

it has become a novelty dish sold in most restaurants and has proven to be popular with tourists and locals alike. Most importantly the project was successful at educating locals about the invasive species and empowered the community by providing them with a way to catch and utilize them. During my field term I conducted numerous interviews and surveys in order to find out the extent of knowledge about Lionfish in the community. The majority of the community members had heard about them, and had learned through outreach program that they are not poisonous and can be eaten. Most community members had already tried eating Lionfish, or had heard it was good and wanted to try it themselves. The Lionfish containment program is a perfect example of how a relatively small grant of $50,000USD could be used to educate and empower a local community, who no longer need assistance in managing the invasive Lionfish population from foreign governing agencies, rather they are now equipped to manage it themselves. Arawak Divers, a dive shop on the island has begun hosting their own self-funded Lionfish culls every other weekend and organizes monthly Lionfish barbeques open to the community.

Discussion and Conclusions:

The lionfish containment program turned out to be far more successful than the coral restoration program at achieving tangible results and engaging the community. The reasons behind these contrasting results had a lot to do with difference in both complexity and execution of the projects. The lionfish containment project was able to run on a much smaller budget and able to engage a much larger group of people. The coral restoration program required a much higher level of continual engagement and consistent monitoring. The lack of monitoring and re-evaluation of objectives ultimately led to project failure, not only in community empowerment, but also in creating a restoration project that could be sustained in the long-term. These results, as well as the conflicts related to the SIOBMPA management can be explained using Geoghehan and Renard’s four key lessons learned from past failed projects from their article “Beyond community involvement: lessons from the insular Caribbean” as a framework.

According to Geoghehan and Renard, the first lesson is that effective management requires the integration of the stakeholders and takes into account the differing ways they are affected by and affect protected areas (2002, p.22). The Fishermen Folk unanimously expressed that they felt they were the number one stakeholder of the SIOBMPA because prior to establishment, most of the L'Esterre community fishermen only fished within the MPA borders, and therefore were affected the most when the area was off limits for fishing. Issues between the MPA managers and the local fishing community would have likely been avoided or at least curtailed had they felt they were given a stronger voice during the planning phase, or felt that they were welcome to share their concerns at SIOBMPA stakeholder meetings. Geoghehan and Renard also state that in order to achieve effective management, stakeholders ever evolving attitudes and relationships with the project and with each other should be factored into the implementation phase (2002, p.22). This was particularly important for the coral restoration program in which the coral gardeners had a high level of respect for and compliance with the program objective in the beginning, but began to feel frustrated and undervalued when their pay was withheld. They also began to feel uncomfortable, and in some cases disrespected, as tensions began to arise between the employees and the dive shop owners. These growing tensions and the ultimate loss of interest in the project could have been avoided if a monitoring protocol had been established as an ongoing part of implementation phase in which participants could voice concerns and offer feedback.

This leads into Geoghegan and Renard's second key lesson, which is that the long-term success of participatory management depends on the suitability of the institutional arrangements such as focusing on being democratic and contributing to the empowerment of disadvantaged groups (2002, p.23). Many of the Fishermen Folk felt that although SIOBMPA managers attempted to provide alternate livelihoods to those impacted by the MPA, the help was offered long after park establishment. This left the fishermen feeling increasingly disadvantaged, thus causing disparagement for the project to grow, leaving a bad taste in their mouths long after alternate options were provided.

Unfortunately, structures and mechanisms were not put in place that promote and sustain linkages between sectors and the involvement of non-traditional actors in management. The

Fishermen Folk president, Cobra, expressed feeling sheepish at SIOBMPA stakeholder meetings because there is a common notion that the fishermen do not possess a formal education, and therefore feel like their insights are invalid. Geoghegan and Renard also suggest that structures and mechanisms need to be put in place to respond to unforeseen circumstances, which the EbA project failed to do when the coral gardeners began to experience feelings of racism and distrust from the dive shop owners. The dive shop should not have interfered with the operations of the program or overstepped their boundaries, which would have been avoided if program managers had clearly communicated the roles of both the dive shop and the EbA project employees. Had the EbA project managers asked for feedback periodically throughout the program, they would have known that the gardeners were contemplating dropping out of the program as a result of having their pay withheld.

The third lesson highlights the importance of transparency. Given the limited resources for protected area management, transparent processes of negotiation are required to determine how much participation is possible and what objectives are given priority (Geoghegan & Renard, 2002, p.24). The EbA project clearly lacked effective management of finances and program implementation. Moreover, the conservation and social objectives should have been approached incrementally, so as to not compromise the integrity of the entire initiative. As previously stated, the project could have benefitted from periodic monitoring, which could be used to re-evaluate the project timeline and objectives. Over the two-year term, as participation began to dwindle, so did the health of the coral fragments. Since a third out-planting event was not on schedule to take place, all operations within the coral nursery ceased once the program had come to an end, proving that the project failed to create a community-based conservation initiative that was sustainable in the long term.

The fourth and final lesson learned from past failed projects in the Caribbean, as outlined by Geoghegan and Renard, is that participatory management of protected areas must yield appreciable benefits for local communities (2002, p.24). If the project does not yield real benefits, community involvement cannot be meaningful. The coral restoration program may have resulted in out-planting of over 1000 coral fragments, but it failed to yield appreciable benefits for the coral gardeners participating in the program. The withheld payments, issues

over race relations and integrity between the dive shop operators and the coral gardeners, as well as a lack of communication and control over inventory and supplies resulted in the overall collapse of the project. When I asked EbA manager Kerricia Hobson if she felt the project was a success she responded with an enthusiastic yes, stating that the coral fragments were doing well, the gardeners were all very happy with the work they were doing and Windward community members were thrilled that the government was rebuilding the reef they had lost to extreme weather events. It was clear that even the program manager was not aware of the current state of the project, but took full advantage of the opportunity to use the EbA project for good publicity for Grenada's conservation initiatives.

The fourth lesson proves to be a recurring argument in literature related to community-based natural resource management, that the fate of these projects lies in the degree to which the community feels they are experiencing positive results from the project. This explains the contrasting success of the lionfish containment program at community engagement. It was not only inclusive of the lionfish hunters, who experienced the highest level of empowerment by receiving dive training and the ability to sell the catch or use it for subsistence, it also engaged the youth who were presented with information sessions and outreach programs at school, the local restaurant owners who were given the opportunity to showcase their dishes at the lionfish derby's as well as generate income by selling lionfish dishes at their restaurants, the local women who learned how to use lionfish fins to make jewelry and were then able to generate income from jewelry sales, and lastly the community as a whole with the quarterly lionfish derby's where locals were able to try eating lionfish and gain exposure to learning about lionfish as more than a poisonous, invasive species.

Overall the EbA coral reef restoration project outcomes failed to match the objectives. This was the result of a lack of monitoring throughout the project. This lack of monitoring has also affected the manager's ability to learn from the project through evaluation as there were no qualitative data collected. This would explain why there has not been a project report published to date. A lack of stakeholder involvement and the flexibility to react to unforeseen circumstances threatens the success of the SIOBMPA as well, as it currently functions mostly as a paper park. Understanding the objectives and attitudes of the local community will allow MPA

and project managers to contribute to the empowerment of disadvantaged groups, and promote active participation in moving towards more sustainable livelihoods.

APPENDIX:

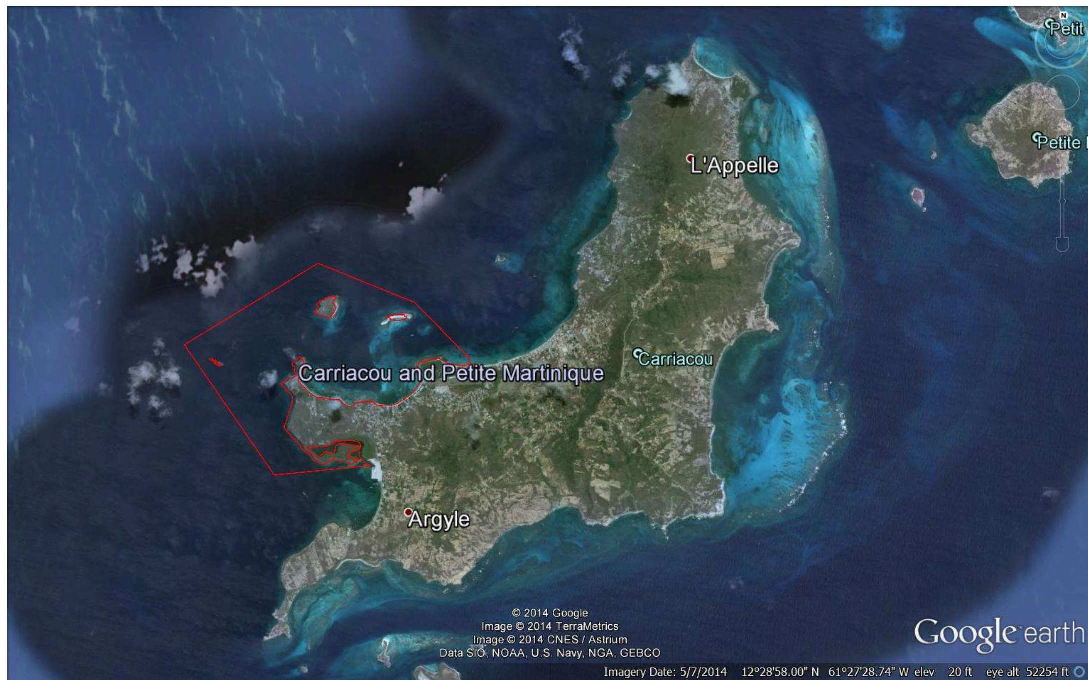

Figure A. Map of Carriacou's SIOBMPA borders.

Figure B. Map of Grenada, Carriacou and Petite Martinique. See Grand Anse Beach located on the South West shore of Grenada.

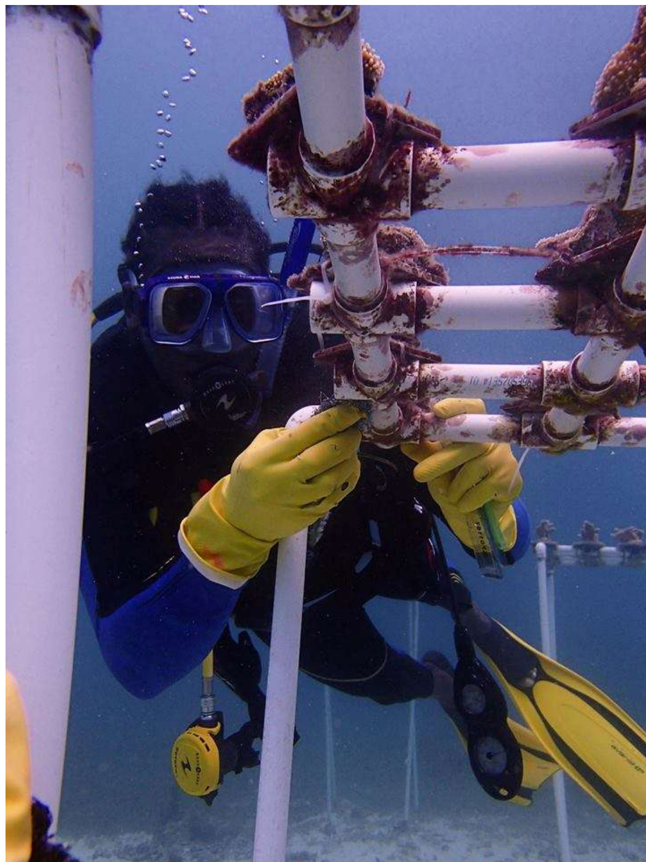

Figure C. Coral gardener scrubbing PVC piping at the Mabouya Island Nursery in Carriacou.

Figure D. Bleached coral at Grand Anse out-planting site.

Figure E. Healthy transplanted Elkhorn coral at Grand Anse out-planting site.

Figure F. Coral gardeners discuss the EBA project with Prince Harry in Grand Anse, Grenada.

Conclusion:

Coral reefs around the world are deteriorating at an unprecedented rate due to overfishing and human related impacts from recreation and tourism, nutrient loading (eutrophication) and the introduction of invasive species. These factors individually reduce the resilience of an ecosystem, which is magnified by cumulative effects when one or more of these factors are compounded together, leading to rapid degeneration of the reefs and in turn, habitat and biodiversity loss. These factors can be managed or reduced with proper management techniques and cooperation from stakeholders, including community members. Developing projects that facilitate co-management between local communities, marine biologists and governing authorities working together is the most effective strategy for implementing change

that can result in reef restoration as well at socio-economic benefits for local communities. Restoration projects in the Caribbean thus far are often met with resistance due to a lack of knowledge sharing, funding or cooperation on the parts of all stakeholders, primarily on the part of governing authorities. This is often a result of political corruption or a lack of vigor in management implementation.

Creating programs that promote inclusivity of community members while achieving environmental conservation goals can be done by considering the following factors: There needs to be a clear understanding of the conservation issue at hand, the causes, and the biological processes that catalyze degradation. Secondly, the correct measures and techniques need to be evaluated and applied based on access to funding, man power and materials. Projects need to be planned with stakeholder and community involvement as a priority, as this will ensure the long-term success and continuation of conservation efforts long after the culmination of the pilot project. As environmental conservation is coproduced with environmental knowledge, ensuring that each project has an outreach and education component is crucial to fostering a sense of inclusivity and passion for environmental protection within the affected community. Lastly, understanding the political, cultural, social and economic factors that affect the success of conservation management is crucial, not only during the project design and planning stages, but also during the implementation and evaluation phases. This will ensure that the projects are staying on track as well as reflect the values of the local community.

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