Cay Bay Post-Restoration Assessment

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Introduction

The Cay Bay restoration site is located within the Seaside Nature Park (thus it has been referred to as "Seaside Nature Park" in previous reports related to this project). The park itself is approximately 10 hectares in size and located on a peninsula between Cole Bay and Cay Bay of St. Maarten. This park presented a unique opportunity to restore undeveloped coastal terrestrial scrub habitat.

Figure 1: *Seaside Nature Park and approximate location of restoration site (Lignum). Coordinates of Lignum site: ~18º 01' 16.35" N 63º 04' 43.11" W.*

The pre-restoration botanical assessment carried out between July 5th and 9th to establish baseline data on vascular plant diversity and structure revealed that the main vegetation types present within the park are secondary and tertiary Caribbean Dry Forest/Shrubland. While the park has had a history of disturbance from farming in the past, it has largely returned to a secondary state of semi-natural vegetation. However, this is characterized by the presence of several invasive species, mainly: Acacia (*Acacia farnesiana*), Corolita (*Antigonon leptopus*), Jasmine (*Jasminum flumense*), and Saw Grass (*Panicum maximum*). This assessment also revealed two areas (Figure 1) ideal for restoration as they both presented degraded land, accessibility with water, and potential for impact in re-establishing natural systems (Freid, 2017).

The “Exposed” site was found to be dominated by invasive Acacia, but unfortunately a layer of topsoil for planting could not be determined. The “Lignum” site, which had been partially cleared of invasive Acacia, presented about 10-20 cm of topsoil throughout. Therefore, after discussion with the site owners, it was decided to focus restoration efforts on the “Lignum” site.

Figure 2: Interior portion of the (Lignum) restoration site before Hurricane Irma with patches of native trees and shrubs (Freid, 2017).

The “Lignum” site (from now on referred to as the restoration site) had been used extensively for agriculture but had lain fallow for decades. The area recommended for restoration was found to be approximately 25 x 50 meters and characterized by patches of native trees and shrubs (Figure 2). The botanical assessment revealed 25 species observed within the restoration area, see Freid (2017) for a full list of species identified. While there is a large Lignum Vitae near the restoration site, there were no actual Lignums within the restoration zone.

A survey of herpetological and invertebrate diversity was conducted on August 9th, 2017 at both proposed restoration locations and an undisturbed part of the park (Yokoyama 2017). During the assessment, approximately 86 species were identified. Both the Botanical and Herpetological Assessment were performed before Hurricane Irma to serve as baseline studies to assess whether restoration actions had increased biodiversity at the end of the project. While they no longer serve as baselines due to extensive storm damage, the information is still used as a basis for this final

assessment. However, we are hesitant to draw any conclusions about changes in biodiversity based on the initial assessments.

Hurricane Irma

The original project timeline dictated that site preparation would take place in September and October 2017. On September 6th, 2017, Hurricane Irma passed directly over St. Maarten, resulting in a shift in the project timeline. Communication with funders, site owners, and overseas EPIC board members was limited, and the EPIC headquarters had suffered great damage. Therefore, for the initial weeks after Irma the project was mostly on hold. Meanwhile, EPIC Project Coordinator (Kippy Gilders) and Intern (Ani Luna) worked to ensure that funding was still available, site owners were still willing to support restoration efforts, native plants could still be sourced, and technicians were still on island and available for work.

On October 4th, Technician 1 started site preparation, and on September 9th, Technician 2 was hired and started site preparation. Shortly thereafter the company which had been selected to source the 500 plants was going out of business but could still sell us the 212 native plants that were on island and in a decent state. Since site preparation was still underway, we continued to source the remaining 288 native trees. Sourcing 1-gallon pots of native trees and plants became difficult as the majority of nurseries have 3-gallon pots as the minimum size for sale. Therefore, price and general volume of plants to care for increased.

Not only had site preparation become more complicated due to hurricane debris and fallen trees, the Technicians time now involved caring for the plants until planting was possible. The sites were cleared towards the end of November 2017. Until planting, Technicians continued to care for the plants on site, clear out the large amount of dead brush (related to hurricane Irma) and prepare the site for planting.

We were able to source the remaining plants through several on-island growers and nurseries. The main nursery to supply the remaining trees imported them from Miami, limited by damage at the St. Maarten port and a series of hurricanes which prohibited ship traffic. Therefore, plant arrival dictated the planting date. The final plant shipment arrived on January 18th, and planting was carried out from January 22nd to 24th, 2018. During this time, Dr. Ethan Freid (botanist) returned to assist with planting.

Since the restoration site at Cay Bay is smaller in size than the site at Sentry Hill, it was decided to divide the plants so that approximately 150 went to Cay Bay and 350 went to Sentry Hill. The species were evenly divided so that both sites would receive approximately the same composition of plant species. Due to complications with water accessibility and plants from Florida possibly undergoing a shock in response to the immediate change in environment, some plants died before planting could begin. Therefore, 125 plants went to Cay Bay and 309 went to Sentry Hill. Before planting, the trees were tagged to allow for easy monitoring (ex. SG_SNP_1, the first Seagrape at the Cay Bay restoration site within Seaside Nature Park, see Appendix 4).

Methodology

While the restoration site had changed greatly as a result of hurricane Irma (Figure 3), it was decided to go forward with restoration at this site because the need for restoration had increased. Since the site had already been cleared of most Acacia, the Technicians cleared the site of what Acacia and other invasive had returned. The cut prickly Acacia was put into a pile and allowed to dry. The dried branches would later be used as a natural protective barrier to deter any roaming livestock from damaging the newly planted trees.

Figure 3: Cay Bay restoration site after the passing of Hurricane Irma.

Planting at Cay Bay was designated for January 24th, 2018. On the day itself the 125 plants were transported to the hilltop restoration site. The 125 plants constituted 11 different species and Table 1 provides a list of these different species. The Technicians, landscaping crew (crew of seven landscapers), EPIC staff and volunteers worked to plant the trees (Appendix 5). Dr. Ethan Freid immediately spread the plants around the site in a random pattern to mimic natural seed dispersal. The Technicians and landscapers then knew at which exact location to start digging holes and planting the trees.

To assist plant survival, TH-1 and Soil Moist Polymer were dispersed around the root ball of the plant after it was placed in the hole and before being covered with topsoil. The TH-1 is a professional growing mix to maintain nutrient retention and proper drainage to create an ideal growing environment. Soil Moist Polymer is a soil amendment which is designed to reduce the need to water plants by up to half, reduce transplant shock and soil compaction and remain effective until it

decomposes after the most vulnerable years of the new plants life. Organic fertilizer and mulch were also applied to each newly planted tree.

After the passing of Hurricane Irma, the owners of Seaside Nature Park experienced many complications and were no longer able to secure consistent plant watering. Therefore, EPIC and Seaside worked to secure a 1000-gallon tank at the restoration site (Appendix 7). When Seaside was able, they would refill the tank and a Technician would use the tank to fill buckets and water the plants every Monday, Wednesday and Friday, or as needed. During these regular watering visits, the Technician noted any damages to the plants and recorded any other species identified on site and sent photos to the Project Coordinator via WhatsApp.

On several occasions the plants were chewed almost bare by the goats that roamed freely on site after Hurricane Irma (Appendix 10). After talking with the site owners, it was discussed that the goats would be fenced in, but this depended on time and availability of a contractor to repair the fence. Meanwhile EPIC explored the option of fencing, but this proved costly and time consuming. Since the Sea Grapes and Pidgeon Plums appeared to be the species targeted by the goats, it was decided to make cages around these plants using upside-down cages usually used to grow tomatoes (Appendix 11). While this allowed the trees to recover somewhat, they still suffered frequent damages. Meanwhile, the goats turned their attention to the rest of the plants and some plants were even found uprooted when the Technician arrived on site (Appendix 9). When needed, the dried Acacia barrier was re-adjusted and other materials found on site were used to barricade expected livestock entry points (see Appendix 3 for an image of the Acacia fence). Eventually the goats were properly fenced in and the plants began to recover (Appendix 12).

Due to the location and different post-Irma situation of most schools, we were unable to recruit student-scientists to monitor this site and monitoring was done solely by Technicians and EPIC staff. The final monitoring data consists solely of a count of plants that survived up until the date of the final assessment on May 15th, 2018.

Results

On the final day of monitoring (May 15th, 2018), a total of 13 plants were recorded as dead. Resulting in a final survival rate of 89.6%. Table 1 lays out which species were recorded at planting and which survived to the post-restoration assessment. Of the 11 species planted, 10 survived on site due to all Sage dying.

	Genus	Specific Epithet	Common Name	Total planted	Total post-restoration	Lost
1	*Tabebuia*	*heterophylla*	White Cedar	9	7	2
2	*Capparis*	*cynphallophora*	Caper Tree	12	11	1
3	*Chrysobalanus*	*icaco*	Coco Plum	9	4	5
4	*Conocarpus*	*erectus*	Buttonwood	11	11	0
5	*Sweitenia*	*mahogonii*	Mahogany	19	19	0
6	*Coccoloba*	*diversifolia*	Pidgeon Plum	8	8	0
7	*Coccoloba*	*uvifera*	Sea Grape	12	12	0
8	*Lantana*	*involucrata*	Sage	3	0	3
9	*Guaiacum*	*officinale*	Lignum Vitae	13	11	2
10	*Plumeria*		Frangipani	16	16	0
11	*Conocarpus*	*erectus var. sericeus*	Silver Buttonwood	13	13	0
				125	**112**	**13**

***Table 1**: Results of final terrestrial monitoring data (January 24th, 2017 to May 15th, 2018).*

The Botanical Assessment performed at the beginning of the project reported 25 different species observed within the restoration site. After restoration, ten more native plant species were added to the site increasing the plant diversity count to 35. While none of the planted Sage survived, the pre-restoration Botanical Assessment records native Sage within the restoration boundary.

	Genus	Specific Epithet	Common Name	Observed pre-restoration	Planted (and survived)
1	*Tabebuia*	*heterophylla*	White Cedar		x
2	*Capparis*	*cynphallophora*	Caper Tree		x
3	*Chrysobalanus*	*icaco*	Coco Plum		x
4	*Conocarpus*	*erectus*	Buttonwood		x
5	*Sweitenia*	*mahogonii*	Mahogany		x
6	*Coccoloba*	*diversifolia*	Pidgeon Plum		x
7	*Coccoloba*	*uvifera*	Sea Grape		x
8	*Lantana*	*involucrata*	Sage	x	
9	*Guaiacum*	*officinale*	Lignum Vitae		x
10	*Plumeria*		Frangipani		x
11	*Conocarpus*	*erectus var. sericeus*	Silver Buttonwood		x
				1	**10**

***Table 2**: Results of final terrestrial monitoring data (January 24th, 2017 to May 15th, 2018).*

The species of plants, insects and retiles recorded on site pre-restoration can be found in the Botanical Assessment (Freid, 2017) and the Herpetological Assessment (Yokoyama, 2017), respectively. The regionally endemic ground lizard, *Pholidoscelis plei analifera*, and the Anguilla bank anole, *Anolis gingivinus*, are both endemic to the Anguilla Bank and are often seen at the restoration zone.

Genus	**Common Name**		**Notes**
Iguana iguana	Green Iguana	*	Nesting on site.
Anolis gingivinus	Anguilla bank anole	*	Regional Endemic.
Ascia monuste	Great Southern white	*	Also, its caterpillar.
Selenops souliga	wall crab spider	*	Regional endemic.
Pholidoscelis plei	Ground Lizard	*	
Argiope argentata	Silver Argiope	*	
	Ant	*	
	Bees	*	
	Lady bug		
	Grasshopper	*	
	Millipedes		
	Pill bugs/wood lice	*	*Family: Armadillidiidae*
	Mealy bug		
	Aphids		
	Red footed tortoise		This is a "pet" that has been released in the park.

***Table 3**: Species of insects, reptiles and amphibians recorded at Cay Bay during monitoring (*= presence during Pre-restoration Assessment).*

Table 3 lays out the species of insects, reptiles and amphibians which were identified during watering/monitoring visits to the restoration site. The Asterix (*) denotes that this was also recorded during the pre-restoration assessment conducted in August 2017. There were also a number of vertebrates that were observed on site, these are outlined in Table 4.

Genus	**Common Name**	**Notes**
Quiscalus lugubris	Carib grackle	
Zenaida aurita	Zenaida dove	
Coenobita clypeatus	Hermit crab	
Columbina passerina	Common ground Dove	
Zenaida macroura	Mourning dove	
Coereba flaveola	Bananaquit	
Falco sparverius	American Kestrel	
Tiaris bicolor	Black faced grassquit	
Loxigilla noctis	Lesser Antillean bullfinch	
Setophaga petechia	Yellow warbler	

***Table 4**: Vertebrate species recorded at Cay Bay during monitoring.*

Discussion

The final terrestrial monitoring data points to an increased diversity of plant species within the restoration site. While this might point to an increased botanical diversity on a technical level, according to Freid (2017), it is the establishment of a forest/shrubland structure that is a better indicator of the restoration of the area to a more natural/semi-natural state. Between the newly planted trees, species of native ground cover such as purslane are starting to flourish (see Appendix 2). This could indicate the return to a healthy Caribbean Dry Forest/Shrubland.

The results of the species inventory establish a baseline for the post-restoration biodiversity of this site. While care was taken to note any species observed during monitoring, there was likely a great deal that went unnoticed. Further study, particularly monitoring of species done during different times of the day (all monitoring was conducted from 0900 hrs to 1100 hrs) and during different seasons, would undoubtedly increase the total number of observed species. Still, it is clear that the Cay Bay restoration site is home to a wide variety of species and restoration efforts will gradually support a higher biodiversity.

Insects in particular are often dependent on specific host plants, and their localized diversity will typically correlate with the diversity of vegetation. Therefore, by adding ten species of native plants to the site, there shows promise for increased insect diversity with time. The main pressures against successful restoration on site include harsh sun, strong winds and damage by livestock. The damage caused by livestock posed the greatest barrier to restoration during this project. While sun and wind are persistent pressures, entire restoration efforts can be destroyed by one overnight “livestock attack”. However, despite the worrying state of most plants, they are still green and will flourish provided that livestock pressures are eliminated.

While much of the tree canopy was eradicated during hurricane Irma, increasing sun and wind exposure at the site, it was still decided to restore the same location since the whole property had suffered a similar loss in canopy and the chosen restoration site would experience the greatest benefit from restoration efforts. Once the newly planted trees have properly rooted into the surrounding soil, the wind pressures will be less of a burden and the supporting sticks and ropes can be removed (Appendix 2). Certain species that were introduced during this project, such as the Mahogany and White Cedar, will grow into tall trees and create considerable canopy cover with time. This will result in reduced sun exposure which will increase the success of continued restoration efforts and the natural reseeding of plants in the area.

While restoration efforts were challenging, the increased native plant species diversity and the potential of re-establishing tree canopy cover over areas of the restoration site point to increased native plant undergrowth, reduced sun exposure and to an increased diversity of habitats to benefit faunal diversity. It is important to note that benefits of restoration will not be visible immediately and care should be taken to foster restoration efforts to reap the eventual rewards of increased biodiversity.

Suggestions
While the site is exposed to sun and wind, the main stressor impacting plant health is grazing by livestock, mainly goats. To maintain plant health, either the goats or the restoration site should be fenced in. Since goat's impact other vegetation (and not just the trees planted during this project), it is suggested that the goats be fenced in.

If the site owners wish to further restore the site, then it can be suggested to put smaller plants around taller shade baring trees. This would allow for the smaller plants to be protected from the elements while they mature. Eventually they will create islands of healthy trees which will seed and spread outwards naturally.

Additional Materials
Photos of some of the species observed during monitoring can be found in the folder "Cay Bay Species Inventory" included with this report.

Sources
Freid, E. H. (2017) Seaside Nature Park Restoration Project Rapid Botanical Assessment. Leon Levy Native Plant Preserve. Bahamas National Trust.

Yokoyama, M. (2017) Seaside Nature Park Terrestrial Diversity Assessment. Les Fruits de Mer.

Appendix

Appendix 1: Looking towards the Lignum Vitae after Hurricane Irma (September 2017).

Appendix 2: Looking towards the Lignum Vitae after restoration efforts (May 2018).

Appendix 3: After restoration work. Dried prickly Acacia fence bordering walking path.

Appendix 4: Plants were cared for until planting was possible. Pictured here: A volunteer tagging plants in the makeshift nursery located at the Sentry Hill restoration site (January 2017).

Appendix 5: Landscapers planted the trees after Dr. Ethan Freid placed them randomly throughout the restoration site (January 2018).

Appendix 6: Water was initially transported by bottle and truck following planting. Pictured here: Dr Ethan Freid (left) and Kippy Gilders (right).

Appendix 7: Shortly after planting, a 1000gallon water tank was installed near the restoration site to facilitate watering.

Appendix 8: Mulch was placed around the plants to facilitate water retention. Rocks were used to keep the mulch in place.

Appendix 9: The plants suffered damages from livestock. On occasions, plants were found fully uprooted.

Appendix 10: The plants suffered damages from livestock. Seagrapes were grazed almost bare.

Appendix 11: Protective cages were made using upside down tomato cages and dried prickly Acacia branches.

Appendix 12: After livestock were fenced in, plants started to make a recovery.

Appendix 13: After livestock were fenced in, plants started to make a recovery. Pictured here: a seagrape protected by an upside-down tomato cage wrapped in chicken wire. This proved most effective while livestock were free-roaming. However, to cage and wire all plants would be too costly and time consuming (Approximately $10 per cage).

Little Key Post-Restoration Assessment

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Introduction

Little Key is an island located within the Simpson Bay Lagoon between Cupecoy and the Princess Juliana International Airport. The island is owned by the government of St. Maarten and it is one of the undamaged ecosystems of the Simpson Bay Lagoon surrounded with some of the last remaining seagrass fields (Bervoets, 2012). Little Key provides an ideal location for restoration since it is isolated from human activity and major developmental plans. Using the encased planting method, 290 red mangrove (*Rhizophora mangle*) propagules were planted on Little Key over the weekends of December 9th (n= 143 single encasement method) and 16th (n= 147 double encasement method) 2017. The growth progress of the propagules was monitored every other week by dedicated volunteers. Five propagules that were planted using the encased method in August 2017 and survived Hurricane Irma were also monitored. Lastly, any species observed on site were recorded and added to a species inventory.

Methodology

The mangrove propagules were planted using the Riley encased methodology (REM) outlined in Riley (1999). This methodology uses full-length PVC tube encasements to reduce wave action and create an environment favorable to the seedlings initial stages of development while protecting the plant long enough to become established. This low-cost method has proven successful along coasts with high wave energy to restore degraded mangroves (Salgado Kent, 1999).

The single encasement method features a longitudinal cut down its entire length. The PVC encasement will remain in place until the plant has matured sufficiently so that the foundations of the prop roots are able to provide for the long-term nourishment and support of the tree independent of the encasement. On average this can take three years, after which the encasement can then be removed.

The double encasement method features a latitudinal cut which splits the encasements into two independent sections that are attached using a PVC coupling. The split should be above the high tide mark, allowing for the propagule to be planted in the appropriate conditions. Holes can be drilled in the bottom section that will be in the ground to facilitate root growth out of the encasement. Once the seedling starts creating prop roots, the top section of the encasement and the adjoining coupling can be removed. The bottom section of the encasement will remain in place for the duration of the mangrove's life.

The PVC pipes were cut and prepared by volunteer-donated time and equipment. Mud to fill the PVC tubes up to the high tide mark was collected from shallow areas of the Simpson Bay Lagoon to ensure that the planting environment in the PVC tube would be similar to the restoration site conditions. Since Hurricane Irma had removed the propagules from St. Maarten's mangroves stands, propagules were ordered and shipped from an aquarium company in Florida. The propagules arrived acclimatized to fresh water, therefore they were then adjusted to the salinity of the Simpson Bay Lagoon. This was done by submerging them in a fresh water bath and then gradually increasing the percentage of salt water (collected from the Simpson Bay Lagoon) present in the bath over a two-week period. Since the water was collected from the Lagoon, the propagules adjusted to the correct salinity and toxicity of the re-planting environment.

Using donated boats, and assisted by staff from the St. Maarten Nature Foundation, the propagules were then planted using the single encasement method on December 9th and then the double encasement method on December 16th. Volunteers worked in groups of two to hammer the pipes into the ground until they could go no further (approximately 30cm), then fill the tubes with mud and insert the propagule vertically into the mud with the thicker end down and the mud covering approximately 1/3 of the seedlings total length. Evidence from Riley (1999) found that seedlings were not highly sensitive to planting elevation relevant to tidal activity. Therefore, volunteers were simply instructed to fill the tubes with mud to the high tide line.

Every second week thereafter the seedlings were monitored by volunteers (using a donated boat) for survival (Yes/No), stem length (cm) and number of leaves present. Any other species observed in or around the restoration site were also recorded and a species inventory created. Monitoring all 295 propagules proved burdensome so efforts were focused on the even numbered encasements of each planting method. Therefore, index plots contained approximately 75 monitored seedlings of each method.

Results

The final complete set of monitoring data was taken on March 16th, 2018. This allowed for three months of growth to be analyzed (see Appendix 7 for photo of monitoring materials used). Table 1 below summarizes the main findings of the final set of monitoring data. The average survival rate of the single encasement method was found to be 75.68% while that of the double encasement method is 93.24%. Therefore, the average survival rate overall is 84.46%.

	Single Encasement	**Double Encasement**
Survival rate	75.68%	93.24%
Average number of leaves	3.72 leaves	3.37 leaves
Average stem length (start)	10.99 cm	11.46 cm
Average stem length (end)	21.16 cm	23.60 cm
Average stem growth	10.17 cm	12.14 cm

Table 1*: Results of final mangrove monitoring data (December 9th, 2017 to March 16th, 2018)*

While the single encasement propagules were found to grow more leaves than the double encasement propagules, it was noted that the average stem length growth of the single encasement was less than those in the double encasement.

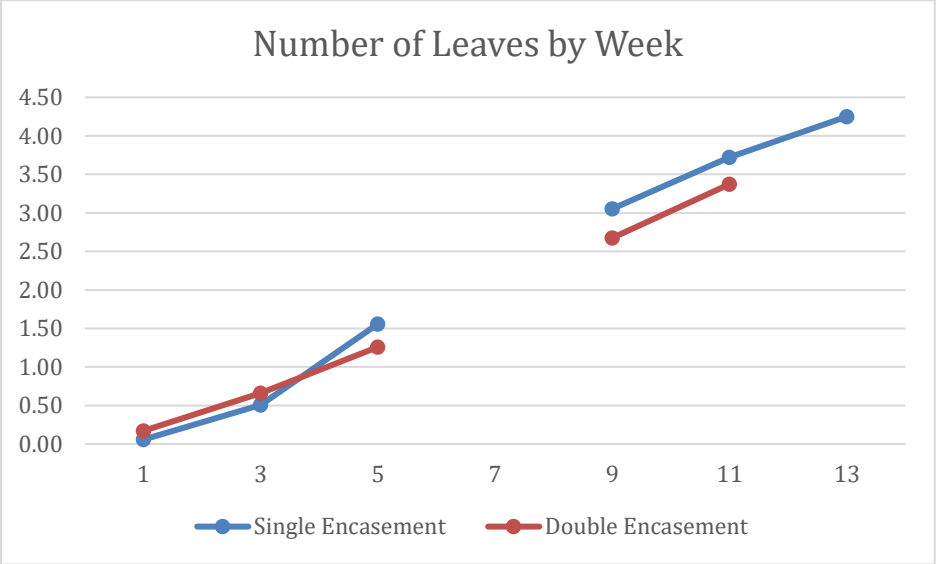

***Figure 1**: Average number of leaves per encasement method by week in 2018.*

Figure 1 shows that while the propagules in the single encasement start with fewer leaves, the rate of leaf growth is greater than those propagules in the double encasements. Meanwhile, the opposite trend is visible for stem growth. Figure 2 shows that while the propagules in the single encasement had a shorter average stem length upon planting, the rate of stem growth is greater in the double encasements over time. EPIC staff and volunteers were unable to monitor during the 7th week, hence the gap in data.

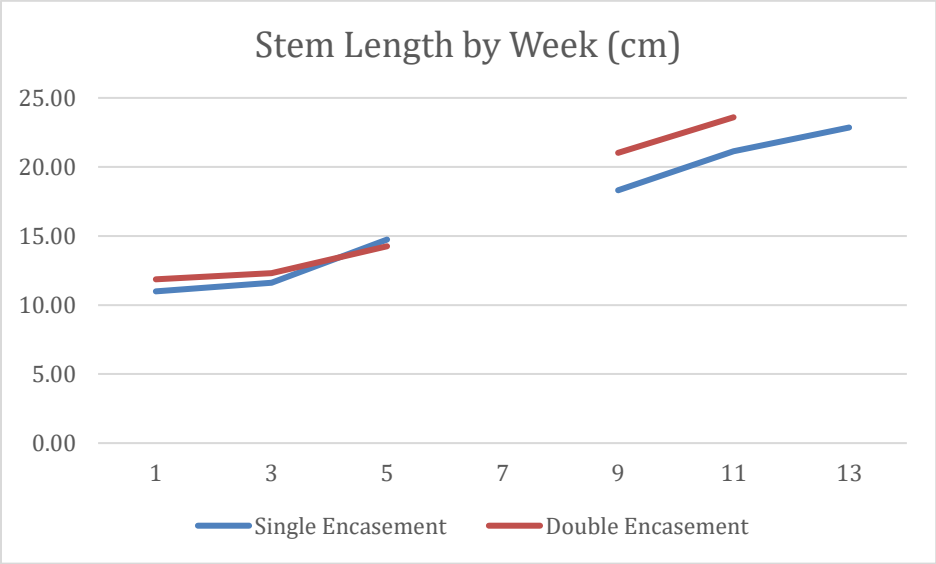

***Figure 2**: Average stem growth per week in centimeters.*

This project resulted in 295 red mangroves being planted at Little Key in the Simpson Bay Lagoon. If the survival rate of 84.46% is maintained, then it can be expected that the mature red mangrove count will increase by 249 trees.

Genus	Common Name	Notes
Cassiopeia frondosa	Upside down jellyfish	
Lobatus gigas	Queen conch	Noticed during final site visit on May 16.
Echinaster echinophorus	Red thorny starfish	
Holothuria mexicana	Sea cucumber	Both in black and orange.
Pelecanus occidentalis	Brown Pelican	Flying over head with a small stop on Little Key.
Tripneustes venricosus	Sea urchin	Dead.
Iguana iguana	Green Iguana	On the island.
Ventricaria ventricosa	Sea Pearl	
Anolis gingivinus	Anguilla bank anole	On the island.
Coenobita clypeatus	Hermit crabs	On the island.
Quiscalus lugubris	Carib Grackle	On the island, in the mangroves.
Egretta thula	Snowy Egret	
Ascia monuste	Great Southern white	On the island (butterfly). Also, its caterpillar.
	Sponge	
	Crab	
	Lycaenid butterfly	

***Table 2**: Species recorded at Little Key during monitoring*

The species of mangrove found at little key include *Rhizophora mangle* (Red mangrove), *Avicennia germinans* (Black mangrove), *Laguncularia racemosa* (White Mangrove) and *Conocarpus erectus* (Buttonwood). The intertwining roots of the mangroves are a nursery ground for numerous juvenile fish species, including Striped Parrotfish (*Scarus croicensis*), Bluehead (*Thalassoma bifasciatum*), Silversides, Herrings and Anchovies (families *Atherinidae, Clupeidae, Engraulidae*). Healthy mangrove stands also act as an important bird roosting and nesting habitat for numerous species.

Discussion

It could be argued that the double encasements were planted a week after the single encasements and therefore their growth progress would be one week behind the single encasement propagules. However, use of the boat to monitor the mangroves could only be secured every other week.

The overall result shows that the single encasements have a higher rate of leaf production while the double encasements display a higher rate of stem growth. At the time of planting it was noted that the height of the double encasements was greater than the single encasements (i.e. there is more PVC above the propagules). This could be due to the PVC couplings which added some height between the two sections of the PVC encasement (see Appendix 10). Therefore, the propagules in the double encasements could have been growing at a faster rate to reach the top of the tube to get sunlight and therefore sacrificing the rate of leaf production as a result. The propagules used in the second planting

included some which were salvaged from the Atlantic shores of St. Maarten. It is also likely that these naturally displayed a different leaf and stem growth rate than those shipped in from Florida.

The 249 surviving red mangroves will mature and create a web of prop roots to further support the nursery function of little Key island. This will feed out to the reefs surrounding Simpson Bay to increase healthy fish populations. The results of the species inventory establish a baseline for the post-restoration biodiversity of this site. While care was taken to note any species observed during monitoring, there was likely a great deal that went unnoticed. However, it can be noted that the appearance of a Queen conch during the final site visit shows promise for increased biodiversity of the site.

Further study, particularly monitoring of species done during different times of the day (all monitoring was conducted from 1600 hrs to 1800 hrs) and during different seasons, would undoubtedly increase the total number of observed species. Still, it is clear that Little Key is home to a wide variety of species and restoration efforts will gradually support a higher biodiversity.

Impacts of Hurricane Irma

Appendix 1 shows Little Key after twelve test encasements were planted in August 2017. It was decided to plant these encasements to gain a better understanding of the preferred method to use for the final planting originally scheduled for November 2017. Meanwhile, Hurricane Irma passed directly over St. Maarten with category 5+ winds on September 6th, 2017. Appendix 2 was taken weeks after hurricane Irma. While five test encasements remained with sprouting propagules inside, the mature mangroves that were established on Little Key were ravaged bare of all leaves and propagules. Since the encasements were able to survive the hurricane while the mature mangrove stands did not, it was decided to go forward with planting. The five propagules that survived in their test encasements revealed no clear preference for the single or double encasement method. Therefore, it was decided to split the final encasements between the two styles and gain a better understanding of the differences over the project period.

Suggestions

Since it can take up to three years for the single encasement mangroves to grow prop roots stable enough to support themselves without the tube, it is suggested to monitor the mangroves at least every 6 months until that time. A full monitoring of survival (Yes/No), stem length (cm) and number of leaves present should be conducted at these 6-month check points. Any PVC tubes containing dead propagules can be removed to reduce chances of the tubes becoming plastic waste in the Lagoon. It is also an option to replace the dead propagule with a healthy one from the nearby mangrove stands if possible. During these check-points debris should be removed from the area and a full inventory of species observed should be recorded.

Once the propagules in the double encasements start making prop roots, it should be assessed if the top section of the PVC encasement should be removed. It is suggested to start monitoring for this in Year 2. Before an impending hurricane, the top sections of the double encasements can be removed to reduce plastic waste in the lagoon if they get blown off. Propagules were found to survive the winds of Hurricane Irma without the top section of the double encasement. However, this could be because

they hadn't grown leaves yet and were therefore more streamlined in the wind. In this case, the top section can also be secured by duct taping the sections and connecting coupling together. Table 3 summarizes the suggested monitoring actions.

	Date	Suggested Action
Year 1	Dec 2017	Mangroves planted.
	Jun 2018	Full monitoring.
Year 2	Dec 2018	Full monitoring. Replace identification numbers on pvc.
	Jun 2019	Full monitoring. Should top section of double encasement be removed?
Year 3	Dec 2019	Full monitoring. Replace identification numbers on pvc.
	Jun 2020	Full monitoring. Possible to start removing single encasements?

Table 3: *Suggested monitoring schedule for mangrove seedlings.*

Additional Materials

Photos of some of the species observed during monitoring can be found in the folder "Little Key Species Inventory" included with this report.

Sources

Bervoets T. (2012) Baseline Environmental and Ecological Assessment of the Mullet Pond Section of the Simpson Bay Lagoon. St. Maarten Nature Foundation

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Appendix

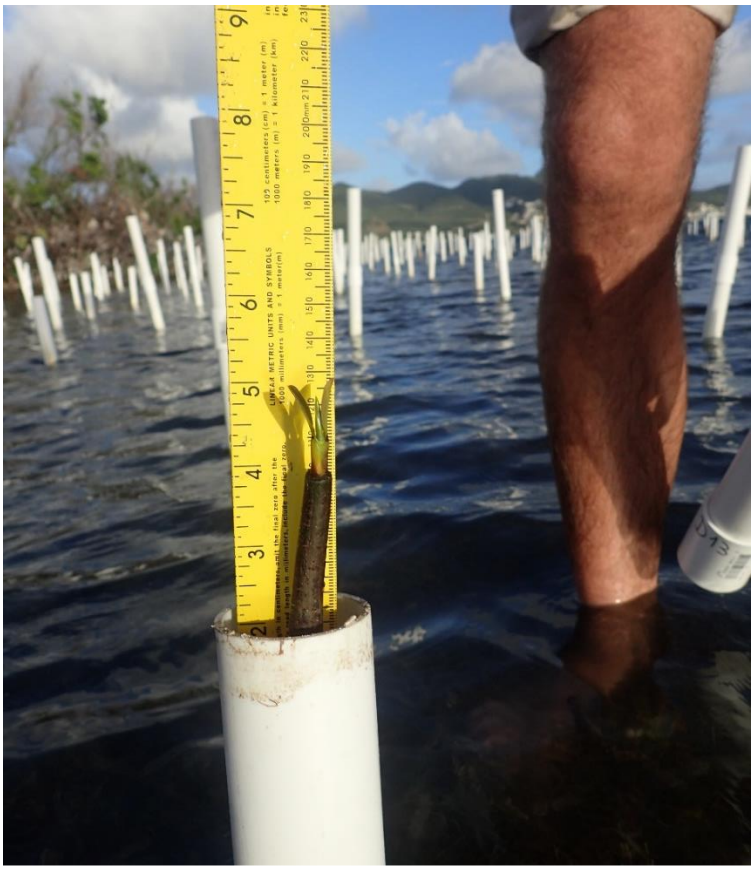
Appendix 1: Little Key before Hurricane Irma, after planting 12 test encasements (August 8, 2017).

Appendix 2: Little Key after Hurricane Irma, five test encasements with surviving propagules (September 2017).

Appendix 3: Little Key post-restoration, 295 PVC encasements in place (May 2018) .

Appendix 4: An encasement with a sprouting propagule that survived hurricane Irma (September 2017).

Appendix 5: Intern, Ani Luna, helping prepare mangrove encasements (November 2017).



Appendix 6: Propagules were monitored for survival, stem length and number of leaves every other week by volunteers and EPIC staff.

Appendix 7: Materials used to monitor the mangroves.

Appendix 8: Mangrove restoration sign.

Appendix 9: View from Little Key over the restoration encasements. Many propagules have started to sprout out of the encasements (May 23rd, 2018).

Appendix 10: On average the double encasement tubes (left) are taller than the single encasement tubes (right).

Sentry Hill Post-Restoration Assessment

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Introduction

The Sentry Hill restoration site is located within the Rainforest Adventures park within the historical Rockland Estate (thus it has been referred to as "Rainforest Adventures" and "Rockland Estate" in previous reports related to this project). The park itself is located on Sentry Hill in Dutch Cul de Sac of St. Maarten. The area designated for restoration is approximately 0.5 hectares in size (Figure 1). This site presented the opportunity to restore degraded secondary forest to what was previously a mature tropical dry forest habitat.

Figure 1: *Map of the Sentry Hill restoration area (Freid, 2017).*
SE corner = 18°02'29.86" N / 63°03'56.98" W elevation 95 ft.
SW corner = 18°02'28.11" N / 63°04'00.75" W elevation 190 ft.
NW corner = 18°02'30.73" N / 63°04'00.55" W elevation 175 ft.

The pre-restoration botanical assessment carried out between July 5th and 9th to establish baseline data on vascular plant diversity and structure revealed that the main invasive species found on site were *Panicum maximum* (Saw Grass/Guinea Grass), Jasmine (*Jasminum flumense*), and *Leuceana leucocephala* (Wild Tamarind). However, it also revealed that the two main vegetation types present within the park were Caribbean Dry Forest and a Saw Grass/Guinea Grass (*Panicum maximum)* grassland. The Caribbean Dry Forest vegetation type was characterized as a *Tabebuia heterophylla* (White cedar*), Leuceana leucocephala* (Wild Tamarind), (*Guapira fragrans* (Black Loblolly*), Pisonia*

subcordata (Mappo*)* Forest/Woodland (Freid, 2017a). The diversity of the immediate restoration area was not as high as areas upslope due to farming and human activity in the past. The assessment revealed that the chosen area for restoration (Figure 2) since it presented a degraded land characterized by invasive species a, rich soil quality and a positive potential for re-establishing natural systems.

Figure 2: An aerial image of the Sentry Hill restoration site (December 2017).

The area recommended for restoration was found to contain semi intact/natural sections with a higher density of native trees and sections almost fully characterized by invasive species. Once invasive species are removed, the density of plants remaining would dictate the planting regime. Figure 2 was

taken in December, after clearing of invasive species was complete. The botanical assessment revealed 41 species observed within the restoration area, see Freid (2017a) for a full list of species identified.

A survey of herpetological and invertebrate diversity was conducted on August 10th (Yokoyama 2017). During the assessment, approximately 73 species were identified. Both the Botanical and Herpetological Assessment were performed before Hurricane Irma to serve as baseline studies to assess whether restoration actions had increased biodiversity at the end of the project. While they no longer serve as baselines due to extensive storm damage, the information is still used as a basis for this final assessment. However, we are hesitant to draw any conclusions about changes in biodiversity based on the initial assessments.

Hurricane Irma

The original project timeline dictated that site preparation would take place in September and October 2017. On September 6th, 2017, Hurricane Irma passed directly over St. Maarten, resulting in a shift in the project timeline. Communication with funders, site owners, and overseas EPIC board members was limited, and the EPIC headquarters had suffered great damage. Therefore, for the initial weeks after Irma the project was mostly on hold. Meanwhile, EPIC Project Coordinator (Kippy Gilders) and Intern (Ani Luna) worked to ensure that funding was still available, site owners were still willing to support restoration efforts, native plants could still be sourced, and technicians were still on island and available for work.

On October 4th, Technician 1 started site preparation, and on September 9th, Technician 2 was hired and started site preparation. Shortly thereafter the company which had been selected to source the 500 plants was going out of business but could still sell us the 212 native plants that were on island and in a decent state. Since site preparation was still underway, we continued to source the remaining 288 native trees. Sourcing 1-gallon pots of native trees and plants became difficult as the majority of nurseries have 3-gallon pots as the minimum size for sale. Therefore, price and general volume of plants to care for increased.

Not only had site preparation become more complicated due to hurricane debris and fallen trees, the Technicians time now involved caring for the plants until planting was possible. The sites were cleared towards the end of November 2017. Until planting, Technicians continued to care for the plants on site, clear out the large amount of dead brush (related to hurricane Irma) and prepare the site for planting.

We were able to source the remaining plants through several on-island growers and nurseries. The main nursery to supply the remaining trees imported them from Miami, limited by damage at the St. Maarten port and a series of hurricanes which prohibited ship traffic. Therefore, plant arrival dictated the planting date. The final plant shipment arrived on January 18th, and planting was carried out from January 22nd to 24th, 2018. During this time, Dr. Ethan Freid (botanist) returned to assist with planting.

Since the restoration site at Cay Bay is smaller in size than the site at Sentry Hill, it was decided to divide the plants so that 150 went to Cay Bay and 350 went to Sentry Hill. The species were evenly

divided so that both sites would receive approximately the same composition of plant species. Due to complications with water accessibility and plants from Florida possible undergoing a shock in response to the immediate change in environment, some plants died before planting could begin. Therefore, 125 plants went to Cay Bay and 309 went to Sentry Hill. Before planting, the trees were tagged to allow for easy monitoring (ex. SG_SNP_1, the first Seagrape at the Cay Bay restoration site within Seaside Nature Park, see Appendix 4).

Methodology

While the restoration site had changed greatly as a result of hurricane Irma (Figure 3), it was decided to go forward with activities as the need for habitat restoration had increased. Since this site (compared to the Cay Bay restoration site) involved the most clearing of invasive species, the Technicians got to work immediately removing hurricane debris and dead brush. The dead brush and broken branches were piled along the boundary wall. This enabled mobility through the site and the eventual mulching of the dead brush with an industrial chipper.

Figure 3: Sentry Hill restoration site after the passing of Hurricane Irma (September 2017).

Planting at Sentry was designated for January 22nd and 23rd 2018. Since the plants were already on site, no transportation was needed. The 309 plants constituted 14 different species and Table 1 provides a list of these different species. Days before planting EPIC staff and volunteers made flags of 14 different colors to match the colors on the plant tags. The day before planting, EPIC staff used the flags to demarcate where the landscapers should plant the trees (Appendix XXX). This was done "blindly" to mimic natural seed dispersal and, following Freid's advice, flags were put no less than 1

meter apart. The Technicians and landscapers then knew at which exact location to start digging holes and planting the trees (Appendix XXXX).

To assist plant survival, TH-1 and Soil Moist Polymer were dispersed around the root ball of the plant after it was placed in the hole and before being covered with topsoil. The TH-1 is a professional growing mix to maintain nutrient retention and proper drainage to create an ideal growing environment. Soil Moist Polymer is a soil amendment which is designed to reduce the need to water plants by up to half, reduce transplant shock and soil compaction and remain effective until it decomposes after the most vulnerable years of the new plants life. Organic fertilizer was also applied to each newly planted tree.

Rainforest Adventures had committed to ordering and installing a water irrigation system for the restoration site. However, impacts of Hurricane Irma had hampered this. Meanwhile, a water hose was installed at the main property of Rainforest Adventures and extended over to the site. Using buckets and backpack sprayers, the Technicians watered the plants. This was done three times a week (Monday, Wednesday and Friday) or as required. When not watering, the Technicians were busy maintaining invasive regrowth and removing any new invasive weed species. In April 2018 the drip irrigation was completely installed, and Technicians no longer had to manually water all 309 plants.

Student scientists from the nearby St. Dominic High School were recruited to monitor the plants at Sentry Hill once a week for 8 weeks. The Student-Scientist program started on January 31st, 2018 with an educational presentation about the project and information on how they would collect the data (XXXX). The program ended on March 28th, 2018 with the final monitoring event. Every Wednesday during the program, nine students worked in groups of 2 (and one of 3) to monitor an index plot of approximately 30 plants per group (XXXX). At the end of each monitoring event the students were given some questions to research for the next monitoring event. This way they also learned about the importance of restoration by active learning and research. They were also in charge of inputting the monitoring data each week in a shared Excel sheet using Google Docs (XXXX). Based on the advice of Botanist Dr. Ethan Freid, they monitored stem height (cm), leaf cover (Good, Medium, or Low), and signs of water stress (Yes or No). Through this program students were taught the basics of terrestrial restoration, plant monitoring, data gathering and data input.

Results

The monitoring data gathered and entered by the Student-Scientists, guided by advice from the Technicians, were used to finalize the post-restoration assessment of Sentry Hill. Despite complications with water accessibility, there were few plant losses after planting. Information from the Student-Scientists pointed to one plant loss in their index plot of 122 plants, a survival rate of 99.2%. On the final day of monitoring (May 15th, 2018), approximately 8 to 12 plants were recorded as dead within the entire restoration area. Approximately 309 plants were planted at this restoration site, resulting in a survival rate of 97.4% to 96.1%. To facilitate plant count, the site was divided into quadrants (Figure 4).

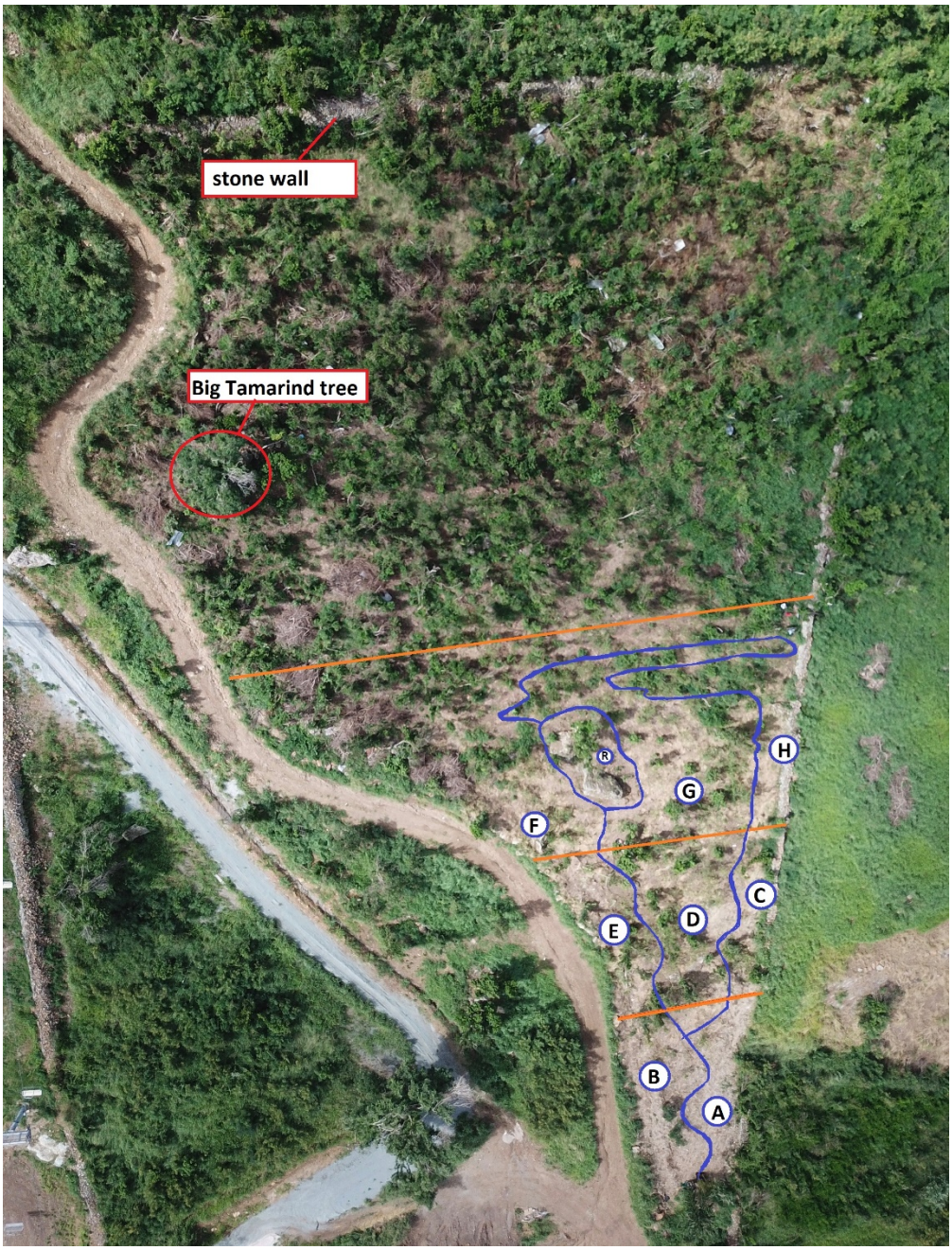

Figure 4: The aerial image of the restoration site demonstrating the different quadrants (A: 36, B: 48, C: 13, D: 34, E: 11, F:25, G: 86, H:47, R:9).

The species that were mainly recorded as dead were Lignum Vitae, Coco Plum, Caper Tree, and a Sage. The Botanical Assessment performed at the beginning of the project reported 41 different species observed within the restoration site. After restoration, eleven more native plant species were added to the site increasing the plant diversity count to 52 (Table 1).

	Genus	Specific Epithet	Common Name	Observed pre-restoration	Planted (and survived)
1	*Tabebuia*	*heterophylla*	White Cedar	x	x
2	*Capparis*	*cynphallophora*	Caper Tree	x	x
3	*Chrysobalanus*	*icaco*	Coco Plum		x
4	*Conocarpus*	*erectus*	Buttonwood		x
5	*Sweitenia*	*mahogonii*	Mahogany		x
6	*Coccoloba*	*diversifolia*	Pidgeon Plum		x
7	*Coccoloba*	*uvifera*	Sea Grape		x
8	*Lantana*	*involucrata*	Sage		x
9	*Guaiacum*	*officinale*	Lignum Vitae		x
10	*Plumeria*		Frangipani		x
11	*Conocarpus*	*erectus var. sericeus*	Silver Buttonwood		x
12	*Bursera*	*simaruba*	Gumbo Limbo	x	x
13	*Bucida*	*buceras*	Black Olive		x
14	*Adenanthera*	*pavonina*	Red Bead Tree		x
				3	**14**

Table 1: Results of final terrestrial monitoring data (January 24th, 2017 to May 15th, 2018).

Observations of the data gathered from the Student-Scientists revealed that measuring stem height may have been more challenging than anticipated. However, despite inconsistencies in data collected, the average stem growth was found to be 5.03cm of all the plants within the index plot during the period of monitoring.

Species		**Average Stem Growth (cm)**
White Cedar	WC	-0.75
Caper Tree	JC	-0.50
Coco Plum	CP	4.22
Green Buttonwood	GB	8.23
Mahogany	MS	12.19
Pidgeon Plum	PP	3.90
Sea Grape	SG	7.22
Lantana/Sage	LI	5.80
Lignum Vitae	LV	1.23
Frangipani	FG	1.47
Silver Buttonwood	SB	12.31
		5.03

Table 2: Average Stem growth per species and overall (in bold).

The average stem growth for the Lignum Vitae (*Guaiacum officianale*) and Caper Tree (*Capparis cynophallophora*) were found to be 1.23cm and -0.50cm respectively. This is in line with the fact that

Lignum Vitae is extremely slow growing and that the Caper trees underwent a shock upon arrival and were trimmed to allow new growth by the Technicians. Meanwhile, the Sage (*Lantana involucrate*) was found to have grown 5.80cm from the data collected and is consistent with onsite observations (XXXX)

The species of plants, insects and retiles recorded on site pre-restoration can be found in the Botanical Assessment (Freid, 2017a) and the Herpetological Assessment (Yokoyama, 2017), respectively. The regionally endemic ground lizard, *Pholidoscelis plei analifera*, and the Anguilla bank anole, *Anolis gingivinus*, are both endemic to the Anguilla Bank were often seen at the restoration zone.

Genus	**Common Name**		**Notes**
Iguana iguana	Green Iguana		Nesting on site.
Anolis gingivinus	Anguilla bank anole	*	Regional endemic.
Anolis pogus	Bearded Anole	*	Endemic to St. Maarten.
Ascia monuste	Great Southern white	*	Very attracted to Sage.
Danaus plexippus	Monarch butterfly		Very attracted to Sage.
Pholidoscelis plei	Ground Lizard		
Argiope argentata	Silver Argiope	*	
	Ant	*	
	Bees	*	
Chilocorus cacti	Lady bug	*	
	Millipedes	*	Multiple species seen, unidentified.
	Tarantula	*	
	Dragonfly	*	
	Moths	*	

Table 3: Species of insects, reptiles and amphibians recorded at Sentry Hill during monitoring (*= presence during Pre-restoration Assessment).

Table 3 lays out the species of insects, reptiles and amphibians which were identified during watering/monitoring visits to the restoration site. The Asterix (*) denotes that this was also recorded during the pre-restoration assessment conducted in August 2017. There were also a number of vertebrates that were observed on site, these are outlined in Table 4.

Genus	**Common Name**	**Notes**
Quiscalus lugubris	Carib grackle	
Columbina passerina	Common ground Dove	
Coereba flaveola	Bananaquit	Nesting in newly planted White Cedar Tree.
Loxigilla noctis	Lesser Antillean bullfinch	
Patagioenas leucocephala	White-Crowned Pigeon	
Egretta caerulea	Little Blue Heron	adult

Table 3: Vertebrate species recorded at Sentry Hill during monitoring.

Discussion

The final terrestrial monitoring data points to an increased diversity of plant species within the restoration site. While this might point to an increased botanical diversity on a technical level, according to Freid (2017b), it is the establishment of a forest/shrubland structure that is a better indicator of the restoration of the area to a more natural/semi-natural state.

The results of the species inventory establish a baseline for the post-restoration biodiversity of this site. While care was taken to note any species observed during monitoring, there was likely a great deal that went unnoticed. Further study, particularly monitoring of species done during different times of the day (all monitoring was conducted from 1400 hrs to 1600 hrs) and during different seasons, would undoubtedly increase the total number of observed species. Still, it is clear that the Sentry Hill restoration site is home to a wide variety of species and restoration efforts will gradually support higher biodiversity.

Insects in particular are often dependent on specific host plants, and their localized diversity will typically correlate with the diversity of vegetation. Therefore, by adding eleven species of native plants to the site, there shows promise for increased insect diversity with time. The main pressures against successful restoration on site is the difficulty of watering all plants. Provided that the drip irrigation system is properly maintained and used, the plants will continue to flourish until their roots reach the ground water and additional watering is no longer necessary.

The increased native plant species diversity and the potential of re-establishing tree canopy cover over areas of the restoration site point to increased native plant undergrowth, reduced sun exposure and to an increased diversity of habitats to benefit faunal diversity. It is important to note that benefits of restoration will not be visible immediately and care should be taken to foster restoration efforts to reap the eventual rewards of increased biodiversity. Overall, restoration was successful

While data gathered from the Student-Scientist proved difficult to analyse, results still pointed to an overall stem growth of the index plot with growth rates of each species in line with what would be expected (i.e. Lignum Vitae is slow growing).

There are semi intact/natural sections of the project area that have higher densities of native trees and once those locations have removal of the invasive species only small numbers of new plants will need to be added. In these areas once the non-natives are removed the native vegetation will continue to grow, set seed and form a more natural forest structure and have the diversity of the surrounding area without heavy management. In areas that have higher densities of non-native invasive species most or all the vegetation will be removed and there will be a need for denser plantings in these areas (one per square meter).

Suggestions

If the site owners wish to further restore the site, then it can be suggested to put smaller plants around taller shade baring trees. This would allow for the smaller plants to be protected from the elements while they mature. Creating islands of healthy trees which will seed and spread outwards naturally.

Additional Materials

Photos of some of the species observed during monitoring can be found in the folder “Sentry Hill Species Inventory” included with this report.

Sources

Freid, E. H. (2017) Rockland Estates Restoration Project Rapid Botanical Assessment. Leon Levy Native Plant Preserve. Bahamas National Trust.

Yokoyama, M. (2017) Rockland Estate Terrestrial Diversity Assessment. Les Fruits de Mer.

Appendix


TRUE TEMPER


Our ongoing restoration projects
European overseas territories host over 70% of the EU's biodiversity!
Planting native trees at:
1. Sentry Hill (Dry forest)
2. Cay Hill/Bay (Dry forest shrubland)
3. Little Key (Wetland/ mangrove)
EPIC to restore key areas of biodiversity
BEST

Drip system

Appendix 1: Looking towards the Lignum Vitae after hurricane Irma (September 2017).

Appendix 2: Looking towards the Lignum Vitae after restoration efforts (May 2018).

Appendix 3: After restoration work. Dried prickly Acacia fence bordering walking path.

Appendix 4: Plants were cared for until planting was possible. Pictured here: A volunteer tagging plants in the makeshift nursery located at the Sentry Hill restoration site (January 2017).

Appendix 5: Landscapers planted the trees after Dr. Ethan Freid placed them randomly throughout the restoration site (January 2018).

Appendix 6: Water was initially transported by bottle and tuck following planting. Pictured here: Dr Ethan Freid (left) and Kippy Gilders (right).

Appendix 7: Shortly after planting, a 1000gallon water tank was installed near the restoration site to facilitate watering.

Appendix 8: Mulch was placed around the plants to facilitate water retention. Rocks were used to keep the mulch in place.

Appendix 9: The plants suffered damages from livestock. On occasions, plants were found fully uprooted.

Appendix 10: The plants suffered damages from livestock. Seagrapes were grazed almost bare.

Appendix 11: Protective cages were made using upside down tomato cages and dried prickly Acacia branches.

Appendix 12: After livestock were fenced in, plants started to make a recovery.

Appendix 13: After livestock were fenced in, plants started to make a recovery. Pictured here: a seagrape protected by an upside-down tomato cage wrapped in chicken wire. This proved most effective while livestock were free-roaming. However, to cage and wire all plants would be too costly and time consuming.

ENVIRONMENTAL PROTECTION IN THE CARIBBEAN

BEST VOLUNTARY SCHEME FOR BIODIVERSITY AND ECOSYSTEM SERVICES IN TERRITORIES OF EUROPEAN OVERSEAS

RESTORATION SITE MAINTENANCE BEST PRACTICES

The following guide summarizes the best practices for restoration site maintenance as learnt by Environmental Protection in the Caribbean (EPIC) Foundation during the BEST 2.0 Project #1645 "Restoration of Key Biodiversity Areas of St. Maarten". The tree saplings were planted during an intensive planting period on January 22, 23 and 24, 2018. Since then, EPIC has monitored the survivorship of the new plants and will continue to do so until May 15, 2018.

Watering & Monitoring

The water needs of different plants vary greatly and monitoring plant water status is paramount to ensuring good survivorship. Some factors that affect water needs include the species and age of the plant, the type of soil in which it is planted, and sun exposure. The signs of water stress may be similar to the symptoms of over watering or even to some pest and disease problems. It is important to identify the causes of the problem to take corrective steps. Staff need to understand signs of water stress so that additional water can be added as needed.

Ideally, new plants should be monitored for the first six months to ensure survivorship. **Table 1** summarizes how EPIC has monitored the plants from Week 1 to 17 (January 22 to May 15, 2018) and how it is recommended to continue until Week 32 (August 31, 2018).

Week	Monitoring
Weeks 1 to 10: (Jan 22 - Mar 30, 2018) [by EPIC]	Water stress: Technicians monitored three times a week (Monday, Wednesday and Friday). On these days they watered all trees but gave specific attention to those trees showing signs of water stress. Weeds and invasive species were removed as needed. Growth and survivorship: Student Scientists monitored the plants once a week.
Weeks 11 to 17: (Mar 31 - May 15, 2018) [by EPIC]	Water stress: Technicians monitored the plants three times a week (Monday, Wednesday and Friday) for signs of water. During this time, they also removed weeds and invasive while they watered the trees. Technicians and EPIC staff were responsible for monitoring growth and survivorship.
Weeks 17 to 32: (May 16 - Aug 31, 2018)	Water stress: It is suggested that site staff monitor the trees for water stress at least once a week. However, this would rely on weather conditions and should be increased to two or three times a week if necessary. Weeds and invasive species: Weeds and invasive species should not be allowed to become predominant. They should be removed at least once a month during the remainder of the six-month period, and then once every ~6 months until the native trees are full enough to naturally inhibit invasive species growth.

Table 1: Recommended plant care regime from week 1 to 32.

It is found that most of the plants can survive with a continuous low level of water stress but will not survive with a high level of water stress for a short period of time (i.e. it is better to water a little bit on a consistent basis than to water adequately on an inconsistent basis). If a plant is in water stress, they will likely recover when watered. Even plants that appear to be dead, having dropped all or most of their leaves, might recover when watered. Scrape the outer layer of a twig or the bark to see

if a green layer exists indicating it is still alive. Do not remove this plant right away, wait a few months to see if it recovers.

<u>Some plant water stress (dehydration) symptoms include:</u>

- Curling or rolling of leaves
- Shiny leaves become dull
- Slowed/no growth, undersized leaves
- Leaves, blossoms, or fruits drop prematurely
- Wilting, limp and droopy leaves (**Figure 2**)
- Leaf scorch, yellowing and/or browning, death of leaf edges
- Dead or brown/dying extremities starting from the outer leaves inward

Figure 1 and 2: Typically, water stress is observed as leaves becoming droopy and flaccid. On the left is a buttonwood (*Conocarpus erectus*) before planting (Figure 1). On the right is one of the buttonwoods after planting in an extreme state of water stress. The leaves are droopy, flaccid and have begun to drop (Figure 2).

Mulching

To avoid water stress from dehydration, mulch can be added around the plant stem. Pine mulch from local hardware stores has been proven sufficient. Take care to keep mulch away from stems. Some of the benefits of mulch include: providing an insulation layer, conserve soil moisture, improve soil's physical structure, prevents erosion and water runoff, and reduces root competition. We found that rocks can be used to ensure that mulch does not get blown away or removed while watering (**Figure 3**).

Figure 3: Mulch is used to improve moisture retention at the Cay Bay restoration site. Rocks ensure that mulch stays in place.

Nature Trail Maintenance

- *Trail Construction:* In most cases, the native material found during trail construction will be satisfactory for surfacing the trail. Therefore, to create and maintain a nature trail, clear the area of plants, weeds and stumps. Many of the stumps along the trail at the Sentry Hill restoration site were too laborsome for EPIC staff and volunteers to remove (**Figure 4**). These should be removed to ensure hiker safety.

Figure 4: Stumps that were too laborsome for EPIC staff or volunteers to remove.

- *Clearing width:* The width cleared for hikers to pass without obstruction by brush, grass, weeds, etc. This width should be maintained by pruning limbs or branches that protrude into the path. Four feet is the average standard trail width, some variation is allowed and encouraged.
- *Clearing height:* It is sometimes suggested to clear the path to a height of 8 feet. This may not be feasible given materials and actual canopy height. Minimum cleared height should be 6 feet at the least.

- *Trail demarcation:* Rocks or logs can be lined up along the trail to demarcate the path which hikers can walk on (**Figure 5**). If the path is clearly marked then hikers are less likely to "shortcut" or go off-trail, this will reduce the demand of trail maintenance because the consistent tread will naturally prevent growth of weeds.

Figure 5: Rocks and logs clearly demarcate the path for hikers to walk on.

Invasive Control

Several highly invasive species are prevalent at the restoration sites. Although they were removed during the project, it is likely that new invasive seeds will germinate, and stumps can regrow. Therefore, it is necessary to maintain the site for invasive species until the native trees have created a tree canopy dense enough to prohibit invasive growth. Until then, monitoring of the sites for invasive species needs to be done regularly (~every six months minimum).

The prevalent invasive species include: Saw Grass/Guinea Grass (*Panicum maximum*) (**Figure 6**), Jasmine (*Jasminum flumense*) (**Figure 7**), Wild Tamarind (*Leucena leucocephala*) (**Figure 8**) and Acacia (*Acacia farnesiana*) (**Figure 9**). Each of these species are aggressive and will out compete local vegetation and reduce diversity.

Figure 6: Invasive grass, Saw Grass/Guinea Grass (*Panicum maximum*).

Figure 7: Invasive vine, Jasmine (*Jasminum flumense*) (Photo by Dr. Ethan Freid).

Figure 8: Invasive Wild Tamarind (*Leucena leucocephala*) (Photo by Dr. Ethan Freid).

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Figure 9: Acacia (*Acacia farnesiana*) (Photo by Dr. Ethan Freid).

For the Acacia (*Acacia farnesiana*) and Wild Tamarind (*Leucena leucocephala*), to fully ensure they do not grow back the stumps need to be killed. This can be done through manual removal of the stump or through the small application of Garlon© to the stump after cutting. During the project we used

Eraser© which is available at Greenfingers. If a small amount of Eraser© is mixed with vegetable oil, it can be "brushed" over the freshly cut stump. It is not as powerful as Garlon©. An organic option is to keep cutting the bark off the stumps as they regrow (**Figure 11**). Eventually they will be weakened, die and decay into the soil. The size of the stump should give a good indication if manual or chemical removal is warranted. **Figure 10** shows a Wild Tamarind (*Leucena leucocephala*) that is "stump sprouting", this will continue until the plant has been killed.

Figure 10 and 11: On the left is a Wild Tamarind (*Leucena leucocephala*) that is stump sprouting. On the right is a stump that has been "barked" to remove the stump sprouts and weaken the plant.

The root systems of Carolito (*Antigonon leptopus*) and Jasmine (*Jasminum flumense*) also need to be killed or manually removed. For the Saw Grass (*Panicum maximum*) it can be removed with the root system with a pic-axe and shovel. To reduce erosion in these areas the removed clumps of the grass should be laid out on the ground. This will reduce water runoff. Sections of the path at the Sentry Hill restoration site will become regrown with Carolito (*Antigonon leptopus*) if not fully removed (**Figure 12**).

Figure 12: Carolito (*Antigonon leptopus*) that will obstruct the path at the Sentry Hill restoration site if not removed and maintained.

Livestock

Free roaming livestock can have a catastrophic impact on plant survivorship. While horses have been found to have a mild but unobtrusive relationship with the new trees, goats have been found to reduce (eat) plants to merely a few inches tall overnight. Some plants seem to be more appealing for the goats - such as seagrapes, pigeon plums and silver buttonwood. Cages (**Figure 13 and 14**) can be made to protect the plants but this method is costly. On average, one cage costs $10. Ideally the impact of the goats should be reduced by caging in the restoration area or the goats, whichever method is more effective.

Figure 13 and 14: On the left are cages made to protect newly planted seagrapes from free roaming goats. On the right are new leaves growing with the removed pressure of the goats.

Sources:

North County National Scenic Trails. A Handbook for Trail Design, Construction, and Maintenance. (August 1996) North Country National Scenic Trail United States Department of the Interior. National Park Service