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Feasibility of a Mangrove-Based Carbon Business in Makoba Bay, Unguja, Zanzibar

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SIT Study Abroad

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1.0 Acknowledgements

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2.0 Abstract

Mangrove ecosystems, along with other coastal vegetation, have tremendous potential to be abundant carbon sinks. With the prospect of carbon sequestered in coastal ecosystems starting to be explored in carbon credit markets, this study attempts to assess the feasibility of a mangrove-based carbon business in Makoba Bay, Unguja, Zanzibar. An aboveground carbon estimation demonstrates that the mangrove forest of Makoba Bay is a recovering ecosystem, but has the potential to be initiated into a program such as REDD+ in the future. Social surveys in both Makoba Bay and Chwaka Bay also indicate that a number of improvements would have to be made to existing project efforts before a carbon business would be successful. Proper attention must be given to issues such as education, support for alternative livelihoods, strengthening of mangrove replantation programs, and the establishment of a Community Forest Management Agreement between the government and the communities of Makoba Bay.

3.0 Introduction

Climate change is unquestionably the greatest global challenge of our time. As greenhouse gases are a large contributor to climate change, it has become increasingly important to employ methods of reducing these gases in the atmosphere. Emission regulations, policy enforcements, and bioengineering are all methods of mitigating climate change, but there are natural biological processes that can achieve similar effects as well.

3.1 Carbon Sequestration in Mangrove Forests

Carbon sequestration is the process of carbon capture and long-term storage (Terrestrial Sequestration of Carbon Dioxide.). When plants photosynthesize, they take in carbon dioxide from the atmosphere, and use it to produce and maintain tissue (leaves, stems, etc.), create storage reserves, and acquire chemical defenses (Terrestrial Sequestration of Carbon Dioxide.). This carbon is taken and stored in the plants, instead of in the atmosphere, until the plant dies and decomposes, releasing the carbon back into the atmosphere.

Mangroves, halophytic trees in the intertidal zones of tropical and subtropical areas, are one species of flora that are particularly capable of sequestering carbon (Carbon Sequestration 101). There are two main categories of mangrove forests: fringe communities, such as the one in Makoba Bay, and creek mangroves, like in Chwaka Bay (Jumah 2009). In addition to acting as carbon sinks, all mangrove forests provide a multitude of other ecosystem services. This includes, but is not limited to, trapping sediments and preventing the introduction of nutrient runoff into sensitive marine ecosystems like coral reefs, serving as nursery grounds for fish and other organisms, and protecting the coastline from disturbances (Mangrove Forests).

As a carbon sink, mangroves, as well as other coastal vegetation, such as sea grasses and salt marsh grasses, are extremely well-fitted to sequester sizeable amounts of carbon dioxide.

Recent studies show that mangroves sequester at a rate of two to four times greater than tropical rainforests, the most efficient terrestrial carbon sink, a year, and can store three to five times the amount of carbon per unit area (Carbon Sequestration 101). This can be attributed to the fact that coastal wetland plants grow a great deal each year, and in the process, capture large quantities of carbon (Carbon Sequestration 101). In addition to this rapid growth, the environments in which mangroves grow allow them to be efficient carbon sinks, as well. The thick, carbon-rich soil or peat that mangroves thrive in stays waterlogged and does not rot or become carbon-saturated as rapidly as in terrestrial forests (New Science 2013). Dead leaves, branches, and roots containing carbon are buried in the soil, allowing for the carbon to recycle within the underground system, rather than being immediately released into the atmosphere. The anoxic condition of the soils allows carbon that gets incorporated in the soils to decompose very slowly, and thus, that carbon can stay stored in the mangrove system for hundreds or thousands of years (New Science 2013).

Unfortunately, it has been estimated that over half of the world's original mangrove cover has disappeared due to deforestation (New Science 2013). As this important natural resource, that provides a multitude of ecosystem services including carbon sequestration, continues to disappear at a global rate of 1-2% a year, it is important that powerful incentives be used to encourage people to conserve, replant, and sustainably manage mangrove forests (New Science 2013).

3.2 Carbon Business

The carbon credit market functions as an approach to encourage developing nations where forests are abundant to conserve these valuable resources. In order to offset excess emissions as cited in environmental regulations, businesses in developed nations are able to purchase carbon credits on an international market. Perhaps the most well-known carbon credit

program is REDD/REDD+ (Reducing Emissions from Deforestation and Forest Degradation), which rewards developing countries for good forest management by means of the revenue made from the sale of carbon credits, theoretically making poor forest management less profitable than the sustainable alternative (REDD 2009).

3.2.1 REDD+ in Zanzibar

Despite all mangroves in Zanzibar being protected under the Forest Act of 1996, deforestation rates of mangroves are estimated to be on par with the global rate, at least 1% per year (The Forest Resources Management and Conservation Act 1996, Community Managed Forest Areas in Zanzibar, Tanzania). This number will only continue to increase with the growing population and demand for products like firewood and charcoal (Community Managed Forest Areas in Zanzibar, Tanzania). To mitigate deforestation and forest degradation, the Hifadhi ya Misitu ya Asili (HIMA) project, a community forest management plan was established in Zanzibar in 2010, and is now approaching its validation period (CARE International 2010). Implemented by CARE International with support from the Department of Forestry and other partners, this project has the chief objective of developing sustainable community forest management, with Community Forest Management Agreements (COFMA) and REDD+ being exercised in 27,650 hectares of forest, including 5,000 hectares of mangrove forest (CARE International 2010). This project will eventually scale up successful approaches to more than 60,000 hectares of forest in Zanzibar after the pilot phase (CARE International 2010). Over 3.6 million tons of carbon emissions will be reduced through the adherence of this project for a duration of 30 years (Community Forest Management Areas in Zanzibar, Tanzania).

Like most REDD+ programs, this pilot program covers almost entirely terrestrial forest, and very little coastal vegetation was considered. It only seems logical to expand carbon

businesses to include coastal vegetation like mangroves, as they are capable of sequestering larger amounts of carbon more permanently. Many coastal nations, including Zanzibar, could gain tremendously from this extension of the carbon market. The aim of this study is to use an aboveground carbon estimation in conjunction with an assessment of local attitudes towards programs like REDD+, in order to determine the feasibility of having a mangrove-based carbon business in Makoba Bay, Zanzibar.

4.0 Study Area

4.1 Makoba Bay

This study was primarily conducted in Makoba Bay, located in the northwest corner of Unguja Island, Zanzibar. Also known as Bumbwini-Mkokotoni Bay, Mahonda-Makoba Bay, among other names, Makoba Bay is roughly 15 square kilometers, with 610 hectares of fringe mangrove forest made up of nine of the ten mangrove species found in Zanzibar (Ngusaru 2006a, Bumbwini-Mkokotoni Bay 2011) (Appendix A). It is sheltered by Tumbatu Island, a small island 5 kilometers away from shore (Figure 1). As a fringe mangrove forest, Makoba Bay is directly exposed to tides, which causes nutrients to be flushed daily, so trees generally do not exceed a height of 10 or 12 meters (Mangrove Forests). In comparison, trees in riverine or creek mangrove ecosystems receive more nutrients and are, therefore, taller.

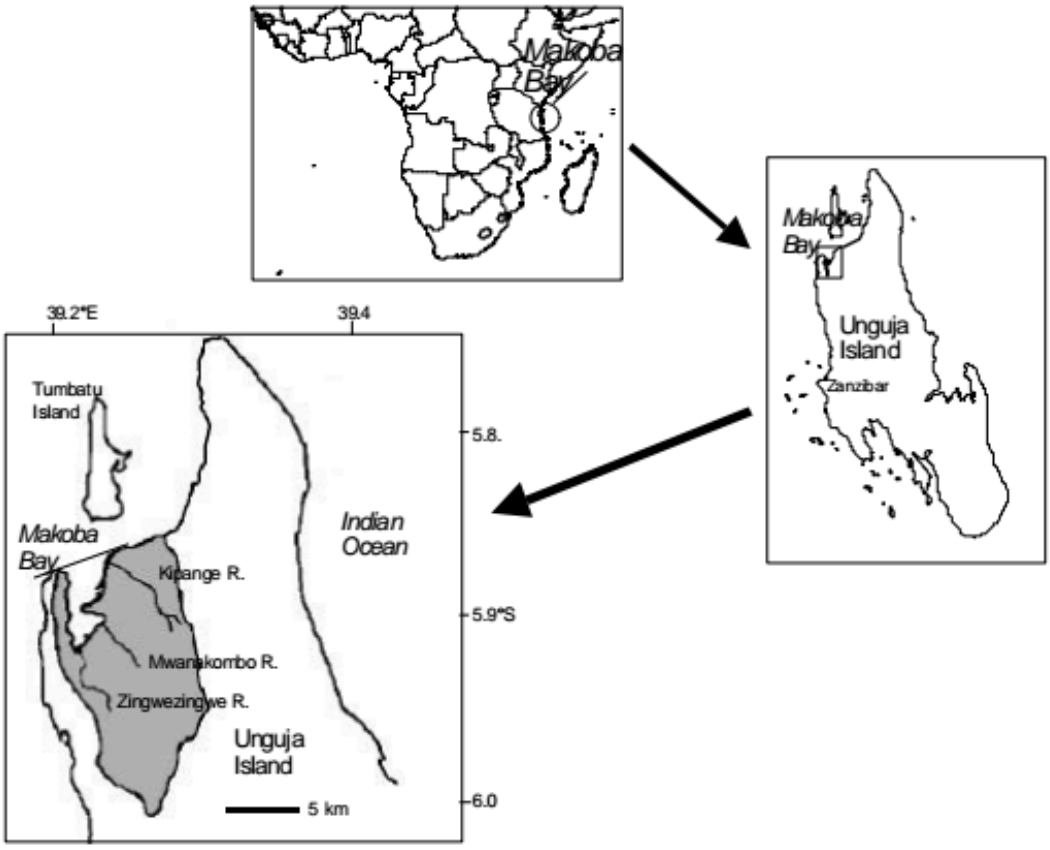

Figure 1. Map of Makoba Bay in relation to Africa, Zanzibar (Unguja Island), and northern Unguja Island (Ngusaru 2006a).

Specifically, the sample plots in this study were set up in the Shehia (village) of Mafufuni, in the Bumbwini area. Home to the bay's office of mangrove conservation and education, Mafufuni is one of six shehias that contribute to the community-based management of natural resources, namely mangroves, in Makoba Bay. The other shehias are, in no particular order, Mkokotoni, Makoba, Muwanda, Fujoni, and Mtowamaji. A non-profit organization called Seacology funded the construction of the office so that it could act as an information and training center, in return for the conservation and restoration Makoba Bay for a duration of at least 14 years (Bumbwini Mkokotoni Bay 2011). However, none of these shehias currently have an official Community Forest Management Agreement with the Zanzibar government.

In Makoba Bay, cutting of mangroves is prohibited, but due to the inability of a small group of communities to enforce such regulations effectively, illegal cutting of mangroves is still occurring. Increasing demand of products like charcoal has created considerable anthropogenic impact, causing the population of mangroves to decrease in the area in recent years despite the loosely enforced policies (Punwong 2013). Thus, it becomes important to incentivize the citizens of Makoba Bay to conserve, properly manage, and replant mangroves, as these forests provide important local ecosystem, and also contribute to the sequestration of carbon dioxide and the mitigation of climate change.

4.2 Chwaka Bay

Work was also done in Chwaka Bay, a shallow system on the east coast of Unguja Island, Zanzibar, where the biggest mangrove ecosystem of Unguja is contained (Lugomela). It is important to note that Chwaka Bay is partially encompassed by Jozani-Chwaka Bay National Park, is heavily supervised by Jozani Environmental Conservation Association (JECA), and that Community Forest Management Agreements have been created between the shehias in the area and the government. In contrast to Makoba Bay, the shehias of Chwaka Bay are presently involved in the REDD+ pilot project in Zanzibar. This includes the Shehia of Charawe, where interviews were conducted for this study in order to assess the current attitude of affected people on the REDD+ project in Zanzibar.

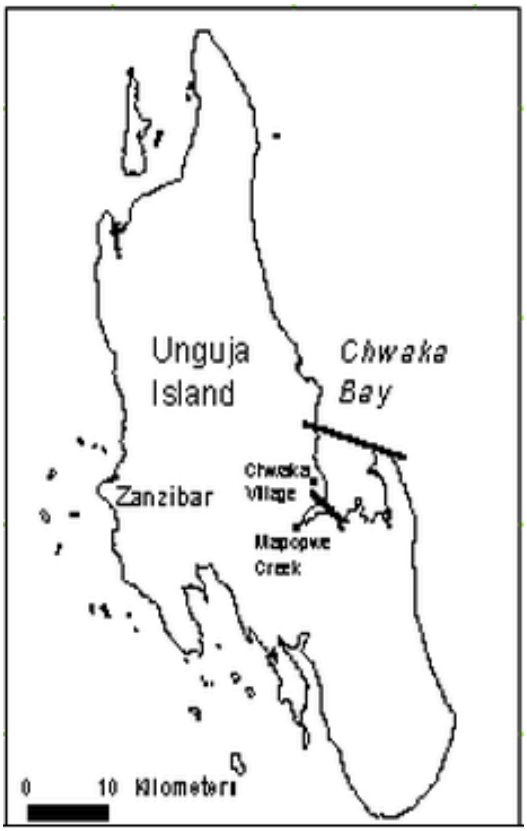

Figure 2. Map of Chwaka Bay (Ngusaru 2006b).

5.0 Methodology

5.1 Field Survey

In the mangrove forest, eighteen circular survey plots were randomly placed (Figure 3). Once the center of a plot was established and GPS coordinates were recorded (Appendix B), a radius of 11.28 meters was measured from this point and the mangroves within this circular plot were surveyed. In this area, mangrove trees with a diameter greater than 2.5 centimeters were evaluated. Individual trees were identified by species based on their physiological traits (such as leaves, seeds, and visible root systems), and then their diameter at breast height and approximate height were measured. For seedlings and saplings (mangrove trees with diameters of 2.5 centimeters or less), a smaller circular plot from the same center point was made with a radius of

1.78 meters. Within this plot, seedlings and saplings were classified and quantified. After all information was collected, a series of equations were used to calculate the carbon stock of the mangrove forest (Table 1). Some figures, such as form factor and wood density, were mangrove or species-specific (Appendix C).

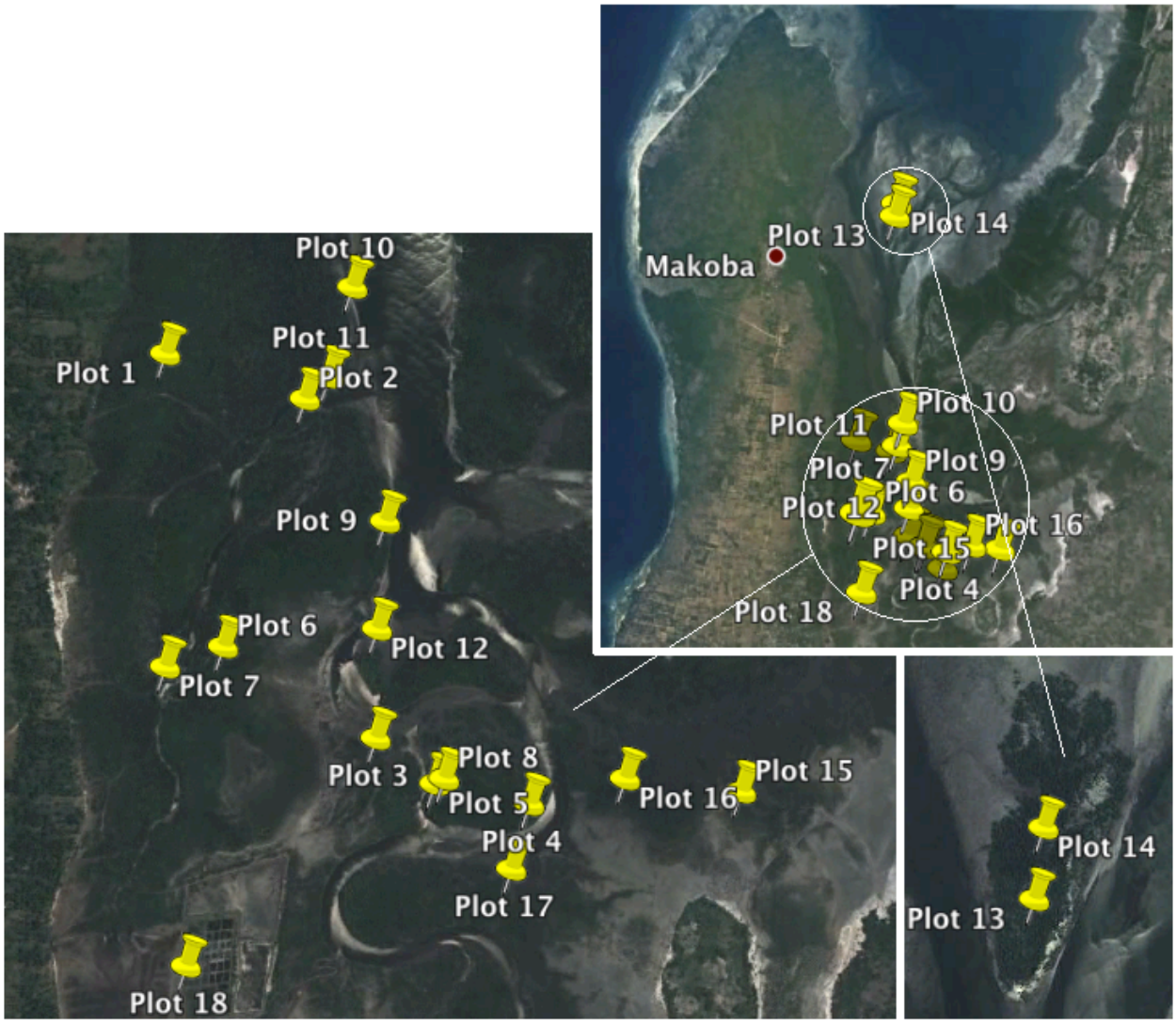

Figure 3. Map of Makoba Bay (top right), with enlarged images of the plots, including Plot 13 and Plot 14 on Kiwani Island in Makoba Bay.

Table 1. The equations used to calculate biomass and aboveground carbon stock of the mangrove forest (Feka 2009, Saenger 2002, Haji 2012).

Output	Equation	
Volume (m^3)	Volume = Basal Area * Height * Form Factor	Form Factor = 0.6
Biomass (tons)	Biomass = Volume * Wood Density	Wood Density varies by species (Appendix C)
Carbon stock (tons)	Carbon = Biomass * 0.49	

5.2 Interviews

In addition to the fieldwork performed, a series of interviews were conducted in Kiswahili with the help of a translator in both Bumbwini-Mafufuni, in Makoba Bay, and Charawe, in Chwaka Bay. Fifteen semi-formal interviews were completed in Bumbwini-Mafufuni, with interviewees ranging in age, occupation, gender, and involvement in mangrove conservation. Questions involved the current use of mangroves, the level of education regarding mangroves, and the anticipated benefits and losses if a carbon business were to be developed in Makoba Bay (Appendix E).

An additional ten interviews were conducted in the Charawe area in order to gauge the existing success of the REDD+ pilot project and to gain further understanding on what issues must be taken into greater consideration before other communities, such as Bumbwini-Mafufuni, adopt the REDD+ program. These interviews consisted of many of the same questions as those in Bumbwini-Mafufuni, but were more concentrated on the progress of alternative livelihoods, which are necessary for a project like REDD+ to succeed in any developing nation (Appendix E).

6.0 Results

6.1 Field Survey

6.1.1 Mangrove Population Dynamics

Although there are nine species of mangroves present in Makoba Bay (Appendix A), and eight species were seen throughout the span of the research period (all except *Xylocarpus granatum*), only five species appeared in the eighteen plots surveyed: *Avicennia marina* (AM), *Brugeira gymnorriza* (BG), *Ceriops tagal* (CT), *Rhizophora mucronata* (RM), and *Sonneratia alba* (SA). The overall density of all mangrove species averaged to be 2668.6 trees/ha, but ranged from 1978.7 to 5553.9 trees/ha (Figure 4). Seedlings and saplings had a total density of 42,055.6 individuals/ha. RM had the greatest relative density amongst adult trees and seedlings/saplings, while BG was the least dense in both categories (Figure 5, Figure 6). The total basal area of all eighteen plots was 21.8 m^2, making the average basal area per hectare 27.7 m^2/ha.

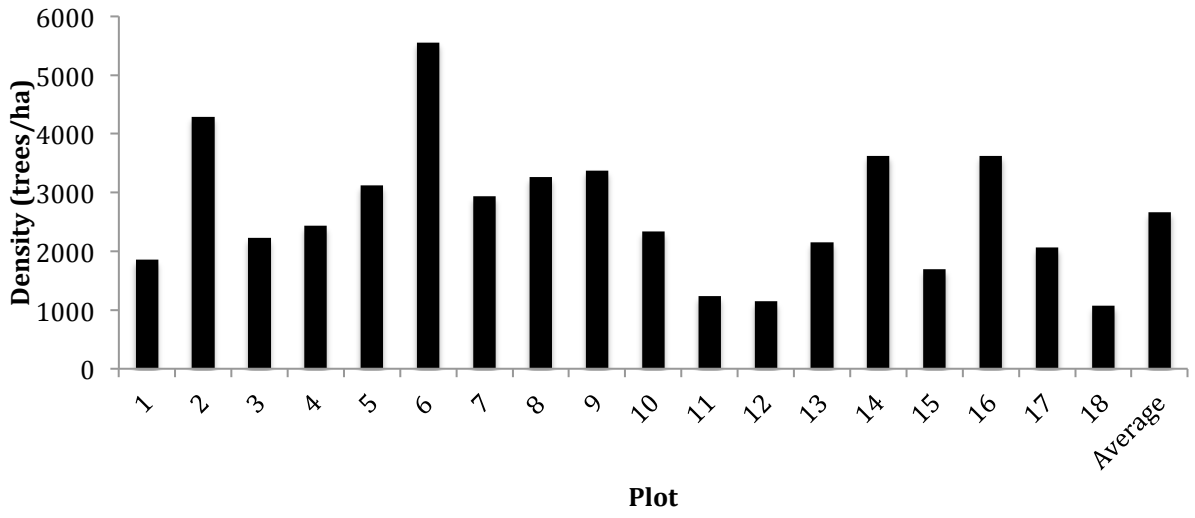

Figure 4. Total density of all species at each plot and an average density based on all 18 plots.

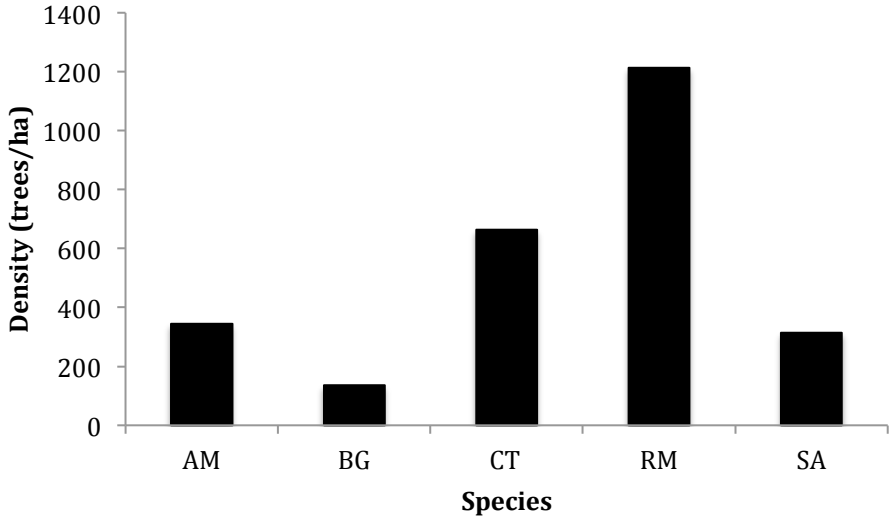

Figure 5. Average density of the five observed species in the eighteen survey plots.

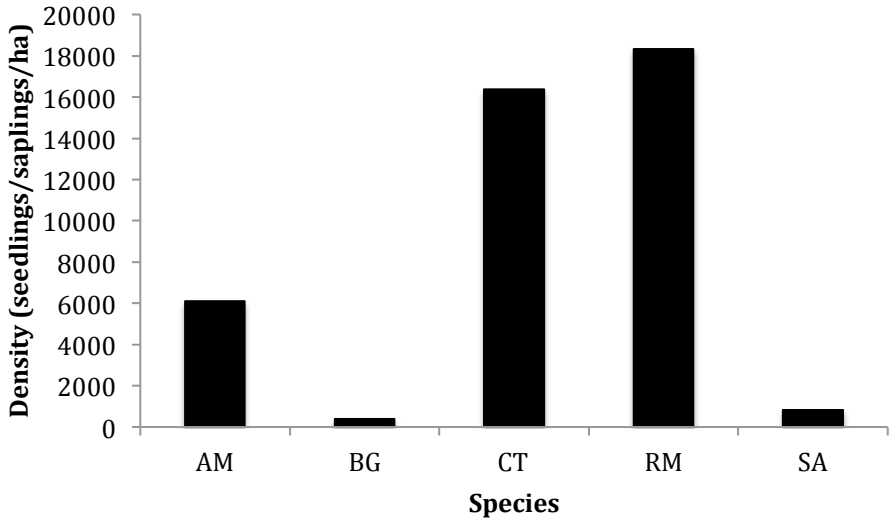

Figure 6. Average density of seedlings/saplings amongst the eighteen survey plots.

6.1.2 Carbon Stock

Using the equations listed in the methodology section (Table 1), the aboveground biomass and carbon stock of the mangrove forest was estimated (Table 2, Figure 7). It was found that the total biomass of all trees found in the eighteen plots was 81.1 tons, making the biomass

per hectare roughly 103.4 tons/ha (Appendix F). Following this calculation, it was possible to calculate that this mangrove forest had an average of 51.7 tons CO_2/ha (tC/ha), or a total of 31,531.8 tC in the 610 hectares that make up Makoba Bay (Table 2, Figure 7).

Table 2. Calculated density, total basal area, total volume, total biomass, and total carbon stock for each plot, as well as the average carbon stock per hectare and the total carbon stock for all 610 hectares of Makoba Bay.

Plot	# of trees	Density (trees/ha)	Basal Area (m^2)	Volume (m^3)	Biomass (tons)	Carbon stock (tons/ha)
1	81	1858.949349	0.55421	2.2230729	1.816677851	20.84637104
2	187	4291.648498	0.281815	0.458283	0.432229517	4.959831975
3	97	2226.149221	0.307111625	0.9219354	0.719363128	8.254689002
4	106	2432.699149	0.244036875	0.586247813	0.545522709	6.259870897
5	136	3121.198908	0.4996525	1.34943855	1.271429646	14.58965008
6	242	5553.898056	0.5596265	1.424975175	1.277369368	14.65780837
7	128	2937.598972	0.815615	2.8865235	2.197176849	25.21259552
8	142	3258.898859	0.542435	1.81784805	1.725309503	19.79791961
9	147	3373.648819	0.42880625	1.32372195	1.253466942	14.38352813
10	102	2340.899181	1.918245625	12.56461973	9.354549016	107.3434124
11	54	1239.299566	6.7713315	39.5601849	28.48333313	326.8461332
12	50	1147.499598	1.035729	4.04930475	2.973609752	34.12215996
13	94	2157.299245	3.4305285	17.7619281	14.17413835	162.6481807
14	158	3626.098731	1.5769865	10.2036027	8.298460923	95.22480576
15	74	1698.299406	0.9626455	2.9516157	2.219816524	25.47238569
16	158	3626.098731	0.487485	1.178235938	1.105884156	12.69001624
17	90	2065.499277	1.09115	3.52381005	2.852709704	32.73483239
18	47	1078.649622	0.267302313	0.499732472	0.383788595	4.403972586
Avg.	116	2668.574066	1.20970626	5.849171149	4.504713092	51.69156464
					Total carbon stock (tons):	31531.85443

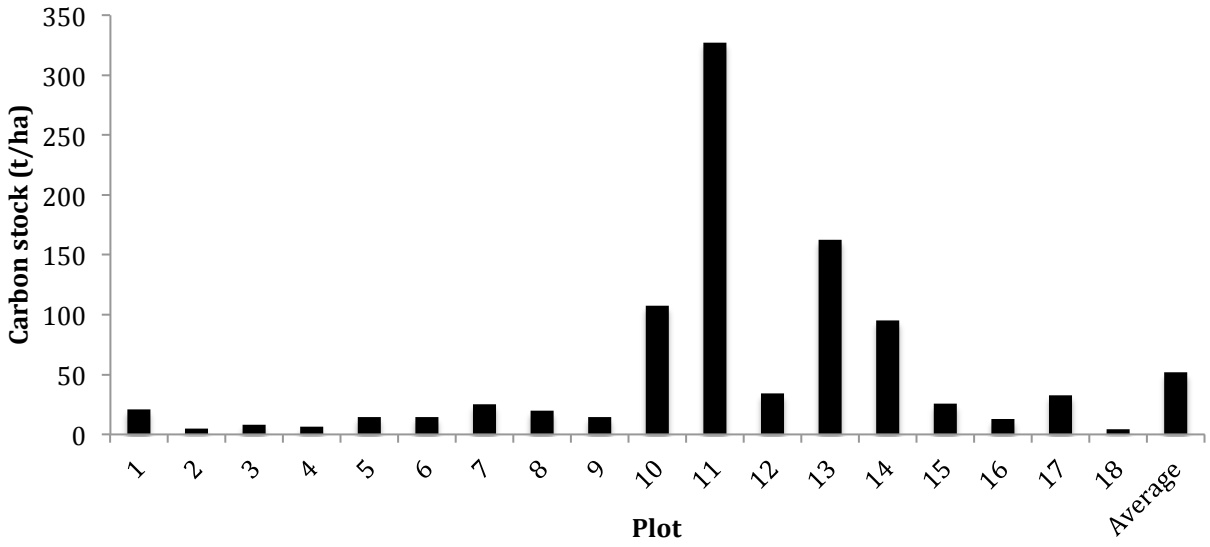

Figure 7. Carbon stock density (tons/ha) at each of the eighteen survey plots, with an overall average of 51.7 tons/ha.

6.2 Interview Responses

6.2.1 Makoba Bay – Bumbwini-Mafufuni

After conducting fifteen formal interviews with citizens of Bumbwini-Mafufuni, the following answers were compiled. The uses for mangroves included charcoal for cooking, collected firewood for heating the house, timber for building material (said to come from Kiwani, an islet within Makoba Bay), and as a place to collect crabs and fish to eat or sell. Every single one of the interviewees had participated in mangrove replantation, and felt that it was important to replace the mangroves that had been cut and to fulfill the needs of the future. Seven of the subjects, including two women, were a part of the Bumbwini-Mafufuni mangrove committee, and planted mangroves for one week at a time, in rotation. In addition to organizing replantation efforts, mangrove committee members also meet with the committees from the five other shehias of Makoba Bay, delegate funding should a donation be made by an non-government organization (NGO) or a foreign non-profit organization, such as Seacology, and act as guards who give out fines should they catch someone cutting down mangrove trees in their

territory. In fact, they are the only acting party in Makoba Bay in enforcing conservation measures, and struggle to do so due to lack of manpower and necessary tools, such as boats. Members and other interviewees alike varied in occupation and placed the importance of mangroves on various ecosystem services. Many recognized that the presence of mangroves improved the populations of fish, crabs, and sea snails that are common food sources for local people. Others noted the mangrove ecosystem's importance in avoiding wind abrasion and soil erosion on the coastline of their shehia. Most participants knew a little about the biological importance of carbon and trees, but only one knew what a carbon business was before the concept was explained. However, all subjects agreed that such a project would be beneficial to Bumbwini-Mafufuni and Makoba Bay as a whole. The only concerns that were expressed were the additional limitations on mangrove use that may incur should a project like REDD+ be introduced to the area, and the possibility that they may receive insubstantial revenue for their efforts.

Most of the education on mangrove conservation and importance in Bumbwini-Mafufuni is internal. The office funded by the non-profit group Seacology is used by the mangrove committee to hold training workshops for mangrove replantation. Many subjects revealed that they had received the bulk of their mangrove education from the head of the mangrove committee. The students from Makoba School also said that their teachers organize school trips for a hands-on learning experience about mangroves and their importance, and have the opportunity to plant them. External groups, such as the Department of Forestry and foreign NGOs, have also had a small presence in the education of the people of Bumbwini-Mafufuni. The community continues to try to educate everyone on the conservation of mangroves, but

despite the general interest of the people, the lack of support, both financially and in gaining knowledge, has limited their ability to do so.

Livelihoods have also already begun to change with the protection of mangroves, as cutting mangroves is nationally prohibited. Many people have been forced to switch occupations to fishing or farming. Subjects claimed that this has changed the economy but has not been devestating for the community because they have access to other natural resources and do rely on mangroves as their main source of revenue. Of course, interviewees regcognized that there are some individuals that do still cut mangroves illegally for personal use.

6.2.2 Chwaka Bay – Charawe

In contrast, ten formal interviews were conducted in Charawe. Like in Bumbwini-Mafufuni, the uses of mangroves ranged from person to person. However, all the uses given, such as firewood, charcoal production, and building poles, involved cutting mangroves, and many subjects referred to their official occupations as mangrove-cutters. Many people have turned to cutting mangroves as a last resort to support themselves and their families, as many other resources, such as coastal fish, have already been depleted. All subjects interviewed were involved in mangrove replantation, and stated that they continued to plant to replace what was being cut in order to continue mangrove-cutting into the future. Current regulations on mangroves are indistinct among the people of Charawe. Conflict over the government's inclusion of a portion of Chwaka Bay as a part of Jozani-Chwaka Bay National Park has created a lot of friction, and despite the protection under the government, people continue to cut mangroves in both the community-managed areas and the national park. Legalities were said to be avoided through bribes or methods of disguising mangroves in transport.

As a part of the Jozani-Chwaka area and a participant in the REDD+ pilot project, the Shehia of Charawe receives support from groups like CARE, JECA, and the Department of Forestry, both financially and in providing education. However, most people interviewed had a very limited understanding, if any, on carbon and mangroves, and carbon business. This included members of the conservation committee, the comparative equivalent of the mangrove committee in Bumbwini-Mafufuni, although they ultimately make the decisions about what will be done with the mangrove forest in Charawe, as it is a community-managed forest. Interviewees in the conservation committee said that their tasks included conducting surveys to monitor the forests, working with other shehias' committees, and occasionally acting as guards. There are also government-issued rangers patrolling the areas that are included in Jozani-Chwaka Bay National Park. Similar to Bumbwini-Mafufuni's patrol, this number of rangers is still not effective in protecting the entire forested region, and additional challenges exist when patrolling mangrove forests, such as tides and the lack of serviceable boats. Despite the REDD+ pilot project having been started nearly four years ago in Charawe, only one interviewee understood how this carbon business would function. Others were not even aware that the program had started and suggested that the government should prepare the community more before having initiated it, although they thought it could potentially benefit the community if executed in a socially equitable manner.

Alternative livelihoods were heavily discussed in all ten interviews in Charawe. Many interviewees suggested that they did not want to cut mangroves, because in addition to it being backbreaking work, there are negative impacts to the ecosystem services that mangroves provide. Organizations have begun to introduce alternative livelihoods to the communities of the Jozani-Chwaka area, such as bee keeping or methods for sustainable farming. However, limited resources have been given to residents to pursue these methods. In an additional interview with

the Deputy Secretary of JECA, it was explained that with the limited funding they are able to bestow, JECA provides resources for a few people in each Jozani-Chwaka area shehia to get started on an alternative livelihood, with the hopes that eventual success would motivate others to do the same on their own. Interviewees in Charawe did not see this as a viable solution, and continue to cut mangroves in order to support their families.

7.0 Discussion

7.1 Ecological Potential of Makoba Bay

After years and years of cutting, the severity of the loss of this invaluable resource has been realized, and the people of Makoba Bay have made a conscious decision to conserve and replant mangroves. The density and distribution of mangrove species in both adult trees and seedlings and saplings, indicate that Makoba Bay is a recovering mangrove forest. The study plots ranged from being very close to the terrestrial environment to areas that are further out in the bay, but the overall relative densities show that *Rhizophora mucronata* (RM), *Ceriops tagal* (CT), and *Avicennia marina* (AM) are the most prevalent species on average. RM, CT, and AM are all highly salt-tolerant species, making them good candidates for rehabilitation of mangrove forests, therefore the high densities in which they are found in Makoba Bay show that this forest is being restored (Ruwa 1993). Species that are the least salt tolerant, such as *Xylocarpus molluccensis* (XM) and *Xylocarpus granatum* (XG) were much less abundant in the field and did not appear in the plots at all. However, it is important to note that these species, along with others such as *Heritiera littoralis* (HL) were observed during the time of fieldwork, and make Makoba Bay an area in need of special conservation, as these species are rarely seen and could easily be wiped out if strides are not urgently taken (Jumah 2009).

The equations used to determine the aboveground carbon stock resulted in a relatively low amount of carbon sequestered per hectare. On average, mature mangrove forests can hold 152 tC/ha aboveground alone. This is only roughly 10% of the total carbon it can store if belowground carbon is taken into consideration, making the total carbon storage of 1520 tC/ha in mangroves forests much greater than the average 170 tC/ha that tropical forests can hold (Carbon Sequestration 101). The aboveground estimation of 51.7 tC/ha in Makoba Bay is comparatively low, but it correlates with the recovering state and immature standing of the mangrove forest. Despite the high abundance of trees, the relatively small size of most individuals measured led to a lower carbon stock. The high density of mangroves in the plots was not associated with a larger carbon stock, but rather, the volume of the trees in each plot impacted carbon stock the most. As replantation of mangroves is already being implemented, this forest will mature on its own in a matter of time. The effectiveness of Makoba Bay as an abundant carbon sink should not be refuted, but rather, it should be realized that more conservation and rehabilitation efforts implemented would improve the status of this already fast-growing ecosystem.

7.2 Assessment of Current Mangrove Conservation and REDD+ Efforts

Throughout the interview process, the general perception of mangrove conservation in two bays of Unguja, Zanzibar was accounted for. In Makoba Bay, where subjects resided in Bumbwini-Mafufuni, it was apparent that people lacked breadth and depth in the education they had received on the subject of mangroves. However, it was also clear that all interviewees had some grasp on the importance of mangroves in providing numerous ecosystem services, such as a habitat for crabs, acting as fish breeding and nursery grounds, and preventing coastal erosion. Carbon businesses were practically unheard of in the area, but all interviewees indicated that they would like further involvement with a project like REDD+, and were extremely interested

and open to the idea. As mangrove use is already strictly regulated in Makoba Bay, the implementation of a program like REDD+ would not radically change mangrove activities and also bring in additional revenue for the community. Although there are people that still cut mangroves illegally, they are not doing so occupationally, but primarily to use as firewood in their own homes. These actions can be reformed and other sources can be used for firewood, including dry wood from mangroves, which does not require the cutting of live trees and is allowed with a permit. In the future, profits from a REDD+ project could even fund the replacement of current cooking methods to the use of appliances like fuel-stoves.

In Charawe, and the entirety of the Chwaka Bay, HIMA has been enacted. Theoretically, the HIMA project should provide all the necessary tools for communities to prepare for the expansion of mangrove conservation efforts and piloting of REDD+ in Zanzibar by executing these five main outputs:

1) Develop new Community Forest Management Agreements (COFMA) and review and improve existing COFMAs based on effective and equitable strategies.
2) Strengthen the REDD+ and climate change capacities of relevant government and local NGOs.
3) Secure Voluntary Carbon Standard (VCS) and Climate Community and Biodiversity Alliance (CCBA) validation and develop marketing arrangements that maximize the benefits to local communities and the environment.
4) Create replicable, equitable, and cost effective measures to reduce degradation and deforestation and to control leakage designed and implemented.
5) Monitor, evaluate, document, and advocate for the processes supported, with particular emphasis on social equity (CARE International 2010).

Through COFMA, the Director of the Department of Forestry is giving a community the right to manage their own forests. The agreement, which is virtually the same in all shehias give or take a few minor figures, details management areas and permitted activities, penalties, and the rights and responsibilities of the community conservation group (Community Forest Management Agreement: Shehia of Msuka Magharibi 2013). In addition, other activities are listed that may be carried out with the permission of the community conservation group, including bee keeping, environmental tourism, and medicine collection. The duration of the agreement is 30 years, during which the management plan will progress in 6 phases, for 5 years each (Community Forest Management Agreement: Shehia of Msuka Magharibi 2013). With the creation of new agreements and the reevaluation of ongoing agreements, it is a supplementary objective of HIMA to develop these contracts in a sustainable, pro-poor, and gender sensitive manner.

In addition to COFMA, HIMA aims to prepare Zanzibar for REDD+ through a series of pilot projects in select shehias (CARE International 2010). Biomass inventories need to be conducted in order to establish forest carbon stock baselines, and carbon feasibility assessments for project areas must be determined under VCS. Once appropriate methodology is developed and the project is validated under the VCS, an aggregation unit must be appropriately identified because no individual community or area has the capacity to function in the international carbon market alone. Three options were considered in the decision of what organizational identity would be responsible for carbon aggregation and marketing for the communities involved in Zanzibar: a non-governmental organization (NGO), a co-operative, or a private sector "social enterprise" (Blomley 2011) Each of these options has its benefits and pitfalls, but an NGO was ultimately created to organize the carbon financing in Zanzibar. JUMIJAZA, created under

CARE, has partnered with Terra Global Capital, the leader in forest gas emissions analytics and carbon marketing, to finance Zanzibar's carbon business (Community Forest Management Areas in Zanzibar, Tanzania). Having an NGO in this role offers many advantages. It is able to cover the objectives of both carbon aggregation and marketing, as well as more general objectives of supporting community forestry (Blomley 2011). In addition, a more transparent system would ensure the maximization of community benefits. In various other countries, many instances of corruption within the forestry sector have come about and have gone unnoticed by the public, press, or honest elements of forest agencies because of a lack of transparency (Brown 2010). Now Zanzibar is nearing the process of VCS validation and marketing of credits to international buyers, by JUMIJAZA, will begin in early 2015 (Blomley 2011). Hypothetically, all the cogs are lined up and the gears of REDD+ are ready to run, but the reality and functionality of this procedure was disputed by the interview results of a community presently involved in the project.

Overall, the community of Bumbwini-Mafufuni is on board with the conservation of mangroves and the possibility of a carbon business. The interviews in Charawe, however, show that there are a lot of flaws with the current REDD+ pilot project and that communities may not be receiving the support that they need to make a carbon business possible to sustain. A surprising lack of knowledge on mangroves was evident in Charawe, even within the conservation committee. The Department of Forestry, CARE, JECA, and other groups have all made attempts to educate and prepare the people of Charawe for the introduction of REDD+, but not with enough consistency. As a people that have traditionally relied on the forest for their livelihood, it would be difficult to change the general mindset from cutting to conserving trees, including mangroves. In order to achieve any permanent transformation in conservation attitude,

education efforts need to be more regular, and include long-term and large-scale issues such as coastal erosion, sea level rise, and climate change – all of which will affect the island-nation of Zanzibar if nothing is done to improve the situation. Furthermore, most time pressing with the implementation and upcoming validation of REDD+, all members of the community must be made aware of the implications of such a project, and be kept up to date with its progress, as the project cannot work without their full cooperation.

Perhaps with further and more in-depth education to a larger proportion of the population about the importance of conserving mangrove forests, the admitted illegal activities, primarily cutting, would be minimized. But as stated before, by signing a COFMA, the government is handing over the rights to govern the forest to the community conservation group. This includes the ability to delegate permits, which can lead to permits being given for wrongful activities, whether that be because of the immoral use of a bribe, abiding to a friend or family member, or just misunderstanding between the government and community over what is to be endorsed and what is not. Although it cannot be generalized and vindicated that this form of behavior is the norm in the Shehia of Charawe, interviews with locals do confirm that permits for cutting mangroves have been known to be given for non-emergency situations.

But of course, the root of the problem in the illegal cutting and overexploitation of mangroves and other types of forest is ultimately poverty. Even though mangrove cutting is prohibited, many people have no other choice in the matter when it comes down to supporting themselves and their families. Since the use of chainsaws has been banned, in an attempt to slow down the deforestation rates, mangrove-cutting with axes has become extremely back-breaking work, as stated in several interviews. But even if people *wish* to give this occupation up, there is still a limited diversity of occupations and a lack of alternative livelihoods in Charawe, so people

reluctantly continue to turn to cutting mangroves as their profession. Alternative livelihoods are hard to establish and sustain, and must be addressed in an equitable way.

Although JECA has supported a small number of people, as chosen by the conservation committee, in starting alternative livelihoods, this limited amount of resources is clearly not enough to motivate an entire community, that has traditionally been completely dependent on forestry, to change the habits in their livelihoods that have been followed generation after generation. Expecting local people to provide for themselves the equipment necessary for alternative livelihoods, such as traps for bee keeping and drip-irrigation systems for sustainable agriculture, is also unrealistic at the moment. Although the initial cost of this equipment would be superseded by the eventual financial, as well as environmental, gain, many local people do not understand the benefits of long-term ventures. The desire for immediate benefits is engrained when one is living on a day to day basis, and to encourage long-term investment in alternative livelihoods would take tremendous education and persuasion.

A consolation of a program like REDD+, which will generate money upon the validation of carbon credits, is that this could become a perpetuating system, in which the income from REDD+ can support alternative livelihoods. Perhaps with more education, they would better understand that the conservation of mangroves would indirectly benefit other potential occupations, for example, fishermen would see an increase in fish stock with the increased area of breeding and nursery habitat. In addition, REDD+ is still in its preparation stages, and the community has yet to reap the financial benefits of the program. They must understand that when this project is validated, they will earn more money if their forest remains intact.

In the mean time, persistent efforts in alternative livelihood training and support are crucial. The current lack of alternative livelihoods is not a problem that can or should be solved

by a sole few organizations, such as JECA, CARE, and the Department of Forestry. Alternative livelihoods serve as a method in alleviating poverty, and many sectors of the government have related programs that can act synergistically with efforts of the forestry sector. For example, it would be realistic for the Department of Agriculture to support sustainable farming and the Department of Tourism to support ecotourism in places where forest conservation and REDD+ are being attempted. A conjoined effort would make the process of stabilizing sustainable alternative livelihoods much more successful.

7.3 Recommendations for Makoba Bay

As a recovering mangrove forest, Makoba Bay has a lot of potential to establish a carbon business in the future. The current estimation of 52.7 tC/ha sequestered aboveground, is lower than the amount of carbon stored in mature mangrove forests, but is still an extremely significant amount. If the additional 90% of carbon stored belowground is taken into consideration as well, this mangrove forest still holds much more carbon than the average tropical rainforest, the most carbon abundant terrestrial forest, which holds 170 tC/ha (Carbon Sequestration 101).

In the mean time, steps need to be taken in preparation for the future induction of REDD+ in the shehias of Makoba Bay. In comparison to Charawe, the people of Bumbwini-Mafufuni, who represent the entirety of Makoba Bay in this study, possess a greater willingness to conserve their mangrove forest at this instant. Their reliance on an array of natural resources, rather than a sole dependence on forestry as income, coupled with their present knowledge and interest in the indirect ecosystem services that mangroves provide compel them to conserve mangroves, making them a pragmatic candidate for the expansion of a successful REDD+ project in Zanzibar in the future. Nevertheless, they still require assistance in moving forward

with many aspects of mangrove forest management before a carbon business can be introduced with ease.

First and foremost, mangrove-specific COFMAs need to be established between the shehias of Makoba Bay and the Director of Forestry. Though the people of Makoba Bay are already unofficially managing their own forests, the recognition from the government through a COFMA would give the community legal authority to dictate the management of their forest. However, the government should still be involved in performing an accurate biomass inventory to better understand the ecosystem potential of Makoba Bay, and continue with sufficient follow-up surveys to ensure the prohibitions procured in the COFMA were being observed by the community. Local guards need to be trained and motivated to take action in the field if illegal activity is witnessed. They also need to be given the mangrove-specific tools to be able to patrol the area without limitations. A boat, for instance, would allow these guards to monitor mangroves during high tide, as well as in places like Kiwani Island, which are farther out of reach and particularly susceptible to mangrove cutting as people recognize the lack of regulation enforcement officers in these areas.

Within the process of commencing a COFMA, it is particularly important to encompass two major facets: education on mangrove conservation matters and the application of alternative livelihoods in order to avoid the same issues that were observed in Charawe in this study. The people of Makoba Bay have shown interest in gaining additional knowledge about mangroves and conservation management and are willing and able to educate internally, but they are currently lacking the support from outside groups to provide further information. Government groups and NGOs alike need to take the initiative to fill this education gap and provide members of the community with information that will assist in their understanding of the importance of

mangrove conservation and regeneration efforts. Furthermore, if the ultimate goal were to create a REDD+ project in Makoba Bay, it would be advised to proactively educate people specifically about carbon sequestration in mangrove forests and the social-economic devices behind a carbon business. By involving and communicating with communities early on and frequently in the implementation of REDD+ in Makoba Bay, it would ensure the social equity of this project and avoid the same counter productivity in Charawe's current REDD+. Makoba Bay's mangrove conservation management plan must also be preemptive about providing training and resources for alternative livelihoods. The interests of the shehias should be taken into account in deciding what alternative livelihoods would be best integrated into the communities, along with the reality of the resources available in the geographic region. Various sectors, including the Department of Forestry, can then be ushered in to create effective methods and resources to prepare for and pioneer such livelihoods. Eventually, with the generation of revenue through the sale of carbon credits, Makoba Bay will be able to support its constituents in sustaining these alternative occupations.

7.4 Study Limitations and Recommendations for Future Studies

Although this study conveyed good baseline information, it was not without its flaws and limitations. In the field, plots were randomly chosen, but there were limitations with transportation that confined plots to a certain vicinity. It would be more indiscriminate if a transect-plot system was established prior to fieldwork, with transects laid out in a grid-like manner, and the centers of survey plots placed at the vertices where transects meet. There was also technical error with the GPS used in this study, and as a result, some of the plot coordinates used were estimations (Appendix B). Though this is not problematic for the validity of the data collected within those plots, it does limit the ability for future researchers to revisit these sites

and do a reassessment of biomass and carbon stock. However, with the sites that do have accurate GPS coordinates, it would be worthwhile to revisit these sites and gain and understanding of the rate at which the mangrove forest in Makoba Bay is recovering and growing. Additional information used in this study that was not accurate due to its nature of being non-site specific were the wood density values used in calculating biomass and carbon stock. These values were mangrove species-specific, but were taken from a previous study that calculated average wood densities from different mangrove ecosystems around the world (Saenger 2002). Future studies should use wood density measurement protocols to extract the exact wood density values of mangrove species and individuals found in Makoba Bay.

The interview portion of the study also had some limitations and can be improved in future studies. With the interviews being conducted entirely in Kiswahili, which is not the author's primary language, there was a definite barrier in communication. Even with a translator present, there was a lot of information that may have been miscommunicated or lost in translation. The subject pool was also small and not the most accurate representation of the entirety of Makoba Bay and the entirety of the shehias currently involved in the REDD+ pilot project. Future studies should interview subjects from all the shehias of Makoba Bay, as well as additional shehias that presently have a REDD+ project through HIMA. Moreover, a similar social survey should be conducted in the shehias involved in REDD+ after the validation of the pilot project in 2015, so the effect of generating revenue from selling carbon credits on an international market can be observed and analyzed.

8.0 Conclusion

In Zanzibar, a range of underlying causes, including a customary lack of functional management regimes, insufficient education, poverty, and limited livelihood diversification fuels the overexploitation of mangroves. Makoba Bay has historically been affected by vast amounts of deforestation and forest degradation, but in recent years, the conservation value of mangrove forests has been realized, and exploitation of the area has been minimized. The mangrove forest has begun recovering to its former state, and now has the ecological potential to become a site for a carbon business through Zanzibar's REDD+ project in the near future. In tandem, the positive feedback from the local people of Makoba Bay suggests that they are socially and economically prepared for a carbon business given that they would be able to secure property rights and equitable rewards for their conservation efforts, and proper attention be given to the tribulations of the existing pilot project. REDD+ has the capacity to involve more communities in Zanzibar, and it is recommended that upon further research, the shehias of Makoba Bay be evaluated and validated for the introduction of a carbon business.

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10.0 Appendices

10.1 Appendix A. A list of mangrove species found in Makoba Bay, with scientific and Kiswahili names.

Scientific Name	English (Common) Name	Kiswahili Name
Ceriops tagal	Indian mangrove	Mkandaa mikundu
Brugeira gymnorriza	Large-leafed orange mangrove	Msisi
Rhizophora mucronata	Red mangrove	Mikoko magondi
Avicennia marina	Gray mangrove	Mchu
Sonneratia alba	Mangrove apple	Mpira
Xylocarpus moluccensis	Cedar mangrove	Mkomafi kijani
Xylocarpus granatum	Cannonball mangrove	Mkomafi mikundu
Lumnitzera racemos	Black mangrove	Kiraramba
Heritiera littoralis	Looking-glass mangrove	Mskundazi

10.2 Appendix B. GPS coordinates of randomly-selected survey plots

Plot	Latitude	Longitude
1*	-5.935861°	39.203954°
2	-5.936889°	39.203528°
3	-5.928368°	39.222189°
4*	-5.942996°	39.208902°
5	-5.942583°	39.206944°
6	-5.939750°	39.202556°
7	-5.940167°	39.201361°
8	-5.942472°	39.207139°
9	-5.937167°	39.205917°
10*	-5.932338°	39.205235°
11	-5.934194°	39.204750°
12	-5.939389°	39.205750°
13*	-5.915167°	39.204556°
14	-5.914139°	39.204694°
15*	-5.942743°	39.213296°
16	-5.942472°	39.210889°
17	-5.944333°	39.208528°
18	-5.946333°	39.201783°

*Due to GPS malfunctions, these plots' latitudes and longitudes are approximations (Section 7.3)

10.3 Appendix C. The wood density values of the five species of mangroves found in the survey plots (Saenger 2002).

Species	Wood Density (tons/m^3)
Avicennia marina	0.765
Brugeira gymnorriza	0.82
Ceriops tagal	0.935
Rhizophora mucronata	0.95
Sonneratia alba	0.72

10.4 Appendix D. Sample data for survey plots (if all raw data is required, please contact the author at jeliang@colby.edu).

Plot 10	S 05°56'14.0"	E 039°12'21.4"
Seedlings/ Saplings:	41 RM, 6 SA	
Species:	Diameter (cm)	Height (m)
RM	3	2
RM	3	2
RM	3	2
RM	3	2.5
RM	4	3
RM	4	3
RM	4	3
RM	4	3
RM	4	3
RM	4	3
RM	4	3
RM	4	4
RM	4	4
RM	4	3
RM	4	4
RM	4	3.5
RM	4	3.5
RM	4	2.5
RM	4	2.5
RM	4	3
RM	4	3
RM	4	3
RM	4	3
RM	4	3
RM	4	3
RM	4	3
RM	4	3
RM	4	4
RM	4	4
RM	4	5
RM	4.5	5
RM	5	3
RM	5	3
RM	5	4
RM	5	4
RM	5	4
RM	5	4
RM	5	4
RM	5	4
RM	5	4.5
RM	5	4
RM	5	3
RM	5	5
RM	5	5
RM	6	5
RM	6	5
RM	6	5
RM	6	4.5
RM	6	5
RM	6	5
RM	6	3
RM	6	4
RM	6	4
RM	6	4
RM	6	4.5
RM	6	5

RM	7	5	RM	17	9
RM	7	5	RM	23	8
RM	7	5	SA	5	3
RM	7	4.5	SA	5	3
RM	8	4	SA	6	4
RM	8	4	SA	6	4
RM	8	4.5	SA	6	5
RM	8	5	SA	7	5
RM	8	5	SA	8	6
RM	8	5	SA	8	7
RM	8	5	SA	8	7
RM	8	5	SA	8	8
RM	8	5	SA	8	6
RM	8	5	SA	8	6
RM	11	6	SA	12	10
RM	12	6	SA	16	9
RM	12	6.5	SA	18	9
RM	12	6.5	SA	27	12
RM	15	7	SA	34	10
RM	15	7	SA	36	12
RM	15	7	SA	68	15
RM	16	8	SA	72	10
RM	17	9	SA	74	13

10.5 Appendix E. List of questions asked to interviewees.

Bumbwini-Mafufuni:

1) What do you use mangroves for?
2) Do you participate in the replantation of mangroves? Why?
3) Why are mangroves important, ecologically, socially, and economically?
4) What education have you received, if any, on mangroves? From whom was this education received? (Local committee member, NGO, Department of Forestry, etc.?)
5) What are the current regulations governing mangroves in Makoba Bay?
6) [If on mangrove committee], what tasks do you perform as a part of the mangrove committee? Are these tasks effective in encouraging members of the shehia to conserve mangroves?
7) What do you know about carbon and trees? Carbon business? REDD+?
8) Do you think a carbon business would be good for the community? Do you want one to be established in Makoba Bay?
9) Do you foresee any negative impacts on the community if a carbon business were to be established in Makoba Bay?
10) How would the community deal with the change in livelihoods if regulations became stricter after a carbon business is established?

Charawe:

1) What do you use mangroves for?
2) Do you participate in the replantation of mangroves? Why?
3) Why are mangroves important, ecologically, socially, and economically?
4) What education have you received, if any, on mangroves? From whom was this education received? (Local committee member, NGO, Department of Forestry, etc.?)
5) What are the current regulations governing mangroves in Chwaka Bay?
6) [If on conservation committee], what tasks do you perform as a part of the conservation committee? Are these tasks effective in encouraging members of the shehia to conserve mangroves?
7) What do you know about carbon and trees? Carbon business? REDD+?
8) How has the REDD+ project progressed in Charawe in the last four years?
9) Have organizations like CARE, JECA, or the Department of Forestry been a consistent presence in Charawe in the last four years?
10) How has the piloting of REDD+ affected those that depend on mangroves for their livelihoods?
11) Has any assistance been given to people to establish sustainable, alternative livelihoods?
12) What changes would you like to see to the current REDD+ efforts?