Designing an Interactive Walking Trail for the Batipa Field Research Station

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Abstract

Our IQP group collaborated with The Batipa Field Research Station (BFRS) and Oteima University to promote academic tourism and create a sustainable business model. The group spent two weeks in the field working at Batipa and completing different research excursions. Through this process, the group decided to design an interpretive walking trail that covers various educational subjects that align with the goals of the BFRS and Oteima University. From the research collected, the group determined that information about nature preservation and restoration, indigenous life and culture, mangroves, sustainability, and modern agriculture should be included as stations along this walking trail.

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Executive Summary

The Batipa Field Research Station (BFRS) provides research opportunities for scholars focusing on conserving natural resources and sustainable development with the intention of developing a research facility for academic tourists and scientific researchers. The creation of an interpretive walking trail for the BFRS will provide research and educational opportunities for students of Oteima University, scientific researchers, and academic tourists interested in studying the biodiversity, natural resources, and the indigenous people of the Mesoamerican Biological Corridor.

Project Goal

The BFRS and Oteima University aim to provide sustainable economic opportunities through academic tourism. To fulfill this goal, the group designed an interpretive walking trail with standalone stations highlighting important aspects of the region including: biodiversity, nature preservation and restoration, indigenous life, mangroves, and modern agriculture in Panama.

Objectives

In order to create a design that attracts academic tourists, the group pursued a variety of research strategies. Surveys were sent to different organizations in Massachusetts with gardens and walking trails to determine the best design approach and important factors to consider when designing gardens and walking trails. Interviews were completed to learn more about local plant life that would be crucial to include in gardens and on our walking trail. Surveys were also sent to local organizations in Panama to learn more about the local plant life. To learn more about indigenous life in Panama, interviews were completed, and the group visited the Ngäbe-Buglé Comarca (a government designated geographical zone for indigenous people). While at Batipa,

the group explored the area and determined where the best location for the trail would be. Measurements were taken at different possible stations that could be included on the trail. Different materials were also researched that could be used in the design of the trail.

Findings

After completing these different research opportunities during our two weeks stay in David, a design of the interpretive walking trail was created. The trail begins at the current building on the property where there will be information about the moth collection and pinning process. In the future, the BFRS hopes to begin a moth collection program where academic tourists can come stay the night at Batipa and learn how to collect and pin moths. The trail will then continue up the hill passing a rainwater collection bin that is already present on the property. Continuing up the hill will be a station focused on nature preservation and restoration. Currently, there are two pairs of scarlet macaw parrots at this station which will highlight Batipa's efforts towards nature restoration. Additionally, there will be signs with information about the scarlet macaw parrots, biodiversity, deforestation, and plant life. The trail continues and leads to a station focused on indigenous life and culture. At this station there will be a garden with different plants utilized by indigenous people, including plants with medicinal properties. There will also be a replica of a ranchero (Ngäbe traditional house) with artifacts and information about indigenous life and history. The next station that looks over the water and focuses on the importance of mangroves and sustainable development. Additionally, there will be a store at this station that sells honey that is harvested from mangroves. Finally, the last station will focus on modern agriculture. Proceeding down the hill from the mangroves station, there will be a collection of different fruit trees that are important to Panama. At the bottom of

the hill, there will be a garden with plants that hold significant importance to agriculture in Panama.

Station 1 focuses on nature preservation and restoration. The main exhibit in this station is a cage with scarlet macaw parrots. The cage, already constructed and populated with 4 macaws at Batipa, is part of an effort to restore the wild scarlet macaws of Panama. In front of the cage there will be a sign with information about the parrots. Scarlet macaws have suffered massive population declines due to poaching, illegal trafficking, and habitat loss. The station will also feature information on deforestation and the damage this has caused which has impacted species like scarlet macaw parrots. Additionally, there will be signs about the biodiversity of Panama and detailed information about the diverse plant life that is present in Batipa.

Station 2 focuses on indigenous life and culture in the Chiriqui area and Panama as a whole. Specifically, the Ngäbe tribe was researched and interviewed for this station. The goal of the station is to educate guests on the complex history of Ngäbe life, some of the challenges that they face currently, and vegetation that they have historically interacted with. There will be two different components of the station. First, there will be an example ranchero that provides information about indigenous life and culture. The history of how tribes formed in Panama is discussed and key historical moments in their history that caused monumental shifts in their societies. Ngäbe indigenous culture is also explored and more specifically, the differences between pre-Columbian and post-colonial traditions. Additionally, there will be a garden that features different plants that have been utilized by indigenous people and information on how tribes have interacted with the environment around them.

The focus of station 3 is to inform and educate visitors about the aquatic life around mangroves in Panama. It also introduces how to create projects using sustainable methods and the importance of sustainable development. The information provided at the station will inspire future research at Batipa to use sustainable development practices.

Mangroves are an important component of Panama's complex natural environment. Around the world, mangrove trees are crucial for the environment, yet they are often destroyed by industry and development to build new infrastructures. The waters in which mangroves grow are rich in bacteria and organic debris, which feed fish and shrimp. In addition, mangroves are used for timber and charcoal production because of their wood quality. Spreading awareness to visitors about the richness of mangroves and their importance to the environment is essential. To do that, sustainable development practices must be utilized when planning to develop new facilities surrounded by nature and wildlife. The environment must stay as untouched and healthy as possible while still using the land for human needs. Since the BFRS is using teak wood as an economic resource, using the excess wood that is not being used is another example of sustainable development. Teak wood is durable and water resistant. Therefore, this wood tends to be widely used for infrastructure and design. Teak can also be used in the interpretive trail as a building block and a decorative material.

Station 4 is focused on modern agriculture in Panama. On the path from station 3 to station 4, there will be different fruit trees that play an important role in Panama's agriculture. At the bottom of the hill there will be a garden with different plants that are grown in Panama. Signage will be created for each plant to give visitors information about the key features of the plants included.

Recommendations

During the completion of this project, multiple possible future IQPs were suggested. Oteima University expressed interest in starting a program that teaches the process of collecting and pinning of moths and hosting a moth collection gallery at the university. Space was set aside for this future project in the creation of the trail. Additionally, the different stations of this trail could be expanded and developed even more.

Conclusions

The creation of an interpretive trail at the BFRS will help promote academic tourism and provide sustainable economic opportunities. There are also additional opportunities for future research to expand on the concepts included in the stations of the interpretive walking trail. Oteima University and the BFRS hope to create more opportunities and grow the programs available at Batipa. Our interpretive trail creates additional opportunities for the BFRS to expand and provide more opportunities in academic tourism.

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Chapter 2	Historical Context - History of Oteima University	Katherine	Gabriel
	Historical Context - What is the BFRS?, Ecological Diversity, Academic Tourism	Gabriel	Katherine
	Guest Experience - Importance of Guest Experience, Trail Erosion, Cultural and Historical Significance	Katherine	Gabriel
	Guest Experience - Seating Area, Store	Armela	Katherine
	Cultural Richness and Indigenous Heritage - Current Social and Political State of Ngäbe-Buglé, Historical Changes/ Forced Migration Patterns in Indigenous Life, Ngäbe-Buglé Culture, Traditional/ Current Indigenous Agriculture	William	Katherine, Gabriel
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Chapter 4	Design Process	Katherine	William
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	Station 3 - Sustainable Development, Use of Teak at the BFRS, and Aquatic Life Around Mangroves, Pollinators, Floor Plan, Signage	Armela, Katherine (Signage)	Katherine, Gabriel, William
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	3. Traditional Cultural Activities	William	
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Chapter 1: Introduction

Lying in a hammock, you hear the pitter patter of the rain drops dripping off the palm roofs of Batipa's pavilion. As you swing back and forth, you feel the calming cool breeze of an afternoon storm rolling in. In the distance, you hear the vibrations of the jungle with howler monkeys and the birds singing in harmony. As you sit here sipping a fresh cup of coffee, you are able to soak in the beauty of Batipa, a perfect little paradise nestled within the Panamanian jungle.

Batipa, located in the Chiriqui province, is full of beautiful biodiversity and mangrove forests to be explored. Our IQP group spent two weeks in David, Panama to explore these natural treasures and collect data for our project. One of the most biologically important countries in the world is Panama, which is situated on the lower isthmus connecting North and South America. Due to its significant geographical location as a land bridge right on the equator, Panama is home to an incredible range of biodiversity. Not only is the country diverse, but it is densely packed. Panama contains more species of plants and birds than all of Canada and the United States combined (Smithsonian Tropical Research Institute, 2022). Through our project, we hope to highlight Panama's unique biodiversity for the purpose of research and education while also providing Batipa Field Research Station with opportunities to promote academic tourism. With this idea in mind, our IQP group is constructing an interactive walking trail at the Batipa Field Research Station with the assistance and sponsorship of Oteima University.

A key objective of this project is to work with the BFRS to co-develop and execute a sustainable development project. Specifically, small farming communities in Western Panama have seen a lack of development and sustainable economic opportunities compared with areas closer to Panama City. In 2015, Chiriqui's Gross Domestic Product (GDP) was measured to be

4,348 million Balboas compared to Panama City's 19,356 million (Banco Interamericano de Desarrollo, 2020). These extreme differences in income come from disproportionate resources and attention being allocated to metropolitan areas in Panama (specifically areas connected to the Canal). There is a cascading effect since private companies are less likely to invest in underdeveloped areas. The BFRS and Oteima University are looking for ways to bring sustainable business opportunities into the Chiriqui province that can encourage growth while preserving the important ecosystem of Western Panama.

In previous Interactive Qualifying Projects (IQP), Worcester Polytechnic Institute (WPI) students have worked with Oteima University to improve water sustainability, teak farming efficiency, sustainability education, and encouraging sustainable energy and efficient resource utilization (Lundblade et.al., 2020). As WPI continues their partnership with Oteima University and BFRS, there are many opportunities to improve the space and positively impact the local community. For our project, Oteima University is interested in building an interactive walking trail to promote research and academic tourism. Our proposal includes an interpretive walking trail with different exhibits showcasing the importance of nature, conservation, and indigenous life around this facility. Different exhibits are broken up into individual stations in our paper.

In the first station where guests enter the walking trail, Oteima University would like to include information about the process of collecting moths. The purpose is to display the diversity of moths in Panama, and they would like to provide programs in Batipa where academic tourists will come to learn how to collect moths. Within the same station, visitors will also find an example of a rainwater collection system created by a previous WPI IQP team in 2019 that will provide water to plants in exhibits. Continuing up the hill is the next part of station 1 with scarlet macaw parrots currently present in Batipa dedicated to nature preservation and restoration.

Further along the trail will be station 2, which is dedicated to indigenous life in the area. The station will feature a ranchero highlighting indigenous history and culture. Additionally, this station will have a garden that highlights plants and traditional agricultural techniques of local indigenous communities. At station 3, there will be an outlook over the ocean featuring mangroves with information about their ecological value and crucial role in mitigating the impacts of climate change. The scenic location of this station will provide individuals with a shaded area for relaxation and reflection. Finally, the trail will conclude with station 4, which contains a garden of modern agriculture.

With the construction of an interpretive walking trail, academic tourists will be able to experience the beauty that Batipa has to offer. The facility will provide researchers with an excellent starting point to learn more about Panama's diverse vegetation and wildlife, contributing to the growing scientific community in Panama.

Chapter 2: Literature Review

The Batipa Field Research Station (BFRS) provides research opportunities for scholars focusing on conserving natural resources and sustainable development with the intention of developing a research facility for academic tourists and scientific researchers. The interactive walking trail for the BFRS will provide research and educational opportunities for students of Oteima University, scientific researchers, and academic tourists interested in studying the biodiversity and natural resources of the Mesoamerican Biological Corridor along with the indigenous people of this region. The BFRS will also help to conserve this unique environment and aid with nature preservation and restoration due to deforestation.

Historical Context

History of Oteima University

Oteima University, founded in 1985, is located in the city of David. When Oteima University was founded, Panama was suffering economically and politically under 20 years of an increasingly repressive military dictatorship. The word “Oteima” is a Spanish acronym that represents the founders’ vision for the university. “O” (Ordenadores) describes the use of computers as an essential tool of the 21st century. “T” (Tecnología) represents technology and its important connection to knowledge. “E” (Educacíon) for education which is the backbone of Oteima’s mission. “I” (Investigación) for research to create knowledge. “M” (Medio Ambiente) represents the environment which is “essential for the sustainability of the human being.” “A” (Agro) stands for agriculture which provides food security. The university’s primary goal is “driving sustained progress and enhancing the well-being of individuals through the

development of agriculture" (Oteima University, n.d.). WPI has been working with Oteima University since 2016 to help support their mission.

What is the Batipa Field Research Station?

Part of Oteima University, the Batipa Field Research Station (BFRS) is located just outside the city of David and encompasses 600 ha Wildlife Preserve and 2000 ha of Mangroves (Mullen, 2017). The research station links Oteima University with the Batipa Private Foundation, which was formed to foster research and opportunities related to sustainable development, as well as improving rural and indigenous communities economically. The BFRS's mission aligns with the goals of the Batipa Private Foundation, with the addition of promoting education of conservation and sustainable management of the unique environment and natural resources. The BFRS would like to encourage academic tourism as well as encourage nature preservation and restoration.

Batipa is one of Panama's largest privately owned areas with an ecologically sensitive and diverse set of ecosystems ranging from marine biology, mangroves, primary lowland forest, grassland, and wildlife corridors (Mullen, 2017). Batipa is the Pacific link to the Gualaca Altitudinal Corridor that connects to the Mesoamerican Biological Corridor of Central America (Mullen, 2017). The research station highlights the value of this area and bolstered Panama's ability to collaborate in research and education in the neotropics to an international level. Previous scientific studies have focused on areas like entomology, botany, biology, ecology, anthropology, etc. (Mullen, 2017).

Ecological Diversity of Panama

Panama is a tropical country with steady temperatures that range from 75-90 degrees, rarely deviating from that range. The coastline typically averages 88 degrees while the

highlands average 10-15 degrees cooler. With a consistently warm climate and many different geographical features including 1,518 islands, 480 rivers, and a mountain range separating the Atlantic and Caribbean coats, it's no wonder Panama is the one of the most ecologically diverse countries in the world. While Panama only takes up 2% of the Earth's land, Panama is home to 12% of its species (Mullen, 2017). Panama's diverse variety of species includes 4,362,079 species of animals, 391,688 species of plants, and 15,023 species of fungi, as well as thousands of variants of microorganisms (GBIF, 2022).

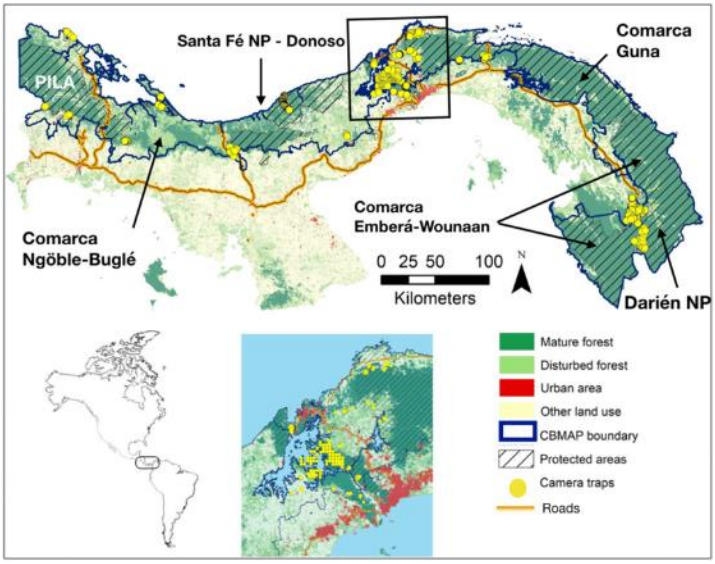

Figure 2.1: *Mesoamerican Biological Corridor in Panama showing the Ngäbe-Buglé Comarca (Meyer et.al, 2019).*

In order to understand why the biodiversity of Panama is so important, the history of how the land bridge was formed and the species that have migrated across it is necessary. According to an article published by the University of Florida titled "Isthmus Of Panama Formed As Result Of Plate Tectonics, Study Finds," the Isthmus of Panama was first a peninsula of North America before the underlying tectonic plates merged with South America 4 million years ago. The merging of these plates, which took place over millions of years, created a land bridge

connecting North and South America (University of Florida, 2008). The creation of this land bridge formed the Mesoamerican Biological Corridor which started the Great American Biotic Interchange (also called the Great American Faunal Interchange or the Great American Interchange), where many species of animals, insects, and plants migrated between the two regions leading to a unique variety of plant and animal life. Historical evidence of this exchange has been found in Panamanian soils through the discovery of fossils belonging to giant sloths, megalodon sharks, corals, primates, rhinoceros-like mammals, saber-toothed cats, etc. (Whitehawk Birding, 2020). The discovery of these fossils during and after the construction of the Panama Canal sparked many investigations into the biodiversity and history of the Isthmus of Panama, the first being the 1910 biological survey of Panama. This survey took place during the construction of the Panama Canal and sought to research and document flora and fauna in the canal zone before its construction would forever change the landscape. This became one of the world's first environmental impact studies. Through the invitation of Panamanian president Pablo Arosemena, Smithsonian scientists were invited to extend their research to all of Panama, leading to the Smithsonian Tropical Research Institute's establishment in Panama (Smithsonian Tropical Research Institute, 2022).

Panama has an overall EPI (Environmental Performance Index) score of 50.50 (Yale, 2022). EPI scores are a representation of how well a country is doing in climate change performance, environmental health, and ecosystem vitality. Panama's strongest sections are biodiversity (83.70), terrestrial biomes (94.10), marine protected areas (100.00), and acidification (89.60). The weakest sections are ecosystem services (22.80, with a particularly low score on tree cover loss of 14.30), fisheries (33.20), and water waste management (23.10) (Yale, 2022).

These scores indicate that Panama has made efforts to protect its unique ecosystem, but that there is still a lot of work to be done.

One of the biggest problems in Panama is deforestation. Panama lost about 2.2 million ha (5.4 million acres) of primary forests in the second half of the 20th century. Most of these important habitats were destroyed for farming and cattle. Only 40% of Panama was still covered by primary forests at the beginning of the 21st century, while 50 years prior there were still 70% of primary forests remaining (Anywhere Panama, n.d.). This level of deforestation poses a significant problem for the Mesoamerican Biological Corridor, which serves a critical role as the habitat for many species and a migration route for migratory birds (roughly 122 species pass through each year). Another large contributor to the deforestation going on is mining for metals such as copper and gold. Petaquilla Gold and Minera Panama are two mining companies that operate under a contract from 1997 from the National Assembly (Panama's Congress), which granted them 13,000 ha (~32,000 acres) of forest within the biological corridor. The Environmental Advocacy Center of Panama, an environmental non-governmental organization, alleges that the contract the mining companies operate under is illegal. Panama's Supreme Court of Justice ruled in favor of the Center's complaint in September 2018. Despite this, construction of the mine continued, and operations began in 2019. The level of deforestation and pollution has caused changes in the local climate, affected crop production, and polluted local rivers to the point where locals can no longer swim there (Arcia, 2018).

Designing an Interpretive Walking Trail

Academic Tourism

According to our sponsors, the main purpose of the BFRS site is to promote academic tourism. Academic tourism is a much more sustainable form of tourism compared to conventional tourism as it has a much larger economic impact and increases knowledge while also creating relationships between students from different countries (Rodriguez et, al, 2013). In the case of the BFRS, the guests' experience will be centered around what they can learn from the different exhibits the walking path has to offer and provide research opportunities. The production of an interpretive walking trail will allow the BFRS to become a starting point in a group or individual's research in the unique ecosystem the BFRS has to offer. Each station will need to be informative and centered around research that has been conducted have the potential for expansion.

Due to the nature of academic tourism, negative impacts to the environment are not significant. Academic tourists will have an interest in preserving the ecosystem they are studying, and most likely will not be inconsiderate towards the environment. Normal tourism often can wreak havoc on natural ecosystems through pollution, the expansion of resorts, and littering. In addition to a minimal impact on the environment, academic tourists have the potential to make a positive impact on surrounding ecosystems and future generations as an increase in knowledge occurs and a connection is made between people of different cultures. By furthering a population's knowledge on surrounding ecosystems and culture, it provides strong reasons for applying pressure on the local government to pass policies protecting vulnerable communities and the environment (Rodríguez et. al, 2013).

Guest Experience

Importance of Guest Experience

Before starting a design, the audience of the interpretive trail must be considered. The signage along a trail plays a crucial role in guest experience. Signage should include mainly graphics and illustrations with very little text to keep the visitor engaged. The ability of the visitors that will use the trail must also be considered to ensure the safety of guests (California State Parks, 2018). The distance and incline of trails are used to determine the difficulty of a trail. Trails with more rough terrain and larger inclines will have slower competition speeds of the trail compared to trails with easier terrain (Schamel et. al, 2017). A shorter trail with smoother terrain and less incline will promote a positive guest experience as it will allow people of all abilities to experience the trail. Adding seating areas and shaded locations also makes a trail more accessible for visitors of all abilities.

Seating area

An additional area to consider when developing an interactive walking trail is including an area for guests to rest, designed to be comfortable and inviting. Guests that are uncomfortable with longer walks or have limited ability to walk longer distances can use this area to relax and rest. A seating area also provides a resting place for people in large groups to sit and socialize with each other while enjoying nature (University of Sheffield, 2015).

Trail Erosion

Depending on the environment of the area, the quality of the terrain on the trail can be impacted. Intense rain can lead to loss of vegetation and increase the likelihood of erosion. In

mountainous regions, intense rainfall can lead to soil erosion and cause large amounts of soil and debris to be pushed towards streams and rivers. If damage occurs due to rainfall, repairs to trails can be large economic investments. When a trail is left unrepaired to natural restoration, there is a high likelihood of biodiversity loss, and it will be difficult to complete repairs in the future. If a trail is designed with intense weather like rainfall in mind, these negative impacts can be prevented (Tomczyk et. al, 2016).

Store

When considering guest experience, resources such as stores can be taken into consideration. The inclusion of a store would require a locked storage area. Additionally, goods will enter inventory through a formal receiving process and leave through a bill of materials. The inclusion of a store is a source that can offer guests souvenirs of the experience they had (Inventory, n.d, 2022). The presence of mangroves gives the opportunity to sell natural products made from mangroves such as honey. When bees pollinate mangroves, the mangrove forest benefits from the pollination being done by the bees. The honey produced here is not only unique because it is made from mangroves, but the consistency of the honey is smoother, and it provides numerous nutrients which are beneficial for health (UNDP, 2022).

Cultural and Historical Significance

The cultural and historical significance of the area should be considered as the land may have held importance to indigenous people. Vegetation must also be considered as it is important to educate about the native vegetation present (California State Parks, 2018). Including information about the cultural and historical significance of the area will help show visitors the importance of the area.

Cultural Richness and Indigenous Heritage

Current Social and Political State of Ngäbe-Buglé

Panama is home to seven different indigenous groups that make up over 12% of the total population (417,559 indigenous people reported in the 2010 census). The largest tribe is the Ngäbe-Buglé which occupies a region in Chiriqui and Bocas de Toros and represents ⅔ of the total indigenous population (Native Future, 2020). Within the Ngäbe-Buglé Comarca (which can be seen in figure 2.1), a dedicated sub-region within Panama reserved in 1997 by the government, families live traditional lifestyles. There are elections for a Cacique General (the governor of the Comarca) as well as local chiefs (Aguilar, 2001). The main sources of income for most families are agriculture, artisan products, or seasonal work outside of the Camarca (ex. Coffee harvests in Boquete and Costa Rica). The Ngäbe-Buglé population is also the poorest in the country with over 92% of the Ngäbe-Buglé population living under the poverty line (Native Future, 2020). Factors such as low infrastructure within the Comarca from a lack of federal funding and difficulty developing the mountainous region, a lack of access to proper education, and families that are monolingual and only speak their native language led to this wealth disparity (30.8% being illiterate in 2010 census) (Native Future, 2020). Language barriers limit their ability to find jobs outside of their Comarca and explore further education. Furthermore, the lack of infrastructure within the Comarca is something that cannot be fully visualized without experiencing it first-hand. Areas of the Comarca have hours between them and the nearest road and the roads themselves are extremely hazardous. It is extremely difficult to explore opportunities outside of the Comarca, reliably source supplies, or receive aid. In an interview with an anonymous Ngäbe-Buglé tribe member, it was expressed that some schoolteachers living outside the Comarcas must fly in on helicopters or trek for hours through the jungle

(Anonymous, 2022). With a lack of government funding for infrastructure expansion within the Comarca, many of the problems that the Ngäbe-Buglé face today will not improve.

Historical Changes/ Forced Migration Patterns in Indigenous Life

Although the Ngäbe-Buglé are under one name in the present day, the history of the Comarca is much more complex. The larger region of Central America was originally home to a family of tribes which have been referred to as the Protochibia Tribes due to their ties to a larger tribe in pre-Columbian times. Although there is not much information known about the Protochibia, it is known that "The Protochibia began to fracture and split apart during the fourth millennium before Christ, which implies a very ancient establishment." (Araya, 2004). After the split of this larger tribe, each region in Central America had various tribes with their own unique customs and traditions. The area of Bocas del Toro and Chiriqui did not show evidence of population until around AD 400-600 and it is believed that farmers from the interior valleys of Central America began to explore and expand into the area (Cooke, 2022). Additionally, an eruption of the Baru volcano caused people that occupied the surrounding areas to relocate. Some tribes migrated to the coast of Bocas del Toro and the lowlands near the Pacific (Araya, 2004).

Spanish introduction into the area also caused a monumental shift in how the indigenous lived. Panama became a major trading area after Conquerors such as Christopher Columbus came upon the Caribbean side of the region in 1502. The indigenous people greeted the conquerors with resistance and unwillingness to give up their land. Spanish conquerors took land by force and enslaved indigenous people. Tribes retreated into the highlands where the Spaniards' attacks were easier to defend against because of the difficult terrain and the tribes'

knowledge of the environment. As Spanish conquerors continued to occupy the area, conflicts between English explorers began when they started to arrive in the region and added another layer of invaders and conflict that indigenous tribes had to deal with. While some indigenous tribes were able to hold off European attacks in the highlands, others found different ways to avoid slavery.

Some indigenous tribes became allies of the English attacking the Spaniards and selling other indigenous people to slavery. The most notable example of this is the Miskito Warriors from Jamaica who allied with the British to attack the Spanish which is an example of how an indigenous tribe adapted to the invaders of their land and held onto their power (Araya, 2004). Some tribes in Central America began worshiping the Miskito and helping the English and the Miskito fight against the Spanish. Most tribes, however, were forced out of their land or taken for slavery due to their unwillingness to abandon their customs. It is important to research the history behind these tribes to better understand what indigenous life in the Chiriqui region was like, and how their past has led them to the situation they are in today. The current Ngäbe-Buglé Comarca is a combination of the Ngäbe and Buglé tribes (with descendants having ties to many other Central American indigenous tribes as well) due to their need to retreat to the highlands during Spanish conquest and subsequent political decisions in Panama. A reflection of indigenous tribes' experiences during these monumental changes in their history highlights their cultural backgrounds and current states.

Ngäbe-Buglé Culture

Ngäbe has a rich and unique culture that has not been widely studied or documented. The way that the Ngäbe interact with their environment and the monumental shifts in their history

have shaped their culture into the unique beauty that it is today. The Ngäbe tribe has a mix of traditional and post-Spanish components of their culture that they practice. A great example of this is the difference between traditional clothes that were worn pre-Spanish contact and present-day clothing. Examples can be seen in figure 2.2.

Figure 2.2. *Nagua dress (left) is traditionally worn in Ngäbe culture (Museum of Applied Arts & Sciences, Australia) and Taparrabos (right) were worn in pre-Columbian times.*

Before the arrival of the Spaniards, taparrabos were worn. Taparrabos were made from fibers of loose barked trees and covered the genital areas. After the arrival of the Spanish, indigenous people began to adopt their clothes because they were widely enslaved by the Spaniards. Without money to buy new clothes, Ngäbe created naguas out of scrap pieces of fabric. From this Ngäbe began to make naguas with white cloth and then dyed the dresses with nance fruit and other natural colors. These dresses were also multifunctional for the Ngäbe as women would tie them and carry harvested agriculture in them (they would carry this over their heads). The Ngäbe tribe created new styles of Spanish clothing to make it better represent their

cultural practices. Another example of the evolution of Ngäbe culture is the transformation of their artesian products. Chacaras are traditional bags that are made from pita fibers that are spun together to form twine. The twine is then dyed with natural colors from sources such as the nance fruit or cucama root. An example of a chacara and twine being dyed can be seen in figure 2.3.

Figure 2.3. *Example of a chacara (left) and the process of dying twine with cucama root (right).*

After the introduction of plastics, chacaras have transformed to be larger with more weight capacity for collecting harvested agricultural products and the traditional bags are used for fashion. Similarly, jewelry is made as a source of income for families within the Camarca that uses plastic beads to create traditional patterns. With the evolution of materials available to the Ngäbe tribe, the Ngäbe people have adapted some of their traditional practices while other more traditional practices are still present to this day. One example of traditional architecture that is still present is Rancheros which can be seen in figure 2.4.

Figure 2.4. *An example of a Ranchero.*

Rancheros have a base level that serves as a living space to sit and eat and an upper level to sleep and store food away from animals. For additional information on Ngäbe culture and specific customs and traditions see (Annex 2).

Although the Ngäbe adopted some components of their present-day culture from the Spaniards, it is important to acknowledge that the Spanish largely reduced the amount of known history for the Ngäbe people. When the Spanish arrived, they tried to destroy any evidence of Ngäbe's way of life or social constructs that were present (government, laws, religion, etc.) and force their Catholic way of life onto the people. Written history was destroyed and lost because of this, which prompted the Ngäbe to pass history down generationally by word of mouth without literature. Although history is still passed down this way today, there are individuals in the comarca that are working to change it (Anonymous, 2022).

Traditional/ Current Indigenous Agriculture

Similarly, to how each region had different migration patterns and reactions to major changes in their history, the agriculture of these tribes also have unique qualities based on their location and interaction with Europeans. Different tribes have different cuisines based on their location which have been modified when new species have been introduced. The Ngäbe tribe has specific agricultural techniques that have been passed down generationally that are unique to their tribe and region (For more information on unique agriculture techniques used by the Ngäbe tribe go to (Annex 2). Other than the Ngäbe tribe, there are various other agricultural techniques that are specific to tribes' geographical positions. The differences in agricultural practices throughout indigenous tribes lie mainly in the difference between lowlands and highlands. Richard Cooke, an archeologist that works at the Smithsonian Tropical Research Institute in Panama, has studied indigenous agricultural practices in Central America. When describing his research, Dr. Cooke points toward the ecological differences in lowlands and highlands that form the agricultural practices of tribes in Panama. He states, "Largest indigenous societies pre-Columbian were mainly along the lower stretches of the pacific rivers where alluviated banks and tidal wetlands provided optimal potential for agriculture based on maize, squash, and root-crops, for hunting white-tailed deer and iguanas, and for exploiting large biomasses of inshore fish and marine invertebrates. Highland valleys in Chiriqui and Costa Rica were optimal for maize and bean cultivation, but local aquatic resources were minimal." (Cooke, 2022) As there is a clear distinction made between lowland and highland agriculture, there is also a distinction between agriculture pre- and post-European introduction.

Current agricultural products of the Ngäbe-Buglé Comarca consist of corn, beans, coffee, roots, bananas, coconuts, papayas, etc. (see modern agriculture section). The influence of European agriculture and plants foreign to the region that were introduced into Ngäbe-Buglé agricultural practices since the Ngäbe-Buglé region has been used as a trading route post-Columbian society as well as the enslavement of the Ngäbe people by Spaniards. The changes in agriculture pre- and post-European contact tells the history of the area as well as how indigenous tribes adapted to changes in their environment with the introduction of new species. Similarly, Ngäbe's use of natural plants from their area for medicine, food, building supplies, equipment, etc. exemplifies the Ngäbe tribe's use of the environment around them for their benefit.

Chapter 3: Methodology

The designing of an interpretive walking trail representing important agriculture, indigenous culture, efforts towards nature preservation and restoration, sustainable development, and biodiversity was completed for the Batipa Field Research Station, Chiriquí, Panama (8°18'38.5"N, -82°15'26.6"W). The site is classified as a tropical rainforest; its temperatures vary from 72F to 92F and are rarely below 69F or above 95F.

To be able to design a walking trail, different forms of background research had to be conducted to create the best possible design. Our primary method of data collections was interviews. The group started by interviewing the local groundskeeper at Batipa, who can point to almost any plant in Batipa and tell you what it is and what it can be used for. An additional interview took place at the Ngäbe-Buglé Comarcas, where we interviewed a Ngäbe tribe member on Ngäbe-Buglé life, customs, agriculture, and beliefs. These interviews provided an excellent baseline for our research and helped us develop a clear picture of what we would like to include in our walking trail and what each exhibit should look like. In order to bolster our research and assist with planning, different organizations in the United States were contacted to complete a survey with questions centered around water usage, design, and guest experience. While designing the walking trail relevant vegetation, cultural significance, sustainable construction, and guest experience were all considered.

Objective 1: Data Collection Methods

Guest Experience and Design

The success of an interpretive walking trail is largely dependent on the guests' experience. We want guests to leave the trail feeling informed and inspired to continue researching aspects of our exhibits. In order to accomplish this, the group sent a google form survey out to different botanical gardens and arboretums located in Massachusetts to determine the best way to start planning the design of the walking trail. These organizations included the New England Botanic Garden at Tower Hill, the Arnold Arboretum of Harvard University, Berkshire Botanical Garden, and Garden in the Woods. From these organizations the group sought to learn more about the process of designing gardens and interpretive walking trails. The information collected in this survey gave the group a better understanding of how to create a good design and the important factors to consider like sustainability, guest experience, and water usage while designing an interpretive walking trail. Questions that these organizations were asked in the surveys are listed in Annex 7.

Indigenous Culture

For our research into Indigenous Culture, our group visited the Ngäbe-Buglé Comarca, conducted interviews, and reviewed various literature. With two interviews of Ngäbe people an understanding of Ngäbe was accomplished. The interview conducted at the Ngäbe-Buglé Comarca was with an anonymous Ngäbe tribe member who welcomed our project group and our sponsor Edmundo González at their farm and home on September 8th, 2022. The Ngäbe tribe member took the group around their property and shared various cultural, agricultural, and political facts about the Ngäbe-Buglé Comarca. Recordings of the information that the Ngäbe tribe member was sharing were taken using Voice Memos on an iPhone. Before any recording

was started, the Ngäbe tribe member was asked for consent to be recorded for the intention of using the information recorded in our project for educational purposes. Additionally, our group also conducted an interview with another Ngäbe tribe member who is currently working at the BFRS as the groundskeeper. The groundskeeper was asked by our group if he would guide us on a nature walk around Batipa and share knowledge of the plants in the area that are used by the Ngäbe tribe. The groundskeeper gave consent to be recorded and took William Leland and Gabriel Ward around the BFRS property and explained culturally important plants. The questions and answers were translated by our sponsor, Edmundo González, since the groundskeeper does not speak English and the group's Spanish skills are not adequate to ask questions and understand the responses.

Plant Life

Our primary method for collecting data on plant life in Batipa was through an interview with the local groundskeeper at the BFRS. We chose to interview them due to their extensive knowledge of the local vegetation; they are capable of pointing out almost any plant and detailing what it is and what it can be used for. Through this interview, the group was able to gain a clearer picture of what should be included in the walking trail, as well as develop a general knowledge of the local vegetation.

Moth Collection

To learn more about moth diversity and the collection process, the group met with a local insect collector and spent time collecting and pinning moths. When catching moths, a light is used to attract the moths because moths use the stars and moon for navigation. However, artificial lights interfere with this navigation which is why moths as well as other nocturnal insects are drawn to the light, they cannot help it. It was found in a study analysis that mercury

vapor, metal halide, and compact fluorescent bulbs contribute to this behavior the most (Boyes et al., 2020). A white sheet is hung underneath the light for the moths to land on to be collected. A white sheet is used because it reflects the light given off by the bulb the best. At night the moths are attracted to the light and will land on the white sheet. A jar full of ethyl acetate powder is used to catch the moths and kill them quickly and painlessly.

In order to preserve their color and prevent their bodies from deteriorating, insects must be kept away from light and stored in a cool dry place with air conditioning. When pinning moths, start by holding the moth by the abdomen being sure to avoid touching the wings of the moth as this will remove the scales. With the wings up, place a pin in the abdomen at a 90-degree angle from the abdomen. Once the pin is straight, push the pin all the way through and place the abdomen in a pinning board. Next, put a pin in the board by the end of the abdomen to keep the abdomen from moving while the wings are being pinned. Cut two slips of printer paper and pin over each wing. Use a thin pin to pull up the top wing to a 90-degree angle relative to the abdomen on each side. Repeat this with the underwings and place a pin in the middle of each slip to hold the wings in place. Cut two more slips of paper to put on either side to secure the wings down for drying and pin it down. Finally use pins to make sure the antennas are facing up for drying (Anonymous, personal communication, September 5, 2022). An example can be seen below in figure 3.1.

Figure 3.1. *Pinned moth (Rothschild Silkmoth), pinned by Katherine Corbin, Batipa Field Research Station, Chiriqui, Monday Sep 5, 2022, 5:00AM.*

Objective 2: Planning Methods

Once the group arrived in David, a better understanding of the project was achieved. Our sponsor Edmundo was able to give suggestions of features that could be included in the design. After a visit from a local insect collector, a request was to have a gallery of moths from a local researcher. Another thought was to include an exhibit featuring indigenous artifacts. Other requests included signage at different stations with QR codes sharing information about the exhibits and the possibility of including a suspension bridge to connect two stations over a small river.

Before planning was started, the group toured Batipa to gain a better understanding of what the land had to offer and what different aspects could be included in the final product of the project. During the tour, the group was able to determine the best locations for stations and the path the trail could follow. The group also analyzed the quality of the trail and determined that there were portions of the trail that can be difficult to walk on due to the consistent rainfall that Batipa receives. Once the group had a greater understanding of the property, the design process could be started.

Measurements and Photography

While in Batipa, measurements of different areas were taken along with pictures. When deciding where to have the walking trail our group found a previously cleared out path. The cleared path was found to be best to use for our interactive walking trail because without being required to clear out a new trail, the overall price would be reduced. To find out the exact distance of the trail our group used an app called Map My Run by UnderArmor. The group walked the path once before measuring it to see the logistical ability to use the trail and after it was determined that this path would be suitable, it was tracked and recorded. Map My Run by UnderArmor tracks useful information for our walking trail including distance and time duration for the trail. The trail is a total of 644 meters (0.4 miles) long with a length of 20 minutes (without stopping for stations). The length of the trail is important to know for guest experience as it allows guests to estimate the time the experience will take, and the physical requirements needed to complete the trail. The information collected by Map My Run by UnderArmor can be found below in figure 3.2.

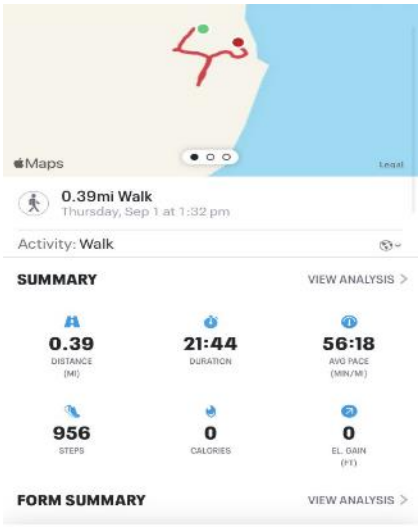

Figure 3.2. *Map My Run by UnderArmor data. Data for steps is for a 6'2'' individual*

Once the path of the trail was created, pictures were taken at each station and at different portions of the trail to help design the stations and trail later in the design process. Figure 3.3, 3.4, 3.5, 3.6, and 3.7 show the different stations present in the walking trail.

Figure 3.3. *Moth collection gallery location and water fountain.*

Figure 3.4. *Nature Preservation and Restoration station with parrots.*

Figure 3.5. *Indigenous Life Station.*

Figure 3.6. *Sustainable Development and Aquatic Life Around Mangroves Station.*

Figure 3.7. *Modern Panamanian Agriculture Station.*

Measuring tape was then used at each station to measure the dimensions of the area. Pictures of the measuring process can be seen in figure 3.8 below. With these measurements, designs could be created for each station.

Figure 3.8. *Measurements being taken at station 1.*

Materials

Walking Trail

After analyzing the quality of the terrain on the trail, it was determined that gravel should be used along the trail to help with water drainage from the consistent rainfall that Batipa receives. When choosing the best gravel for our walking surface, we looked at durability and safety in wet weather. The 57 Gravel and P gravel fulfill this criteria, but their price can vary according to the amount purchased and the distance the truck must travel for delivery. However, the gravel requires edging and packing. More information is provided in table 3.1 (TDH, 1998).

Table 3.1: Surface materials (TDH, 2003).

Gravel	Typical Costs	Sources
57 Gravel	$10-30/ton	Rock quarries, gravel companies, and concrete plants
Pea Gravel (P Gravel)	$10-30/ton	Gravel companies and rock quarries

Railroad tie timber and landscape timber are suitable edging materials because they handle weather well and are low maintenance. Prices are not specific, so there is a possibility of these options being expensive due to the length of the trail, but these materials blend well with the natural settings. There is another edging material option that is less expensive, which is beveled dirt banking. However, there is a high possibility of erosion in the long term if it is used. More information is provided on table 3.2 (TDH, 2003).

Table 3.2: Surface Edging Materials (TDH, 2003).

Surface Edging	Typical Costs	Sources
Landscape Timber	$3-4/2.5-meter timber	Home Improvement/ Industrial Supply
Railroad Tie Timber	$12.50/timber	Industrial/Railroad Supply

A good walking trail road must have good lighting, so installing dusk-to-dawn lighting will provide visibility and safety. Lighting utility engineers are a great source to ensure the lighting layout is functional, economical, and attractive. The standard for a lighted area is a 9-meter pole, and 2 meters buried. Different types of lights are provided in Panama and costs can vary. Table 3.3 shows different options (TDH, 2003).

Table 3.3: Lighting (TDH, 2003).

Type	Lighted Area
100-Watt Sodium	36.6 m/ Diameter Round
High-Pressure 250-Watt sodium	55 m/ Diameter Oval
400-Watt Metal Halide	Variable/ Rectangle (based on directional angle)

When including signs on a walking trail, the signs must merge well with the environment and theme of the trail. Additionally, making the signs reflective and at eye-level would help night users and the maintenance team to be easily guided around the area. One of the most common materials used to build outdoor signs is aluminum (Gregory Signs, 2019), and the tube itself could be made from teak. Due to our focus on attracting academic tourism, bilingual signs on this walking trail are required which include languages such as English and Spanish.

Seating area

Having a seating area allows visitors to take a break in the scenic surroundings while being introduced to information about what they are seeing in front of them. The area can be a great spot to be used by professors to accommodate their academics by providing detailed information about aquatic life and sustainable developments in Panama. Keeping in consideration that the walking trail has many hills and is indeed a long walk, this seating area will provide a place for visitors to rest (Broxap, 2017).

Materials that could be used to accommodate a bench could be concrete pads or specialty pavement. When designing a seating area, every bench that is included in this area needs to be set a minimum of 3’ away from the trail surface to provide a trail shoulder. These benches need to provide a 5’ width of pavement alongside the bench to accommodate ADA access (*Small seating nodes - Standard layout - Great rivers Greenway*, 2018).

Teak As a Construction Material

From our visit to the BFRS, we have realized the importance of using teak wood as a sustainable material. Finding ways to represent this plant in our project is essential for maintaining the values of the BFRS like sustainable development practices.

Teak can be used for significant structures that require strength and durability to the conditions of a tropical landscape and weather. In this project, the trail road includes four stations and some of them will have structures. Taking in consideration the need to continue to be as sustainable in our project as possible, we should consider using a natural product such as timber made from teak wood. A great deal of energy is used to dry and process it so it can be utilized. Timber can have economic benefits for construction, because it is factory prepared and brought to the site for rapid assembly. Timber, as a structural material from teak, is less stiff and a more concrete material with a low density, making it efficient for bigger structures due to the most significant part of the load being carried by its weight. Good examples of where it can be well utilized is in roofing or a gravity load-resisting system for a building, like our stations (Harte, 2009).

Teak wood can also be used as a decorative material along the trail. Ways that teak could be utilized as decoration is by making benches and teak vases used around the facility and inside stations. Small areas with teak planted around the stations can provide shaded areas and an aesthetic to how this trail is presented to academic tourists.

Objective 3: Design Process Methods

SmartDraw

Floor Plan

SmartDraw is a free software that can be used to create visual representations of almost anything, with an impressive customer base including well-known companies like Tesla, Dole, FedEx, etc. Some documents that can be created include diagrams, development plans, legal documents, and most importantly floor plans. The group chose to use this software to design floor plans for our exhibits because of its reputation, accessibility, and ease of use. The software allows us to create accurate representations of our exhibits by utilizing measurements taken in the field and importing graphics of specific plants we want to use. The production of floor plans helps us develop a better picture of what each exhibit could look like and provides Oteima University and the BFRS with a nice visualization of our work.

Canva

Signage

For the purpose of creating infographics, signage, and other informative pieces of our project, Canva was used. Canva is a free graphic design platform that was used as it is user friendly and simple for beginners to use. The design of the project requires multiple signs to be created that are able to effectively display information to guests in an appealing way. When creating an infographic, information must be presented in a manner that is informative and pleasing to the viewer's eyes. To accomplish this each station has a style that matches the themes of their topics. Additionally, signs cannot contain too much information that is overcrowding the sign and overwhelming the guests' experience. To ensure a balance of informative writing and visuals that appeal to guests, each sign has been reviewed by each group member, sponsors, and

advisors. The peer and sponsor review allowed for an assurance that the quality of signs for the project were desirable.

Challenges

During the duration of our time in the field collecting data, there were many challenges that arose. The group had limited time in Batipa to work on our trail design since we were completing other research opportunities while staying in Chiriqui. Although our group was with Oteima University for two weeks, this time was mostly spent exploring research opportunities in other locations besides the BFRS. Throughout our project there were also multiple language barriers which made research in the field more difficult. Since our group is not fluent in Spanish, a translator was often needed to communicate with people we interviewed. Additionally, there were interviews done with Ngäbe tribe members who spoke Ngäbe. While completing research, there were also some potential contacts that were not able to meet and others that were not able to complete surveys that were sent out. The group also had a hard time finding information about the Ngäbe-Buglé since there is not much research done on them and the sources that were found were in Spanish and had to be translated. A lot of the information collected about the Ngäbe-Buglé was gathered through interviews. There were also challenges in determining how to design the trail. Due to the significant amount of rainfall in the area, hills on the trail are difficult to walk on while wet. Since the rainy season lasts for a good portion of the year, the trail consistently had issues with hills being wet from rain. Because of this, the group had to think about ways to make the trail safe to walk on while wet. The group also had a difficult time determining the difficulty of the walking trail. Without being experts in the subject, it was hard to determine a level of difficulty that would not be subjective.

Chapter 4: Findings and Analysis

Design Process

The New England Botanic Garden at Tower Hill provided useful information in our survey that details the important factors to consider when designing a garden and interactive walking trail. When starting to design a garden, they stated that site conditions, aesthetics, and functional goals like stormwater, screening, and pollinator support are important aspects to consider. A garden can promote a positive guest experience through a good design that inspires the viewer through colorful plant combinations. They also mentioned that a good design should create a positive experience with plants for the guest so that they can create an appreciation for nature. A garden can be made sustainable by "using plants that are well suited to the site conditions that will not need water and fertilizer once established" according to the New England Botanic Garden at Tower Hill. They also mentioned that it is important to think about stormwater and drainage in a garden and use materials with little manufacturing that come locally. Water usage can also be managed through good management practices like using mulch. The information collected from this survey will be useful in planning the design of the interactive walking trail.

Interpretive Walking Trail Design

From the research collected, a trail was designed. The map for the trail can be seen in figure 4.1.

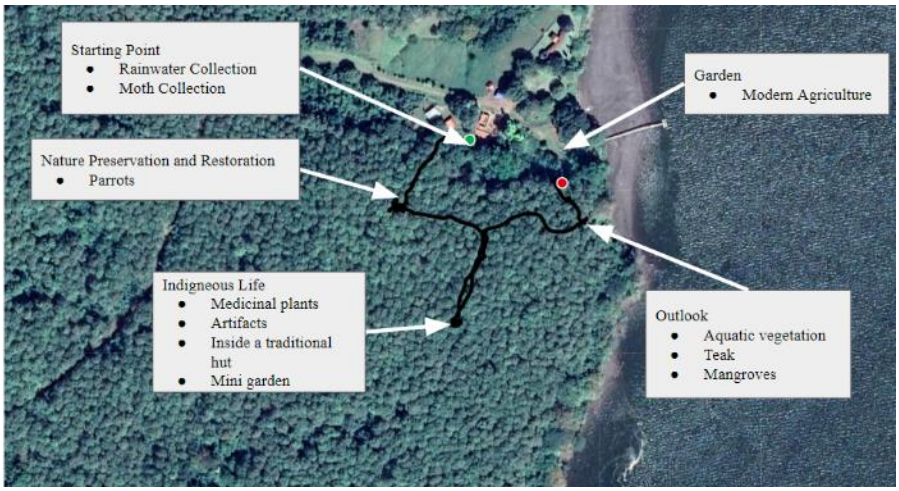

Figure 4.1. *The groups map laying out the interpretive trail* (Google Earth, 2022).

Station 1

Moth Diversity

Oteima University would like to focus on starting a collection in the BFRS of the diverse types of moths that can be found in Batipa. An area at the building present will be set aside at the beginning of the trail for information about moth diversity and the collection process. According to a local insect collector, there are ten times more species of moths in Panama than butterflies because of the diversity of botany in the area as different species of moths are attracted to different types of plants (Anonymous, personal communication, September 5, 2022). In fact, the diversity of moths in Panama is so vast that two family field biologists named Linda and Jerry Harrison caught and photographed over 1,600 moth species using one light trap on the upper

deck of their home in Cerro Azul (a mountainous area in the Panama Province of Panama). Among their findings are more than a dozen undescribed moth species. According to Dr. Gunnar Brehm, a Geometridae specialist based in Denmark, 2 large genera, Eois and Idaea (both family Geometridae), each contain hundreds of species that are undescribed (*Panama's Undescribed Moths*, 2020). These gaps in our knowledge provide a need for a moth collection station in Batipa. Moths have been known to contribute to our ecosystem through pollinating flowers, however due to the lack of knowledge there is still much to learn about how moths are important to the environment. A group of collected moths can be seen in figure 4.2.

Figure 4.2. *A collection of moths caught at the Batipa Field Research Station.*

Nature Preservation and Restoration

Continuing up the trail will be a section dedicated to nature preservation and restoration. Current preservation efforts made by the BFRS include a project where two pairs of endangered scarlet macaw parrots are kept in captivity at Batipa to reproduce. Scarlet macaw parrots are an endangered species native to the tropical rainforest areas of Central and South America. There are around 20,000-50,000 scarlet macaw parrots left in the wild. However, there are only about 4,000 left in Central America, 2,000 of which are in Costa Rica. However, green macaws and

yellow-naped parrots are critically endangered. There are between 500 - 1,000 green macaws left in the wild with about 300 in Costa Rica and 1,000-2,499 yellow-naped parrots left in the wild. The parrots live in humid lowland rainforests (Macaw Recovery Network, 2018). The most prominent threat to the macaws is habitat destruction caused by deforestation (Clubb, 2019).

The endangered scarlet macaws are an example of one of the many outcomes a lack of environmental protection has. Due to its biodiversity Panama faces many challenges in protecting a growing list of endangered species. According to Panamanian authorities, deforestation is one of the most pressing environmental issues in Panama (Office of the United States Trade Representative, 2004). Between 2001 and 2019, about 7.3% of tree coverings in Panama were lost. About 414,000 hectares were lost with 73,000 hectares of primary rainforest being lost (Rainforest Foundation US, n.d.). About 2.2 million ha (5.4 million acres) of primary forests were destroyed in the second half of the 20th century. A majority of these important habitats were destroyed for farming and cattle. Only 40% of Panama was still covered by primary forests at the beginning of the 21st century, while 50 years prior there were still 70% of primary forests remaining (Anywhere Panama, n.d.). However, in the last two decades, there have been efforts made to reforest parts of Panama through reforestation projects. The Restoring a Lost Rainforest Project is an example of the efforts being made in Panama to restore the rainforests. The goal of this project is to reforest around 25,000 acres of rainforest along the Pacific Coast of Panama in abandoned cattle pastures. Over 7,00 acres of over 1.9 million trees have been replanted since the beginning of the project in 2005 *(Panama Tropical Reforestation Project,* 2022).

The BFRS hopes to educate guests about conservation and the inclusion of nature preservation and restoration in the walking trail will help complete this goal. The floor plan for

this station can be seen in figure 4.3. The signage for this station can be seen in figure 4.4. Station 1 will include the scarlet macaw parrots that are already present at Batipa to display an example of nature restoration. There will be signs giving visitors information about the scarlet macaw parrots along with additional signs about deforestation, biodiversity, and plant life. The QR code on the plant life sign will lead to a table with information about the plant life present in Batipa.

Floor Plan

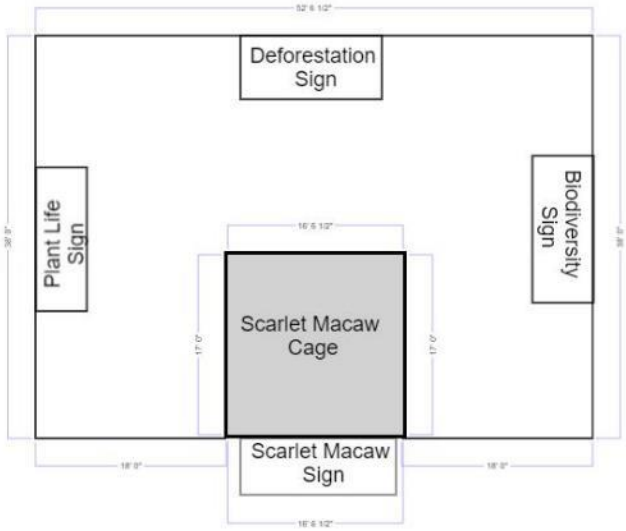

Figure 4.3. *Floor plan of the nature preservation and restoration station.*

Signage

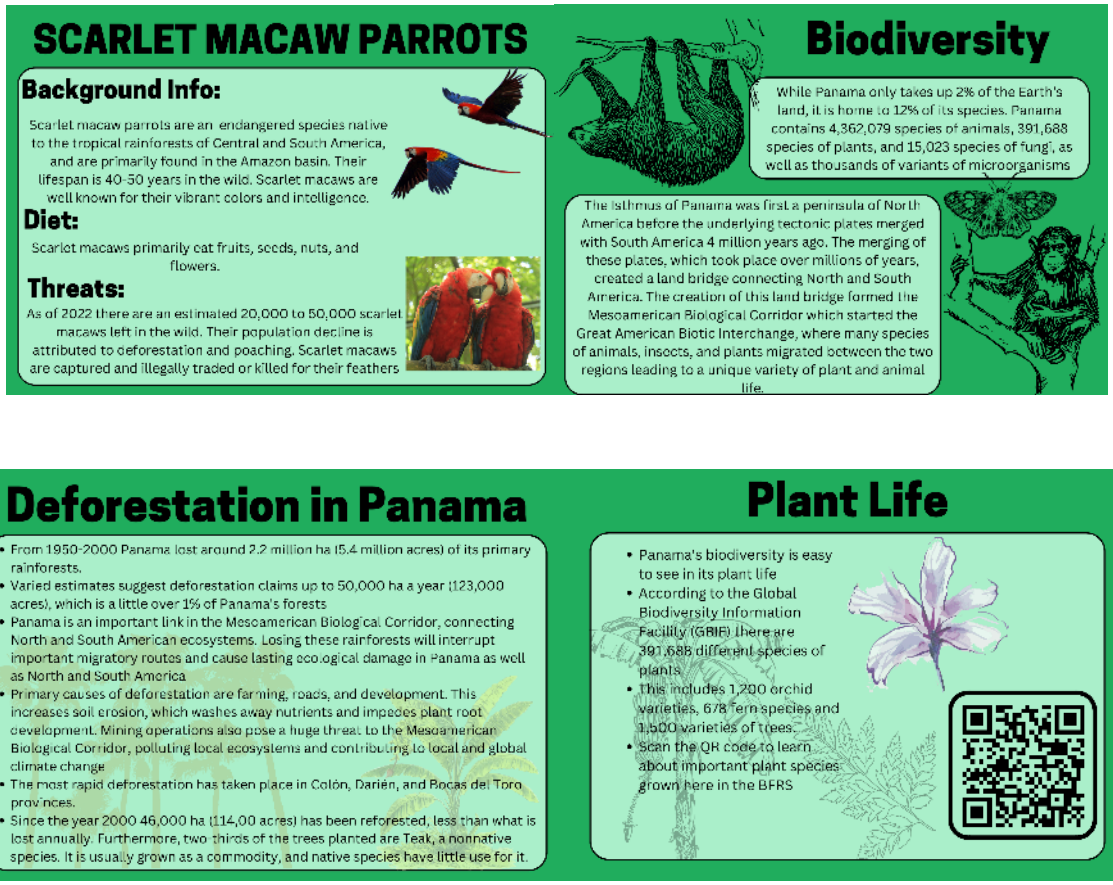

Figure 4.4. *Signage for the nature preservation and restoration station.*

Station 2

Continuing down the trail will be the next station of the trail which focuses on indigenous life and culture. Information on the history of indigenous tribes, their culture, and their interaction with the nature around them are discussed.

Plan & Measurements

For Station 2, two different sections of the trail were measured to display information on indigenous life in Panama. The first section measured was for a model of a Ranchero. The area

was measured to be 30ft long by 35ft wide. A model of the Ranchero was created on Smartdraw and can be seen in figure 4.5 below.

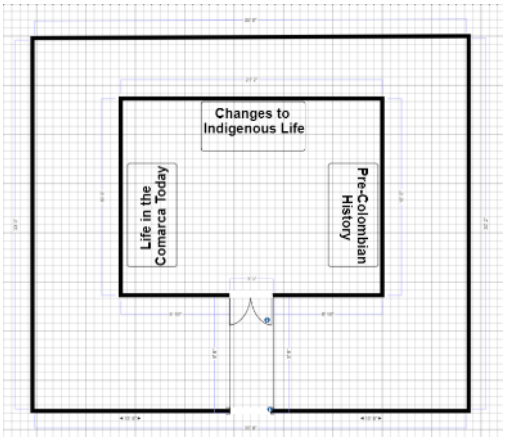

Figure 4.5. *Floor Plan Model of Ranchero*

The Ranchero is 16ft long by 21.2 ft wide. The second section of Station 2 is an indigenous garden. The garden was measured to be 30ft long and 10ft wide with a 3ft wide walking trail in the center. A model of the indigenous garden can be seen in figure 4.6 below.

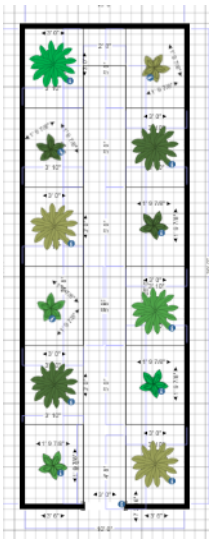

Figure 4.6. *Floor Plan Model of Indigenous Garden*

The garden is split up into 12 different 5ft long by 3ft 10in wide boxes for the different vegetation included in the garden.

After the floor plans were created signs for the two sections of Station 2 were created. A general sign for the introduction of Station 2 was created to inform visitors on what they can expect for the station (As seen in Figure 4.7).

Figure 4.7. *Station 2 Introduction.*

Content of the Ranchero

For the Ranchero portion of station 2, various signs were created for guests to experience. The first sign design is a sign welcoming the guests into the ranchero and describing what a ranchero is (as seen in figure 4.8).

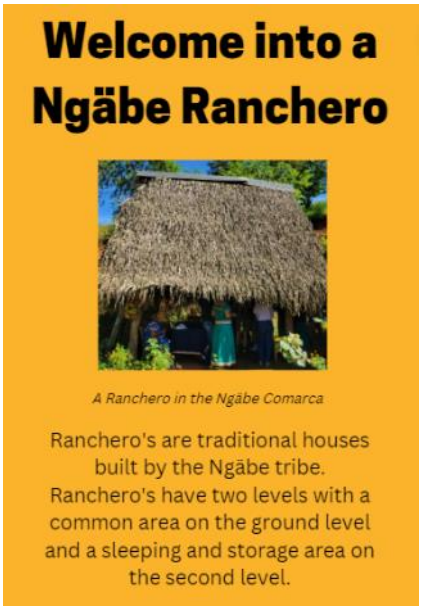

Figure 4.8. *Entrance Sign of Ranchero*

After entering the ranchero, guests will have three different stations to look at. The first station is the Pre-Columbian History Station. The station's sign can be seen below in figure 4.9.

Figure 4.9. *Pre-Columbian History Sign*

Additionally in the future, any artifacts that have been found in BFRS that are properly identified by archaeologists would be properly displayed here. The next exhibit in the ranchero is

a station on the changes to indigenous life. The exhibit describes monumental shifts in the way of life for indigenous people in Panama and the sign for this station can be seen in figure 4.10 below.

Figure 4.10. *Changes to Indigenous Life Exhibit's Signs*

Another part of the changes to indigenous life exhibit is an example of taparrabos compared to naguas and a comparison of a traditional and current day chacara are displayed. For these displays the sign above has been made to inform guests on the changes to these examples of Ngäbe culture.

The last exhibit within the Ranchero describes the current struggles people face in the Comarca today. Current social-political and economic positions of the Comarca are discussed. The sign for this exhibit can be seen below in figure 4.11.

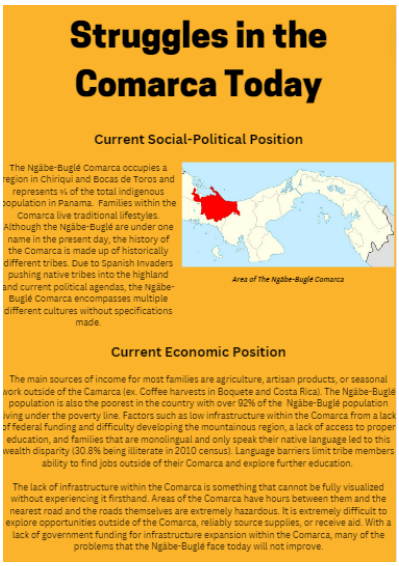

Figure 4.11. *Struggles in the Comarca Today Sign*

Content of the Indigenous Garden

The next section of station 2 is a garden highlighting plants that have been historically used by the Ngäbe tribe. Highlighted plants have medicinal, agricultural, or other cultural importances to the Ngäbe tribe. Plants inside of the indigenous garden can be seen in table 4.1 below.

Table 4.1. Plants of the Indigenous Garden.

Plant (scientific name)	Function	Picture
Ortiga (*Urtica*)	• Potentially harmful, can cause itchiness, pain, and a rash if touched (Anonymous, 2022) • Used to treat arthritis, eczema, gout, anemia, and enlarged prostates (Mount Sinai, n.d.) • Also used in organic agriculture as a pesticide (Anonymous, 2022)	
Guayaba (*Psidium guajava*) (Guava in English)	• Treats a variety of ailments such as stomach pain, diarrhea, fever, arthritis, toothaches, skin irritations, wounds, etc. (Gutiérrez et al., 2008) • See annex #4 for the full list of benefits this incredible tree has to offer	

Mastranto (*Mentha rotundifolia*)	• Can be used in tea to reduce fever • Treats worms in the stomach (Anonymous, 2022) • Contains essential oils with antimicrobial properties and antioxidants. This is useful for food preservation and medical treatment of infections (Riahi et al., 2013)	
Marañon Leaves (*Anacardium occidentale*) (Cashew tree)	• New leaves can be brewed to treat stomach problems • Treats diarrhea and frequent defecation (Anonymous, 2022)	
Ginger (*Zingiber officinale*)	• Boiled in water to treat sickness related to colds (Anonymous, 2022)	

Pigeon Pea (*Cajanus cajan*)	• Leaves can be put in water, boiled, and then smelled to release mucus from sinuses (Anonymous, 2022) • Peas can be dried out and prepared in a variety of dishes	
Ñampí (*Dioscorea trifida*)	• Roots can be eaten like a bread with other food • Cooked in a soup like a vegetable (Anonymous, 2022)	
Marañon (*Anacardium occidentale*) (Cashews)h	• Two main parts: the apple-like fruit and the famous cashew nut that hangs below it • Typically referred to as Marañon, the fruit is described as sweet with mixed flavors of cucumber, strawberry, mangos, and bell pepper with a heavy bitter taste. While it can be eaten raw, it is often cut into thin slices and salted to make it more palatable (*Cashew Fruit*, n.d.). • The nut itself contains dangerous and corrosive chemicals, and cannot be eaten raw. It must be roasted before being eaten to remove these chemicals (Anonymous, 2022). • Can be used as coffee. First roast the nut, then remove the shell. Next roast the nut to preferred darkness, then grind and brew (Anonymous, 2022).	 *Marañon fruit (Cunningham, 2013)*

Bijao (*Calathea latifolia*)	• Stems can be cut and unraveled to be eaten as a kind of lettuce • Leaves have historically been used by the indigenous population to store and prepare lunch and fold into cups for drinking (Anonymous, 2022)	

Note. Unless noted otherwise, photos in this table were taken by Gabriel Ward.

The signs with information about the plants that will be included can be seen below in figure 4.12.

Figure 4.12. *Signs for Indigenous Garden.*

Station 3

Further along the trail, the visitors will be brought to an outlook looking over the mangroves. Here, visitors will find information about the significance of mangroves and sustainable development while admiring the view.

Sustainable Development

According to an article titled Environment: Science and Policy for Sustainable Development by Brundtland Commission, sustainable development is "the ability to make development that meets the needs of the present without compromising the ability of future generations to reach their own needs". The transition towards sustainability means preserving nature, life support systems (oxygen, food, and water), and the community. In this case, economic development cannot be ignored as it provides focus on improving employment, desired consumption, and wealth (Kates, 2005). Through our project, social concepts like the empowerment of indigenous people, gender equality, and justice, must be considered through sustainable development as well (Baker, 2015). One of the values of the Batipa Field Research Station is to pursue research opportunities in sustainable development.

Different goals should be considered when composing a green design. While creating one, there should be no material waste. The use of scarce materials should be avoided, and other reusable materials, such as Teak, should be used instead. The layout must also adapt to the location; therefore, utilizing nature with strategies used by indigenous people could be helpful. In addition to using natural resources, like renewable energy and locally abundant resources will also contribute to keeping this design green. Finally, the environment created must be livable because, in this project, it's important that sensitive ecosystems must be protected, damaged habitats should be actively restored, and toxic materials should be avoided. (Vallero et. al., 2008).

Use of Teak at the BFRS

Teak plantations are abundant in the BFRS and would make an excellent resource to use in the trail. We propose that the BFRS could use excess teak wood to create different components of the trail like signs.

One way Teak will be used is the construction of forest roads. Forest roads are essential infrastructures for utilizing renewable natural forest resources and are a sustainable plan for this project. However, these road constructions can cause environmental problems if not planned with consideration. One of these major environmental problems when constructing forest roads is the acceleration of soil erosion, so wood-based materials like Teak wood chips will be used to reduce sediment loss. The BFRS is located in a tropical forest, so these conditions were considered (Turk, 2018).

In this project, teak chips were chosen as a material to use on the walking trail to prevent erosion in this facility. Since teak wood is a strong material, it will be used to build structures at some of the stations to protect the materials inside from the tropical weather that the area has.

Mangroves Interaction with the Environment

Panama is home to a significant piece of aquatic vegetation called mangroves. In the Chiriquí province, there is a collection of mangrove forests that hold an important role in the ecosystem. Mangroves are trees or shrubs that grow in coastal areas that flood during high tides. These ecosystems are rich in biodiversity and provide many benefits to the environment. Mangroves help with water filtration as the roots can absorb nutrients from runoff that could cause harm to the soil on the land (Feller, 2018). Along with providing habitats for thousands of species, mangroves prevent erosion. The roots in mangroves slow down the amount of sediment going into the ocean, which helps protect coral reefs, beaches, and reduces inland flooding.

Non-renewable exploitation and coastal development projects pose a large threat to mangroves as they are often destroyed in production (Wang et. al., 2004). So far, Panama has lost 56 percent of its mangroves, with mangrove cover shrinking from 360,000 ha to approximately 158,000 ha (McKinley et. al, 2007). Accidents like oil spills have also contributed to a major loss of mangroves along with deforestation, livestock grazing, and agriculture. The World Wide Fund for Nature (WWF) indicates that the most significant loss is seen around the coast of Chiriquí due to shrimp farming. It is also suggested that pollution from ships carrying chemicals through the Panama Canal has negatively impacted mangrove forests (Warner, 2022).

Despite the harm being done to mangroves in 1994 in Panama, it became illegal to harvest trees. Since then, there were also requests about new developments that may directly impact mangrove forests to do environmental assessments. Human planting has helped with some mangrove regrowth as well (Warner, 2022). Some of these plants that are found in David, especially around Port Pinzone's, are “Twister” mangroves, which get its name from their twisted strong roots. The Piedra gosa (also known as the rock mangrove), is predominantly formed from rocks (Warner, 2022).

In BFRS, the red mangroves, which has its name from the red tips of the roots, are the ones that dominate the most in this area. The scientific name of the red mangrove is Rhizophora mangle and is the tallest of all local species in Panama. Red mangroves grow to heights over twenty-five meters and have large, broad leaves that grow to twelve centimeters and terminate with a sharp point. The color shades that the leaves have are dark green and pale green. The trunk and limbs have gray bark that covers a dark red wood. The critical characteristics of red mangroves are the "prop roots" derived from the crate and "drop roots" from the branches. These

mangroves survive by filtering out as much as 90 percent of the salt found in seawater as it enters their roots (Stewart et al., 2022).

Mangroves' aerial roots form living subtidal habitats recognized for their diverse fish and epibiont communities. The salt in its leaves makes these mangroves tasty for aquatic animals like tree crab, horseshoe crab, or Aratus Pisoni, an arboreal grapsid crab. Red mangroves especially are the only ones that restore the most amount of carbon because of their size and they are crucial for controlling climate change. Since they grow in salt waters, they can hold the land structure of an island as well (Stewart et al., 2022). There are many other species that do live among the mangroves like birds, monkeys, iguanas, shellfish, and other fish like red snapper. There are also crocodiles that could reach a length of 18 feet (Wetlands International, 2016). Mangrove forests because of their roots are vital to shoreline communities as natural buffers against storm surges which are an increasing threat in a changing global climate with rising sea level. Knowing the importance of mangroves in this area makes them a crucial part to introduce in this project. A map of the mangroves areas in Panama can be seen in figure 4.13.

Figure 4.13. *Map demonstrating mangrove area in Chiriqui, Panama (Panama 2018, n.d.).*

Pollinators

When talking about pollinators, we know that they are critical for plant survival in ecosystems around the world. Pollinators provide people with various ecosystem services, including nutritious foods (fruits, vegetables, and nuts), raw materials (fiber, lumber, and oils), and economic benefits for various industries such as livestock and farming. Pollinators include bees, butterflies, bats, beetles, birds, etc., but the ones we care about the most are honeybees and how they help pollinate mangroves (Mason et.al., 2022).

To collect nectar, bees will use their proboscis to suck up droplets of it. The nectar is stored in the bee's stomach until it returns to the hive. Their stomach has an enzyme that turns the nectar's sugar into diluted honey. The unripe honey gets stored in comb cells. Mangroves' yellow flowers bloom from mid-May to early July, and the honey made from this flower has a delightful taste, moisty, and a delightful touch of tartness (Sartell, 2017).

Floor Plan

In this floor plan, there is a demonstration of station 3 and each component that it has. Visitors will be introduced to teak, its importance for Batipa, and its usage in this project. Then on their right, they will learn about sustainable development and its importance in this project and how we used this concept when designing this trail. Afterwards, they will learn about the importance of mangroves as a plant for Panama. The station provides them with a store and a seating area for improving their experience. The floor plan can be seen in figure 4.14 and the signage can be seen in figure 4.15.

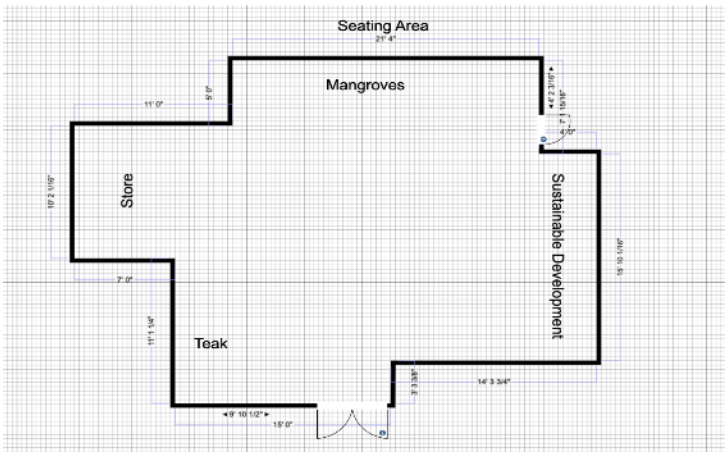

Figure 4.14. *Floor plan of mangroves*

Signage

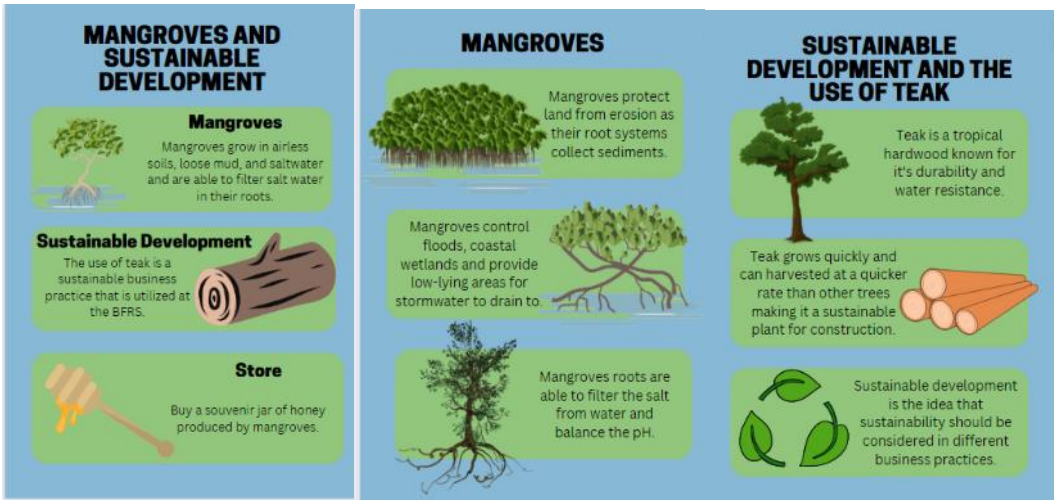

Figure 4.15. *Signage for Mangroves and Sustainable Development.*

Station 4

Modern Panamanian Agriculture

The trail will finally lead to the station dedicated to modern agriculture. Panama has a diverse variety of agricultural products that are exported including sugar cane, bananas, rice, poultry, milk, plantains, pineapples, maize, beef, pork (CIA, 2022). There are many native species that have been utilized by indigenous people and are still used to this day by both indigenous people and the rest of the nation. There are other plant species that are native to Panama and some that even hold medicinal properties. Some species and cash crops currently present in Panama did not originate specifically in Panama but were introduced from other tropical countries in the region and Asia.

A large portion of Panama's agriculture is native to the region and was utilized by the local indigenous people. Native species include maize, squash, beans, quinoa, and root-crops including cassava and sweet potatoes (Richard Cooke, n.d.). Many regional tropical fruits that are now grown in Panama include pineapple, soursop, and papaya (Ayngelina, 2022).

There are also economically important crops that have been introduced to the region over time and have played a key role in commercial agriculture. Some of these tropical plants include bananas, coffee, sugarcane, rice, rambutan, and plantains (Ayngelina, 2022). All these different plant species now play a crucial role in modern agriculture in Panama.

After completing research about Panama's diverse plant life, plants were chosen to be included in our modern agriculture station. There are two parts of this station. First, there is the main garden which will include cassava, coffee, pineapple, sugarcane, sweet potatoes, squash, maize, and rice. All these plants require full sun and are crucial components to Panama's agriculture. Finally, there will be trees along the path going down the hill. These trees will include papaya, plantains, soursop, bananas, and avocados. Additionally, the bitter ginger that is already at the bottom of the hill will be labeled. A floor plan of the main garden and trees going down the hill can be seen in figure 4.16. Information collected about all these plants can be seen in table 4.2. The signage for each station can be seen in figure 4.17.

Table 4.2. Agricultural Plants Utilized in the Modern Panamanian Agriculture Station.

Plant	Agricultural Function	Picture
Purple Sugar Cane (*Saccharum officinarum*)	● Multi-step process to turn sugarcane into sugar: 1. Sugarcane is crushed to release juice (not uncommon to just drink the juice) 2. Juice is heated and filtered 3. Goes through crystallization 4. Is placed in a centrifuge to separate the sugar and syrup (*Sugar Production*, n.d.). ● Consuming raw sugarcane strengthens teeth (Anonymous, 2022)	

Yuca	● Akin to a dense potato ● Can be prepared in some of the following ways: ○ Made into yuca flour ○ Yuca fries ○ Grilled as part of a barbeque ○ Yuca stew ○ Mashed yuca ○ Can be made into chips (like potato chips) ● Drought resistant ● Good source of choline, potassium, antioxidants (in the form of beta-carotene), vitamin C and A, phosphorus, and magnesium (Cassoobhoy, 2020).	
Pineapple	● Rich in vitamin C and manganese, while also having copper, thiamine, and vitamin B6 ● These vitamins and minerals improve immune health, iron absorption, development, and metabolic function and provide antioxidants (Wartenberg & Jones, 2022).	
Maize (corn)	● Improves gut health ● Lowers risk of cancer, type 2 diabetes, colon cancer, diverticulitis, and heart disease ● Rich in vitamin C ● Contains carotenoids lutein and zeaxanthin, which are good for eye health and prevent cataracts ● It's high in sugar and carbohydrates which raise blood sugar levels ● Usually prepared by boiling, steaming, roasting, or grilling corn on the cob (Watson, 2022).	

Coffee	• Contains lots of antioxidants • Reduces the risk of type 2 diabetes and Alzheimer's disease • Coffee beans are ground and brewed to produce a caffeinated drink that provides energy • (Gabrick, 2009)	
Squash	• Nutrients: magnesium, calcium, iron, vitamin A, and vitamin B6 • Improves eye health, reduces risk of depression, and enhances skin health • Although squash can be eaten raw, it can be steamed, roasted, fried, or pureed • (Brennan (Ed.), 2020)[2]	 *A picture of squash from Getty Images (Getty Images, n.d.).*
Papaya	• Papaya has been shown to reduce risk of heart disease, diabetes, cancer, aid in digestion, improve blood glucose control in people with diabetes, lower blood pressure, and improve wound healing. • Eaten raw as sliced pieces (Ware, 2017).	

Sweet Potatoes	• Rich in antioxidants
	• Improves healthy gut bacteria
	• Contains soluble and insoluble fibers which aid in digestion
	• Good source of vitamin A. Improves immune system function
	• Many ways to consume including:
	  ○ As chips
	  ○ As fries
	  ○ Mashed
	  ○ Baked
	• (Julson, 2019)
		
		A picture of a sweet potato from wikipedia (*Sweet Potato*, n.d.)

Rice	• Cooked by boiling or made into flour by grinding • Eaten in many traditional Panamanian dishes • White rice is generally diminished in nutrients, while brown rice contains thiamine, niacin, riboflavin, iron, and calcium (*Rice*, 2022).	 *A picture of uncooked rice from Encyclopedia Britannica* (*Rice*, 2022)
Bananas	• Moderates blood sugar levels • As bananas ripen, their flavor becomes sweeter, but the starch content drops • Significant source of vitamin C, copper, potassium, and magnesium • (Bjarnadottir, 2021)	
Plantains	• Plantains are a starchier version of bananas, and are usually cooked before eating (fried, baked, or boiled) • High in vitamins A, C and B6, potassium, and magnesium • (Richards, 2020)	

		Picture of plantains from wikipedia (*Plantains*, n.d.)
Soursop	• Soursop contains vitamin B1, vitamin B2, vitamin B3, vitamin C, folate, calcium, iron, potassium, magnesium, phosphorous, zinc, and copper • These nutrients improve digestion, boosts the immune system, fight inflammation, and may fight against bacteria. • Usually eaten raw or drank as a juice • (Brennan (Ed.), 2020)	
Avocado	• Significant source of monounsaturated fat and fiber • Nutrients: B vitamins, vitamin C, vitamin E, vitamin K, folate, potassium, magnesium, carotenoids (lutein, zeaxanthin) • Used in sandwiches, guacamole, baked goods, and salads • (*Avocados*, 2022)	 *Picture of an avocado from Harvard School of Health* (*Avocados*, 2022)
Guava (fruit) (*Psidium guajava*)	• Significant source of vitamins C and A, iron, calcium, and potassium • Fiber content improves digestion and helps relieve symptoms of diarrhea and constipation • Guava can be eaten fresh or cooked into baked goods for a sweet flavor • (Pathnak (Ed.), 2020)	 *Picture of guava fruit from wikipedia* (*Guava*, n.d.)

Note. Unless noted otherwise, photos in this table were taken by Gabriel Ward.

Floor Plan

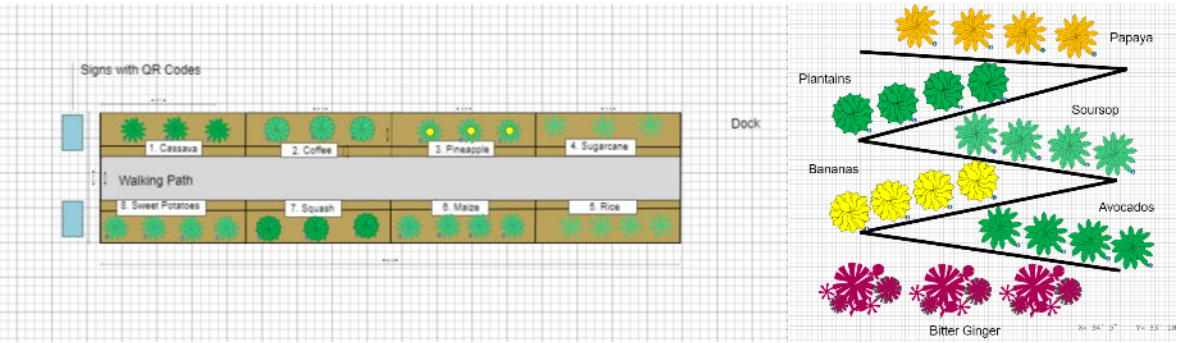

Figure 4.16. *Floor plan of main garden (left) and trees going down the hill (right).*

The area set aside for the garden is 15ft wide and 66ft long. There will be a 5ft path in the middle with a 5ft path with plants on either side. The garden will start 6 ft from the dock.

Signage

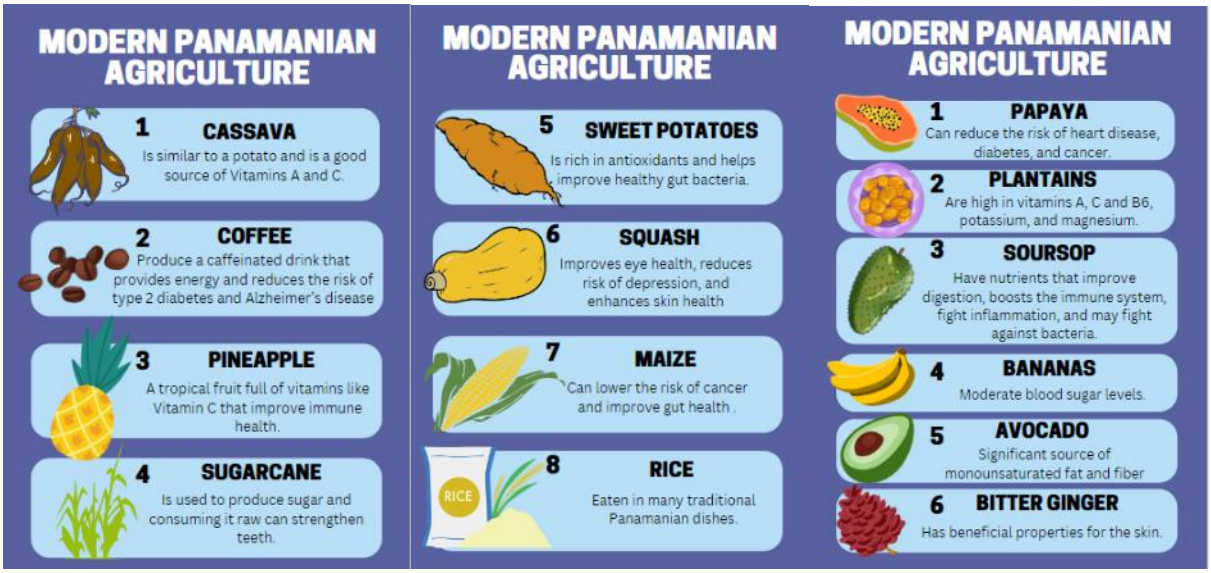

Figure 4.17. *Signage for Modern Agriculture.*

Chapter 5: Conclusions and Recommendations

Conclusions

The proposed interactive walking trail contains four stations. It begins with the existing building where there will be information about moth diversity and the moth collection process which will be developed possibly by a future IQP.

A sign will guide people to walk straight ahead, and the gravel road will lead them to the first station. The first station is focused on nature preservation and restoration. Here there are two pairs of parrots that Batipa is trying to help reproduce. Additionally, there will be signs providing visitors with information about biodiversity, plant life, scarlet macaw parrots, and nature preservation and restoration.

Visitors will then follow signs to the second station. At the second station, there will be information about the history of indigenous people and their culture, gardens, and uses for medicinal plants. There will also be a garden that contains some of the plants utilized by indigenous people.

Visitors will then head to the third station by following the signs. At this station, there will be information about aquatic life, mainly focusing on mangroves. Additionally, station 3 will also discuss sustainable development and provide information about Teak as an example. Station 3 offers an excellent view of the ocean and mangroves, so there will also be an area for visitors to sit and enjoy the beautiful view.

Finally, the trail will loop down the hill where there will be a collection of different fruit trees. At the bottom of the hill by the dock will be the fourth station. Here there will be a garden with modern panamanian agriculture.

Recommendations

Interaction with the Community

One of the goals of BFRS is to be a place for academics and the local community to interact. A problem with the current signage in the project is that it is all in English. A suggestion to create this type of interaction is to have students at Oteima University that are studying English to translate the signs and put them in Spanish for the majority of guests visiting. Additionally, it is suggested that the signs also have the Ngäbe language to highlight the culture and be more interactive. Oteima University students could work with Ngäbe students that are learning Spanish to create Ngäbe signage. Students working on these translations will both practice their current studies while also learning about the information and subjects found in the signs. Additionally, QR codes could be used in order to display information so that users can use their phones to learn more information about each exhibit and reduce the amount of materials needed for the signs. QR codes can be created using QR Code Generator Powered by Bitly. The QR codes could lead users to PDFs of signs in Spanish and Ngäbe. Student field trips to BFRS are also recommended to be advertised to local schools and Universities. Visits to the walking trail have the benefit of giving local students a real representation as to why studying the subjects within the walking trail are important and interesting.

Additional Technical Data Required

When creating a walking trail for visitors, the data collected must include the slope percentage of the hill. Since the location where we are building our track has ridges, this project must contain this information for the future. In general, it is important to remember that in the end, the slope percentage needs to be 8.3% for individuals with disabilities using hand-propelled

wheelchair ramps. If the hill has a higher rate, when building this trail, this data needs to be considered so the facility can be all-inclusive and friendly to be used by all (Just a Moment n.d, 2022).

Other Uses of Teak

In addition to creating chips, Teak can also be used to build elevated structures designed to maximize rainwater collection and utilize photovoltaic solar panels (Cloutier et. al., 2017). These structures could be implemented in the design of ecomuseums and laboratories to provide the BFRS facilities with an eco-friendly and sustainable source of water and electricity. Since the BFRS is in a remote location, looking into ways of supplying water and electricity in sustainable practices is essential.

Rainwater Collection

As shown in the figure 5.1, Panama traditionally receives heavy rainfall throughout the months May to December, with a dry season occurring yearly from January to April. On average, September is the wettest month with 16.1 inch (410 mm) of precipitation while February is the driest month with 0.8 inch (21 mm) of precipitation (weather-and-climate.com, 2022).

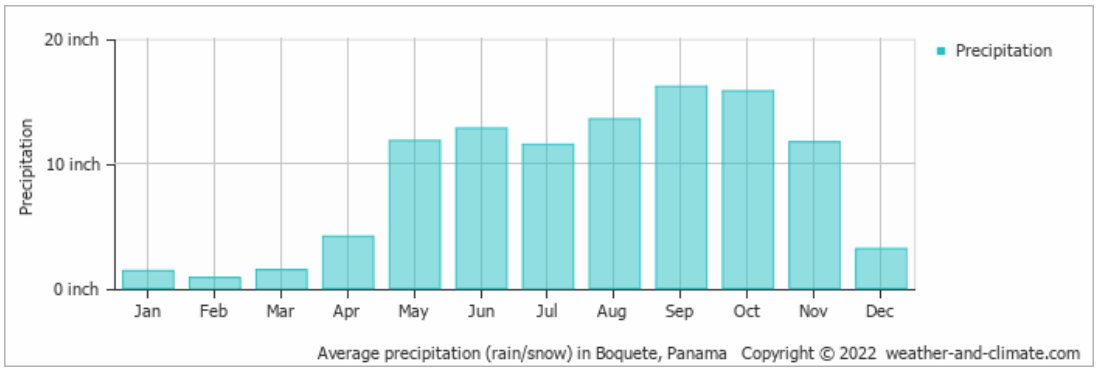

Figure 5.1. *Chart showing the amount of rainfall during each month in David (weather-and-climate.com, 2022).*

According to Panama's First National Communication to the United Nations Framework Convention on Climate Change (UNFCCC), a number of the country's sectors are vulnerable to climate change and variability. Due to this, extensive measures must be taken to improve resilience to climate change (Climate Change Knowledge Portal, 2011). Current trends are showing an 80% increase in yearly precipitation by 2080, with a 60-70% increase during the dry season. However, drought events are expected to be exacerbated due to the El Niño/ La Niña Phenomenon (Climate Change Knowledge Portal, 2011).

The need for these collection systems in Batipa is critical, especially with a garden's additional freshwater requirements. An IQP paper published in 2019 titled "Sustainable Water Systems for Batipa" stated that in recent years Batipa has struggled to find a reliable source of freshwater during the dry season. In the past, Batipa has resorted to leading livestock to brackish water (salty seawater mixed with freshwater) as a supplement. Despite preserving most of the cattle, it was still enough to cause the loss of over 30 animals and resulted in lower fertility rates across the board (Argyrakis et. al., 2019).

In the IQP paper mentioned above, the authors recommend using a double filtration rainwater collection method. We recommend utilizing this same system for collecting rainwater in Batipa due to its cost effectiveness and ease of use. The system, shown in detail in figures 5.2 and 5.3 below, will collect rainwater from the roof of the main facility at the BFRS. The water will first flow through a titled mesh design, which can filter out large particles of biomass. The water will then flow into a first flush divergent tube, which can filter out smaller particles and potential chemical contaminants, contributing to cleaner water collected that won't harm the plants (Argyrakis et. al., 2019).

Product	Tiled Mesh	
Cost	$20+	
Environmental Footprint	Plastic	
Advantages	• Easy to Install • Cheap • Filters out Large debris • Self cleaning	
Disadvantages	• needs daily maintenance	
Additional Info	Due to the advantages outweighing the disadvantages	

Figure 15: Leaf-eater available for purchase at most hardware stores

Figure 5.2. *Tilted mesh (Argyrakis et. al., 2019).*

Product	First Flush Divergent Tube	
Cost	$50	
Environmental Footprint	Trivial	
Advantages	• Protects water • Easy to install	
Disadvantages	• Need to replace ball occasionally* • Consistent maintenance for longer use	
Additional Info	The placement of BFI puts them in a vulnerable situation for large debris to accumulate in the conveyance step.	

Figure 16: Buyable first flush system

Figure 5.3. *First flush divergent tube (Argyrakis et. al., 2019).*

This example effectively filters out large particles and funnels water into a storage system located next to or within the building. For this storage system, we recommend using an above ground water tank set aside specifically for use in the garden containing around 100 gallons. It is also important to note that this water doesn't necessarily need to be potable for human consumption but is only intended to alleviate extra strain on Batipa's already vulnerable water supply caused by the hydrological needs of the garden areas. Therefore, it is not necessary to spend extra money and resources on making the water potable.

In addition to a functioning rainwater collection system, having this on the property provides an example for those who want to utilize Panama's abundance of rainwater for their own needs. These simple do-it-yourself methods offer low-cost solutions to a wide variety of people from farmers to average citizens seeking to improve their water supply. Droughts caused by the El Niño effect have been known to heavily reduce crop yields and contribute to increases in crop failure which leads to famines, similar to the famine in Panama in 1999 (Climate Change Knowledge Portal, 2011).

Potential Future IQPs

Through the process of completing this project, potential future IQP projects were discovered. Each station designed in this project covers subjects that lie in BFRS and Oteima's goals of expanding academic tourism. Each station has the ability to be expanded on with further research into the specific area. Oteima University would like to have their own moth collection gallery at their university and hopes to start a program where academic tourists could come to Batipa and learn how to collect and pin moths. They showed great interest in this being a possible future IQP. Another potential IQP that was expressed by Oteima University is working within the Ngäbe-Bugle Comarca to help bring similar sustainable business models as those in BFRS to the Comarca. The indigenous groups in Panama have been relatively under researched and there is potential for various IQP projects involving the different tribes. Additionally, BFRS has expressed interest in expanding their parrot restoration efforts by creating additional cages for other species of birds. An IQP project can be developed that focuses on this effort in collaboration with BFRS and Oteima University. Our IQP project allows for a multitude of future IQP projects to be worked on with Oteima University and expand on the already proposed designs of each station.

The Importance of Designing an Interpretive Walking Trail

The creation of an interpretive trail at the BFRS will help promote academic tourism and provide sustainable economic opportunities. There are also additional opportunities for future IQPs to expand on the concepts included in the stations of the interpretive walking trail. The creation of the trail in this area gives the opportunity to expand on different areas and develop other areas at Batipa. Oteima University and the BFRS hope to create more opportunities for academic tourism and grow the programs available at Batipa. Our interpretive trail opens additional opportunities for the BFRS to expand and provide more opportunities in academic tourism.

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Appendix

1. History of David

Officially known as San Jose de David, the city is Panama's largest city outside of Panama City and is surrounded by mangroves and teak plantations. The city is an important commercial center and is supplied by different seaports in the region. The most prominent industries include meatpacking, food processing (sugar, fruits, coco, etc.), distillation, tanning, as well as saddles and harnesses. David gained recognition as a city in 1738 and was known for being a gold prospecting camp and still retains much of its traditional practice in addition to the expanding industries listed above (*David*. *Encyclopedia Britannica,* 2013*)*. However, the city is considered to be founded in 1602 and was used as a rest stop by people traveling the trail that connected Central America with Panama City. In the early 1900s, the development of the Panama Railway, which joined the two oceans surrounding Panama, heavily contributed to the economic growth of the region via agricultural exports mentioned above. In recent years, David has also seen an influx of expats and tourists, further contributing to its economic development ("David - History," 2019). Due to its increasing wealth and popularity, David has become a hot spot of growth and opportunity for Panamanians on the western coast.

2. Ngäbe Traditions, Political Struggles, and More

While conducting research for this project, an abundance of information was collected on the Ngäbe Tribe that was not in the scope of this paper. The data was collected in various methods which included a visit to the Ngäbe-Bugle Comarca. Due to the extensive personal accounts and information that our group gathered about the Ngäbe tribe, we felt that it was

important to include this information in our paper. The purpose of this Annex is to highlight some customs and current struggles Ngäbe face that were shared with us as well as expand on the history of indigenous life in Panama. It is also worth noting that there was discussion of a future IQP project opportunity with Oteima on working on a similar interactive trail in the comarca itself. The information contained in this Annex can be used in future projects of this kind. Some Ngäbe words were attempted to be spelled below but without proper translation they may be misspelled.

3. Traditional Cultural Activities

Hegee- The traditional dance that has four different dances to it that represents typical things you will see in a village. The first represents a drunk man as you are happy when you are drunk but stumbling (Name is borache). The second dance represents butterflies (mariposa dance). In gnobe culture a butterfly is very significant and the dresses of the girls in the dance represent the different colors of the butterflies (each girl wears different colored dresses of blue, green, red) . The next dance is the (Mono dance), the dance of the monkey. It is the thought of gnobe that the monkey is a part of human life and that monkeys dance represents how humans move. It is also said that monkeys dance when the rain is coming and that this is representative of it. The leader of the dance who controls the maracas is called a white face monkey due to their intelligence compared to the howler monkeys which are the dancers following. Lastly is the trabajo dance (working dance). The dance represents the village working together and starts off with the men in front dancing. This part of the dance represents men cutting down the forest for women to plant seeds. The next part of the dance the women step up and this

represents them planting their seeds. The dance concludes with the men stepping up next to the women and them being in unison to represent the whole tribe working together. The only instrument used for the dance is traditional maracas for their dance.

Balsirea (american football like) - The game is played during tribe gatherings and special occasions and a conch shell is used to call the game (blowing into it). The conch shell is also played to symbolize an arrival of someone to the game. The game is considered very ceremonial and a piece of wood is carved (el baso tree) to be thrown between the legs of players.

4. Traditional Agricultural Practices

Yuca Harvest - The yuca is said to be best to be planted with the new moon because the moon's effect on water in the ground. Yuca is also harvested and re-planted on the same day as they cut the stem of the yuca and plant in two pieces for each area they plant them.

Importance of Cacao - It is tradition to drink cacao in a ceremonial way and is also given to the chief as a gift.

Soup Culture (se rema) - A chicken and corn based soup that has a story of being used to control the animals that do harm to the corn crop (ex. Monkeys, chickens, etc.) and take the heads of the animals to put into the soup. The village then comes together and eats the soup together as a “punishment” to the animals that harm the corn.

Farming Mentality - The tribe likes to use the most diversity as possible when farming and doesn't believe in cutting down natural plants when not necessary. They believe that it is better for agriculture to have a diverse set of plants growing around them whenever

possible. For example (ngapee) is allowed to be grown on the trees of agriculture because it is a natural vine that grows in the area.

Burned Salt (sal quemala) - The village has had problems in the past with not having enough sodium to control their thyroid and lymph nodes and to resolve this problem they boiled sea water and burned the salt. It is now also used with pepper to season cooking.

5. Political Struggles

Problems comarca has with the government - The comarca doesn't have enough help from the government to explain and show to the rest of the world their culture. The government (of Panama) doesn't help them in their mission to show their culture to academic tourists. The panama government does not promote their products, does not work on the roads to the comarca (the people feel left out even though they are citizens). When I mentioned that there was not a lot of information on the internet about their tribe an anonymous tribe member said that this is something they really want to change.

6. Guayaba (Guava) Medicinal Properties Table:

Table 4.1. Ethnomedical uses of *Psidium guajava* (Guava) (Gutiérrez et al., 2008)

Place, Country	Part(s) Used	Ethno Medical Uses	Preparation(s)
Colombia, Mexico	Leaves	Gastroenteritis, diarrhea, dysentery, rheumatic pain, wounds, ulcers, and toothache	Decoction and poultice
Indigenous Maya, Nahuatl, Zapotec and Popoluca of the	Leaves	Cough, diarrhea	Decoction or infusion

region Tuxtlas, Veracruz, Mexico			
Latin America, Mozambique	Leaves	Diarrhea, stomach ache	Infusion or decoction
Mexico	Shoots, leaves, bark and leaves mixed, rip fruits	Febrifuge, expel the placenta after childbirth, cold, cough hypoglycaemic, affections of the skin, caries, vaginal hemorrhage, wounds, fever, dehydration, respiratory disturbances	Decoction, poultice
Panamá, Cuba, Costa Rica, México, Nicaragua, Panamá, Perú, Venezuela, Mozambique, Guatemala, Argentina	Leaves	Anti Inflammatory	Externally applied hot on inflammations
South Africa	Leaves	Diabetes mellitus, hypertension	Infusion or decoction
Caribbean	Leaves	Diabetes mellitus	Infusion or decoction
China	Leaves	diarrhea, antiseptic, Diabetes mellitus	Infusion or decoction
Philippines	Leaf, bark, unripe fruit, roots	Astringent, ulcers, wounds, diarrhea	Decoction and poultice
India, Ghana	Leaves, shoots	Febrifuge, antispasmodic, rheumatism, convulsions, astringent	Decoction or infusion
Peru	Flower buds, leaves	Heart and constipation, conjunctivitis, cough, diarrhea, digestive problems, dysentery,	Infusion or decoction

		oedema, gout, hemorrhages, gastroenteritis, gastritis, lung problems, shock, vaginal discharge, vertigo, vomiting, worms	
Kinshasa, Congo	Leaves, bark	diarrhea, antiamoebic	Infusion or decoction, tisane
Senegal	Shoots, roots	diarrhea, dysentery	Infusion or decoction
Uruguay	Leaves	Vaginal and uterine wash, especially in leucorrhoea	Infusion or decoction
Fiji	Leaves, roots, ripe fruit	diarrhea, coughs, stomach-ache, dysentery, toothaches, indigestion, constipation	Juice, the leaves are pounded, squeezed in salt water
Tahiti, Samoa	Whole plant, shoots	Skin tonic, painful menstruation, miscarriages, uterine bleeding, premature labour in women, wounds	Infusion or decoction, paste
New Guinea, Samoa, Tonga, Niue, Futuna, Tahiti	Leaves	Itchy rashes caused by scabies	Boiled preparation
Cook Islands	Leaves	Sores, boils, cuts, sprains	Infusion or decoction
Trinidad	Leaves	Bacterial infections, blood cleansing, diarrhea, dysentery	Infusion or decoction
Latin America, Central and West Africa, and Southeast Asia	Leaves	Gargle for sore throats, laryngitis and swelling of the mouth, and it is used externally for skin	Decoction

		ulcers, vaginal irritation and discharge	
Panama, Bolivia and Venezuela	Bark and leaves	Dysentery, astringent, used as a bath to treat skin ailments	Decoction
Brazil	Ripe fruit, flowers, and leaves	Anorexia, cholera, diarrhea, digestive problems, dysentery, gastric insufficiency, inflamed mucous membranes, laryngitis, mouth (swelling), skin problems, sore throat, ulcers, vaginal discharge	Mashed, Decoction
USA	Leaves	Antibiotic and diarrhea	Decoction

7. Guest Experience and Design Survey Questions

1. What are some important aspects to think about when starting to design a garden?
2. How can the design of a garden promote a positive guest experience?
3. Do you have any ideas on how to make a garden sustainable?
4. How do you manage your water usage?
5. How much electricity is used to power a garden? (sprinkler systems, lighting, greenhouses, etc.)
6. How much of this power comes from local renewable resources such as solar panels, windmills, etc.?
7. Do you utilize rainwater collection to reduce water usage? If so, how do you do it?
8. Is there anything else you think we should know about planning a garden and herbarium?

8. Gravel coverage formula:

To calculate how many tons are needed on our walking trail, we need the trail surface area, width, and depth.

1. Convert trail surface area into square feet (length x width = square feet).

2. Square feet/324 = # of cubic yards needed to cover 1" deep.

3. Multiply cubic yards by the depth of surface desired.

4. Multiply this figure by 1.25 = # tons of surface material needed.