The creation of a sustainable mangrove planting model: Benefits for local fishing communities and local ecosystem health on the island of Santa Catarina, Brazil

GEOG 203 Research Concept Note
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Research question: How does the implementation of a sustainable mangrove planting model benefit South American local fishing communities and local ecosystem health? How can South American local(impoverished) communities and local ecosystems benefit from a sustainable mangrove management plan?(instead of south america, instead our model is specific to (eg) prevent soil erosion)

Summary

In Brazil, the coastal mangrove ecosystems have been steadily declining in both size and scope. Although coastal mangrove populations are not solely threatened within Brazil. Generally speaking, the same factors that affect mangrove populations in Brazil are also affecting populations globally. Since 1980, it is estimated that 26% of global mangrove populations have disappeared (Peng, et. al, 2013). Quite often these coastal wetlands are replaced by land covers viewed as more productive or efficient economically such as urban zones, agriculture or even artificial reservoirs and aquaculture ponds (Walton, et. al, 2006).

Our objective is to create and implement a sustainable, reproducible reforestation model that can be reused in various regions of Brazil and the world. This project will focus on the island of Santa Catarina as this region has a dwindling native mangrove population. The island is slowly being eroded from the ocean's relentless bombardment. Many of the local settlements have large fishing populations with ties to the coastal wetlands. This will synergize well with our reforestation effort as planting the mangroves will bring an increase in biodiversity including dramatically increasing the population of fish. Our approach will require the assistance of various institutions which we intend to appeal to, such as NGOs like the SER (Society for Ecological Restoration), government organizations such as Fatma, Santa Catarina's environmental protection agency, and the IDRC (International Development Research Centre) as well as the community who will comprise the largest portion of our volunteer labour force.

Sustainability is one of the core attributes the proposed reforestation model should accomplish. The community will be able to continue reforesting long after the project is executed and completed. The seeds can be seasonally harvested from other mangrove forests on the island. These seeds will then be transported and planted at the mangrove nursery we plan to create. The mangroves will stay at the nursery until they have developed root systems strong enough to be harvested and planted in the wild with a high rate of viability.

Our finished project will have planted 5000 trees along the coastline West of Barra de Lagoa, a fishing community on the East end of Santa Catarina. An established nursery will have been built to provide a place for the seedlings to develop before planting, which can be reused for future planting needs. The Santa Catarina Coastal Wetland Community Council (SCCWCC) will have been instituted and given jurisdiction over the nursery, the planted site and the coastal fisheries to ensure responsible and sustainable management of its common resources. After the completion of the planting stage of this project the SCCWCC will be responsible for future management logistics as our researchers turn our focus to how the model can be adjusted for, or integrated into new communities within Brazil or other countries with similar areas of interest.

Objectives

The broadest objective of this proposal is the creation and implementation of a sustainable long-term coastal mangrove reforestation model that can be used for future mangrove planting initiatives. In terms of the specific goals of our model, we hope to:

- Improve the socioeconomic development of local fishing communities
    - healthier coastal wetlands
    - more abundant and diverse fish populations
    - sustainable management and harvesting of common resources (i.e. fish) through the creation of The Santa Catarina Coastal Wetland Community Council
- Improve the ecosystem health
    - Improve the biodiversity of fish, birds, insects and other species known to inhabit mangrove populations
    - Reduce the impacts of coastal erosion
    - Reduce the impacts of storm surge and coastal flooding
- At the end of our project we also hope to critically evaluate the work that was done and identify areas in need of improvement to increase the effectiveness of future recreations of our model

Research Problem and Context

Due to their unique habitat, mangrove populations are susceptible to a wide variety of threats. Although they are efficient at removing pollutants from water, thicker substances can suffocate the root systems and kill the plants. Chemical pollution from anthropogenic sources, for example, flowing downstream (fertilizers, pesticides, oil by-products and other toxins) can have an adverse effect on animals within mangrove populations (Mater et al, 2004; Blue Planet: Mangrove forests, n.d.). Mangrove forests also require stable sea level for long-term survival. This is because of the delicate saline balance they require as well as to prevent the delicate sediment around their roots from being washed away. Sea level rise associated with climate change provides a threat to these systems (Blue Planet: Mangrove forests, n.d.). Water use changes upstream can also affect this balance, via a reduction in the amount of water flowing downstream. Clear cutting of mangroves is done for both aesthetics as well as to harvest the wood resources (Polidoro BA et al, 2010). The wood from the mangrove is often very resilient to weathering and sturdy making it an efficient building tool, especially for local low-income communities (Blue Planet: Mangrove forests, n.d.). Mangrove forests tend to have a swampy appearance and release an unpleasant odour, often times it is cut down for more productive land uses such as agriculture or tourism (Blue Planet: Mangrove forests, n.d.).

Despite the fragile nature of the coastal mangrove, the plant is capable of providing many essential functions for not only the species living within its habitat but for

those living in adjacent habitats as well. For example, the complicated root system of mangroves is a common home for many species of fish, crab, shrimp, molluscs and more as well as providing a home for many birds and insects within the branches and canopy (Blue Planet: Mangrove forests, n.d.; Mangroves, n.d.). The study have found that animal species such as oysters experience a population density increase of over 10% in ecosystems where mangroves are present versus ecosystems where mangroves are not. Also, mangrove litter-fall is believed to contributed of up to 26% of the diet of cultured fish. The forests also act as nurseries for many migratory species. Some fish species are born and mature in the mangrove forest before migrating to coral reefs where they perform functions such as providing an essential food source (Blue Planet: Mangrove forests, n.d.; Mangroves, n.d.). Being located in the uncommon niche of coastal wetlands also means that mangrove populations are the first to experience storm surge from the oceans. Due to their strong root system they are adept at buffering inner ecosystems from the surge's effects as well as reducing the impacts of erosion by stabilizing the soil (Blue Planet: Mangrove forests, n.d.). Another important role that mangrove trees fill is acting as an efficient carbon sink by removing CO_2 from the atmosphere (Kathiresan, 2012).

Mangroves can also offer many benefits to the local communities as well as ecosystems. For instance its resilience to storm surge can protect human populations just as well as it can protect ecosystems. The greatest benefit to the local communities will be the increase in fish population and biodiversity. Commercial fishing comprises the majority of economic stimulation for poor, local communities, especially those situated near mangrove populations.

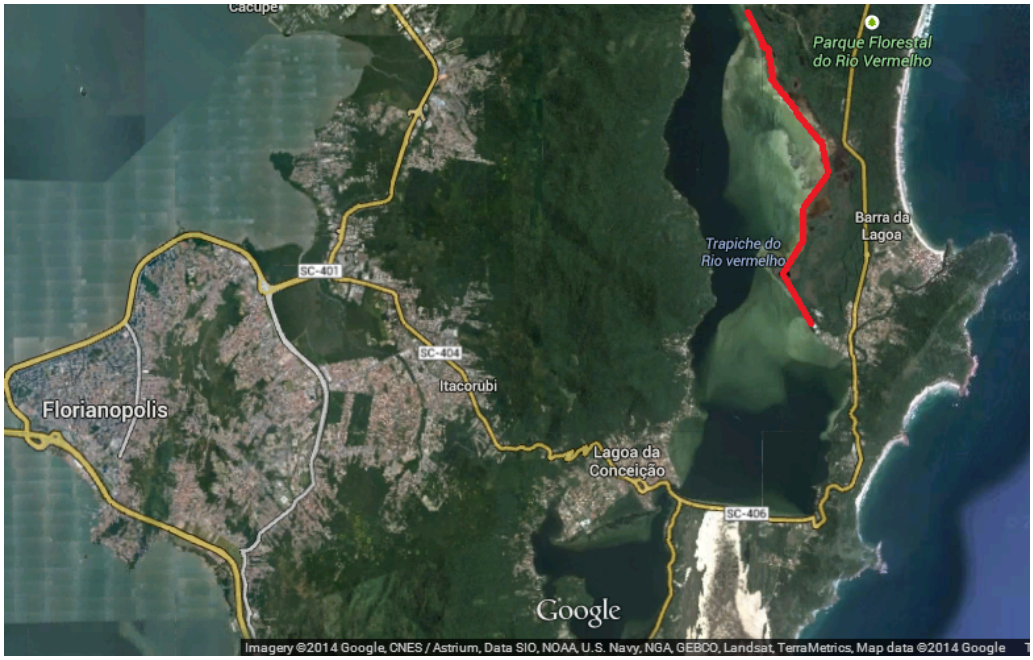

Figure 1: Map of central Santa Catarina Island and proposed sample area

There is significant erosion damage occurring on the island of Santa Catarina. The island is especially vulnerable relative to inland Brazil due to its coastal location and often acts as a buffer for storms. Cyclones and tropical storms have impacted this region in the past, the most remarkable of which being cyclone Catarina (Marcelino, 2004). Fishing is a popular occupation due to its coastal location.

Planting mangroves along the coast will reduce soil erosion. There are mangrove forests on the island, particularly in the Northern regions, however they are sparsely spread around the island. There are currently no mangrove forests that are due east of the island's population centre, Florianopolis. There is major erosion happening within the waterbodies in the centre of the island. As illustrated in Figure 1, much of the waters off the coast of our proposed planting site (outlined in red) are tainted green due to the soil that has been eroded from the island. If this planting plan was only for a finite number of trees or duration, the mangrove populations may fail to endure. Therefore this plan is intended to be sustainable past the duration of the project.

This region is not the only one being threatened. Other coastal regions throughout Brazil and other countries with the correct climate could benefit from a similar type of initiative. The secondary attribute to this tree planting model is that it can be reproduced in other locations while providing the same benefits. This project can be used as a stepping stone in order to start similar programs in other locations.

Research Gaps

Typically these projects intended the replanting of mangroves for the purpose of the harvesting of their wood resources (Peng, et. al, 2013). These initiatives would look at mangrove populations as a resource to be extracted, where we wish to look at them more so as an ecosystem to be sustained. Some more recent initiatives examined the benefits of mangrove populations in terms of reducing disturbances such as storm surge and coastal flooding, as well as improvements made to the livelihoods of locals (Peng, et. al, 2013). Our model does attempt to focus on the perceived benefits for local populations as well, but we also view the improvements made to ecosystem health as equally important.

In 2006 a study was released of the results of a community based reforestation initiative conducted within the Philippines. This study examined mangrove populations in terms of their socioeconomic benefits that they provide to local communities (Peng, et. al, 2013). This study effectively examined these benefits in terms of their dollar value, for example, it valued mangrove populations at US$ 9900/hectare/year (Peng, et. al, 2013). Yet many of the mangrove's benefits are intangible or very difficult to price,

such as improvements to biodiversity or reduction of coastal erosion. Another negative to this model which we aim to improve upon is their lack of an efficient management system. The replanted mangrove populations lacked a governing body or institution to regulation the extraction and usage of the forests by local populations (Peng, et. al, 2013). With five local communities with open-access fishing rights, the potential for 'tragedy of the commons' scenario is great (Peng, et. al, 2013). Two positive aspects of this model which we intend to incorporate in ours is their use of community involvement and their use of institutions. Participation within the community was encouraged via a survey of the local populations asking for their opinions on mangrove populations in terms of value and function for example (Peng, et. al, 2013). Locals were also questioned about their desires to maintain and sustain the mangrove populations. Institutions were also effectively used through bodies such as the NGO USWAG (United Services Welfare Assistance Group), the local government and the community cooperative KASAMA (Kalibo Save the Mangrove Association) who provided the majority of the volunteer labour (Peng, et. al, 2013).

A similar study released in 2013, focused on a replanting model enacted along the coasts of the South China Sea (Walton, et. al, 2006). This model attempted to find ways of increasing the appeal of mangrove populations, specifically by incorporating them into Integrated Mangrove Aquaculture Systems (IMAS) (Walton, et. al, 2006). The added benefits of an IMAS is that by the addition of an aquaculture pond, biodiversity within the mangrove populations will be enhanced (Walton, et. al, 2006). The IMAS can also be incorporated into a water treatment system, allowing the mangroves to filter contaminants from wastewater before it is discharged into a larger body of water or reused (Walton, et. al, 2006). Although this model appears to be successful in terms of its goals, our goals do not include the purification of water and we are also of the opinion that mangrove's natural biodiversity is not in need of enhancing. In terms of site selection the focus was on degraded aquaculture ponds, whereas our model focuses on coastal wetlands. This model also only maintained a very minimal cooperation with other institutions.

The majority of the step by step process that our model follows was taken and adapted from a mangrove nursery raising manual released in 2004 (Ravishankar & Ramasubramanian, 2004). This model outlines a proven nursery management process, starting from the harvesting of seeds, and growing them in a nursery until they are strong enough to be planted in the designated site with a high chance of viability (Ravishankar & Ramasubramanian, 2004). This model provided a thorough description of this process but it failed to address what comes after the seedlings are harvested from the nursery. It was also designed specifically for a site in India, so adjustments had to be made to account for things such as climate, typical weather conditions and usage by the locals. Another shortcoming of this model was that it provided little

analysis as to the benefits or issues of this process (Ravishankar & Ramasubramanian, 2004).

The benefits of our mangrove planting model when compared to previous models is twofold: First of all, most planting initiatives have focused on the benefits toward the ecological health of the region and its biodiversity or the benefits to the local human populations. Few studies have attempted to incorporate both of these aspects into one model. Our proposed model attempts to do just that, under the ideology that sustainability requires an approach that has both ecological and anthropogenic benefits.

The second, and most important benefit of our model, which our research failed to identify in other management initiatives, is a sustainable long-term management plan. Most other models tend to focus on the replanting of mangroves but provide little guidance as to what happens after. Our model, as outline in Table 1, provides an indepth management plan to ensure the sustainability of the areas we plant for years to come. In doing so, we also allow for the control and management to fall in the hands of the locals, those most tied to the region and who have the most incentive to manage the forests efficiently.

Methodology

Data Collection and Analysis

For our research, we will be conducting field testing and environmental assessments in several neighbourhoods in the outskirts of Florianópolis on the Brazilian Island of Santa Catarina. In order to begin our research, our team will travel to the neighbourhoods of Barra da Lagoa, Santo Antônio de Lisboa and Jurerê. These three regions of Florianópolis were chosen to be the focus of the study because they are the most susceptible to damages caused by storm surges. The environmental assessments in these three regions will contrast the environmental and ecological contexts for each site and allow the research team to determine what plan of action must be taken. When the research is complete, the active phase of the project will begin to unfold.

In order to achieve our goals and objectives, the team will be conducting fieldwork and background research on many different aspects of the geography, climate and ecology of the region. With the help of Fatma, the Santa Catarina government state level environmental agency, IBAMA – the administrative portion of The Brazilian Ministry of Environment (IBAMA, n.d.), The Society for Ecological Restorations NGO (SER) and the IDRC, the research team will have access to many databases. Through these institutions we can retrieve information from past mangrove reforestation efforts in the area if possible. Once the research team is on the Island, they will identify the most vulnerable communities where the implementation of mangrove reforestation would be

most effective. In order to protect the communities at risk, we have to converse with local citizens and institutions to provide an incentive and good reasoning for their cooperation in the initiative. The research team will work together with ecological experts from the Brazilian Ministry of Environment to help guide the assessment of the regions to be monitored. To maintain our work schedule, volunteers will be required. A group of 50 to 100 volunteers on a continuous basis are needed throughout the process. Volunteers will consist of local experts, families and stakeholders. Gender considerations will generally not be made and the work will be divided equally among both genders.

Another major Agency that will be beneficial towards our success in the initiative is the Nature Conservancy. The Nature Conservancy is a non-profit organization based in the United States whose mission statement is to “conserve the lands and waters on which all life depends” (The Nature Conservancy, 2014a). The Nature Conservancy has done conservation work in all seven Continents, across many countries. The Nature Conservancy has done restoration and reforestation efforts before, in particular a project in Papua New Guinea with a goal of 20,000 mangroves by 2015 (The Nature Conservancy, 2014b). The Nature Conservancy has recognized mangrove forests as vital to the development, protection, economy of coastal regions worldwide and a major buffer of atmospheric Carbon Dioxide. The information from past restoration and reforestation efforts conducted by the Nature Conservancy will be very helpful. The assistance and previous research provided by the Nature Conservancy can improve the productivity of our assessments and increase the expertise and knowledge of our experts, volunteers and all other stakeholders on the subject. Reviews of previous scientific research papers, government documents and case studies will be conducted with the help of the Ministry.

Before the active fieldwork phase will begin, the volunteers will be trained. After all volunteers are properly trained and informed on the topic, the gathering of seedlings/saplings and regional environmental data will take place. The gathering of data and mangrove saplings across the Island will take six and two months respectively. The research team will extract data on many different variables including; soil erosion, soil quality, hydrogeology, geomorphology, elevation, temperature, climate and growth of various mangrove species. Data collection and analysis will be done using equipment and tools provided by the Brazilian Ministry of Environment. Analysis of all collected data and information will take place within facilities provided by the Brazilian Government.

User Participation

To understand the importance of Mangrove forest development and protection in the Island of Santa Catarina, we must conduct surveys and interviews of the local

Communities. The goal of the surveys is to identify the impact of Mangrove forests on the livelihood of the communities. We will target 20,000 locals on the Island through a random sampling technique. The questions that will be asked during the surveys include:

1) Are you concerned about the decrease in Mangrove Forest coverage in the region?
2) Does your livelihood depend on the protection of these forested regions?
3) Are you employed? If so, does your field of work depend on the health of the mangrove trees?
4) Is the protection of the mangrove forests vital for the growth of the economy in your region?
5) Do you support the initiative of mangrove reforestation along the coastal regions of the Island? Why or why not?
6) If you support the reforestation initiative, what do you hope the initiative will achieve in a short or long term basis (how will it affect your community?)
7) Would you be willing to volunteer for the Data collection and planting stages?

Conducting these surveys will provide important information which will aid in the execution of the project. Knowledge of the local inhabitants' opinions regarding the reforestation initiative will give a better understanding of situation on the ground. All surveys will be analyzed, recorded and archived. This data will help the team reach our objectives, better analyze and understand the research gaps.

Species Selection Process

The mangrove's natural habitat is within the tropics and subtropics. Mangrove trees grow partly submerged in seawater. All mangrove species develop based on specific adaptations and tolerance levels to their surrounding environment (De-Rosa et al., 2008). For this proposal, the research team will focus on three specific species of mangroves:

Rhizophora Mangle also known as the red mangrove, has prop roots for stability and oxygen ("The IUCN red list of threatened species," n.d.). Red mangroves blossom biannually in mid-winter and spring within the wider Caribbean ("The IUCN red list of threatened species," n.d.; Lacerda et al., 2001). Red mangrove trees usually grow along the shore ("Smithsonian marine station at fort pierce," 2009). Their roots are submerged extremely deep within salt water, this depth allows the red mangrove to survive in harsh condition where its sister Brazilian mangroves species would fail ("Encyclopedia of life," n.d.; Lacerda et al., 2001). Their propagule size varies and this species of mangrove can also grow larger in areas with higher amounts rainfall ("Smithsonian marine station at fort pierce," 2009; Lacerda et al., 2001). The red mangrove is one of the mangrove

species that are viviparous; the seeds germinate while still attached to the parent ("Smithsonian marine station at fort pierce," 2009). Production of viviparous propagules is abundant and maintained on the parent tree for 3-6 months ("The IUCN red list of threatened species," n.d.; Lacerda et al., 2001). Once dropped, the propagules can subsist for extended periods afloat prior to rooting (Lacerda et al., 2001). Successful growth of the red mangrove tree requires a canopy break ("The IUCN red list of threatened species," n.d.; Lacerda et al., 2001). After they have grow into seedling they need to transport the propagules to the planting sites where they remain ("Smithsonian marine station at fort pierce," 2009).

The white mangrove tree, *Laguncularia Racemosa*, grows on higher ground than it's red and black counterparts ("CHTHYOLOGY at the Florida Museum of Natural History," n.d.). One of the white mangrove's distinguishing characteristics is that it has no visible aerial roots unlike most other types of mangroves. ("CHTHYOLOGY at the Florida Museum of Natural History," n.d.). White mangroves produce greenish-white spiked shaped flowers, which bloom from spring to early summer. White mangroves are one of the mangrove species that are semi-viviparous, and germinate its seedlings while the propagules are still attached to the parent plant ("The IUCN red list of threatened species," n.d.).

The black mangrove tree, specifically *Avicennia Germinans* have pneumatophores. Pneumatophores are roots of wetland plants that function in respiration ("CHTHYOLOGY at the Florida Museum of Natural History," n.d.). It grows slightly higher than the red mangrove because tidal changes expose the roots to air. Black mangroves blossom in mid-winter to spring and produce white flowers. The parent mangrove trees retain viviparous propagules for about 3 to 6 months prior to falling into the ocean ("The IUCN red list of threatened species," n.d.). This specific mangrove species originated from Southern Brazil and Atlantic coastal region of Florida, and western Africa. The black mangrove tree matured as a shrub from 1m to 8m and can be smaller than 1m ("The IUCN red list of threatened species," n.d.). A unique characteristic of the *Avicennia Germinans* is that it handles hypersaline conditions better than other mangrove species, even with saline levels greater than 50 psu ("The IUCN red list of threatened species," n.d.).

Out of all three species black mangroves comprise over 90% ("The IUCN red list of threatened species," n.d.). We chose these three mangrove species because they are all native to Santa Catarina.

<u>Nursery Development and Replanting process</u>

Once all the data from the institutions and fieldwork has been collected, a nursery area will be created near the desired planting site. The nursery will contain 5,500 seedlings to be grown and all seedlings will be placed into biodegradable bags,

filled with mud and soil. Holes will be made in each bag to allow for discharge of excess water. These bags will be placed into sunken beds located near tidal regions and each sunken beds will contain 500 bags. An irrigation system will be created. The nursery will be monitored for eight months to document growth, water on a regular basis, maintain pest control until they are ready to be planted at the planting area nearby. All data gathered during the nursery stage will be analyzed and reported for future projects to identify and deal with issues that may arise. Once the planting stage finished, a local agency will be created and given jurisdiction to monitor and manage the site. The Santa Catarina Coastal Wetland Community Council (SCCWCC) will collect and report all post-planting data to the research team. Our researchers will evaluate how the model can be adjusted to regions and countries with similar interests and requirements.

Project Schedule

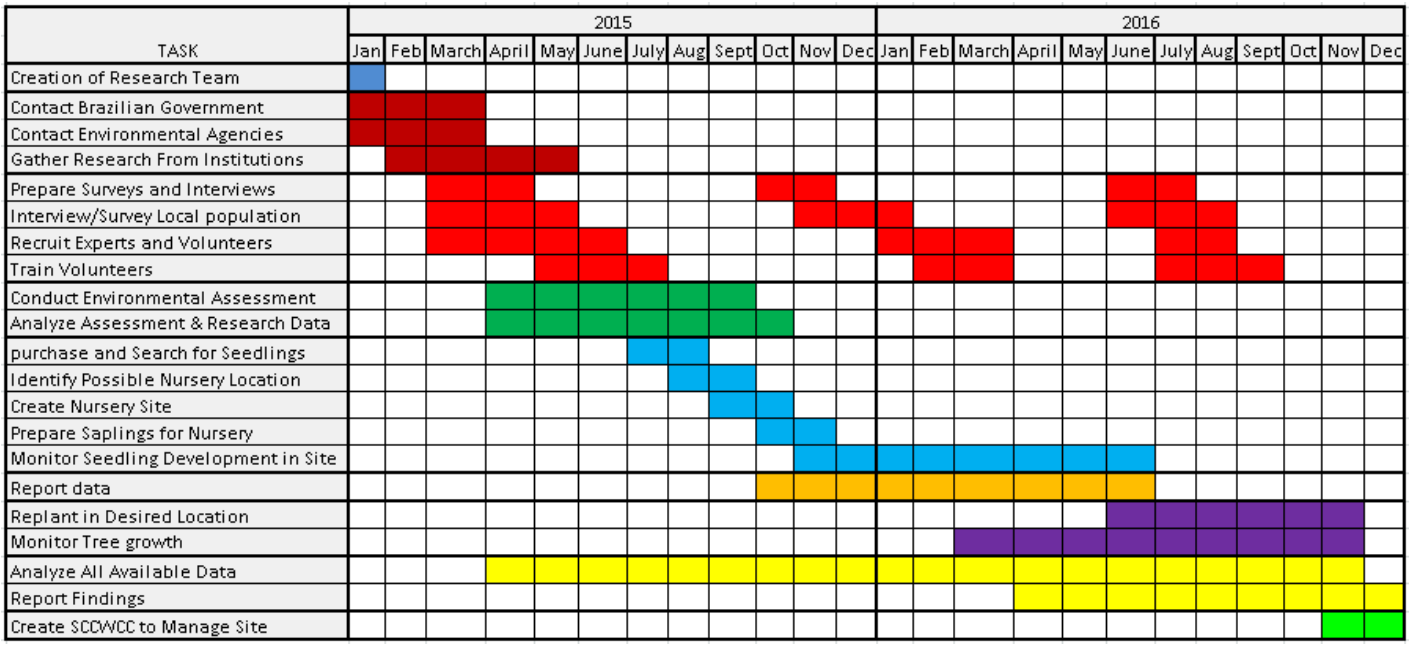

Figure 2: Proposed Project Schedule

Institutions and Personnel

Due to the potential scale of this initiative, we will require assistance from a wide variety of sources. Volunteer labour is expected to be our biggest need and thus we intend to appeal to the local communities, seeing as they are the biggest benefactor of this project. Volunteers will be responsible for the majority of the necessary labour including the harvesting of seeds, management of the nursery and planting of the seedlings and saplings along the proposed site. We also intend to question the locals to acquire a sense of the local knowledge as well as the knowledge deficits.

Non-government organizations will also be expected to play a role in this initiative. SER (Society for Ecological Restoration) for example has many goals in line with our own and so we are anticipating cooperation from them. We will appeal to them for volunteers as well but we expect to use their volunteers from primarily a management perspective, since they have had more experience than our current team with the management and implementation of such projects.

Our project also intends to incorporate assistance from government bodies as well. Fatma (Fundação do Meio Ambiente) is the Santa Catarina state environmental protection agency (Fatma, n.d.). We intend to appeal to them for support, particularly in regards to sanctions in accordance to our management plan outlined in Table 1. In order to maintain a sense of autonomy with our community based project, we intend for the government to maintain only a minimal role, thus keeping control of the project in the hands of the locals. The IDRC (International Development Research Centre) will also play a prominent role in our project particularly by providing funds. In their objectives for Latin America they claim to focus on both the sustainable use of natural resources as well as inclusive economic growth and innovation ("International development research," n.d.). Both of these goals are aligned with our own.

In terms of scientific knowledge the University of Waterloo will be the leading institution in this area, particularly due to our researchers belonging to this body. Despite this however, we intend to seek assistance from the University of Santa Catarina, located just to the West of our proposed site, in the city of Florianopolis. We anticipate them having a greater understanding of the local processes, both ecological and anthropogenic, due to the study area being situated so close to them.

Due to budget restraints however, we intend to be very flexible with our expectations for assistance from other institutions and are willing to take help where we can to ensure our initiative is a smoothly flowing process.

Conclusions

Expected Results

At the end of our project we are anticipating having planted 5000 trees along our designated coastline West of Barra de Lagoa. The nursery from which these trees were grown will be established and repurposed for future initiatives. Both of these sites will be under the jurisdiction of the newly established Santa Catarina Coastal Wetland Community Council. The role and logistics of this council has been outlined in an understandable and user-friendly manner to allow for ease of use with the locals, as discussed in Table 1. Once the planting is done and the Community Council is in place, our researchers will take a lesser role in the project and allow the locals control of the management practices. At this point we hope to have greatly improved both the

community's understanding of ecological issues, particularly those related to sustainable coastal wetland management, as well as concern for maintaining their newly replanted ecosystem. It is our belief that allowing ownership and control of the ecosystem and its management will encourage locals to want to protect it and ensure its success.

Next steps

After the project is taken over by the local community council, the management of the newly reforested region, the nursery and the coastline will fall to them. It's at this point that our focus will shift towards the dissemination of our model. To do this we will attempt to have local media sources cover the story of our project, in an attempt to illustrate the changes we brought to the region and the community. Two sources in particular that would find our story of interest is the local television station 'Tv Floripa' and the local newspaper 'Floripa News.' The former claims in their objectives that they emphasis material on environmental, health and education issues as well as being a close partner and supporter of the community, thus a story about improving community development and environmental health would likely be popular among their viewers ("Tv floripa: Objectives," n.d.). Floripa News claims to emphasize socioeconomic and cultural development of Florianopolis and the region ("Floripa news: The Journal," n.d.). They would also be of interest in our story due to the impacts on the local communities, as well as providing an efficient tool for circulating our model due to their association with Cities News Network Online Journal, one of Brazil's largest news networks.

As time goes on we do not wish for our model to only be spread and recreated but also enhanced and adjusted. Issues that occurred during our project, which we failed to predict in advance, need to be addressed so as future initiatives will be more sustainable and more productive. The established mangrove nursery that we created could also be reused both for further planting of Santa Catarina but also, if need be for the replanting of other locations, should they not wish to build a new nursery. From location to location as well there may be cause for change in our model to suit various requirements not present in our study site. Each time this model is reproduced provides a chance to add revisions and increase its potential for the next future restoration initiative.

7 Principles of Sustainable Environmental Institutions	
Boundaries	Outlining of specific territories: ● Such as the length of coastline to be planted

	● Once the mangroves develop, other species will fill this ecosystem and biodiversity will greatly increase, thus this area will need protecting in order to be sustained.
Proportionality	To have costs in line with the benefits: ● We are bearing the majority of the expenses, until the project is established and sustainable.
Collective Choice	To keep decision making in the hands of the resource users rules need to be established: ● The creation of a council of community members will be responsible for this, as well as managing the common resources. ● These council members will be nominated and voted on by the resource users to encourage cooperation and effective management.
Monitoring	A system is needed to monitor the usage and behaviours of resource users so as to keep the status of the resource in check: ● Community members as assigned by the established council will be responsible for this.
Sanctions	A form of punishment should be imposed on violators, nothing too harsh at first, so as to encourage voluntary compliance over coercion: ● With government assistance to punish violators via fines or exclusion, if the fines should prove ineffective.
Conflict Resolution	A mechanism is needed to effectively resolve conflicts between resource users and maintain peaceful cooperation: ● Via a system of appeals presented to the community council, where resource users are able to voice their grievances and have them resolved peacefully.
Autonomy	A common property requires a sense of self-governance to be managed efficiently so to avoid the interference of outsiders or government officials with differing objectives: ● This can be done by allowing the council the right to govern its interests with support only received

	when requested, in the form of sanctions, for example. ● By maintaining an efficiently working and well organized system, outside influence might be discouraged if there does not appear to be a need.

Table 1: Principles of a Sustainable Environmental Institution (Robbins, Hintz & Moore, 2014)

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