Project Report

Threatened and Endangered Plant Surveys of Northwest Field

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Naval Facilities Engineering Command Marianas

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1 ABSTRACT

In 2015, fourteen plant species were added to the federal list of Endangered and Threatened Wildlife and Plants from the Marianas, joining Serianthes nelsonii, which was federally listed as endangered in 1998. Approximately 200 acres of non-contiguous limestone forest habitat at Anderson Airforce Base (AAFB), Northwest Field (NWF) were surveyed to determine distribution and abundance of these species. State of the art GIS techniques were employed to carry out 5-10m wide transects throughout the entire survey area from November 2016 through January 2017. Of the thirteen listed plant species known from limestone forests, only six (Cycas micronesica, Dendrobium guamense, Eugenia bryanii, Heritiera longipetioluta, Tabernaemontana rotensis, Tuberolabium guamense) were recorded during the survey on both subdued and pinnacle eogenetic karren habitats. High densities of the threatened species Cycas micronesica (total count of 12,505) were observed throughout the survey area, and an almost continuous band of the threatened species Eugenia bryanii (total count of 228) was found along the cliff line. However, both species are vulnerable to various existential threats, including invasive ungulates and invertebrates. Of the three listed epiphytic orchids, Tuberolabium guamense (total count of 1,684) was observed at high densities in limited areas. T. guamense grows mainly on understory tree species, which can regenerate under ungulate pressure, but still needs canopy trees to provide shade. Other orchid species like Dendrobium guamense (total count of 21), which was relatively rare, grew on outer branches of large canopy trees. Bulbophyllum guamense was not observed. An increase in the number of intense storms and lack of regeneration of phorophytes (plants on which an epiphyte grows) are likely contributing to their scarcity. The endangered Heritiera longipetioluta (total count of 12) and the threatened Tabernaemontana rotensis (total count on 125) occurred in very low numbers. Given the presence and scarcity of some of these species, habitat protection and the
implementation of conservation management practices are recommended in the survey area and adjacent habitats.

2 INTRODUCTION

The overall objective of this Cooperative Agreement (Agreement) is to assess the number and location of federally protected plant species within a pre-determined 200.52-acre area at Northwest Field, Andersen Air Force Base, Guam. The species in question are listed under the Federal Endangered Species Act (ESA) and include *Bulbophyllum guamense*, *Cycas micronesica*, *Dendrobium guamense*, *Eugenia bryanii*, *Hedyotis megalantha*, *Heritiera longipetiolata*, *Maesa walkeri*, *Nervilia jacksoniae*, *Phyllanthus saffordii*, *Psychotria malaspinae*, *Serianthes nelsonii*, *Solanum guamense*, *Tabernaemontana rotensis*, *Tinospora homosepala*, and *Tuberolabium guamense*.

2.1 STUDY AREA

2.1.1 GENERAL

The area of study is primary and secondary limestone karst forest located at the Northwest Field of Andersen Air Force Base (AAFB NWF) on Guam (Maps 1 & 2). This study unit includes 200.52 acres of forest at the northern part of Northwest Field. The term “survey area” will refer to the entire 200.52 acres surveyed under this Agreement. The survey area consists of a plateau with a conspicuous increase in limestone karst features towards the cliff margin. We further divided the non-contiguous portions of the survey area into “Zones A-E” for comparative purposes (see methods).
2.1.2 Topography

The limestone plateau (Map 3 & 4) is dominated by a sloping plain, intricately intermingled with rock outcrops covering 40-80% of the surface (Soil Science Division Staff, 2017). The interior platform consists of subdued karst, called eogenetic karren. Eogenetic refers to young immature limestone, which still has its original depositional character. The karren is not smoothed and averaged by deep burial diagenesis (Taborosi et al., 2004; Taborosi and Kazmer, 2013; personal communication Danko Taborosi, June 1th, 2017; personal communication John Mylroie, June 2th, 2017). This area is approximately 134.17 acres. The term “subdued karren” will be used to refer to this topography and the portion of the survey area it comprises. (Figure 1a, Maps 3 & 4)

Towards the cliff edge or rim, the terrain develops a more pronounced jagged, pinnacled karst topography, called eogenetic pinnacle karren (Taborosi et al., 2004; Taborosi and Kazmer, 2013; Danko Taborosi, personal communication, June 1th, 2017; John Mylroie, personal communication, June 2th, 2017). This terrain is very rugged. Here the karren features densely packed pits, which can be very deep and form small craters (Taborosi and Kazmer, 2013). This area is approximately 66.35 acres. The term “pinnacle karren” will be used to refer to this topography and the portion of the survey area it comprises. (Figure 1b, Maps 3 & 4)

2.1.3 Soils

The soil classification from the Official Series Descriptions (OSD) by the USDA Natural Resources Conservation Service for this area is:

“Ritidian rock outcrop. The Ritidian series consists of very shallow, well drained soils of moderately rapid permeability on limestone plateaus and escarpments (Map 5). They formed in slope alluvium, loess, and residuum from sediments overlying coralline limestone. Slopes range
from 3 to 99 percent. The soils are usually moist from July through November. Clay content is dominantly 35 to 60 percent, with rock fragments at 40 to 80 percent (about two-thirds as cobbles and one-third as gravel). Depth to bedrock is 5 to 25 cm. Neutral or slightly alkaline” (Soil Science Division Staff, 2017).

2.2 HABITAT INFORMATION

2.2.1 HISTORICAL VEGETATION

The survey area originally consisted of a mixed mesophytic, broad-leaved forest growing on raised limestone terraces (Fosberg, 1960). These forests were comprised of native and endemic species, which made up the functional ecology components of the forest. This limestone forest with large, intermediate and smaller trees had a high percentage of canopy closure and a rich understory (Wiles et al., 1995; NAVFACPAC, 2015). The forest was previously identified as a Mixed Moist Forest (Fosberg, 1960). Species commonly found include: *Ficus prolixa, Premna obtusifolia, Tristiropsis obtusangula, Intsia bijuga, Pisonia grandis, Macaranga thompsonii, Pandanus dubius,* and *Pandanus tectorius*. The understory typically consisted of understory trees like *Aglaia mariannensis, Ochrosia mariannensis, Eugenia reinwardtiana, Ochrosia oppositifolia, Maytenus thompsonii, Guamia mariannae* and *Cycas micronesica* (WERI & IRIE, 2016). This terrestrial forest type was mainly found in northern Guam. Today, the only remnants are along the clifflines in the pinnacle karren (Taborosi, 2013; WERI & IRIE, 2016).
2.3 Federal Threatened & Endangered Plant Species Information

2.3.1 Bulbophyllum guamense – Siboyan Halom Tano (Family: Orchidaceae)

*B. guamense* (Figure 2) is an epiphytic orchid with pyriform pseudobulbs, about 2.5 cm long. Each pseudobulb has a single oblong, elliptic leaf 10 to 15 cm long and 2.6 to 3.8 cm wide. The flowers are greenish yellow and are about 1.5 cm long (Figure 2b). The inflorescence is commonly longer than the leaves and starts at the base of the pseudobulb. The flower has a faint, carrion-like scent. The scape is typically up to 25 cm long. The orchid is mostly found in moist and humid areas (Raulerson & Rinehart, 1992; Stone, 1970). *B. guamense* is federally listed as threatened. *B. guamense* occurs on Guam and Rota, but is extirpated on Saipan and Pagan (Department of Interior, 2015).

Another Bulbophyllum sp., *Bulbophyllum longiflorum*, is also found in the area. This species can be distinguished from *B. guamense* in its vegetative stage by its pseudobulbs. The deeply defined sharply ribbed pseudobulbs are connected by creeping rhizomes. *B. guamense* pseudobulbs appears ribbed when dry. *B. longiflorum* exhibits stiff, golden fibers that cover the young pseudobulbs. *B. guamense* typically does not exhibit this trait. *B. guamense* forms mats of pseudobulbs while *B. longiflorum* is a trailing epiphyte which doesn’t forming dense mats (Raulerson, 1992).

2.3.2 Cycas micronesica (Family: Cycadaceae)

*C. micronesica* (Figure 3) is a palm-like tree with rare cases of branching. The glossy leaves, which are restricted to the top of the trunk, usually grow to be 1 to 2 m long. *C. micronesica* are dioecious. The male trees are born in elongate, upright terminal cones (Figure 3f) at the center of the leaves. The females have soft, wooly leaves that bear ovules (Figure 3c,d). The seeds are green (Figure 3e) when young and are ripe when chocolate brown and wrinkled. These trees used to be the most
common understory tree in limestone forests (Raulerson & Rinehart, 1991; Stone, 1970, Donnegon et al., 2004). The species is federally listed as threatened on Guam, Rota, Saipan, and Pagan (Department of Interior, 2015).

2.3.3 **Dendrobium guamense** (Family: Orchidaceae)

*D. guamense* (Figure 4) is an epiphytic orchid with crowded stems that grow up to 60 cm tall. The stem shows several pseudobulbous segments. Leaves are alternate, lance-oblong, and up to 10 cm long, and 7-15 mm wide, with cylindrical leaf sheaths. The flowering racemes are 2-flowered and are shorter than the leaves. The two flowers (Figure 4a) are white with curved petals and arise together from the same sheath. The lip is yellow. These orchids are often found in moist areas on tree trunks or branches of canopy trees (Raulerson & Rinehart, 1992; Stone, 1970). *D. guamense* is federally listed as threatened. *D. guamense* occurs on Guam, Rota, and Tinian, but is extirpated on Saipan and Agrihan (Department of Interior, 2015; U.S. Fish and Wildlife Service, 2015).

2.3.4 **Eugenia bryanii** (Family: Rubiaceae)

*E. bryanii* (Figure 5) is a low-lying shrub. Due to deer browsing *E. bryanii* can only grow up to 1m. This shrub is small, and has opposite, elliptic-ovate leaves that appear fleshy. Flowers (Figure 5b) are small with four white petals and numerous stamina. The fruit is a bright red berry 5 to 8 mm thick. These shrubs are often found growing on the exposed limestone cliff lines (Raulerson & Rinehart, 1991; Stone, 1970). This species is only found on Guam and is federally listed as endangered (Department of Interior, 2015).

2.3.5 **Hedyotis megalantha – Paudeo** (Family: Rubiaceae)

*H. megalantha* (Figure 6) is a short, erect herb with glabrous, 4-angled stems. The chartaceous leaves are glossy, oblong-elliptic or ovate-elliptic, 9 to 11 cm long and 3 to 5 cm wide. The flowers
(Figure 6b) are on a branched panicle. They are white with purplish anthers, are arranged in parts of 4 (tetramerous), and show determinate inflorescence. The seeds are black. *H. megalantha* can be found in open savanna habitats (Raulerson & Rinehart, 1991; Stone, 1970). *H. megalantha* is federally listed as endangered. Historically the species is known to occur on Guam, Rota, Tinian, and Aguiguan, but currently the species is only known from Guam. The species is extirpated on Saipan and Agrihan (Department of Interior, 2015).

2.3.6 **HERITIERA LONGIPETIOLATA — UFA HÅLOM TĀNO’ (FAMILY: STRECULIACEAE)**

*H. longipetiolata* (Figure 7) is a large tree which can be considered as a canopy tree in limestone forests. The trunk of the tree is light brown with white flakey patches. Along coastlines, the trunk tends to twist. Interior trees exhibit upright, straight trunks. *H. longipetiolata* has buttress roots (Figure 7b) to support itself in karstic habitats. The alternate ovate-oblong, 15 to 30 cm long and 8 to 15 cm wide, leaves have long petioles. The upper leaf surface is dark green, while the lower surface is silvery-tawny (Figure 7c). The flowers (Figure 7d) are arranged on axillary open panicles, which are shorter than the leaves. The keeled brown fruits have thick walls (6-7 mm) and have a keel about 5 mm high with no wing (Raulerson & Rinehart, 1991; Stone, 1970). The species is federally listed as endangered and is limited to Saipan, Tinian, Rota, and Guam (Department of Interior, 2015).

2.3.7 **MAESA WALKERI (FAMILY: MYRSINACEAE)**

*M. walkerii* can come in the form of a straggling shrub or a little tree. The stems show prominent lenticels. The dark leaves are alternately arranged and ovate. The bases of the leaves are obtuse or slightly cordate. This species is many-flowered with an axillary, simple raceme arrangement. The fruit is a small, pinkish, pea-sized ball. This species can be found on limestone ridges without an overstory (Raulerson & Rinehart, 1991; Stone, 1970). The species is federally listed as threatened
and is limited to Rota and Guam (Department of Interior, 2015). No photos are available for this species. The Guam herbarium has a specimen in their collection to view.

2.3.8  **NERVILIA JACKSONIA (FAMILY: ORCHIDACEAE)**

*N. jacksoniae* (Figure 8) is a terrestrial orchid with fleshy globose tubers. Flowers form first followed by leaves, making it possible to find a flower with no leaves or pods formed yet. Leaves (Figure 8b) are kidney shaped 5x3 cm in size, covered in small hairs with seven main veins. *N. jacksoniae* occurs in the rainy seasons and wither afterwards through the dry seasons (Raulerson & Rinehart, 1992; Stone, 1970). The species is federally listed as threatened and is limited to Rota and Guam (Department of Interior, 2015).

2.3.9  **PHYLLANTHUS SAFFORDII (FAMILY: EUPHORBIACEAE)**

*P. saffordii* (Figure 9) are erect woody shrubs. They are sparsely branched, with terete stems ranging from 30-70 cm tall (rarely over 40 cm). Branches are dark reddish-brown with side branchlets 10-12 cm long containing many small shiny dark green oblong leaves 5-12 mm long and 1.5-3 mm wide. The male flowers are on 0.5 mm long pedicels, while the female flowers are divaricate. The fruits are round and light-colored, maturing from green to red. *P. saffordii* is endemic to south to south-central Guam in savannah areas (Raulerson & Rinehart, 1991; Stone, 1970). The species is listed as endangered and is limited to Guam (Department of Interior, 2015).

2.3.10  **PSYCHOTRIA MALASPINAEE – APOKATING-PALAO’AN (FAMILY: RUGIACEAE)**

*P. malaspinae* are small trees or shrubs with terete reddish-brown branches. Leaves are chartaceous, moderately dark and glossy on the top-side and pale and dull on the underside. The leaves are elliptic-oblong to obovate oblanceolate, mostly 6-10 cm long and 2-4 cm wide. The stipules are calyptrate (Fosberg et al., 1993). This feature differentiates *P. malaspinae* from *P.*
hombroniana, which has sheathing, strongly bifid stipules (Fosberg et al., 1993). Flowers are yellow green on one to three flowered cymes. Fruits are fleshy and red. P. malaspinae is exclusively found in limestone community forests that are undisturbed (Raulerson & Rinehart, 1991; Stone, 1970). The species is federally listed as endangered and is limited to Guam (Department of Interior, 2015). No photos are available for this species. The Guam herbarium has a specimen in their collection to view.

2.3.11 Serianthes nelsonii – Håyun Lågu (Guam) – Trongkon Guåfi (Rota) (Family: Fabaceae)

S. nelsonii (Figure 10) are small to large trees that grow up to around 20 meters tall. The trunk grows to around 2 meters in diameter. Leaves (Figure 10a) grow to about 23 cm long, pinnae 10-20 pairs, subalternate with leaflets growing in 22-30 pairs. The flowers (Figure 10a) are brush-like with long pinkish filaments. Seed pods (Figure 10b) are 12x2.3 cm, brownish, hairy, and slightly constricted between the seeds. Seeds are hard, shiny, smooth, brown, and elliptic (Raulerson & Rinehart, 1991, Stone, 1970). The species is endemic to Guam and Rota, was originally listed as endangered in 1987, then changed to critically endangered in 1998 (Department of Interior, 1987).

2.3.12 Solanum guamense – Biringenas Halumtanu (Family: Solanaceae)

S. guamense is a stellate, tomentose shrub. Branches are erect, 3-4 mm thick, with crowded leaves on petioles 1-3.5 cm long. Leaves have chartaceous blades, and are ovate to elliptic-oblong. Hairs are white to pale yellowish, and fruits resemble small tomatoes. The base is usually asymmetric and rounded to an obtuse or subacute shape. Endemic to the Marianas Islands. S. guamense is found on Guam reach heights of 1-2 meters, along limestone cliffs or terraces near the sea (Raulerson & Rinehart, 1991; Stone, 1970). The species is listed as endangered for Guam, Rota, Saipan, Tinian, Asuncion, Guguan, and Maug, but has been extirpated from the wild on all islands.
but Guam (Department of Interior, 2015; U.S. Fish and Wildlife Service, 2015). No photos are available for this species. The Guam herbarium has a specimen in their collection to view.

2.3.13 *Tabernaemontana rotensis* (Family: Apocynaceae)

*T. rotensis* (Figure 11) is a slim tree that grows to about 8-10 meters tall. Leaves (Figure 11b) are light green, opposite, elliptic-oblong and 15-30 cm long, 5-10 cm wide. It has copious milky sap. Flowers (Figure 11c) are longate and white. The terminal flower buds branching from the tree. Fruits (Figure 11d) are twinned or single, almost 3 cm long and 1 cm thick and grow bright red with seeds encased inside. Endemic to the Marianas Islands, found on Rota and Guam and may be limited to limestone environments (Stone, 1970). The species is federally listed as threatened for Guam and Rota (Department of Interior, 2015;).

2.3.14 *Tinospora homosepala* (Family: Menispermaceae)

*T. homosepala* (Figure 12) are woody climbing vines endemic to Guam and very rare. Leaves (Figure 12b) are simple and long-petiolate, cordate or subcordate and grow up to 10-12 cm long. Flowers (Figure 12c) are unisexual with drupaceous fruits (Stone, 1970). No fruits have been found on Guam, only male plants have been reported. The species is federally listed as endangered for Guam (Department of Interior, 2015).

2.3.15 *Tuberolabium guamense* (Family: Orchidaceae)

*T. guamense* (Figure 13) is an epiphytic orchid with succulent ovate-oblong leaves. Flowers (Figure 13b) are small and white up to 4 cm long. Found in moist and shady areas in high elevations or limestone karst, mostly on understory trees. The species has been federally listed as threatened (Raulerson & Rinehart, 1992; Stone, 1970). The orchid is only found on Guam and Rota, and has
been extirpated from Tinian and Aguiguan (Department of Interior, 2015; U.S. Fish and Wildlife Service, 2015).

2.3.16 Threats to the Federally Listed Plants

Landscape dysfunction and a decrease of biodiversity are caused by degradation of the landscape due to ungulate pressure, invasive plant species, invasive invertebrates, loss of seed dispersers and pollinators, as well as human activity.

Ungulates like feral pig (*Sus scrofa*) and Philippine deer (*Cervus mariannus*) do not occur naturally in the Pacific islands. Therefore, forest species have not adapted to grazing. After the introduction of ungulates, soil disturbance and ground cover loss occurred. Consequently the limestone forest structure, function and species composition has been altered (Sailer, 2006). Ungulates also promote the establishment of invasive species by trampling and browsing native species and dispersal of invasive plant propagules (Diong, 1982; Sailer, 2006; Oduor et al., 2010). The negative impacts feral ungulates have on regeneration of forest plant species is documented on Guam (Morton & Perry, 1999). Feral ungulates feed and damage plants, spread invasives, and disturb the forest uprooting plants and establishing trails (Morton & Perry, 1999). Ungulates have been excluded from the Habitat Management Unit (HMU) at AAFB, which led to substantial increased native plant regeneration (E. Demeulenaere, unpublished observation; B. Lawrence, NRCS, unpublished data).

Indirectly the brown tree snake has disrupted the fruit-frugivore mutualism of many forest species. Rogers et al. (2017) estimated a 61%-92% decline in seedling recruitment highlighting the cascade of extinctions this invasive predator caused across Guam’s native fauna and flora. The introduction
of the brown tree snake has almost eliminated all endemic bird species and fruit bats, both responsible for seed dispersal and pollination of native flora.

Invasive plant species can alter forest species composition and structure, by eliminating native plant species (e.g. *Mikania micrantha* will smother native trees). Invasive plant species are currently not abundant in the survey area, but when gaps occur in the forest, invasive species can spread easily. Therefore, it is important to follow phytosanitation rules when surveying or managing the forest.

Invasive invertebrates and pathogens can do considerable ecological damage to an ecosystem. Invasive forest insects or pathogens can cause a decline in biodiversity and impact the health of native plant species. Biological surveys to identify pests, as well as control mechanisms are recommended.
3 METHODS

3.1 TRAINING

Prior to the field surveys, the Principle Investigators (Else Demeulenaere and George C. Fiedler) trained all field biologists in the following:

(1) Navigation techniques (compass and GPS) and transect methodology

(2) Plant identification, focusing upon rare plants and orchid host plants

(3) Endangered animal species identification

The project safety officer (Phillip Cruz) provided additional training on first aid and emergency management protocol. Naval Facilities Engineering Command (NAVFAC) provided the data dictionary and other data management procedures.

3.2 FIELDWORK

3.2.1 SURVEY LOCATION

The survey was conducted at Anderson Air Force Base, Guam, at Northwest Field from October 25th, 2016 to January 13th, 2017. The area surveyed consisted of 200.52 acres in five predetermined zones (A, B, C, D, E: Map 1). These five zones were noncontiguous, and each spanned an area of the upper plateau from the cliff line margin inland 0.1-0.3 km (see Introduction for description). The largest of these zones, D, comprised 156 acres of contiguous habitat; the others ranged from 6-19 acres in size. The intervening areas were surveyed by NAFVAC, and the data were not available for comparison purposes.
3.3 TRANSECT LINE METHOD

3.3.1 OVERVIEW

The goal of the survey was to locate listed plants species: *Bulbophyllum guamense*, *Cycas micronesica*, *Dendrobium guamense*, *Eugenia bryanii*, *Hedyotis megalantha*, *Heritiera longipetiolata*, *Maesa walkeri*, *Nervilia jacksoniae*, *Phyllanthus saffordii*, *Psychotria malaspinae*, *Serianthes nelsonii*, *Solanum guamense*, *Tabernaemontana rotensis*, *Tinospora homosepala*, and *Tuberolabium guamense*.

3.3.2 SURVEY TEAMS

Teams of two to four field biologists conducted transect surveys for the federally listed plants species in the survey area. Surveys were conducted collaboratively with the University of Guam (UOG) and Naval Facilities Engineering Command (NAVFAC) personnel and co-coordinated by NAVFAC and the University of Guam. Teams were typically deployed six days per week, and a designated safety officer at UOG logged daily entry and exit from the survey area and monitored the safety of field teams. The survey crews covered 200.52 acres of forest in approximately two and a half months. Teams walked parallel transects spaced 5 m or 10 m apart (dependent on the habitat complexity) throughout the prospective survey area (Cypher, 2002). Survey work was conducted carefully to avoid trampling on or damaging host plants, threatened or endangered plants, whether occurring singly, in small patches, or in dense stands. Since pinnacle karren is difficult to navigate through, and is more complex, it was necessary to move slowly through these areas to adequately search for host plants.

3.3.3 SURVEY LINES: SPACING AND NAVIGATION

Distance between transect lines varied according to terrain. In relatively flat subdued karren, with open understory forest, survey lines were spaced ten meters apart. However, in areas of pinnacle
karren, the visual range was impaired by the complex terrain. Here the teams surveyed every five meters to ensure that all areas were adequately covered (Map 6, Figures 1a & 1b).

Each field team was composed of two to four people with at least one scout and one person handling a Trimble GEO 7 Series GPS unit (Figure 14). The Trimble units used a data dictionary provided by NAVFAC to ensure the quality of surveys in the area and compatibility of the data to other plant surveys. The scout lead each team along a compass bearing determined by the GPS unit. At the start of each transect line, the GPS operator would set a target to the end of the transect line, determine the bearing, and started recording a transect survey data line. The survey team walked along this transect line, searching for any of federally listed plant species in the line of sight. The GPS operator frequently checked the unit to ensure that the scout and other team members did not stray from the line. For three-person teams, two scouts walked approximately two and a half meters on either side of the line. For four-person teams, two scouts would walk five meters left and right of the line, and the remaining scout would walk directly on the line. Upon spotting a federally listed plant, the scout would flag a nearby rock, branch, or vine to indicate that a target species was recorded. The GPS operator would then record a data point on the GPS unit along with specific data required for each species or category (see below). Using the Trimble Units, the following were recorded for all target species encountered: species, geographic location, date. For the listed orchids, individual counts, height or height range, facing direction (the orientation of the orchid’s growth along its host plant), habitat type, and phorophyte (supporting host tree) was recorded.

Data collected on the federally listed plants included: counts, maturation level, height, phenology, and habitat type. No additional data were recorded for *Cycas micronesica*, because of its high
abundance. As the data were collected along the transect line, the team marked the location of all target species with flagging tape (Figure 14c) within the respective five- or ten-meter zone around the line.

3.3.4 Post-Processing
The GPS data (i.e., the location of plants and the transects) were downloaded after each field day using GPS Pathfinder Office software by Trimble (version 5.85). The data were exported in a shapefile for further processed with geographic information system (GIS) software, ESRI’s ArcMap 10.3. The shapefiles were then imported into a file geodatabase (GDB) along with a survey area shapefile provided by the NAVFAC. Maps were created weekly to show continual progress. The GDB was checked for consistency and additional attributes like coordinates, location, and type of limestone were added and populated. Finally, a metadata file, which is information about the GIS data, was created and integrated into the GDB.

The data from the GDB were used to create the final maps along with base layers obtained from the Digital Atlas of Guam (hydroguam.net). Next, density maps were generated to show population densities of individual plant species or groups of plants in terms of magnitude-per-unit-area (ESRI, 2018). The density values were calculated from the density of plants within a 20-meter radius using the "Point Density" tool in ArcMap 10.3 and displayed as number of plants per hectare. In addition, a heat map was generated using weighted population densities to visualize areas of relative importance. Endangered plants were given a factor of "3", while threatened plants a factor of "1" to codify the listing status.
3.3.5 **Vegetation Assessment**

The plant communities in the survey area were identified following Fosberg (1960). After the line-transect method to locate the endangered plants was completed a vegetation assessment was conducted using the qualitative ACFOR method (Wright, 1991). This method is used to describe abundance within a given area. The following codes were used to estimate the frequency of occurrence for particular species occurring in each habitat type: ABUNDANT (greater than/equal to 30%), COMMON (20% to 29%), FREQUENT (10 % to 19%), OCCASIONAL (5% to 9%), and RARE (1% to 4%).

4 **Results**

4.1 **Overview**

Only 6 of the 13 listed limestone forest species were recorded: *Dendrobium guamense*, *Cycas micronesica*, *Eugenia bryanii*, *Heritiera longipetiolata*, *Tabernaemontana rotensis*, and *Tuberolabium guamense* (Table 1). The most common listed plant species was *C. micronesica*, which was found throughout all five survey zones (Table 1, Maps 7A-C, 8). The orchid *T. guamense* was the next most common plant, found mostly in Zone D (Table 1, Maps 9A-C). The other orchid, *D. guamense* was sparingly found only in Zone D. Next, *E. bryanii* was found exclusively along the cliff margins of Zones C, D & E (Table 1, Maps 10B-C). *H. longipetiolata* was very rare in Zone D, which had two specimen growing next to each other (with one in Zone E) (Table 1, Maps 10B-C), and there was only a single *T. rotensis* noted at the central southern edge of Zone D (Table 1, Maps 10B). An overall density comparison of all listed species (Map 11) indicates a ~0.3km long contiguous band of relatively high densities in the center of Zone D, perpendicular to the cliff line, and a few high-density pockets scattered throughout the same zone.
A heat map of densities weighted according to listing status (Map 12) shows the plants most at risk. Zone A, B, and C show low weighted densities of listed plants (Map 12). Zone D depicts several small clusters, an elongated L shaped patch in the center, and high weighted densities in the east and northeast of zone D. Zone E shows the highest weighted density of listed plants in the northeast and overall in the middle and south. Orchids accounted for most of density pattern for listed species (Map 13).

4.2 **Cycas micronesica**

The survey recorded a substantial number (12,505) of *C. micronesica* (Table 1). The overall *C. micronesica* density (#cycads/per acres) is very high; 62.36 cycads per acre (Table 1). The overall density (population/per acres) is about 8.6% higher the pinnacle karren, compared to the subdued karren (Table 1). All five zones contained *Cycas micronesica*. The highest densities of the cycad in eastern portions in Zone D and most of zone E (Map 8). Low densities of cycads compared to zone D and E were found in the remaining zones. Though this project did not specifically record insect damage, most cycads bore evidence of damage from introduced pests (i.e., *Aultacaspis yasumatsui*, *Chilades pandava*, and *Erechthia* sp. *Dihammus marianarum*: Marler and Muniappan, 2006; Moore et al., 2006; Marler and Lawrence, 2012).

4.3 **Listed Orchids**

4.3.1 **T. guamense**

As indicated above, *T. guamense* was the second most common listed plant found. A total of 1,684 *T. guamense* were recorded, with a density of 8.4 individuals per acre (Table 1). The density (population/per acres) is 10.20% higher in pinnacle karren than in subdued karren (Table 1). About 60% occurred on phorophytes (supporting trees) in the pinnacle karren. *T. guamense* was mostly found on midstory trees like *E. reinwardtiana*. The vast majority (1,250) were recorded on 126 *E.*
reinwardtiana trees (Table 2). Large numbers of this orchid were often encountered on a single host tree. The most observed was 100 orchids on a single *E. reinwardtiana* tree. Other phorophytes include *Aglaia mariannensis*, *Cynometra ramiflora*, *Eugenia palumbis*, and *Eugenia thompsonii* (Table 2). No *T. guamense* was found in zone A, B, and C (Map 9A). Zone D had a high density on the eastern portion and in zone E, where only three trees with *T. guamense* were found (Maps 9A, B).

4.3.2 **D. GUAMENSE**

*D. guamense* was rare in the survey zone, with only 21 individuals located (Table 1). Of the 21 individuals, nine individuals were found growing on seven *Ficus prolixa* (Table 2). It was seen singly on both *H. longipetiolata* and *Macaranga thompsonii*, respectively, on single occasions. The only understory tree this orchid occurred on was *Eugenia reinwardtiana*. *D. guamense* was only found in zone D (Maps 9A-C). The species was not recorded in Zone A, B, C, and E. Twelve of these orchids were found in the pinnacle karren, 9 were found in the subdued karren (Table 1).

4.4 **EUGENIA BRYANII**

*Eugenia bryanii* (approximately 228 individuals) was found alongside the cliff line of zone C, D, and E (Maps 10A-C). In only a few instances (4 times) did we observe *E. bryanii* away from the cliff. *E. bryanii* became denser and more continuous towards eastern cliffs of zone D, although another line appears to start at the western side of zone D (Maps 10B,C). It should be noted that 380 *E. bryanii* were found along the cliffline. These plants however were outside of the survey area. These 389 plants were not added in the tables of this report but are included in the geodatabase.
4.5 *Heritiera Longipetiolata* and *Tabernaemontana Rotensis*

This tree was rare; only 12 *H. longipetiolata* were recorded. None were found in zone A, B, and C, while Zone D had 12 *H. longipetiolata* in the pinnacle karren and 8 in the subdued karren (Table 1, Maps 10A-C). Most of these trees were found in the western half of zone D. One single tree was found in zone E. Similarly, only a single *T. rotensis* patch was found in the subdued karren of zone D, in the south (Fig 1, Map 10B).

4.6 *Serianthes Nelsonii*

The last remaining adult tree of *Serianthes nelsonii* occurs in zone C of Northwest Field. The tree has a fence surrounding it to protect the adult tree and its seedlings from ungulate pressure.

4.7 *Vegetation Assessment*

The vegetation composition and structure of the limestone forest was assessed in the pinnacle karren and subdued karren, using the qualitative method ACFOR (Wright, 1991), walking six transect lines in both habitats after the host plant and butterfly survey was completed. Species composition and structure are presented in Tables 3 & 4. Most native and endemic indicator species for this habitat are still present (Tables 3 & 4). Both the limestone forest growing on pinnacle karren and subdued karren still harbor the forest indicator *Ficus* species. Overall understory trees are more abundant than emergent canopy trees. Higher species diversity was found in the limestone forest growing on the pinnacle karren, compared to the subdued karren. The limestone forest in the subdued karren is more short-statured compared to the pinnacle karren, where the different forest layers are still more prevalent. The ground cover vegetation was more diverse in the pinnacle karren with species like *Laportea ruderalis, Peperomia guamense, Asplenium nidus, Procris pedunculata* and *Elatostema calcareum* covering the karst. Tree epiphytes like the fern *Asplenium*
*laserpitifolium* and other *Asplenium* sp. were also observed in the pinnacle karren. The presence of *Laportea ruderalis* and *Peperomia guamense* are an indication for entering the pinnacle karren. *Elatostema calcareum* preferred growing in the karren pits, while *Procris pedunculata* grew in the pits and on overhanging rock outcrops. The cliffline although considered a part of the pinnacle karren had a slightly different species composition. *Eugenia bryanii, Excoecaria agallocha, Maytenus thompsonii, Bikkia tetrandra, Scaevola sericea, Pemphis acidula, and Ochrosia mariannensis* border the edge of the cliffline with canopy trees like *Casuarina equisetifolia, Ficus prolixa* intermixed.

5 DISCUSSION

5.1 FEDERALLY LISTED PLANT SPECIES ASSESSMENT

5.1.1 OVERVIEW

The results of this survey provide the most thorough assessment available of threatened and endangered plants species for AAFB NWF, and perhaps any comparable area of coverage on Guam. Previous studies noted the presence of proposed threatened and endangered plants using only a few transect lines in portions of the same survey area (Lindstrom & Benedict, 2014; HDR, 2012). In contrast, the present study used 5-10 m transect lines over the entire survey 200.52-acre area (Map 6). The density and heat maps (Maps 11 & 12) show several dense concentrations of listed plants (note that *Cycas micronesica* was not included in the analysis), likely due to the presence of orchids (Map 13).

Six of the fifteen listed plant species were found. Not all of them were anticipated in the survey zone. *Hedyotis megalantha* and *Phyllanthus saffordii* are savanna species and were therefore not expected to be found in the limestone forest habitat at NWF (Stone, 1970). Some of the other
species are very rare anywhere on Guam (e.g., *Maesa walkerii*, *Nervilia jacksoniae*, *Psychotria malaspinae*, *Solanum guamense*, *Tinospora homosepala*).

### 5.1.2 *CYCAS MICRONESICA*

*C. micronesia* was very abundant throughout the survey area. However, most plants appeared to be infested with *Aulacaspis yasumatsui*, which harms the trees and slowly kills them. This scale insect damages the leaves, which plants have to drop and replace. Leaf regeneration is inhibited, due to *Aulacaspis yasumatsui* infestation on small seedlings (Else Demeulenaere, personal observation, cycad survey 2013).

### 5.1.3 *FEDERALLY LISTED ORCHIDS*

Although transect coverage of the survey zone was thorough, it is likely that some orchids may have been underrepresented in our counts. The forest canopy was routinely scanned for epiphytic orchids, but some of the orchid species might have been overlooked, since they are either small, very high in the canopy, or hidden behind ferns or branches. The data from this survey are still the best estimate of true orchid populations. It has been observed that these orchids thrive in humid forests, which are less windy (Raulerson & Rinehart, 1992; Lauren Gutierrez & Else Demeulenaere, personal observations). *T. guamense* was mostly found on midstory trees like *Eugenia reinwardtiana*, *Aglaia mariannensis*, and understory trees like *Cynometra ramiflora*, which all regenerate easily under the high ungulate pressure. Hence, a high abundance of phorophytes is available for these orchids in the study area. This is in contrast with the availability of large canopy trees for orchids, like *D. guamense*. *D. guamense* occurs in higher levels of sunlight, and is mostly found on exposed higher branches of emergent canopy trees (Lauren Gutierrez & Else Demeulenaere, personal observations). The orchid is therefore mostly found on the outside branches of large canopy trees. Although the subdued and pinnacle karren are refugia
for older canopy trees, many trees like *Intsia bijuga* and *Heritiera longipetiolata* have fallen due to storms (Wiles, 2005, Else Demeulenaere, unpublished survey data), and have not been able to regenerate, due to intensive grazing and browsing of ungulates, and lack of seed dispersers. These large canopy trees are declining rapidly, and could themselves become threatened, if no adequate management is established. *Ficus proliqua* is probably the only exception because it sustains its existence by expanding its canopy via additional areal roots, and therefore expand vegetatively. Its sexual reproduction relies on bird dispersal.

It should be noted that five GPS entries documented Vitex parviflora as phorophyte. We think this is an entry error. Therefore, these phorophytes have indicated as ‘other’ in the ‘host plant’ column. In the comment section however, it mentions ‘Possible entry error for host plant: Vitex parviflora’.

5.1.4 **EUGENIA BRYANII**

*E. bryanii* was found alongside the cliff lines in virtually all zones (Maps 10A-C), which is its natural habitat. This species seems to sustain itself, but it is not clear if the plant produces seedlings. A few insects were observed on *E. bryanii*, suggesting the need for research to study these pests, given there may only be limited, contiguous areas containing this plant (Else Demeulenaere, personal observation 2015). Hence, these species may be quite vulnerable, as any insect infestation can spread throughout the entire contiguous population. Deer browsing confines *E. bryanii* to the cliffline, reducing its reproductive ability (Lauren Gutierrez, personal observation 2014). In 2014, *E. bryanii* was known from five occurrences (Gutierrez 2014, in litt.), which makes the habitat vulnerable.
5.1.5 *Heritiera longipetiolata* and *Tabernaemontana rotensis*

The low number, 12, of *H. longipetiolata* is of concern, not just in the study area. A combination of threats likely impacts this species including ungulate browsing of seedlings, seed predation by ants and termites, and typhoons (E. Demeulenaere, unpublished 2014 survey data; Mario Martinez, personal observation).

Only one patch of *T. rotensis* was found in the subdued karren. This patch consisted of similar size seedlings. During a germination study in 2007 it was observed that *T. rotensis* seedlings emerge in high densities under the mother tree. These high densities will lead to competition for light (University of Guam, 2007). Therefore, this observation was counted as one. The map of a 2007 study also depicts this species at the same location. *T. rotensis* is more common in other parts of the AAFB (University of Guam, 2007; E. Demeulenaere, unpublished 2013 and 2014 survey data). This species also suffers from ungulate browsing, and seed predation (University of Guam, 2007). It is unclear if seed predation is caused by slugs, ants, or ungulates.

5.2 **Vegetation Assessment**

This area was originally identified as a “Mixed Moist Forest” (Fosberg 1960). This mixed moist forest is similar to the forest dominated by *Artocaprus*, but almost completely lacking the genus (Fosberg 1960). In this case, no particular tree stands out in the landscape. Compared to the pristine primary limestone forest, the forest structure, and species composition is altered. Extensive ungulate pressure and bird loss due to the brown tree snake changed the forest structure into a short-statured forest with native forest species experience lower regeneration (Wiles, 2005; Rogers et al., 2017). This is more pronounced in the subdued karren compared to the pinnacle karren. This likely because it is relatively inaccessible terrain, and ungulates frequent this area less than the subdued karren. Additionally, introduced plant and invertebrate species have invaded this habitat.
Most other native and endemic indicator species for this habitat are still present. Understory and midstory trees, like *Aglaia mariannensis*, *Ochrosia oppositifolia*, *Guamia mariannae*, *Cynometra ramiflora* and *Eugenia reinwardtiana* are still very common and do regenerate better than the larger canopy trees like *Macaranga thompsonii*, *Ficus prolixa*, *Ficus tinctoria*, *Intsia bijuga* and *Tristiropsis obtusangula*. *Heritiera longipetiolata* is now extremely rare and experiences seed predation from termites (Mario Martinez, 2015, unpublished observation). *Cycas micronesia* used to be the most common understory tree (Donnegan et al., 2004). Although densities are still high, *C. micronesia* are often infested with *Aulacaspis yasumatsui*, *Chilades pandava*, and *Erechthia* sp. *Dihammus marianarum* (Marler and Muniappan 2006, Moore et al. 2006, Marler and Lawrence 2012) and don’t regenerate (personal observation Else Demeulenaere, 2014). This project did not record insect damage, but overall most plants showed signs of damage from scale or other pests.
6 MANAGEMENT IMPLICATIONS AND RECOMMENDATIONS

Endangered species management often requires both in situ and ex situ conservation measures to ensure the long-term survival of at risk species. In situ conservation will protect the natural habitat of the species, while ex situ conservation aims to protect the species outside of its habitat by growing plants in tissue culture labs or nurseries and by seed collection for seed storage. Wild populations can be replenished and genetic variation increased by out-planting nursery grown plants.

6.1 THE NEED TO PROTECT FEDERALLY LISTED PLANT SPECIES

The Micronesia/Polynesia region is considered a biodiversity hotspot (Myers et al., 2000). Due to their isolation, islands have high rates of endemism. The high diversity of limestone karst features further increases the levels of endemism. This has also been observed in other regions with exceptional karst feature diversities. Kumar et al. (2016) found that limestone formations are hotspots for endemic orchids. The identification and status of these biodiversity hotspots is needed to prioritize ecosystem protection (Myers et al., 2000). Comprehensive inventories of rare species, as well as habitat indicator species, are necessary to outline conservation management goals (Kumar et al., 2016). The results of this study will fill existing information gaps about the abundance and ecology of the federally listed endangered and threatened species of Guam.

6.2 IDENTIFICATION OF MANAGEMENT GOALS

The management goals can be described on two levels: (1) Habitat management (2) Individual species protection.

In order to protect rare species in a sustainable long-term manner, habitat management and restoration is critical. The subdued and pinnacle eogenetic karren harbor the limestone forest
microhabitat these species need to thrive. The functional ecological components of the limestone forest need to be improved by increasing the species composition and the horizontal and vertical forest structure. Habitat restoration will encourage native birds and Mariana fruit bat to forage, roost and breed in the limestone forest. A healthier limestone forest will also improve the habitat for skinks, geckos, tree snails and coconut crabs.

The existing trees, which are remnants of the primary limestone forest, should be protected from ungulates. Limestone forests need to be protected from ungulates with exclusion fences. Management plans need to consider high biosecurity measures to minimize opportunities for invasive plants and animals to enter these habitats.

6.2.1 ERADICATION AND EXCLUSION OF NONNATIVE UNGULATES

The exclusion and eradication of nonnative ungulates (pig and deer) are required to effectively restore the limestone forest. An absolute barrier is necessary to reach this goal. Forests can be excluded of ungulates by using discrete management units (Sailer, 2006). Fences will need to have a minimum height. The fence should be between 78” and 84” to keep deer from jumping over the fence. A mesh with graduated line wire spacing is recommended to keep both deer and pigs out. Fence skirting is necessary to keep pigs from digging underneath the fence (Sailer, 2006).

6.2.2 INVASIVE PLANT SPECIES CONTROL

Invasive weeds like *Mikania micrantha* can suffocate large canopy trees, and are therefore a treat to endangered species when they invade the forest (APFISN, 2016). *M. micrantha* fills in gaps in the forest easily, which occur when trees fall, or when ungulates destroy the understory of the forest. Suppression of the weeds is an important management goal. Hand pulling and herbicides can be applied to control the weeds. Glyphosate (the active ingredient in Roundup® and Rodeo®)
and triclopyr (the active ingredient in Brush-B-Gone® and Garlon®) are recommended herbicides (APFISN, 2016; Mattrick, 2006).

*Leucaena leucocephala* is mostly found on the edges and doesn’t seem to encroach the forest. Since this tree can’t be removed mechanically foliar application with triclopyr is required. It not recommended using this unless the species invades towards the inside of the forest.

6.2.3 **OUTPLANTING OF NURSERY GROWN SPECIES**

The recovery of threatened and endangered species can only occur when ungulates are excluded from the area to encourage natural regeneration. It is also recommended to outplant nursery grown species to assist natural regeneration.

7 **CONCLUSIONS**

- Only six of thirteen federally listed limestone forest species were found at the 200-acre survey zone.

- Although a few species were found at higher densities (*Cycas micronesica, Eugenia bryanii, Tuberolabium guamense*), they face long-term survival challenges due to invasive plant and animal species. Browsing, insect infestation, seed predation, and habitat quality (species composition and forest structure), are all factors threatening their existence.

- *Dendrobium guamense, Tabernaemontana rotensis, and Heritiera longipetiolata* occur in very low numbers. Aside from habitat restoration and invasive species control, ex situ conservation is recommended to augment their numbers and increase their genetic diversity.
- The other six listed species expected in this habitat (*Bulbophyllum guamense*, *Maesa walkeri*, *Nervilia jacksoniae*, *Psychotria malaspinae*, *Serianthes nelsonii*, *Solanum guamense*) can be reintroduced. *Ex situ* conservation can supplement areas that have ungulate exclusion.

8 ACKNOWLEDGEMENTS

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Christiana Quinata

Biological Monitors:
Maria Cruz
Gerard Aguon
Wien Winner
11 Tables (1-5)
Table 1. Summary of federally listed plant species

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<tr>
<th>Plant Name</th>
<th>Subdued karren</th>
<th>Pinnacle karren</th>
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Table 2. Orchid Phorophytes

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<th>D. guamense</th>
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<td><em>Cynometra ramiflora</em></td>
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<td><em>Eugenia palumbis</em></td>
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<td><em>Eugenia reinwardtiana</em></td>
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<td><em>Eugenia thompsonii</em></td>
<td>3 (36)</td>
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<td></td>
</tr>
<tr>
<td><em>Ficus prolixa</em></td>
<td>–</td>
<td>7 (9)</td>
<td></td>
</tr>
<tr>
<td><em>Heritiera longipetiolata</em></td>
<td>–</td>
<td>1 (2)</td>
<td></td>
</tr>
<tr>
<td><em>Macaranga thompsonii</em></td>
<td>–</td>
<td>1 (1)</td>
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<tr>
<td>Other</td>
<td>30 (256)</td>
<td>5(8)</td>
<td></td>
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</table>
Table 3. Vegetation Mapping for Pinnacle Karren Area (ACFOR: ABUNDANT (greater than/equal to 30%), COMMON (20% to 29%), FREQUENT (10% to 19%), OCCASIONAL (5% to 9%), and RARE (1% to 4%))

<table>
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<tr>
<th>Species Name</th>
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<th>Vegetation Structure</th>
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<th>Growth Habitat</th>
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Table 4. Vegetation Mapping for Subdued Karren Area (ACFOR: ABUNDANT (greater than/equal to 30%), COMMON (20% to 29%), FREQUENT (10% to 19%), OCCASIONAL (5% to 9%), and RARE (1% to 4%))

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<td>Ficus saffordii</td>
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<td>Flagellaria indica</td>
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<td>Woody Vine</td>
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<td>Guamia marianne</td>
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<td>Guettarda speciosa</td>
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<td>Jasminum marianum</td>
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<td>Laportea ruderalis</td>
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<th>Status</th>
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<td>Syzygium thompsonii</td>
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<td>Tristirops obtusangula</td>
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<td>Tubelolabium guamense</td>
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<td>Wikstroemia elliptica</td>
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<td>Zehneria guamensis</td>
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1 FIGURES (1-14)
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Figure 11: *Tabernaemontana rotensis* (a) habitat (b) leaves (c) flowers (d) fruit
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Figure 14: Survey work (a) Matthew Putman and Jocelyn Emia navigate through the karst (b) Arthur Perez enters data into the Trimble (c) Wien Winner, Matthew Putnam, Christa Shen, Christiana Jo Quinata & Lauren Guiterrez continue their transect after tagging.
2 GIS MAPS (1-13)
Map 1: Topographic Map of Survey Area & Zones

Listed Plant Species Survey

Sources: USGS Topographic Quadrangle Maps (2001); Lidar data by USGS, 2012; Digital Atlas of Guam by WERI.

Map created by Maria Kottermair | March 2018

Quaternary Beach deposits
Pliocene & Pleistocene
Mariana Limestone - Reef facies
Mariana Limestone Detrital facies

Survey area
1:11,000

0 0.2 mi
0 0.3 km

Mount Machanao

Pajon Point

Jinapsan Point

Sources: USGS Topographic Quadrangle Maps (2001); Lidar data by USGS, 2012; Digital Atlas of Guam by WERI.

Map created by Maria Kottermair | March 2018
Map 2: Satellite Map of Survey Area & Zones

Listed Plant Species Survey

Map created by Maria Kottermair | March 2018

2016 WorldView-3 satellite imagery by DigitalGlobe; 2012 Lidar data by USGS.
Map 3: Terrain Map of Survey Area & Zones

Eogenic karren
- Pinnacle
- Subdued
- Survey area

Map created by Maria Kottermair | March 2018
Map 4: Geology Map of Survey Area & Zones

Listed Plant Species Survey

Geologic units

Quaternary
- Beach deposits

Pliocene & Pleistocene
- Mariana Limestone - Reef facies
- Mariana Limestone Detrital facies
- Survey area

Eogenic karren
- Pinnacle
- Subdued

Sources: Geology by Siegrist and Reagan, 2008; 2012 Lidar data by USGS; Digital Atlas of Guam by WERI iREi; 2016 WorldView-3 satellite imagery by Digital Globe.
Map created by Maria Kottermair | March 2018
Soil units

- Guam cobbly clay loam, 3 to 7 percent slopes
- Guam-Urban land complex, 0 to 3 percent slopes
- Ritidian-Rock outcrop complex, 15 to 60 percent slopes
- Ritidian-Rock outcrop complex, 3 to 15 percent slopes
- Rock outcrop-Ritidian complex, 60 to 99 percent slopes
- Shioya loamy sand, 0 to 5 percent slopes

Survey area


Map created by Maria Kottermair | March 2018
Map 6: Transect Map of Survey Area & Zones

Listed Plant Species Survey

Field transects

- Actual transect
- Survey area

1:11,000

Sources: 2016 WorldView-3 satellite imagery by DigitalGlobe; 2012 Lidar data by USGS

Map created by Maria Kottermair | March 2018
Map 7C: *Cycas microsperma* Occurrence

Source: 2016 WorldView-3 satellite imagery by DigitalGlobe. Map created by Maria Kottermair | March 2018
Map 8: *Cycas micronesica* Density

Listed Plant Species Survey

2016 WorldView-3 satellite imagery by DigitalGlobe. Map created by Maria Kottermair | March 2018
Map 9A: Epiphytic Orchid Occurrence

Listed Plant Species Survey


Orchids

- Dendrobium guamense
- Tuberolabium guamense

Survey area

A

B

C

Survey area

0 0.1 mi

0 0.2 km

1:5,000
Map 9B: Epiphytic Orchid Occurrence

Listed Plant Species Survey

Orchids
- *Dendrobium guamense*
- *Tuberolabium guamense*

Survey area

Source: 2016 WorldView-3 satellite imagery by DigitalGlobe. Map created by Maria Kottermair | March 2018
Map 9C: Epiphytic Orchid Occurrence

Listed Plant Species Survey

Source: 2016 WorldView-3 satellite imagery by DigitalGlobe. Map created by Maria Kottermair | March 2018

Orchids
- **Dendrobium guamense**
- **Tuberolabium guamense**

Survey area
Map 10A: Other Listed Plants Occurrence

Listed Plant Species Survey

Other listed species
- Eugenia bryanei
- Heritiera longipetiolata
- Serianthes nelsonii
- Tabernaemontana rotensis
- Survey area

Source: 2016 WorldView-3 satellite imagery by DigitalGlobe. Map created by Maria Kottermair | March 2018
Map 10B: Other Listed Plants Occurrence

Other listed species

- Eugenia bryanii
- Heritiera longipetioluta
- Serianthes nelsonii
- Tabernaemontana rotensis

Survey area

Source: 2016 WorldView-3 satellite imagery by DigitalGlobe. Map created by Maria Kottermair | March 2018
Map 10C: Other Listed Plants Occurrence

Listed Plant Species Survey

- **Eugenia bryanii**
- **Heritiera longipetiolata**
- **Serianthes nelsonii**
- **Tabernaemontana rotensis**

Survey area

Source: 2016 WorldView-3 satellite imagery by DigitalGlobe. Map created by Maria Kottermair | March 2018
Map 11: Density of Other Listed Plants

Listed Plant Species Survey

Survey area

Other listed plants*
Density per hectare

- 0
- 1 - 31
- 32 - 79
- 80 - 134
- 135 - 198
- 199 - 325

Survey area

Sources: 2016 WorldView-3 satellite imagery by DigitalGlobe; 2012 Lidar data by USGS
Map created by Maria Kottermair | March 2018

* Eugenia bryanii, Heritiera longipetiolata, Serianthes nelsonii, Tabernaemontana rotensis;
Listed Plant Species Survey

Map 12: Heat Map of All Listed Plants

Weighted density heat map of listed plants

Endangered species (weight of "3"): Eugenia bryanii, Heritiera longipetiolata, Serianthes nelsonii; Threatened species (weight of "1"): Cycas micronesica, Dendrobium guamense, Tabernaemontana rotensis, Tuberoabium guamense.

Survey area

Sources: 2016 WorldView-3 satellite imagery by DigitalGlobe; 2012 Lidar data by USGS.
Map created by Maria Kottermair | March 2018
Map 13: Density of Listed Epiphytic Orchids

Legend:
- **0**
- 1 - 162
- 163 - 354
- 355 - 647
- 648 - 1,234
- 1,235 - 2,568

Survey area

Sources: 2016 WorldView-3 satellite imagery by DigitalGlobe; 2012 Lidar data by USGS

Map created by Maria Kottermair | March 2018
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2 GIS MAPS (1-13)
Map 2: Satellite Map of Survey Area & Zones

Listed Plant Species Survey

Map created by Maria Kottermair | March 2018

2016 WorldView-3 satellite imagery by DigitalGlobe; 2012 Lidar data by USGS.
Map 3: Terrain Map of Survey Area & Zones

Listed Plant Species Survey


Map created by Maria Kottermair | March 2018

Eogenic karren
- Pinnacle
- Subdued

Survey area

Scale: 1:11,000

Legend:
- 0.2 mi
- 0.3 km
Map 4: Geology Map of Survey Area & Zones

Geologic units

**Quaternary**
- Beach deposits

**Pliocene & Pleistocene**
- Mariana Limestone - Reef facies
- Mariana Limestone Detrital facies

**Eogenic karren**
- Pinnacle
- Subdued

Survey area

Sources: Geology by Siegrist and Reagan, 2008; 2012 Lidar data by USGS; Digital Atlas of Guam by WERI/ iREi; 2016 WorldView-3 satellite imagery by Digital Globe.

Map created by Maria Kottermair | March 2018
Listed Plant Species Survey

Map 5: Soils Map of Survey Area & Zones

Soil units

- Guam cobbly clay loam, 3 to 7 percent slopes
- Guam-Urban land complex, 0 to 3 percent slopes
- Ritidian-Rock outcrop complex, 15 to 60 percent slopes
- Ritidian-Rock outcrop complex, 3 to 15 percent slopes
- Rock outcrop-Ritidian complex, 60 to 99 percent slopes
- Shioya loamy sand, 0 to 5 percent slopes

Survey area

1:11,000

Sources: Geology by Siegrist and Reagan, 2008; 2012 Lidar data by USGS; Digital Atlas of Guam by WERI/IREI; 2016 WorldView-3 satellite imagery by Digital Globe. Map created by Maria Kottermair | March 2018
Map 6: Transect Map of Survey Area & Zones

Listed Plant Species Survey

Field transects
- Actual transect
- Survey area

1:11,000

Sources: 2016 WorldView-3 satellite imagery by DigitalGlobe; 2012 Lidar data by USGS
Map created by Maria Kottermair | March 2018
Map 7A: *Cycas micronesica* Occurrence

Survey area

Source: 2016 WorldView-3 satellite imagery by DigitalGlobe. Map created by Maria Kottermair | March 2018
Map 7B: *Cycas micronesica* Occurrence

Source: 2016 WorldView-3 satellite imagery by DigitalGlobe. Map created by Maria Kottermair | March 2018
Map 7C: Cycas micronesica Occurrence

Source: 2016 WorldView-3 satellite imagery by DigitalGlobe. Map created by Maria Kottermair | March 2018
Map 8: *Cycas micronesica* Density

**Listed Plant Species Survey**

Survey area

*Cycas micronesica* Density per hectare

- 0
- 1 - 76
- 77 - 181
- 182 - 299
- 300 - 452
- 453 - 809

Survey area

2016 WorldView-3 satellite imagery by DigitalGlobe. Map created by Maria Kottermair | March 2018
Map 9A: Epiphytic Orchid Occurrence

Listed Plant Species Survey


Orchids
- *Dendrobium guamense*
- *Tuberolabium guamense*

Survey area
Map 9B: Epiphytic Orchid Occurrence

Listed Plant Species Survey

Source: 2016 WorldView-3 satellite imagery by DigitalGlobe. Map created by Maria Kottermair | March 2018

Orchids
- Dendrobium guamense
- Tuberolabium guamense

Survey area

0 0.1 mi
0 0.2 km
0 1:5,000
Other listed species

- *Eugenia bryanii*
- *Heritiera longipetiolata*
- *Serianthes nelsonii*
- *Tabernaemontana rotensis*

Survey area

Source: 2016 WorldView-3 satellite imagery by DigitalGlobe. Map created by Maria Kottermair | March 2018
Map 10B: Other Listed Plants Occurrence

Listed Plant Species Survey

Other listed species
- Eugenia bryanii
- Heritiera longipetiolata
- Serianthes nelsonii
- Tabernaemontana rotensis

Survey area

Source: 2016 WorldView-3 satellite imagery by DigitalGlobe. Map created by Maria Kottermair | March 2018
Map 10C: Other Listed Plants Occurrence

Listed Plant Species Survey

Other listed species
- Eugenia bryanii
- Heritiera longipetiolata
- Serianthes nelsonii
- Tabernaemontana rotensis
- Survey area

Source: 2016 WorldView-3 satellite imagery by DigitalGlobe. Map created by Maria Kottermair | March 2018
Map 11: Density of Other Listed Plants

Listed Plant Species Survey

Sources: 2016 WorldView-3 satellite imagery by DigitalGlobe; 2012 Lidar data by USGS

Map created by Maria Kottermair | March 2018

Other listed plants*
Density per hectare

- 0
- 1 - 31
- 32 - 79
- 80 - 134
- 135 - 198
- 199 - 325
- Survey area

* Eugenia bryanii, Heritiera longipetiolata, Serianthes nelsonii, Tabernaemontana rotensis;
Listed Plant Species Survey

Map 12: Heat Map of All Listed Plants

Weighted density heat map of listed plants

Survey area

1:11,000

Endangered species (weight of “3”): Eugenia bryanii, Heritiera longipetiolata, Serianthes nelsonii; Threatened species (weight of “1”): Cycas micronesica, Dendrobium guamense, Tabernaemontana rotensis, Tuberalabium guamense;

Sources: 2016 WorldView-3 satellite imagery by DigitalGlobe; 2012 Lidar data by USGS. Map created by Maria Kottermair | March 2018
Map 13: Density of Listed Epiphytic Orchids

Listed Plant Species Survey

Map created by Maria Kottermair | March 2018

Sources: 2016 WorldView-3 satellite imagery by DigitalGlobe; 2012 Lidar data by USGS