HURRICANE EFFECTS ON MAGENS BAY ARBORETUM AND MANAGEMENT RECOMMENDATIONS

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COVER PHOTO: MEGAN'S BAY PARK BEFORE THE 2017 HURRICANES, AFTER HURRICANE IRMA, AND 18 MONTHS AFTER THE HURRICANES (FROM LEFT TO RIGHT.

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INTRODUCTION

Arthur S. Fairchild established the Magens Bay Arboretum in 1946 with the intent for it to be open and nondiscriminatory of "race, creed, color or national origin"[1]. Unfortunately, due to the two devastating category 5 hurricanes that hit St. Thomas in September of 2017, the Arboretum is currently inaccessible. Previous uses of the Arboretum included photography, running, spiritual activities, bird watching, nature hikes, and research. However, without a trail, these are no longer possible because the trails are unidentifiable and unnavigable. Due to its ecological importance, recreational and educational potential, and cultural attributes such as the historical ruins and Fairchild trees, the Arboretum retains significant value to the community.

Hurricanes Irma and Maria in September 2017 caused significant wind damage in the Magens Bay Arboretum. Climate change is predicted to cause more frequent and intense hurricanes, so it is important to understand how the wetlands in the USVI have responded to two intense back to back hurricanes and how the system will respond moving forward. The Arboretum provides a unique opportunity to predict how other Caribbean forests may be affected by similar scenarios. The purpose of our research was to understand the resistance to and recovery from severe storm damage of native and non-native trees in the Arboretum. Native trees have evolved adaptations that ensure their survival in their habitat and as such are potentially more resilient to severe wind damage from hurricanes[2]. Non-native tree species lack these adaptations and will therefore incur more damage[3]. Native Caribbean tropical forests have been shown to have low tree mortality after disturbance and trees are able to regrow allowing for a faster recovery compared to forests comprised of non-native species[4]. It is important to consider the ecological resilience of the Magens Bay Arboretum because it provides ecosystem goods and services. Ecosystem services are benefits provided by nature that benefit humans[5].

FIELD WORK IN THE ARBORETUM

The 2018 UVI Master of Marine and Environmental Science (MMES) Cohort collected data in the Arboretum on the species of trees and the damage associated with them from the hurricanes. We recorded fallen trees that were still alive and sprouting, as well as data on young trees (seedlings and saplings) that began growing in the wake of the storms. We randomly situated a total of 18 plots sized 10m x 10m throughout the Arboretum to provide an adequate sample to represent the entirety of the Arboretum.

We evaluated the resilience of the Arboretum by measuring resistance and recovery from the hurricanes for native and non-native tree species. Post major wind disturbance events, we expected: 1) non-native trees to have more damage than native trees, 2) native trees to have recovered more quickly than non-native trees, measured by the presence of sprouts, and 3) non-native tree species to have more new growth than native tree species, measured by the number of seedlings. We identified, measured, and assigned all trees to damage categories: no apparent damage, loss of main branches,

leaning, snapped, and uprooted/fallen. We assessed all trees, standing and fallen, for the presence of sprouts, and in the first ten plots, we measured and categorized the sprouts. Within each plot, we established nine subplots where we identified and measured seedlings.

For long-term recovery research, we will establish 3 permanent plots from the 18 plots used in this study (see Figure 2). University of the Virgin Islands' researchers will use the long-term plots to evaluate the disturbance recovery and ecological changes to the unaltered habitat over time. The data collected in this study will serve as a baseline to compare to future studies in the permanent plots.

Figure 2. Site map outlining of Magens Bay Arboretum with the 18 plots with long term plots outlined in red.

Figure 3. MMES Students, Jessica Michael, Dan Mele, and Naomi Huntley (left to right), conducting research at Magens Bay Arboretum in February 2019

RESULTS

We discovered that the majority of trees in the Arboretum are not native to St. Thomas (see Appendix A). These tree species have the potential to cause adverse effects to the Arboretum's natural habitat. Non-native species will continue to sustain greater damage from future hurricanes, and also may become invasive and outcompete native species for light and water.

The adult native trees received less damage from the hurricanes compared to the adult non-native tree species. We found 58% of non-native trees experienced some degree of damage, while only about 40% of natives displayed visible damage (see Figure 5). The most prominent tree species found across our 18 plots was the copperpod (*Peltophorum pterocarpum*). Of all tree species that had fallen over within our plots, copperpod was the only species to grow sprouts from its trunk to continue living (see Figure 6). This observed trend has serious implications about the invasiveness of copperpods. Successful invaders are stronger competitors than native species, due to their weedy characteristics, such as fast growth rates and high reproductive rates[6,7]. Copperpod is a fast growing tree that prefers open or disturbed forest conditions[8,9]. These trees sustained heavy damage and likely caused damage to surrounding native trees as they fell over. Once knocked over, the trees remained alive and began growing sprouts out of the trunk and now cover a larger area of the forest floor than before the storms.

A key result we observed was the higher diversity and abundance of juvenile native tree species compared to non-natives (Appendix B). We found 16 species of native juvenile trees while only 10 species of native adult trees were identified. There were equal number of non-native juvenile and adult trees. Of the juvenile trees that started growing following the storms, non-native trees were larger in size but not in abundance. This implies that both native and non-native juvenile trees have begun to recover, but the non-natives are growing at a faster rate, may soon over shade the natives, and become more dominant in the Arboretum (see Figure 7 and 8).

NEXT STEPS AND PROPOSED ACTIONS

Surveys were conducted, to determine stakeholder values to identify restoration targets (Appendix D. Figure. 9). Structured Decision Making (SDM) protocol and field research was used during the development of this report because it allowed us to prioritize necessary actions for the restoration of the Arboretum while equally representing the ecological, recreational, and cultural needs of the space and community.

ECOLOGY

Due to the frequency of hurricanes, policies and procedures should be established and enacted now, before future severe storm events, to minimize the overall damage within the Arboretum. The first steps in restoration should focus on establishing a mostly native plant/forest vegetation population within the Magens Bay Arboretum because we found that natives are better adapted to withstand wind disturbance. Selective removal of aggressive, non-native tree species will reduce the amount of damage and debris within the Arboretum following future hurricanes. To ensure that the juvenile native trees are protected, we recommend some debris removal be conducted by hand (with the aid of chainsaws) instead of using heavy machinery[10]. This will help preserve the native seedling biodiversity, which will help increase the resiliency of the forest. It is important to restore native wetland plants (See Appendix A) because they affect the water quality within the system, which in turn affects the water quality input into Magens Bay[11]. The vegetation and hydrology are interdependent, as they rely on each other to maintain balance.

Some species within the arboretum are capable of exceedingly rapid regeneration (such as copperpod) and in order to keep the Arboretum functional and healthy, removal and control of these species are critical. Reduction of non-native species will allow the natives the opportunity to recover and thus increase the resiliency of the Arboretum. In studies conducted elsewhere, biodiversity was higher in areas in which the invasive trees were removed compared to areas that had no invasive vegetative species management[12]. The following suggestions are aimed at controlling the non-native copperpod, as it is the dominant species, but can be applied to other unwanted non-natives. The recommended removal strategy is adapted from local guidance for removal and control unwanted non-native species[13].

- Marking trees for removal and for protection (i.e., Fairchild trees, natives)
- Cutting adult copperpod trees to ground level with a chainsaw
- Treating copperpod stumps with concentrated herbicide to prevent sprouting
- Removing juvenile copperpods

Other management suggestions for the arboretum include removal of some debris and management of non-native mammalian predators. The removed debris can be repurposed to create trail substrate by wood chipping the debris to maintain nutrient cycling[14]. Even though copperpod is not a hard wood, it can potentially be used for building fencing, signage, or boardwalks. Consideration of trail placement should ensure minimal disruption or damage to the native habitat, including the wetlands, allowing the juvenile natives the ability to mature and claim a larger proportion of the Arboretum. Invasive mongoose, rats, and cats have led to the decline and extinction of numerous fauna, and show considerable overlap in prey selection, ranging from birds, reptiles, amphibians, insects. Control efforts by trapping and euthanizing invasive animal species are essential for improving and sustaining the ecological functionality of the Arboretum[15,16,17]. The ecosystem services of the Arboretum have not fully assessed, however other forests provide regulating ecosystem services such as carbon sequestration and storage and improved hydrology by reducing erosion and storm water runoff. The actions necessary to complete this goal include:

- Establishing permanent research plots (see Figure 1)
- Removing debris from potential trails by hand
- Repurposing removed debris as wood chips for a trail
- Restoring plant community with native plants
- Reducing and controlling the invasive wildlife populations

Although the initial effort will be laborious, the long-term resiliency of the Arboretum will be improved, and ecological integrity and function will be restored more quickly following severe storms with a habitat comprised of mostly native tree species.

RECREATION AND EDUCATION

The Arboretum is currently not safe for visitors to pursue recreational activities or educational opportunities. To restore these aspects of the Arboretum, the following actions have been outlined:

- Debris removal and relocation
- Planning and establishing trails
- Creating signs and plaques out of copperpod debris for the Fairchild trees
- Establishing usable outdoor spaces (i.e. education space, benches, exercise stations)

Hurricane debris has made the Arboretum unsafe to access and diminished the potential function for recreation. First, trails should be mapped with consideration for allowing access to the historical ruins, length of trail, potential for educational aspects

(such as learning about the Fairchild trees), consideration for ecological features, and other activities based on public need. Once trails are mapped, removal of debris, such as dead trees, brush and trash, can begin along potential trails. Vegetative debris outside the proposed trail areas should be left to provide nutrient input back into system. We recommend involving the community to provide and foster a sense of ownership and accomplishment for locals, as well as increase awareness about the changes being done to the Arboretum. In addition, we recommend signs, plaques, and maps be created and installed to increase educational potential through identifying characteristics within the Arboretum.

CULTURE AND HISTORY

The Arboretum is an important cultural location on St. Thomas because of its rich history and evolution of use. To preserve the historical and cultural significance of the Arboretum, several actions need to be taken including:

- Permanently marking Fairchild trees (Appendix E)
- Improve safety to visitor sand preservation of ruins by establishing barriers to access
- Creating trails to ruins and Fairchild trees

Even though the Fairchild trees are not native plants, they are an important part of the historical significance of the Arboretum. Identified Fairchild trees need to be marked for protection (see Appendix E). Additionally, there needs to be consideration for preserving and displaying the ruins in the Arboretum. Allowing access can act as an educational opportunity for the community about historical land use, which in turn can encourage more local efforts to protect other ruins[18]. Once the ruins are protected, trails to the ruins can be added to allow the public to access this historical aspect of the Arboretum.

LONG-TERM MAINTENANCE PLAN AND RESEARCH

Many of these actions require long-term attention to ensure their persistence, thus a maintenance plan needs to be developed by stakeholders, including UVI researchers and Magens Bay Authority. This plan should build upon the recommendations made in this document and include a timeline of actions to be taken by a designated maintenance team. For reference, there is a comprehensive and user-friendly booklet highlighting invasive species that contains potential management strategies for each species identified that could be applied to the Arboretum[13].

Figure 4. Locations of long-term plots to be established within the Arboretum. These plots will be used for long term research of the non-managed natural progression of the Arboretum. These plots can be compared to the managed areas in the Arboretum to evaluate differences overtime.

APPENDIX A – ADULT TREES IN THE ARBORETUM

List of adult trees found within the survey plots.

	Common Name	Scientific Name	Count of Species
Native			**53**
	Tyre Palm	*Coccothrinax alta*	23
	Gre-gre	*Bucida buceras*	12
	Pig Turd	*Andira inermis*	6
	Royal Palm	*Roystonea borinquena*	4
	Pigeonberry	*Bourreria succulenta*	2
	Spanish Cedar	*Cedrela odorata*	2
	False chiggergrape	*Coccoloba venosa*	1
	Shortleaf Fig	*Ficus citrifolia*	1
	Sugar Ant	*Ginoria rohrii*	1
	Velvetseed	*Guettarda oderata*	1
Non-native			**104**
	Copperpod	*Peltophorum pterocarpum*	54
	Thatch Palm	*Thrinax spp.*	15
	Christmas Palm	*Veitchia merrillii*	9
	Genip	*Melicoccus bijugatus*	8
	East African Mahogany	*Khaya anthotheca*	3
	Noni	*Morinda citrifolia*	3
	West Indian Almond	*Terminalia catappa*	2
	Martinique Magnolia	*Barringtonia spp.*	1
	Papaya	*Carica papaya*	1
	Wild Almond Tree	*Sterculia foetida*	1
		Unidentified non-native	7
Unidentified		Unidentified	5
			Total: 162

APPENDIX B – SEEDLINGS FOUND IN THE ARBORETUM

List of seedlings found in the survey plots.

	Species of Seedlings	Number of Individuals
Native		**235**
	Eugenia biflora	72
	Guettarda odorata	37
	Coccoloba venosa	30
	Eugenia procera	19
	Andira inermis	15
	Ginoria rohrii	15
	Bourreria succulenta	10
	Citharexylum spinosum	10
	Cedrela odorata	7
	Manilkara bidentata	5
	Capparidastrum frondosum	4
	Casearia guianensis	3
	Eugenia monticola	3
	Cordia alliodora	2
	Coccothrinax alta	1
	Terminalia buceras	1
Non-native		**106**
	Peltophorum pterocarpum	75
	Melicoccus bijugatus	7
	Triphasia trifolia	6
	Couroupita guianensis	4
	Leucaena leucocephala	5
	Melia azedarach	2
	Morinda citrifolia	4
	Carica papaya	1
	Veitchia merrillii	1
	Non-Native Palm	1
Unidentified		13

APPENDIX C

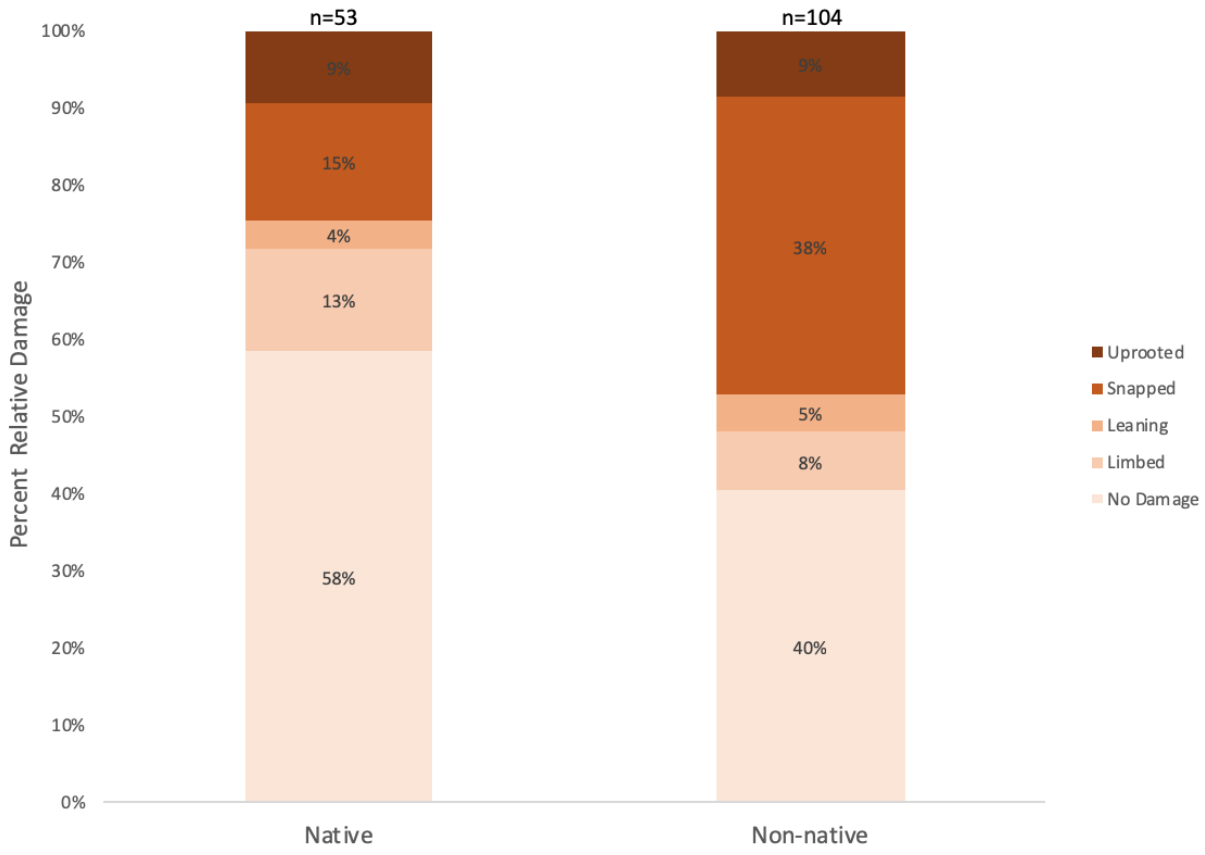

Figure 5. Abundance and damage category of native/non-native trees

Each of the bars show the percentage of native or non-native trees in each damage category. The colors represent the different damage categories. The number above the bars indicates how many individuals were found within our plots. Non-native trees (58%) have a higher frequency of damage than the native trees (40%) (Pearson's Chi squared test; $p<0.01$). Non-natives were more abundant than native trees. (Pearson's Chi squared test; <0.05)

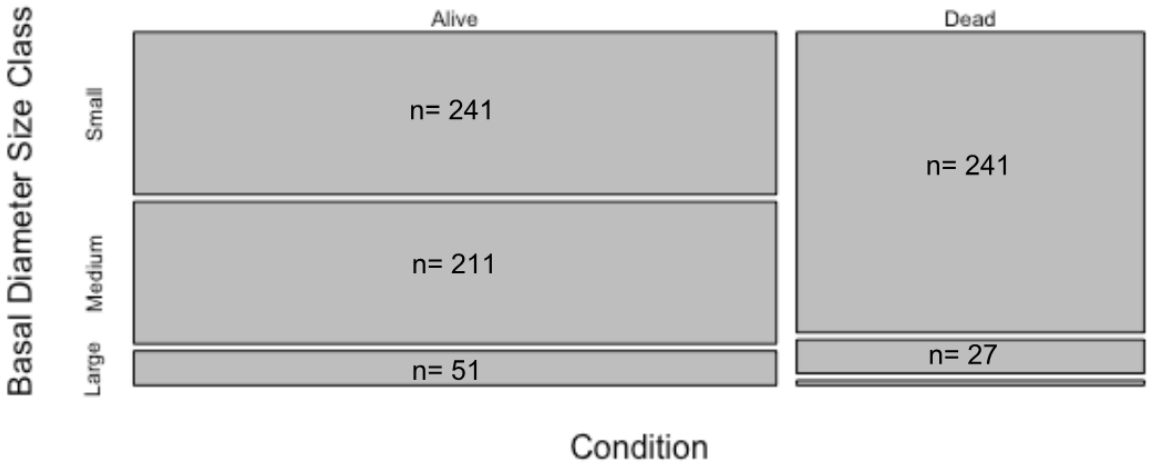

Figure 6. Size and condition of sprouts

Columns represent alive sprouts and dead sprouts (left to right), and the width represents the abundance, visually showing there were more alive sprouts compared to dead. Row height represent the abundance of sprout size categories (small, medium, and large, from top to bottom), visually showing that the majority of living and dead sprouts were small, with only a few large living and dead sprouts. Within our plots, no native downed trees had sprouts and only one species of non-native downed trees had sprouts (Copperpod).

These results demonstrate that the non-native copperpod, although not resistant to wind damage, is resilient because it is able to fall down and resprout. Although the majority of the sprouts are currently alive, their small size suggests potential for future mortality. The overwhelming number of sprouts on downed copperpods implies that they are growing back at alarming rates and have the potential to further spread throughout the Arboretum.

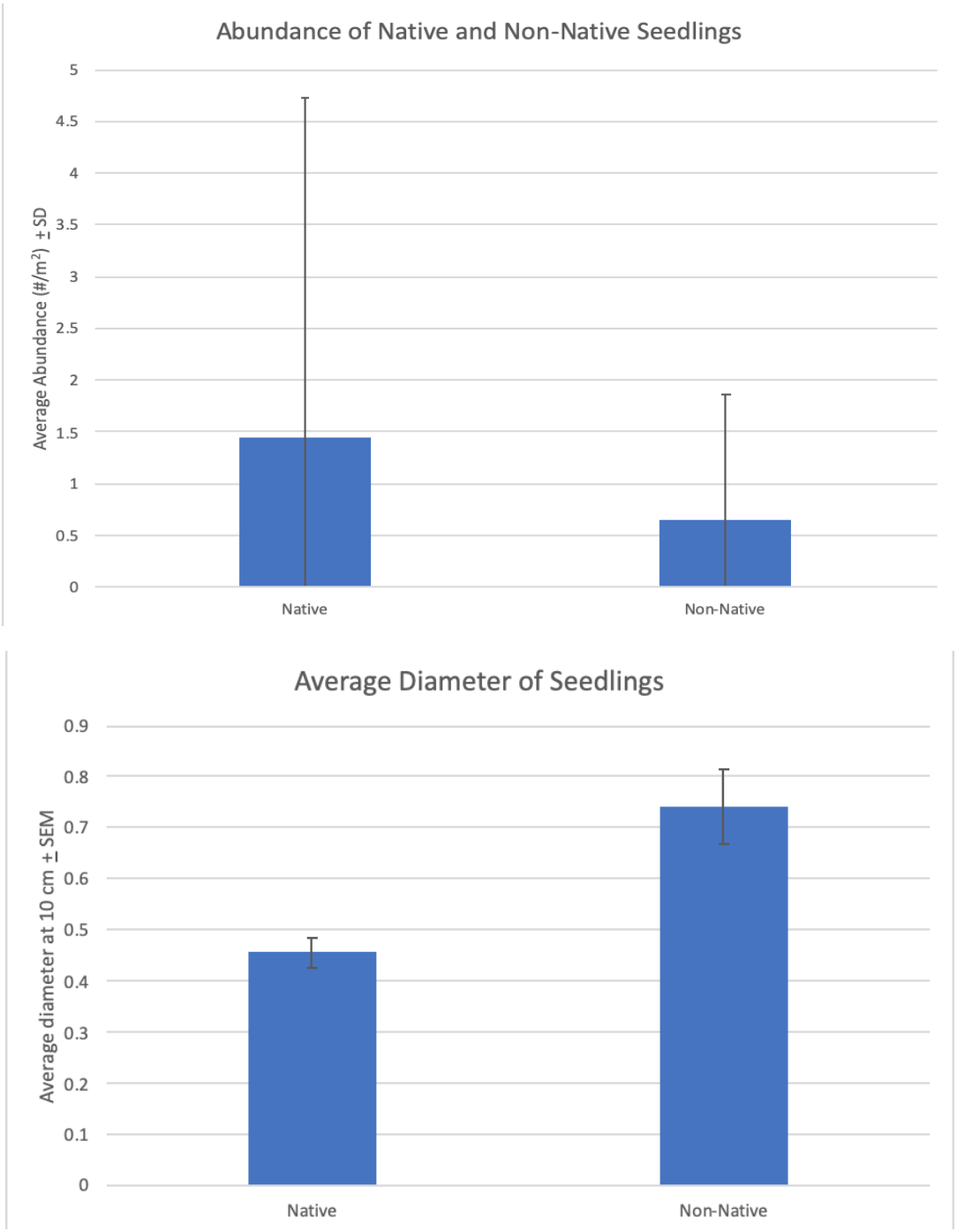

Figure 7 and 8. Abundance and size of seedlings by category

The height of the bars corresponds with the abundance or diameter of the seedlings. For the abundances of the seedlings (top graph) the black error bars overlap therefore there is no significant difference between the abundance of native and non-native seedlings. For the diameter of the seedlings (bottom graph) the black error bars do not overlap indicating that there is a significant difference between native and non-native seedlings. Non-native seedlings were significantly larger in diameter. This suggests that

while both native and non-native seedlings are regenerating, non-native seedlings tend to be larger in diameter suggesting faster growth rates. (#/m^2)

APPENDIX D

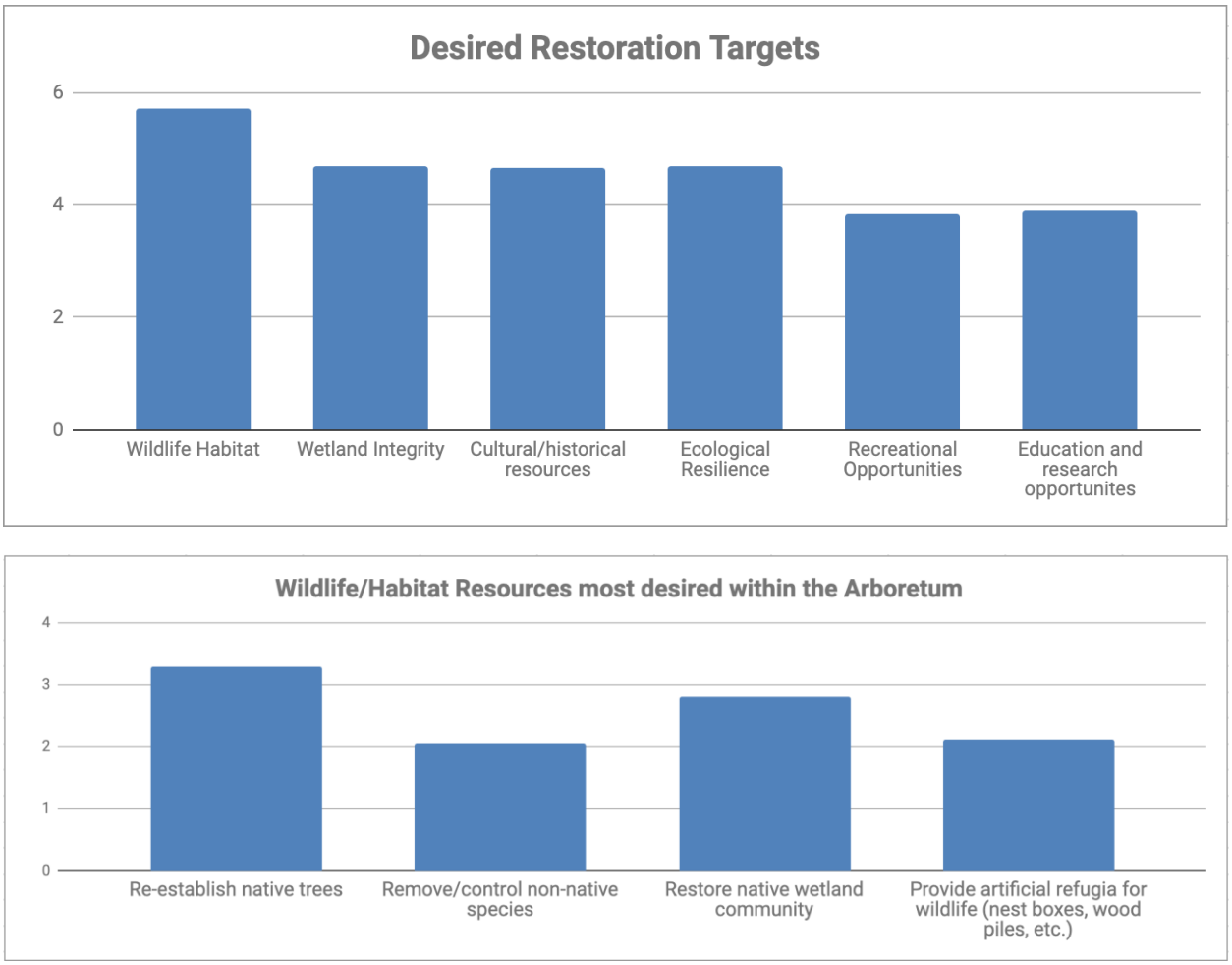

Figure 9. Surveys of the community and MBA members were conducted during an MBA community meeting and found that the stakeholders support work being done in the Arboretum to restore a native community. Additionally, these surveys helped to focus restoration efforts by prioritizing activities based on stakeholder desires.

APPENDIX E

Fairchild Legacy Identified and Mapped by 2017 MMES Cohort

- P.R. Royal Palm (*Roystonea borinquena*)
- Honduras Mahongany (*Swietenia macrophylla*)
- Malta Cross
- Gre-gre (*Bucida buceras*)
- Sausage tree (*Kigelia spinosa*)
- Brazil Rose
- Ceder
- Kapok (*Ceiba pentandra*)
- Sabal Palm
- Mystery Palm
- Mahogany (*Swietenia mahogany*)
- Rare Palm

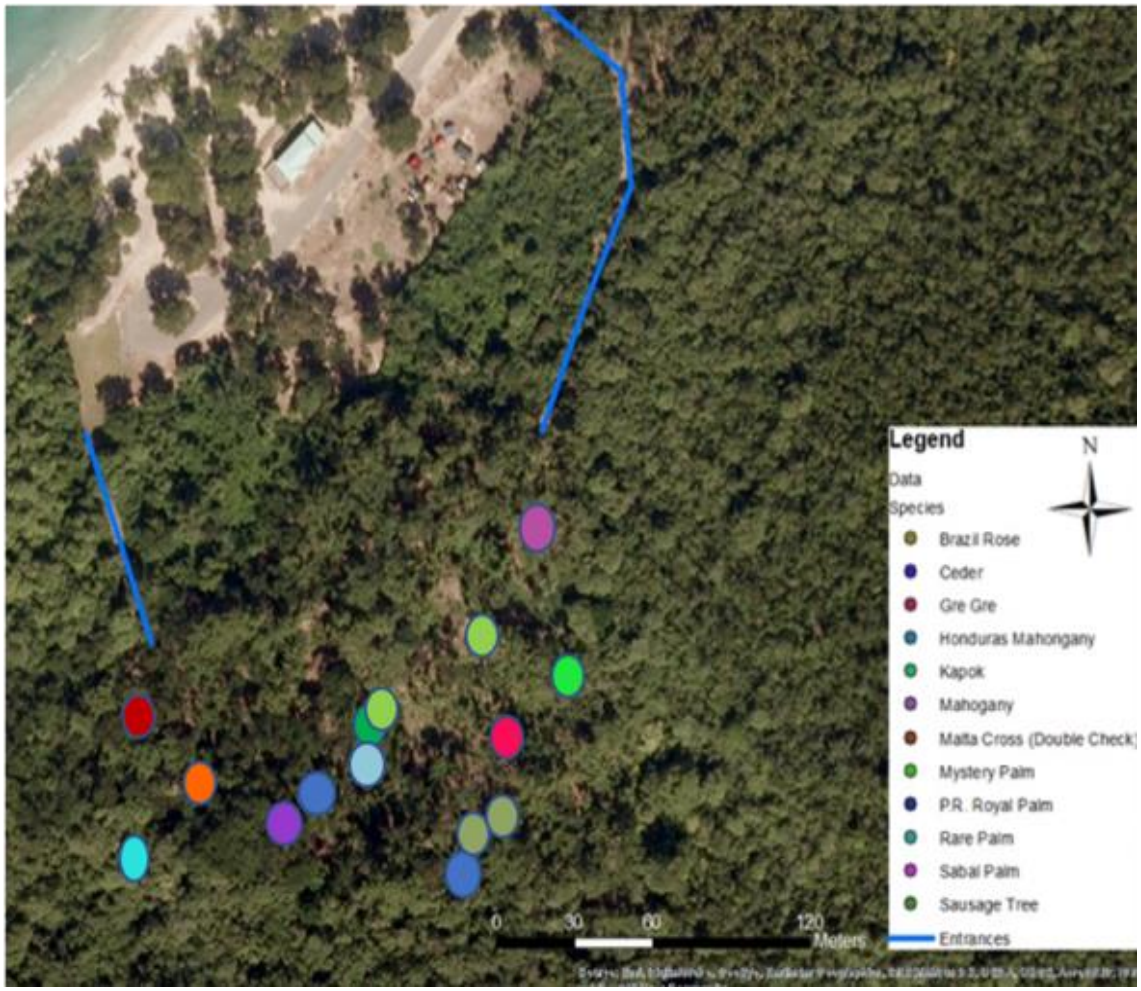

Figure 9. Map of Arboretum highlighting the Fairchild trees. These 12 species were identified as original Fairchild trees by the MMES 2017 Cohort.

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Useful Resources

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