Mangrove Management Strategies for Social and Ecological Integrity

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Executive Summary

As sea levels rise due to global climate change, bolstering the intertidal zone will be critical for the protection of coastal ecosystems and coastal communities. The preservation and restoration of mangrove trees is thus vital for long-term shoreline stability. Currently 35% of mangrove forests have been destroyed globally; meanwhile, removal of mangrove forest nears 50% in developing countries such as India, Vietnam, and Colombia (Oswell 2016). Over five billion people live in water stressed countries, the poorest of whom carry the burden of environmental stress which then leads to further socioeconomic vulnerability. According to the Millennium Ecosystem Assessment (MEA), the poor in developing countries are highly dependent on ecosystem services for their livelihood; therefore, protecting vulnerable populations requires protecting the resources they are dependent upon. This research seeks to determine if mangrove restoration projects successfully contribute to improved ecological and social well-being in case-studies from three different countries: Colombia, Vietnam, and Kenya. By comparing these three cases of mangrove restoration, this study outlines successful and unsuccessful mangrove restoration practices in order to improve ecosystem recovery and social justice in the future.

Mangrove forest restoration contributes to improved ecological and social well-being through the ecosystem services, provided both directly and indirectly. Mangroves are unique wetlands that colonize tropical and subtropical coasts, between 25°N and 25°S of the equator, and are adapted to anaerobic soils and hypersaline waters. Their intricate root system is ideal for macroinvertebrate communities, promoting diversity across all trophic levels and providing essential nursery habitat for fish, crabs, and shrimp. Local communities benefit from mangroves as they help to regulate water quality and water temperature, protect against shoreline erosion and storm surges, and provide forest products such as firewood and construction material. These benefits are rapidly being lost due to anthropogenic effects including population growth, coastal urban development, shrimp aquaculture, agriculture, and clear-cutting. As mangrove ecosystem goods and services decrease, the local poor are less likely to achieve basic capabilities such as secure homes and proper nutrition.

The comparative analysis between Colombia, Vietnam, and Kenya deemed the mangrove restoration project a success if, and only if, both the ecological and social well-being improved. A common trend in successful restoration projects was that local stakeholders were involved and

consulted throughout the restoration process. Tables 1a-c compare the three cases being examined, looking specifically at the restoration process, pros, cons, successes, and also the ecosystem services that the project was aspiring to restore. In Colombia the restoration project was conducted on the Pacific coast and the Caribbean coast, sponsored by the International Tropical Timber Organization (ITTO). Although the stated goal of the ITTO was to increase biodiversity, as a timber trade organization there is the risk of bias towards future harvesting practices. The restoration was not successful in Colombia, however, because the mangroves were only partially restored. Success requires long-term ecological and social well-being. One mangrove restoration project was conducted in Northern Vietnam and the other in Southern Vietnam; Northern Vietnam intended to restore mangroves to protect their dike infrastructure while Southern Vietnam restored mangroves to alleviate poverty and increase biodiversity. Northern Vietnam's restoration efforts are considered a failure because local stakeholders were forbidden from accessing the land, thus hindering their use of vital resources provided by restored mangroves. Southern Vietnam was successful, however, because the management of the restored mangroves was redistributed to local village associations through land tenure arrangements.

The exemplary case study was Swahili, Kenya. The goal of the Swahili Seas Project was to restore mangroves and incentivize sustainable use through a carbon credit program. The local community was involved in the planning and implementation of the restoration project so that the income from the carbon credit system was distributed directly to the community. Both the needs of the ecosystem and the needs of the community were met and improved by this reforestation project.

Mangrove restorations projects are most successful when local stakeholders are fully involved because these stakeholders become long-term stewards of the environment. Long-term mangrove resilience is promoted when the community is educated on sustainable use practices and aware of the full-value of resources mangroves provide. As biodiversity increases through restoration, the local community has greater access to resources, thus making them more capable of trade and specialization. Biodiversity also contributes to enriched ecosystem resilience and stability. Just as poverty is a multidimensional issue, restoration practices must also include numerous perspectives in order to promote improved environmental quality and well-being.

Research Question:

What programs for mangrove restoration have most successfully contribute to improved ecological integrity as well as social justice?

I. Introduction

Mangrove deforestation threatens the social and ecological integrity of coastal communities. Developing countries with low income experience the greatest pressure to develop mangrove wetlands because of external debt pressures which results in government support for unsustainable harvesting practices that produce short-term monetary gains instead of long-term diversified export portfolios (Martínes-Alier, 2002). The consequence of short-term and exploitative land use is a destabilized ecosystem no longer capable of supporting needs of local communities. The Millennium Ecosystem Assessment (MEA) showed that the poor in developing countries are highly dependent on ecosystem services for their livelihood; therefore, protecting vulnerable populations requires protecting the resources they are dependent upon. Mangroves are capable of poverty alleviation due to their adaptability, climate control services, and ability to sustain biodiversity. In order to prioritize both ecological systems and these organisms, including ourselves, that inhabit mangrove ecosystems, we must analyze the liminal spaces that mangroves occupy because this biome serves as an interface between land and sea. However, in order to promote ecological integrity, human well-being must also be taken into consideration because biological and anthropogenic forces are interdependent. According to the literature, the linear relationship between ecosystem degradation and poverty intensification highlights the need for environmental consciousness in economic development as well as the improvement of well-being (Adger, 2006). The focus of this paper will be to assess the productivity of mangrove forest restoration, as recovering these ecosystems is essential for tropical coastal community health and ecological health. In an attempt to alleviate pressures upon both mangrove ecosystems and local impoverished communities, I will analyze the successes and failures of existing mangrove reforestation programs that have been implemented, ultimately offering an alternative mangrove restoration plan capable of improving conservation as well as societal well-being

Mangrove forests are threatened on a global scale as a result of anthropogenic pressures such as population growth, aquaculture, agriculture, coastal urban development, clear-cutting, and salt works (Ashton et al., 2003; Kairo et al., 2001). Since 1980 the global distribution of mangroves has fallen by 25% and now mangrove forests occupy less than 15 million hectares (ha) (Datta et al., 2012). Continued destruction disrupts the resilience of mangrove forest ecosystems because of habitat fragmentation. With fragmentation each community of mangroves becomes less productive and less capable of supporting biodiversity because the environment has been shocked with stressors. Globally, 1-2% of mangroves are being depleted annually, yet the highest rates of depletion occur in developing countries where the majority of mangroves are concentrated (Duke et al., 2007). As demonstrated earlier by the MEA, developing countries are more dependent on ecosystem services for local livelihood; thus as mangrove forests are depleted, these local communities will be forced to live in a state of diminished well-being. Mangrove ecosystems provide both direct and indirect ecosystem services (Twilley and Day, 2012). Some direct benefits to humans include: water quality control, habitat value, shoreline stability, forest products (ex. charcoal, tannins, medicines), water temperature moderation, and protection against storm surges (Twilley and Day, 2012). Beyond these localized benefits, mangroves are an essential part of the global carbon cycle. Carbon export in mangroves is double the rate of carbon export by salt marshes, thus mangroves may be responsible for up ~10% of the global export of terrestrial particulate organic carbon (Twilley and Day, 2012). As a carbon sink, mangroves help to naturally sequester and store carbon from the atmosphere and fix it underground. Mangroves act to moderate the global carbon cycle, compensate for anthropogenic fossil fuel burning, and also limit oceanic acidity. Thus the continued destruction of mangrove forests has global repercussions disastrous to both ecological and anthropomorphic communities.

i. Background

In order to fully understand the relationship between an ecosystem and its local people, I must first can examine the dynamics of poverty that provoke local dependence on natural resources. From there I examine how the biological functioning of mangrove ecosystems is capable of sustaining local livelihoods. The poorest nations and the poorest individuals receive an unjust share of the burden of global climate change (Lubchenco 1998). A large portion of their burden stems from a lack of mobility; if the conditions in their environment become threatening they are forced to adapt or perish (Lubchenco 1998). Economic disadvantage is merely the beginning because global climate change introduces unpredictable environmental stressors capable of destroying food security and physical well-being. Poverty is multidimensional and thus ecosystem management must also be.

ii. Measuring Poverty

In order to manage ecosystems so that local communities also benefit from improved well-being we must reevaluate current definitions of poverty. This study looks to improve well-being instead of alleviating poverty because current poverty measures are founded upon welfarist principles such as income, real income and per capita real income (Deaton 1980). Monetary income, however, is not favorably applied to developing countries because local households are generally both in-home producers and consumers. Their production is not accounted for in the formal economy, yet this trade-based exchange is hugely influential to the production structure of local economies in developing countries (Chander et al., 1980). Most developing countries look at nutrient attainment to evaluate poverty as well as development. Therefore an income-based poverty line serves no purpose towards assessing local livelihoods or measuring how effective governmental policy has been towards improving local livelihoods (Ravillion, 1999). Instead, this study examines poverty through the perspective of well-being. The Standard Living approach, adopted by the World Development Report in 1990, recognizes that more weight should be put towards opportunities and rights in developing countries rather than only using a measurement of income (Ravillion and Datt, 1992).

I use the philosophy of Dr. Amartya Sen to redefine poverty. Sen theorized that an individual is poor, or lacking well-being, if he or she lacks the “ability to achieve various valuable functionings as a part of living” (Sen, 1993). This concept of “functionings” was developed by Sen to describe the actions or qualities or thoughts that make up a person. A collection of various functionings, and the freedom to choose from this collection, reflects the true “capability” of a person in her or her lifetime (Sen, 1993). When people have more functionings they are more capable and have more choices in life. According to Sen, for an individual to truly live well he or she must have “well-being freedom,” which is the ability of a person to experience many well-beings (Sen, 1993). Lack of access to basic functionings such as food security, water security, and dependable shelter results in socioeconomic vulnerability. Well-being is one of the most central inherent human functionings, therefore achieving improved well-being is the central focus for this experiment. By focusing on improving well-being we are able to move away from monetary measurements that otherwise constrict successful policy. Successful policy would then represent the defense of ecological resources so that local populations have access to environmental resources and are further capable of improving community well-being.

iii. Ecology of Mangroves Forests

Environmental services and climate control mechanisms provided by mangrove forests support ecological health by maintaining ecosystem resilience, organization, and vigor (Costanza and Mageau, 1999). Mangroves are recognized as keystone species because they promote greater diversity as well as stability within their immediate ecosystem (Moberd and Rönnbäck, 2003). These forests are unique because mangroves colonize intertidal zones along tropical and subtropical coastal areas, largely between 25° N and 25° S of the equator (Twilley and Day, 2012). Due to their coastal disposition, mangrove forests are classified as wetlands. Mangroves are capable self-regulators adapted to survive fluctuations in salinity as well as anaerobic soils. Their complicated root system provides the adaptations necessary for these trees to survive the anaerobic soils of muddy intertidal environments (Twilley and Day, 2012). The root system is both horizontal and vertical, horizontal roots increase area of uptake while the role of the vertical roots is to take in more fine and nutritive substances. Nearly all the roots, however, have lenticel cells which facilitate the uptake of oxygen into the internal tissues of the fine root systems (Twilley and Day, 2012). These roots produce ethylene and tannins to promote greater root growth and reduce the toxic effects of iron and sulfide deficiency in the soil (Twilley and Day, 2012). Soils vary in anoxia levels between the wet and dry seasons, thus oxygen microsites are formed by the release of oxygen from the roots and these microsites help protect the roots from toxic anaerobic by-products (Twilley and Day 2012). As halophytes, mangroves have physiological adaptations to manage intertidal salt levels. The adaptation of salt glands occurs more prominently for mangroves occupying interior intertidal zones because the salt accumulates in the soil making it hypersaline (Twilley and Day, 2012). The metabolic process of mangroves are adapted to avoid accumulating ethanol and instead produce malic acid after anaerobic respiration because it is less toxic (Twilley and Day, 2012). This process allows mangroves to thrive in low oxygen environments and break down existing carbon in order to trap methane.

Mangrove wetlands support extensive biodiversity and intricate food webs. The secondary production within tropical mangrove wetlands contributes to energy and nutrient cycling by acting as a sink, a regulator of energy flow, and as a source of mobility across ecosystem boundaries (Twilley and Day, 2012). The year round leaf litter produced by mangroves results in high organic matter which sustains secondary production and the diversity of estuarine-dependent consumers (Twilley and Day, 2012). The organic detritus from mangroves is the dominant food source for lower level consumers within the food webs. There is a positive catch rate of fish and shrimp harvests to mangrove area (Twilley and Day, 2012). The presence of an extensive mangrove habitat results in a productive fishery and a higher dependency on fish yield to sustain local diets (Twilley and Day, 2012). At low tides the mangrove mudflats serve as a feeding ground for shorebirds, while the bivalve and crab populations contribute to local income and food security (Moberd and Rönnbäck, 2003). Mangroves consume light, water, nutrients, and space for growth which then promotes competition for those resources, creating a more complex series of ecological interactions among plants within the intertidal zone (Twilley and Day, 2012).

iv. Ecosystem Services and Poverty Alleviation:

The reforestation of mangroves has the potential to improve local well-being during an age of ecological uncertainty. The restoration of mangrove forests is capable of recovering ecosystem services as public goods. By principle, a public good provides a public benefit that cannot be excluded, and that the consumption by one individual does not reduce the level of service provided to another consumer (Brander et al., 2012). With proper management, mangroves can provide habitat and nursery services to support fishermen without excluding the greater community, and by increasing coastal protection, all members are included in the benefit provided by this ecosystem service (Brander et al., 2012).

Local communities, however, are often excluded from accessing mangrove forests as public goods. Despite their dependence on mangroves for natural resource use, the demand for short-term economic yields exceeds the demand for long-term ecological stability. The reality is that most governments own the rights to mangrove forests because of their coastal nature. Therefore when developing nations are pressured to increase export production, in order the repay debt, the ecosystem services provided by mangroves are redistributed to an external consumption base (Martínez-Alier, 2002). Shrimp aquaculture is one of the leading causes of mangrove deforestation because of its popularity as a global export. Also known as “pink gold,” shrimp farming was actually encouraged by the World Bank in the 1990s to improve export-led growth in developing countries (Martínez-Alier, 2002). This private enclosure movement has alienated local communities and destroyed natural resources these communities once depended upon. In building shrimp ponds to farm, mangroves are cleared and the waste from the farms is returned unfiltered to the surrounding environment. This is evidence of how forbidding land access and ownership for local communities results in the loss of natural resources and greater pollution (Martínez-Alier 2002). The World Bank now rejects their previous support for shrimp aquaculture, after realizing the environmental externalities associated with shrimp farming, however the market itself remains profitable which reduces the disincentive to farm. Meanwhile, the benefits from shrimp farming do not compensate for the losses from mangrove deforestation because the wealth is confined to the economically elite. The ecosystem services provided by mangroves must be made available to local communities if restoration intends to improve well-being ecologically and socially.

Table 1 (a). Ecosystem services provided by mangroves.

Ecosystem services	Mangrove Ecosystem
Erosion control	**
Storm and flood protection	**
Nursery, feeding and breeding ground	**
Maintenance of biodiversity and genetic resources	*
Interrupts freshwater discharge	**
Trap sediments and pollutants	**
Nutrient filter	**
Remineralization of organic and inorganic matter	**
Export of organic matter	**
Carbon dioxide sink	**
Oxygen production	**
Top soil formation	**
Water catchment and groundwater recharge	*
Habitat for indigenous people	**
Sustaining the livelihood of coastal communities	**
Cultural, spiritual and artistic values	*

Table 1 (a). Ecosystem services provided by mangroves. This table was adopted from Moberd and Rönnbäck 2003. The original study compared mangroves to seagrass, coral reefs, and sing-services substitutions. Of the four tropical seascapes, mangroves provided the most ecosystem services and at the greatest significance (* - significant, ** very significant).

Table 1 (b). Direct use ecosystem services from mangroves provided to local communities.

Mangrove ecosystem services	**Direct benefit to locals**
Fisheries (fish, crustaceans, and mollusks)	Reliable source of protein
Timber	Fuel, construction materials, paper, fishing poles and floats
Plant biodiversity	Forage for livestock, medicines, dyes and tannins

Availability of mangrove resources is directly related to ecological and social capability within local communities. For every kilometer of mangrove forest, 90-280 tons of fishery production is produced annually (Moberd and Rönnbäck, 2003). The total economic value of mangroves as a natural resource, including "direct, indirect, option, bequest, and existence values," is $181 billion US dollars (Vo et al., 2012). Although economic valuation varies depending on the region, scientific literature increasingly recognizes the ecosystem services provided by mangroves. The predicted economic loss in Southeast Asia due to mangrove deforestation $2.16 billion by 2050 (Brander et al., 2012). The cost of life as a result of mangrove loss, however, is remembered by the cyclone that struck Bangladesh in 1970, one of the deadliest natural disasters in modern times. Had the coast of Bangladesh not been converted into rice paddies the mangrove forests would have reduced the height of the cyclone waves and storm surge, potentially reducing the death toll of hundreds of thousands of lives (Moberd and Rönnbäck, 2003). Mangroves provide ecological, economic, and social services necessary for humans to inhabit coastal regions as they do today. Without mangrove forests coastal communities will be forced to abandon their homes as climate change increases the likelihood of natural disaster.

II. Literature Review

In Colombia many mangrove restoration projects focus on multiple-use development and coastal recovery. The degradation of mangroves on both coasts of Colombia is a result of hypersalinity, erosion and agriculture, although national efforts to repair these environments have been very active. Between 1995 and 2000, the Conservation and Management for Multiple Use and Development of Mangrove Swamps in Colombia, funded by the International Tropical Timber Organization (ITTO), set up 15 permanent growth plots and restored 450 ha of mangrove. In addition to this restoration, local communities were trained in sustainable use management (Spalding et al., 2010). Another project was established and named the Sustainable Management and Restoration of Mangrove Forests by Local Communities on the Caribbean Coast of Colombia (2002-2004). From this project 35,000 ha of Caribbean mangrove were restored and set aside: 28% as preservation, 29% as restoration, and 43% for sustainable use (Spalding et al., 2010).

For the Vietnam case study, two distinct approaches to restoration were evident for both the northern and southern coasts. North Vietnam has implemented mangrove restoration projects that prioritize the mitigation of natural disaster and protect against flooding (Powell et al., 2011). North Vietnam's most extensive restoration project was conducted though the International Red Cross Disaster Risk Program, from which 18,000 ha of mangrove were planted along 100 km of coastline (Powell et al., 2011). The goal of North Vietnam's restoration was "to enhance and improve the sustainability of sea dikes," and therefore mangrove plantations were constructed as monocultures (Powell et al., 2011). The mangrove species *Rhizophora stylosa*, *Kandelia candel*, and *Sonneratia caseolaris* were elected for planting because of their ability to reduce incoming wave height (Powell et al., 2011). Meanwhile, in South Vietnam the primary objective of restoration was "rehabilitation as a multi-functional policy to alleviate poverty and diversify livelihoods" (Powell et al., 2011). As a result, the restoration process in Southern Vietnam focuses on mangrove species richness and human well-being. The conflicting management strategies in Vietnam alone demonstrate the lack of environmental consensus for mangrove restoration project planning.

The Swahili Seas project, of Swahili, Kenya was sponsored by the Ecosystem Services for Poverty Alleviation (ESPA). In March 2013 the ESPA published their results from the

Swahili Seas Project (January 2011 to March 2013) which managed mangrove restoration through a carbon credit project (Huxham, 2013). The Mikoko Pamoja community was the first to experiment with a community-based carbon credit project through mangrove conservation. Swahili Seas made an independent accreditation of mangrove carbon storage based on research on Kenyan carbon stocks, and made legal instruments for community tenure-ship of government-owned forests. The yearly income for Mikoko Pamoja through this restoration program is worth $13,000 (Huxham, 2013). The community's first investment was towards continued mangrove protection and the building of a new school room for their community (Huxham, 2013). Beyond carbon credits, mangroves in the Swahili Seas served as a source of timber, crab and shrimp sites, and fuelwood, demonstrating the multi-use function of health mangrove stands (Huxham, 2013).

A constant theme in these case studies is that the inclusion of local communities is understood as vital for continued prosperity within these restoration projects. Success is seen though stakeholder involvement facilitated by the project sponsors, whose goal is proper education in mangrove management and valuing of mangrove forests as living entities instead of cash products. Of course, success is also marked by mangrove health and recovery, although this data is collected over a longer time frame. A few of the many factors that determine successful mangrove forestation include: community participation, available income, the proper selection of mangrove species, the condition of the environment, and both coastal and oceanic hydrology (Primavera, 2000). A successful project is defined as an operation that improves long-term ecological integrity and promotes improved well-being for the community dependent upon mangrove ecosystem services.

III. Methods

In this study I compared mangrove restoration programs on a global scale in order to examine various management strategies and ultimately determine what practices provide the most successful mangrove restoration. To repeat, a successful project is determined when, and only when, both ecological integrity and social well-being are improved through restoration. The goal of this research is to establish long-term and sustainable relationships between the land and their immediate communities. I examine mangrove restoration projects in Colombia, Vietnam, and Kenya in order to evaluate various methods according to their global distribution.

Table 2 (a-c) compares the three regional case studies being examined. I look specifically at the restoration process, pros, cons, successes, and also the ecosystem services that the project was aspiring to recover. Specifically, the case studies I compared were located in the Pacific and Caribbean coast of Colombia (Table 1.a.), Northern and Southern Vietnam (Table 1.b.), and Swahili, Kenya (Table 1.c.). These regions were compared because each region occupies some of the most varied mean mangrove area distributed across a global scale. The South American mean mangrove area is 2,509,463 ha, while Southeast Asia has the highest mean mangrove area with 4,901,429 ha, and Eastern and Southern Africa has the lowest mean mangrove area of 1,050,958 ha (Hutchinson et al., 2014). With this range in mangrove density I hoped to evaluate the restoration projects across regions of varying mangrove composition. The final data is provided in Table 3 and demonstrates the most successful features from each of the mangrove restoration cases studied. Ultimately, these data offer a mangrove restoration project policy that betters the ecology as well as the social institutions dependent upon ecosystem health.

i. Mangrove Restoration as a Tool for Well-being

I examined various forms of existing literature to better understand what properties of mangrove restoration have historically promoted long-term ecological recovery and social progress. Datta et al. (2012) include ecological, economic, socio-cultural, and institutional components when initiating mangrove restoration projects. Meanwhile, Moberd and Rönnbäck (2003) emphasize the need for "ecological memory" for restoration success, including "external memory" of support areas for species colonization and "internal memory" to restore biological legacies. Both Hamilton and Snedaker (1984) and Martínez-Alier (2002) agree that education and use awareness are vital to promoting local sustainable-use practices. From Brown and Yuniarti (2008) I found a three-step approach to project identification and implementation through political, economic, and ecological analysis.

Datta et al. (2012) exposes the social relationships between local communities and ecosystem services provided by mangroves. They argue that unsustainable ecological practices result in a loss of social sustainability, citing the increase in alcoholism and deviant behavior as a consequence of a weakened social fabric (Datta et al., 2012). One example of this behavior is that the prosperity of mangroves is particularly critical for women in traditional societies. The role of women in traditional societies is to handle the crabmeat post-capture and responsible for transmitting cultural and practical knowledge of crabmeat to following generations (Datta et al., 2012). Crabmeat as a dependable source of local protein is dependent upon healthy mangrove forests. However, the most substantial contribution of Datta et al. (2012) to this research was the concept of Community Based Mangrove Management (CBMM). This process mandates that the local community be prioritized over the management plan because they are community participation in the management process increases when the community is promised increased well-being (Datta et al., 2012). The alienation of the local community results in misconstrued perception as well. When not included, locals begin to perceive the mangrove forests as extra means of income immediate instead of an investment in future ecological health and services. The planning follows as such: determine the cause of degradation, determine appropriate rehab, select successful seedlings off of traditional/local knowledge, and finally monitor growth and outcomes (Datta et al., 2012). Through a multiple use strategy the mangroves are managed by the community as long as they are willing to use mangrove resources sustainably (Datta et al., 2012). Ultimately what is produced by a CBMM is an ecologically and socially sustainable community.

Moberd and Rönnbäck (2003) also support stakeholder involvement, yet they focus on the need for ecological memory to guide restoration and reforestation. They argue that mangrove restoration projects need to promote local recruitment so that, in time, the ecosystem redesigns itself (Moberd and Rönnbäck, 2003). Their data shows that afforestation efforts, meaning the planting of trees in previously unforested areas, accomplished less net gains compared to the restoration of former mangrove stands (Moberd and Rönnbäck, 2003). Because most restoration projects last 2-3 years, they argue that ecological restoration will be accomplished when surrounding habitats, upstream and in deeper waters, are restored as well. Increased biodiversity promotes greater resilience in mangrove forests (Moberd and Rönnbäck, 2003). Approaching mangrove management beyond the immediately damaged system can improve ecological health in the long-term.

Although it will be emphasized further in this paper, Hamilton and Snedaker (1984) and Martínez-Alier (2002) touch upon the impact of language and communication in mangrove restoration. Hamilton and Snedaker (1984) praise the need for local education of sustainable resource use. They acknowledge that mangroves are a renewable resource, however they are not finite, thus modern and traditional local needs must be met through sustainable use practices. Stakeholders must be made aware of the greater, more indirect, benefits provided by mangrove forests such as storm buffering or water filtration (Hamilton and Snedaker, 1984). Martínez-Alier (2002) insists that local communities be armed with language, biological terms specifically such as “environment” and “ecology.” Understanding these terms helps to communicate the interdependence of human communities and ecological communities. These terms also help to establish a sense of ownership of this land as well as a sense of pride in the cultural identity of the mangrove systems.

Brown and Yuniarti (2008) offer the research plan conducted by the Mangrove Action Project (MAP), an organization conducting mangrove education projects and mangrove restoration projects on across the globe. They highlight the need to establish clear objectives as well as benchmarks for success when designing a restoration project that includes community involvement. One key point they made was the need to monitor results during project implementation instead of only monitoring after implementation (Brown and Yuniarti, 2008). The three main steps to project identification include: identifying problems and gauging stakeholder interest, proposing an integrated rehabilitation plan, and the consideration of social, political, economic, and ecological factors. The three main causes of failed mangrove restoration result from project managers losing sight of end goals, not considering failure or risks, and/or lacking a coherent decision making process (Brown and Yuniarti, 2008). An understanding of the local community’s culture and existing institutions must be included, however they caution to include the perspectives of all members of the community so that no “elite interests” are favored (Brown and Yuniarti, 2008). Traditionally, the larger the restoration project the lower the cost of restoration per hectare so the cost and size of the project must be considered for optimum economies of scale before implementation. Local stakeholders are more willing to use the mangrove resources sustainably when they are aware of the full potential economic benefits that they could gain. As stated repeatedly above, local stakeholder involvement in the management process is pivotal to mangrove restoration success.

IV. Results

Local stakeholder involvement in mangrove restoration projects is the determining factor for long-term ecological and social success. Both Southern Vietnam and Kenya demonstrate that the mangrove management plan must also include the needs and perspectives of the local stakeholders at the inception of the management project. The defined purpose of the management plan must also explicitly include the improved well-being of local community members. Meanwhile, the management projects that were initiated by governmental forces were least likely to be successful. North Vietnam, for example, explicitly excludes local stakeholders as part of their mangrove restoration project plan. Biodiversity, however, proves to be the second most vital factor in restoring ecological and social resilience. An increasingly diverse ecosystem supported by the mangroves is responsible for increased species richness and thus more diversified local production and trade.

Looking first at the data from Table 2 (a), the Colombian case study, both the Caribbean Coast and the Pacific Coast participate in mangrove management plans. In Colombia industrial development of salt pans, shrimp aquaculture, urbanization, untreated sewage and agricultural development have resulted in mangrove degradation. To correct against these threats, the International Tropical Timber Organization (ITTO) initiated a Multiple Use and Development project for mangroves swamps to restore degraded areas and promote biodiversity (Spalding et al. 2010). This management plan uses zoning policies to allocate land use behavior. The ITTO establishes 35 mangrove management units total, dividing this restored area between preservation, restoration, multiple/sustainable use plots. Ecosystem services such as fisheries production and shore stabilization resume due to the presence of the mangrove forests. However, I cannot classify the Colombian mangrove restoration project as successful. Despite the increase in mangrove forest cover on both the Caribbean and the Pacific coasts of Colombia, I am warry of the long-term intentions of the ITTO. Due to their relationship to the timber trade, and the potential for mangrove timber harvesting in the future, I could not assert that ecological well-being or social well-being remain intact.

Table 2 (b) provides the data from Northern and Southern Vietnam. The Vietnam case study is unique because the stated restoration goals are conflict within this single peninsular nation. Mangroves were devastated by the Vietnam War and aquaculture developments. While Northern Vietnam's stated mangrove restoration goal is to enhance the lifetime of sea dikes and mitigate coastal storm damage, Southern Vietnam's stated mangrove restoration goal is to alleviate poverty and diversify local livelihoods. Northern Vietnam's restoration project was bolstered by the International Red Cross Disaster Risk Program, meaning the Red Cross paid local community members to plant and protect the established mangrove plantations. The monoculture of stilted mangroves (*Rhizophora stylosa*) planted in Northern Vietnam were selected because of their ability to reduce wave height. These forests were also designated as protected habitat which eliminates local rights to resource use. The exclusion of locals results in failure because when the Red Cross no longer pays local community members to maintain the mangrove plantations the community returns to unsustainable resource use. Although storm wave height was successfully reduced by the mangrove plantations, the local community suffered from being alienated during the management process and from being excluded from the natural resources they once depended upon for their livelihood. Northern Vietnam fails to satisfy the qualifications for mangrove restoration success because human well-being is reduced throughout the lifetime of this project.

The mangrove restoration project in Southern Vietnam takes on a multidimensional approach to rehabilitation. This project is led by the Second National Strategy and Action Plan for Disaster Mitigation and Development which unites the efforts of National Disaster Committee and outside NGOs. The stated purpose of this project is to design a "multi-functional policy to alleviate poverty and diversify livelihoods" (Powell et al., 2011). Biodiversity in the restored mangrove area increased unlike Northern Vietnam which planted storm barrier monocultures. The reforested area in Southern Vietnam establishes three types of forest land-use: protection, special use, and production. The responsibility of protecting the designated forests is allocated to local village associations, while management is the responsibility of the district government. The project in Southern Vietnam also established "collective mangrove forest land tenure arrangements" to arm local stakeholders against climate uncertainty, particularly increases in sea level and storm frequency (Powell et al., 2011). By including the needs of local community members in the planning of this restoration project local stakeholders are more willing to participate in management. Establishing local land ownership through land tenures promotes long-term land use because of their renewed stewardship towards mangrove forests. Southern Vietnam is successful because it restored both the ecological integrity of the land and improved the quality of life for local community members.

The exemplary mangrove restoration project is that of Kenya. The Swahili Seas Project was successful due to its ecological rehabilitation and development of a non-extractive resource market. The Swahili Seas Project is led by the ESPA with aid from Earthwatch. The stated goal is to manage mangroves through a carbon credit project so that local stakeholders receive payments for ecosystem services. Due to the role of mangroves as a carbon sink, a carbon negative environment, large industries can buy these carbon negative rights in order to lower their net carbon output. This system only works when a carbon tax is in place because the tax is applied to industries who overproduce carbon and are financially penalized for doing so, thus creating a market for carbon negative environments. The communities with mangroves under the highest pressure to develop over mangrove forests were paid more for maintaining those mangrove forests. Local stakeholders and project members form the ESPA restored 615 ha of cleared mangrove stands. Through the accreditation of mangrove carbon storage the local community receives $13,000 every year. Long-term economic incentive is a key way to promote land preservation and educate local communities on the economic benefits that mangroves provide. The $13,000 yearly income for this community is managed by a village council to protect spending. This carbon credit income allows for investment within the community, including a new schoolroom. Although carbon sequestration occurs in all mangrove environments, this was the first community based carbon credit program and it proved to be highly successful in restoring both ecological integrity and human well-being.

V. Conclusions

After comparing the three case studies, I found that a successful outcome depends upon local stakeholder involvement, species diversification, and minimal governmental management. Across the cases studied, I observed ten positive features of mangrove restoration, presented in Table 3, that have the potential to improve the ecological and social success of future mangrove restoration projects. I divided these ten features into three categories: ecosystem rehabilitation, ecosystem services, and social justice, although frequently the features overlap. Three features overlap across all three categories, the first feature is, “Consult scientists, stakeholders, and parties of interest to develop a plan of action,” the second is, “Implement restoration method with constant stakeholder feedback,” and finally, “Ensure the management is community based in the long-term.” Each of these three features depends upon the continued involvement of local stakeholders. All management projects include identifying the vulnerable region and original causes of degradation, but true success is accomplished when management teams engage beyond the physical land being restored.

These features contribute to improved ecological and social well-being when each is applied to the mangrove restoration process, yet each mangrove restoration project must be designed with the ecological, economic, and social context of that environment in mind. The local ecology as well as hydrology of an area anticipating mangrove restoration critically defines how the management team proceeds with developing a mangrove management plan. Although I had hoped to offer new policies capable of increasing mangrove restoration success rates, what I have learned is that no single policy can be universally applied to mangrove restoration. Local ecology determines which mangrove species is best fit to take seed and local hydrology determines what time of year seeding will prove most fruitful. In order to improve local well-being, the mangrove management teams must be aware of stakeholder expectations for the end product of the restored area. Arming local stakeholders with education about sustainable resource use and ecosystem services will encourage the conversation about ecological integrity to endure. This data provides an idea as to what restoration practices have been successful and unsuccessful in the past. Ultimately, however, the restoration of mangrove ecological integrity and social well-being depends on local stakeholders and their willingness to act as stewards of their environment.

The findings of this research brings to light the compatibility of ecosystem recovery and local community betterment. Local stakeholders are dependent upon the natural resources that the surrounding ecosystems provide, just as the surrounding ecosystems depend upon sustainable harvesting by the local stakeholders. This relationship of interdependence applies to every community across the globe. Interdependence is defined by Norgaard (1994) as socio-ecological coevolution, where “the social system affects the bio-physical environment, which in turn affects evolution in the social system” (Kallis and Norgaard, 2010) Looking to the future of mangrove restoration, the socio-ecological coevolution of both communities must be understood so that local communities can develop a new social niche for sustainable mangrove use (Kallis and Norgaard, 2010). Developing this niche will allow both communities to thrive.

Again, no universal policy can be applied to mangrove management because each community has a unique social structure which must be compatible with the restoration plan. One example of this can be seen in the social consequences that result from degraded ecosystem habitats. When ecological resources are lacking local communities become economically and socially stressed. In Brazil it was found that low crab yields resulted in higher incidences of alcoholism and school absenteeism, as children were made to work to increase household yields (Glaser and Diele, 2004). In many traditional societies, women are dependent upon biodiversity for basic survival and social influence (Vanninayakae, 1999). In Colombia, women depend upon mangrove crab harvesting to provide household income and supplemental food sources (Martínes-Alier, 2003). Similarly in Vietnam, women in coastal communities are dependent upon mudflats in order to harvest “non-cultivated seafoods” and are responsible for educating younger generations on how to process crabmeat (Brown and Yuniarti, 2008). Therefore, female community members dependent upon mudflats are less willing to support mangrove forest development because they fear their social roles will be threatened, thus marginalizing female community members even more. The will of all community members to participate in mangrove management is necessary for sustainable restoration. The ten features of a successful mangrove restoration project shown in Table 3 demonstrate how mangrove restoration can alleviate ecological and social stress through community based management policies.

Although no single method of restoration can be applied universally to degraded mangrove areas, the single factor that most contributes to long-term success remains stakeholder involvement. This includes the interests of all community members, not only those considered elite. More research is needed to understand the social and ecological mechanisms that drive and maintain ecological and social integrity by way of mangrove restoration; however this data provides the foundational support for socio-ecological coevolution, because coexistence requires collaboration.

In the future we must look at the global implications of mangrove restoration in the context of climate change remediation. As the case study of Swahili, Kenya demonstrated, carbon credit systems are capable of regulating carbon pollution on the small-scales as well as on the national-scale. As explained earlier, the carbon credit system only operates where a carbon tax exists. It is often argued that carbon taxes are an economically efficient way to regulate carbon dioxide emissions because it also provides an opportunity for revenue while simultaneously creating incentives for sustainable energy sources (Aldy et al., 2012). Carbon taxes can improve economic growth when the tax is revenue-neutral, meaning that the revenue gained from the carbon tax will be redistributed back into the economy by lowering taxes elsewhere or reducing national debt (Aldy et al., 2012). If carbon taxes are applied to nations where mangrove forests are located, then mangrove restoration will promote ecological restoration, carbon dioxide sequestration, economic growth, and local stakeholder betterment. As greenhouse gas emissions continue to rise, we risk increasing global temperatures by 4°C within this century ("Turn down the heat," 2012). An increase in temperature by 4°C will exceed the natural temperature tolerance of ecosystems, and are of particular concern for the tropics which will see an increase in sea-level 15-20% greater than the global mean, an increase cyclone intensity, and an increase drought/aridity ("Turn down the heat," 2012). As these ecological risks increase, the economic growth rate of developing countries decreases due to lost ecosystem services, thus exacerbating already extreme poverty and diminished well-being. As a global community we must continue to consider ecological restoration a tool for poverty alleviation and a defense against climate uncertainty.

Appendix:

Table 2 (a). Colombia.

					Ecosystem Services		
Case Study	Restoration Process	Pros	Cons	Successful	Carbon Sequestration	Fisheries Production	Shore Stabilization
Colombia	"Conservation and Management for Multiple Use and Development of Mangrove Swamps in Colombia" was implemented by the ITTO Permanent growth plots & Sustainable use zones	Balance preservation and restoration Restore degraded areas & Promote biodiversity	ITTO is a timber organization … biased Government and biased led funding & Some community involvement	No	No	Yes	Yes

Table 2 (b). Vietnam

Case Study	Restoration Process	Pros	Cons	Successful	Ecosystem Services: Carbon Sequestration	Ecosystem Services: Fisheries Production	Ecosystem Services: Shore Stabilization
Northern Vietnam	Government mandated with dike program, and assistance from the Red Cross (temporal assistance)	Red Cross local engagement incentivized. Mandate mangroves be built with the Dike program.	Political threat of corruption and misuse of funds. Incentive is removed (2006) Government prohibits local use of mangroves = endanger women and marginalized	No	Not accounted for	Harmed due to the monoculture policy	Main objective. Reduce wave height, protect dike system.
Southern Vietnam	Coastal Wetlands Protection and Development Project (Mekong Delta: 1997-2007) Restoration and rehabilitation 3 types of forest zoning	“alleviate poverty and diversify livelihoods” Species rich with many land use arrangements (eco goods and serves) Forest land leases decrease criminal acts -more fertile for growth	Political threat of corruption and misuse of funds	Yes	Not counted for	Encouraging greater biodiversity	One objective: Implement/ protect dike infrastructure. Main: diversify and help people.

Table 2 (c) Kenya.

Case Study	Restoration Process	Pros	Cons	Successful	Ecosystem Services		
					Carbon Sequestration	Fisheries Production	Shore Stabilization
Kenya	PES: carbon credit for mangrove reforestation. -restore cleared stands and implement carbon credit program (sell stores)	Independent accreditation "community-based carbon credit project" Restore cleared mangrove stands Community tenure-ship of government-owned forests Village council to manage money Highest value mangroves were those most threatened by urban development	Requires outside funds (Earthwatch)	Yes ($13,000/year and part to conservation/ community improvements. Community based program.)	Highest value mangrove restoration area assigned to those under most pressure for development. Restore 615 ha, gain $13,000/year. Based off of Kenyan carbon stocks.	Increase the network root system	Yes.

Table 3. Features of a Successful Mangrove Restoration Project.

Restoration Practice	Factors of Success		
	Ecosystem Rehabilitation	Ecosystem Services	Social Justice
Define the vulnerable region	✓		
Initiate relationship with stakeholders			✓
Clarify land ownership/land use issues			✓
Inquire governmental interest	✓		
Identify cause of harm		✓	
Consult scientists, stakeholders, team for plan of action	✓	✓	✓
Implement restoration method with constant stakeholder feedback	✓	✓	✓
Community Based Mangrove Management	✓	✓	✓
Educate local community on sustainable use		✓	✓
Incentivize sustainable use		✓	✓

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