Final Project Report

Federal Candidate Species Surveys on Guam

Prepared for:
Naval Facilities Engineering Command Marianas

Prepared by:
University of Guam

Under
Cooperative Agreement N40192-12-2-8001

January 2014

Acronyms and Abbreviations

AAFB	**Anderson Air Force Base**
AAFB-NWF	**Anderson Air Force Base - Northwest Field**
AH	**Apra Harbor**
BA	**Barrigada**
BOLD	**Barcode of Life Database**
bp	**Nucleotide base pairs**
CATR	**Cooperative Agreement Technical Representative**
cm^2	**Square centimeters**
CNMI	**Commonwealth of the Northern Mariana Islands**
COI	**Cytochrome Oxidase Subunit I**
DNA	**Deoxyribonucleic Acid**
DoD	**Department of Defense**
DON	**Department of the Navy**
ESA	**Endangered Species Act**
EtOH	**Ethanol**
FG	**Finegayan**
GPS	**Global Positioning System**
HERA	**Haputo Ecological Reserve Area**
m	**Meters**
m^2	**Square Meters**
mm	**Millimeters**
mtDNA	**Mitochondrial DNA**
NAVFAC	**Naval Facilities Engineering Command**
NBGAH	**Naval Base Guam Apra Harbor**
NBGTS	**Naval Base Guam Telecommunications Site**
NWF	**Northwest Field**
PAUP*	**Phylogenetic Analysis Using Parsimony**
PCR	**Polymerase Chain Reaction**
RT	**Route 15**
SBS	**Simultaneous Bidirectional Sequencing**
UoG	**University of Guam**
UHM	**University of Hawaii at Manoa**
USFWS	**United States Fish and Wildlife Service**

FEDERAL CANDIDATE SPECIES SURVEYS ON GUAM

Prepared by

Daniel P. Lindstrom, Ph.D. & John C. Benedict, Ph.D.

University of Guam
Unibetsedåt GUAHAN
College of Natural and Applied Sciences

Prepared For

Naval Facilities Engineering Command Marianas

January 21, 2014

FEDERAL CANDIDATE SPECIES SURVEYS ON GUAM

TABLE OF CONTENTS

APPENDICES

List of Figures & Tables

Figure **Page**

Table **Page**

ABSTRACT

Surveys for five Endangered Species Act candidate species were conducted on Guam under a cooperative agreement between the University of Guam and the Department of Navy (DON) (N40192-12-8001). The target species include two nymphalid butterflies, *Hypolimnas octocula marianensis* and *Vagrans egistina*, and three partulid snails, *Samoana fragilis*, *Partula radiolata*, and *Partula gibba*. The survey was divided into two temporal components, a dry season (March and April 2013) and wet season (June and July 2013); both were aimed at locating candidate species and recovering DNA for molecular analyses. The dry season survey consisted of 47 transects (>42 km distance) of forested regions of Guam, which were surveyed via visual census methods to determine the presence of candidate species and butterfly host plants. *H. octocula marianensis* was discovered on two transects, one on Andersen Air Force Base Northwest Field (AAFB-NWF) area, and the other on non- Department of Defense (DoD) lands adjacent to Route 15 on the eastern side of Guam. The host plants of *H. octocula marianensis*, *Procris pedunculata* and *Elatostema calcareum*, were only encountered in heavily forested cliff line/tower karst dominated areas of Guam, which are inaccessible to invasive ungulate herbivores. The host plant of *V. egistina*, *Maytenus thompsonii*, was present on multiple transects, but no evidence of *V. egistina* was found. Three individual populations of *P. radiolata* were discovered near a small freshwater stream and living on large *Annona reticulata* and *Morinda citrifolia* trees on one transect in Navy Base Guam, Apra Harbor (NBGAH). No populations of *S. fragilis* or *P. gibba* were found during the dry season, transect based, surveys. The wet season surveys consisted of targeted searches that were a combination of revisits to sites with candidate species observed in the dry season, visits to sites on DoD property most likely to contain suitable target species habitat based on previous work and non-DoD land with previous reports of candidate species. This was done in order to collect a greater geographic set of DNA samples for comparison to populations found on DoD property. Multiple instances of *H. octocula marianensis*, eggs, larvae and adults were reported, as well as both its host plants *E. calcareum* and *P. pedunculata*. *P. radiolata* were observed in many targeted search areas around the island, but *P. gibba* were found only on

Naval Base Guam Telecommunications Site (NGBTS) and *S. fragilis* were also observed on NGBTS as well as one on non-DoD lands.

Genetic analyses of candidate species found during surveys were used to confirm field species identifications for all three partulid snail species and some life history stages of *H. octocula marianensis.* Genetic information indicated that sequence heterogeniety is virtually identical between individuals of three of the candidate species found in this study (*H. octocula marianensis, P. gibba and S. fragilis)* indicative of recent populational bottle necks and small extant population sizes. *P. radiolata* showed some slight genetic variability, but still a similar state of affairs to the other species even though its numbers and geographic distributions are greater.

Numerous management and recovery recommendations for each of the candidate species are put forth in light of the results of the present and previous studies. These include extant population protective and enhancement measures along with the identification of basic scientific information gaps and suggested lines of inquiry that will further inform conservation efforts in the future.

1.0 INTRODUCTION

1.1 General Background

The USFWS has developed a multi-year listing work plan for species listed on the 2010 Candidate Notice of Review to determine if they should be added to the Federal Lists of Endangered and Threatened Wildlife and Plants (USFWS, 2012). The multi-year listing work plan was first developed through an agreement with the plaintiff group WildEarth Guardians and filed in the U.S. District Court for the District of Columbia on May 10, 2011. On July 12, 2011, the USFWS reached an agreement with plaintiff group Center for Biological Diversity that reinforces the multi-year work plan. This complimentary agreement includes additional scheduling commitments for a small subset of the actions in the work plan that is consistent with the USFWS' objectives and biological priorities. These historic agreements were approved in Washington, DC on September 9, 2011 (USFWS, 2013).

The plan lists 6 species for Guam, 4 of which currently occur on Guam (Mariana eight-spot butterfly *H. octocula marianensis*, fragile tree snail *S. fragilis*, Guam tree snail *P. radiolata*, and humped tree snail *P. gibba*) and 2 that are extirpated and do not currently occur on Guam (Pacific sheath-tailed bat *Emballomura semicaudata* and Mariana wandering butterfly *V. egistina*) (USFWS, 2012). The USFWS work plan specifies that these species will be proposed for listing (if warranted) and designation of critical habitat will be proposed (if prudent and determinable) in FY2014 and a final listing and critical habitat determination in FY2015 (USFWS, 2013).

Field surveys of the federal candidate invertebrate species on Guam are necessary to adequately assess their present distributions and status of extant populations. The five taxa investigated in this study include three partulid snail and two nymphalid butterfly species. The snails include the Fragile tree snail (*S. fragilis*), Guam tree snail (*P. radiolata*), Humped tree snail (*P. gibba*), while the butterflies include the Mariana eight spot butterfly (*H. octocula marianensis*) and the Mariana wandering butterfly (*V. egistina*). These assessments are vital for the future management of these species and the conservation and most beneficial use of the habitats upon which they depend.

1.2 Candidate Species Descriptions

Partulid Snails

The Partulidae are a family of pulmonate (air breathing), terrestrial gastropods endemic to Pacific islands (Cowie, 1992). Most of the 120 known partulid species are arboreal, and endemic to single islands or a few adjacent islands (Cowie, 1992). A large number of partulid species have gone extinct or are close to extinction. Reasons for their decline include habitat destruction from construction and wartime activities and introduction of feral ungulates (pigs, deer, goats and cattle), introduced predators (e.g., rats, ants, predatory snails, and flatworms), as well as collection by humans for ornamental purposes. There are three partulid genera: *Eua*, *Partula*, and *Samoana*. Only members of the latter two genera occur in the Mariana Islands, including three extant species on Guam (see below). Although the term "host plant" or "host tree" has often been used (e.g., Cowie, 1992; Smith et al, 2008) to describe the plant, tree, or shrub that partulids are found on, no obligatory relationships between particular plant species and partulid snails on Guam are known. In this report, plants occupied by partulids are referred to as "home plants" in order to avoid the potentially confusing assumption of high specificity that the term "host" carries. All three extant partulid species on Guam are candidate species.

Fragile tree snail *(S. fragilis)*

S. fragilis (Figure 1) is arboreal, endemic to the islands of Guam and Rota of the Mariana Islands, and the only species of the genus found outside of southern Polynesia (Smith and Randall, 2007; Smith *et al.*, 2008; See Appendix A for a review of Partulidae on Guam). This species is currently threatened by habitat loss/modification and by predation from nonnative predatory flatworms and is currently known from a single population on Guam and one other on Rota (Hopper and Smith, 1992; Smith *et al.*, 2008; USFWS, 2012). Large numbers of introduced ungulates, such as the Philippine deer (*Cervus mariannus*), pigs (*Sus scrofra*), goats (*Capra hircus*) and water buffalo (*Bubalus bubalis*) directly alter the understory plant community and overall forest microclimate, making it unsuitable for snails. Predation by the New

Figure 1. *S. fragilis*.

Guinea flatworm (*Platydemus manokwari*), and, possibly, ants and rats (*Rattus* spp.) is a serious threat to the survival of *S. fragilis*. Field observations have established that the New Guinea flatworm will readily feed on native Pacific Island tree snails, including the Partulidae, such as those of the Mariana Islands (Smith *et al.*, 2007). *P manokwari* has also been considered the cause of multiple extinction or extirpation events of native land snails on the Pacific islands. Recently, *P. manokwari* have been shown to be effective tree snail predators that ascend trees to locate arborescent snails and even track partulids by following chemical signals in slime trails secreted by the snails (Sugiura and Yamaura, 2009). The rosy wolf snail (*Euglandina rosea*, Figure 2) has caused the extirpation of many native or endemic species of snails throughout the Pacific islands and the deliberate introduction of this alien predator as a supposed means of controlling the agriculture pest giant African snail (*Achatina fulica*) has become a conservation crisis for over thirty years (Lee *et al.*, 2009), though this snail has not been formally recorded on Guam in recent years (A. Kerr, pers. comm.).

Figure 2. Dead *E. rosea* shell.

Guam tree snail *(P. radiolata)*

P. radiolata (Figure 3) is an arboreal partulid that is endemic to Guam and is restricted to cool, shaded forest habitats on the island (USFWS 2012, See Appendix A for a full review). As with other members of the Partulidae, *P. radiolata* is primarily threatened by predation from the nonnative predatory flatworm *P. manokwari*, ants, and possibly rats (*Rattus* spp.) and is currently known from 22 populations on Guam (USFWS, 2012). Although it is the most widely distributed partulid on Guam, this species is also threatened by habitat loss and degradation (see summary for the fragile tree snail, above).

Figure 3. *P. radiolata* on *Morinda citrifolia*.

Humped tree snail *(P. gibba)*

The humped or fat tree snail, *P. gibba* (Figure 4), is another arboreal member of the Partulidae, and was originally known from the island of Guam and the Commonwealth of the Northern Mariana Islands (islands of Rota, Aguiguan, Tinian, Saipan, Anatahan, Sarigan, Alamagan, and Pagan), but is now only documented on Guam, Saipan, Sarigan and Pagan (USFWS, 2012). Although still the most widely distributed endemic tree snail in the Mariana Islands, current population sizes are reported to be small and isolated. Throughout all the Mariana Islands, feral ungulates pigs (*S. scrofa*), Philippine deer (*C. mariannus*), cattle (*Bos taurus*), water buffalo (*B. bubalis*), and goats (*C. hircus*) have caused severe damage to native forest vegetation by browsing, causing erosion and inhibiting forest growth and

regeneration. This in turn reduces the quantity and quality of forested habitat for the humped tree snail. Currently, populations of feral ungulates are found on the island of Guam (deer, pigs, goats and water buffalo). Predation by the introduced New Guinea flatworm (*P. manokwari*) is a serious threat to the survival of the humped tree snail (see summary for the fragile tree snail, above).

Figure 4. *P.gibba on Alocasia macrorriza.*

Nymphalid Butterflies

Nymphalids are the largest family of butterflies, with perhaps 6,000 species known worldwide. There are four species known from the Mariana islands; *Hypolimnas bolina, H. anomala, H. octocula marianensis* (Figures 5-7), and *V. egistina*. All four have been found on Guam, with the latter two endemic to the Marianas; both are candidate species.

Mariana eight spot butterfly *(H. octocula marianensis)*

The Mariana eight spot butterfly is a nymphalid butterfly subspecies that feeds in its larval form upon two host plants, *P. pedunculata* (Figures 7 & 8) and *E. calcareum* (Urticaceae), and is endemic to Guam and Saipan, but may have become extirpated from Saipan as suggested by previous studies (Schreiner and Nafus, 1996; Campora and Lee, 2009; See Appendix B for a review). On Guam, *H. octocula marianensis* is currently known from six locations and not the ten incorrectly reported previously (USFWS, 2012): Orote Point, Hilaan, Tweed's Cave area, Pagat Cave area, Mangilao golf course and Fadian cove (Schreiner and Nafus, 1996; HDR, 2012). In addition to the ecological threats posed by grazing of obligate host plants and habitat destruction by feral vertebrates described above for snails, members of this genus are additionally threatened by predation by ants and egg parasitism by wasps, including *Telenomus* sp., *Oencyrtus* sp. and *Trichogramma chilonus* (Nafus, 1993; Schreiner and Nafus, 1996; Campora and Lee, 2009; USFWS, 2012).

Figure 5. *H. octocula marianensis* adult.

Figure 6. *H. octocula marianensis* eggs on *E. calcareum.*

Figure 7. *H. octocula marianensis* chrysalide on *P. pedunculata.*

Figure 8. Field team member searching for butterfly eggs, larvae and chrysalides on *P.pedunculata.*

Mariana wandering butterfly *(V. egistina)*

The Mariana wandering butterfly is a nymphalid butterfly species is known to feed as a larva upon the host plant species, *M. thompsonii* (Schreiner and Nafus, 1997, Figure 9). *V. egistina* has not been reported from Guam since the 1970's, but was identified on Rota in the 1980's, and 10 individuals were found in one location (The Bird Sanctuary) on Rota in 1995. *V. egistina* is suspected to be a target of the same three hymenopteran egg parasitoids that threaten other *Hypolimnas* species on Guam: *Telenomus* sp., *Oencyrtus* sp. and *T. chilous*, but this predation and parasitism has not been documented in this species (Nafus, 1993; Schreiner and Nafus, 1996; Campora and Lee, 2009; USFWS, 2012).

Figure 9. *M. thompsonii*.

1.3 Project Objectives

The main goals of this study were to methodically survey selected DoD controlled lands for presence of candidate species and to describe habitat qualities in terms of vegetation in surveyed areas (Figures 10 & 11). This study was conducted in two phases: dry season & wet season. In dry season surveys, detailed transects of delineated areas were performed (Figure 10). During wet season surveys, a set of targeted searches for the candidate species was conducted to gain a deeper understanding of their distribution and to collect additional DNA samples for molecular analyses (Figure 11). During all surveys when individuals of candidate species or known host plants were discovered, they were subjected to closer inspection in order to determine population characteristics. In addition to physical identifications of candidate species, their locations and descriptions, genetic analyses of a subset of individuals from each population were conducted. This genetic information carries potential answers to questions on an island-wide geographical and long-term temporal scale.

Figure 10. Candidate Species Dry Season Survey Areas

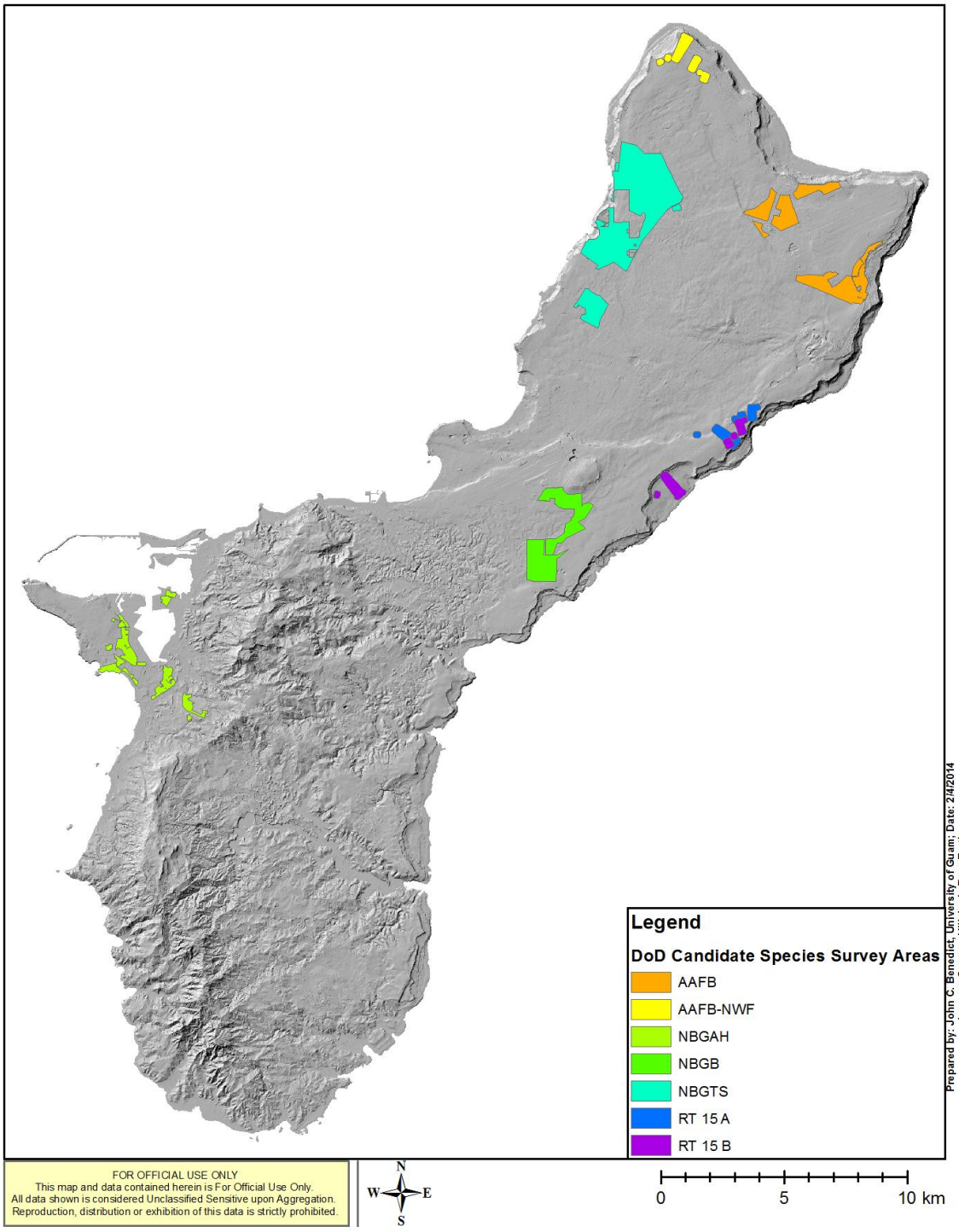
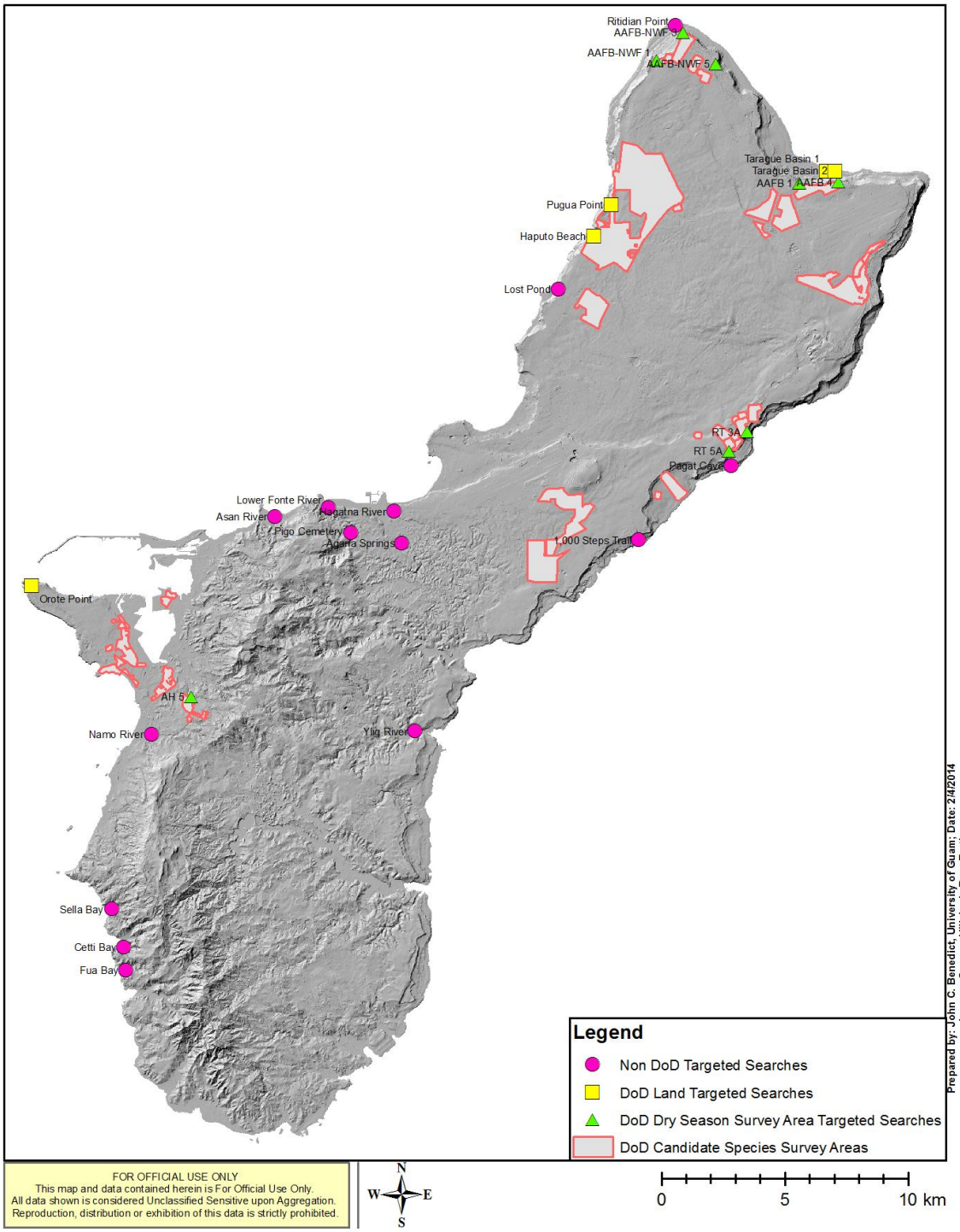


Figure 11. Candidate Species Wet Season Search Areas



2.0 METHODS

2.1 General Survey Methodology and Timelines

A total of 2,700 acres of primary and secondary forest were considered for these transects from the total 6,077 acres in the proposed survey areas provided by the DON. Forested areas were chosen, because both the tree snails and butterflies have been previously found in such areas, as have the host plants for the two nymphalid butterflies. The areas surveyed included five areas on Guam with suitable habitats for the candidate species; one on privately owned lands adjacent to Route 15 (RT 15), two on Andersen Air Force Base (AAFB and AAFB-NWF) and two on Navy property (NBGAH and NBGTS). The survey was conducted in two phases. An initial survey in the dry season was conducted between 3/25/2013 and 4/17/2013 and consisted of 47 transects equaling over 42 linear kilometers (Appendices C and D). The second phase, during the wet season (7/1/2013 – 8/2/2013), used targeted searches of locations known to contain candidate species from and adjacent to our dry season transect surveys and those identified from previously published surveys, word of mouth and some identified as likely to be suitable habitat based on GIS information.

Transect Surveys: When dry season transect surveys were conducted, each of the 47 transect was split into 250 m intervals and waypoints were uploaded to two GPS receivers to facilitate location of transects and data collection stations. At the beginning and end of each transect, as well as at each data collection station, the team recorded the dominant flora, noted signs of ungulate presence, soil type, and any other information pertinent to the study or of potential scientific merit (Appendix D). Candidate species were surveyed along the transect via visual census methods. When candidate species or butterfly host plants were identified, the team stopped the transect survey and employed consistent methodologies for documenting the location and species of host/home plants and any candidate species present (See sections 2.2 and 2.3 for methods and section 7 below for a list of field participants). When documentation for candidate species was completed, the survey crew continued along the transect path.

Targeted Surveys: Areas with candidate species reported during the dry season survey were revisited in the wet season (July and August 2013) to note any seasonal trends and to obtain a larger sampling for molecular analyses. Areas visited included previously visited areas within the dry season survey areas, areas on DoD property with previous reports of candidate species and areas not on DoD land previously reported to have candidate species. Targeted searches during the wet season involved team members spanning out over the above defined areas and visually searching for candidate species and butterfly host plants in the same manner as used along previous transect searches. Once any of these taxa were recognized, the following protocols were employed.

2.2 Butterfly Specific Survey Methodologies and Field Data Collection

In the event that an adult butterfly, or butterfly host plant (*P. pedunculata, E. calcareum* and *M. thompsonii)* was discovered, the survey team began a focused search to locate and identify the candidate species, *V. egistina* and *H. octocula marianensis* at any life stage (egg-larva-pupa-adult, Figures 7 - 10). When host plants were identified, all members of the survey team stopped transect advancement and analyzed each leaf and branch of the plant within reach for the presence of any butterfly life stages. The number and life stages of any individuals were recorded, photographed and GPS coordinates were taken (Appendix E). Focused searches lasted from five to thirty minutes depending on the size of the plants and the number of butterfly individuals present. Upon completion of the focused search, the transect surveys and targeted searches resumed until the end of that transect was reached.

2.2.1 Field Sampling for Butterfly Genetics

When *H. octocula marianensis* or *V. egistina* adults, or host plants containing larvae, larval molts, frass, vacated eggs or chrysalides were found, non-lethal tissue sampling protocols were followed. Larval molts, frass, vacated eggs and chrysalides were photographed and preserved in 95% EtOH for later DNA extraction and analysis. Live adults were caught using a method consisting of careful hand-net capture and handling of adults. Adults were released after careful excision of a small sample (0.25 cm^2) of hind

wing tissue using iris scissors, which was preserved in 95% EtOH for later DNA extraction and analysis. This technique has been thoroughly tested and shown to not be detrimental to butterfly flight characteristics or long term survival when released after this procedure (Koscinski *et al.*, 2011).

2.2.2 Butterfly Genetic Sequencing and Analysis

Field preserved wing tissue, vacated eggs, larval frass, larval molts and vacated chrysalides were brought to the laboratory where they were stored for processing and analysis. Samples had genomic DNA isolated and purified using a standard kit according to manufacturers protocols (Genomic DNA Mini Kit Plant, IBI Scientific, Peosta, IA U.S.A.) with the following modifications to increase DNA yeild; 1. Samples were macerated using a razor blade instead of grinding. 2. GPX1 buffer replaced GP1 buffer. 3. Samples were incubated overnight rather than the 10 minutes suggested by manufacturer in order to increase lysis effectiveness. 4. A final elution volume of 30 µl was put through the filter twice. This purified DNA was then used as a template to amplify a targeted homologous 710 bp segment of the mitochondrial (mtDNA) Cytochrome Oxidase Subunit I (COI) gene from each sample using the following PCR protocol. The following "universal" PCR primers (Folmer *et al.*, 1994) known to work across a wide range of animal taxa, were employed: LCO-1490, 5'GGTCAACAAATCATAAAGATATTGG3' position 1490 on the *Drosophila yakuba* 5' nucleotide, and HCO-2198, 3'TAAACTTCAGGGTGACCAAAAAATCA5', position 2198 on the *Drosophila yakuba* 5' nucleotide (IDT, Integrated DNA Technologies, Coralville, IA U.S.A.) amplifying a DNA segment of approximately 700 base pairs. For PCR reactions, 2 µl of the above extracted genomic DNA was used as a template in a 50 µl reaction containing 1X reaction buffer (10 mM Tris HCl, pH 8.3, 1.5 mM $MgCl_2$, 50 mM KCl, 0.01% NP-40, 0.01% TritonX 100); 2.0 mM each of dATP, dGTP, dCTP, dTTP; 0.5 µM of each primer; and 1 unit of DNA polymerase (AmpliTaq Gold® 360 DNA Polymerase, Applied Biosystems, Foster City, CA U.S.A.). DNA amplification was performed in a Eppendorf Mastercycler Pro thermal cycler with the following temperature profile: 94°C for 150 seconds, followed by 35 cycles of 60 seconds at 94°C, 90 seconds at 44°C and 150 seconds at 72°C with a final 5-minute extension at 72 °C and a hold at 4°C until samples could be frozen for later analysis and

use. Aliquots of the PCR reaction products (3 µl) were analyzed on a 1.0%, ethidium bromide stained, agarose gel. If sufficient amounts of amplified DNA were present, these were cleaned using a commercially available kit according to manufacturer's instructions (QIAquick® PCR Purification Kit, Qiagen Corp., Hilden, Germany) with a final elution volume of 30 µl run through the filter twice. Purified PCR products were sequenced using a kit (USB Thermo Sequenase™ cycle Sequencing Kit. Affymetrix, Inc., Cleveland, OH. U.S.A.) according to *LI-COR* specifications (Simultaneous Bidirectional Sequencing, SBS™ protocol) and sequenced using a *LI-COR* 4300 DNA analyzer/autosequencer. Sequence of an analogous 710 bp region of COI for all isolated DNA samples was generated for each specimen in both directions using each of the primers employed in initial PCR amplification. These complementary sequences were then aligned, compared, edited and combined to produce a complete primer-to-primer sequence for each specimen using Sequencher software (Gene Codes Inc., Ann Arbor MI). All sequences generated from individuals collected in this study were aligned for comparisons to each other and provided needed information on the extent to which Guam subpopulations may have been isolated from each other. The COI sequences produced will be submitted to both the Barcode of Life Database (BOLD) and GenBank, where they will be accessible to scientists worldwide.

Genetic information from all collected life history phases of the two candidate butterfly species were produced and analyzed as a possible means to verify species identifications as some of the target species and life history phases are difficult or impossible to discern visually. Prior to this study, *H. octocula marianensis* could only be unambiguously identified from morphological characticsas adults. Their eggs, larvae, and pupae are similar to congeners, *H. bolina* and *H. anomala,* which are common on Guam (Schreiner and Nafus, 1997). The inability to unambiguously identify immature individuals has been an impediment to surveys of these and other rare butterflies. For example, Campora and Lee (2009) sighted one male and possibly one female adult in their 2009 survey of "Route 15 Lands". However, they also found nineteen eggs, seven larvae, and three empty chrysalides on the two known host plants for *H. octocula marianensis*, but they could only be reliably identified to genus (*Hypolimnas*) based on adult

morphology. This study attempted to isolate sequencable DNA from vacated butterfly frass, eggs, larval molts and empty chrysalides found on known host plants as a means of positive species identification of these life stages for this study and possibly as a means of verification of non-genetic physical and ecological characteristics that can be used in future field studies.

2.3 Tree Snail Specific Methodologies and Field Data Collection

When target snail species (*S. fragilis, P. radiolata* and *P. gibba*) were located along a transect or targeted search, forward progress was stopped to conduct an intensive, timed search of the area in the manner of Smith *et al.* (2008). When an individual of a target snail species was located and identified, a quadrat with a diameter of eight m (50 m^2) centered on the trunk of the home plant was searched for one person-hour, noting the species of snail found, number of individuals found, and what plant or substrate they were found on. One person-hour was divided by the number of individuals searching to keep a standard search effort to infer population size, and if four individuals searched, each occupied a quarter of the quadrat and searched for 15 minutes. Snails found during this timed search were identified to species when possible, photographed and GPS coordinates recorded. Upon completion of the timed search and field sampling for tree snail genetics (Section 2.3.1), the surveys resumed.

There were two additional methods employed to better assess *S. fragilis* and *P. gibba*, species with extraordinarily limited distributions on Guam. For *S. fragilis* at Pugua, it was not possible in all cases to distinguish this species from *P. radiolata* during the timed search, as some individuals were poorly lit and high in the canopy. Here, the photographer used a GPS photo tagger, and walked in increasing distance from the center of the time search, photographing each *S. fragilis* encountered with a camera equipped with a telephoto lens. For *P. gibba* an attempt of a "total count" was also made, as it was clear that the distribution of this species was spatially limited at Haputo. The five-person survey team formed a 15m line and walked from the beach side towards the slope to the east. Whenever *P. gibba* was encountered, all individuals were counted, occupied plants were identified, and photographs were taken.

2.3.1 Field Sampling for Tree Snail Genetics

A maximum of five individuals of each species of varying sizes from each colony were removed and allowed to crawl and leave a mucus trail on a substrate (Figure 12) engineered to bind and stabilize DNA (FTA™ cards, Watman Ltd. Kent, UK.). Snails were then returned, unharmed, to their collection location. This technique has been successfully utilized and shown to be non-harmful in previous studies with tropical land snails (Regnier *et al.*, 2011). These cards were stored in sealed plastic bags containing a desiccant for later DNA extraction and analysis.

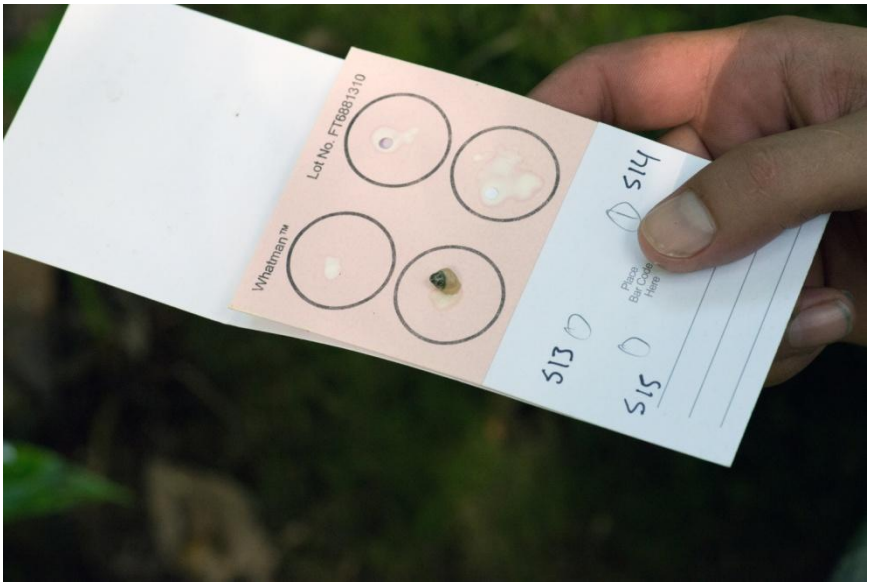


Figure 12. *P. radiolata* on FTA™ card.

2.3.2 Snail Genetic Sequencing and Analysis

DNA isolation and purification, PCR amplification, sequencing and analysis from the FTA™ preserved mucus trails of the three candidate snail species followed the same extraction, PCR amplification and cycle sequencing, genetic analysis protocols/treatments as butterfly samples described above with the following modifications; 1. A 3 mm diameter plug of the FTA™ card containing the snail slime trail was excised and subsequent DNA extraction was performed on it, treating it in a manner similar to a tissue sample. 2. Genomic DNA was isolated and purified from the FTA™ plug using a standard kit according

to manufacturer's protocols (QIAamp DNA Micro Kit, Qiagen Corp., Hilden, Germany) with a final elution volume of 20 µl put through the filter twice. Genetic COI barcode sequences were produced and will be submitted to the BOLD and GenBank systems, which presently contains no sequence for *S. fragilis* and only one each for *P. radiolata* and *P. gibba.*

3.0 RESULTS

3.1 Dry Season General Survey

The dry season survey for federal candidate species on Guam was conducted between 4/25/2013 and 4/17/2013 and consisted of 47 transects over 19 days of field work (Appendices D and E). Throughout the transects, the survey team searched for butterfly candidate species *H. octocula marianensis* and *V. egistina,* their host plants *P. pedunculata, E. calcareum* and *M. thompsonii,* and tree snail candidate species *S. fragilis, P. radiolata* and *P. gibba*. Of the 47 transects, three were found to harbor two of the five federal candidate species (Appendix E).

On non-DoD lands in areas adjacent to Route 15, transect RT 2, near vegetation point RT 2A, more than 60 *H. octocula marianensis* eggs were discovered on the host plant *P. pedunculata* on 3/26/2013 (Appendix C - Figures 15A, 15B). The eggs were green or black, and were located on the underside (abaxial) and margins of leaves in a oviposition pattern consistent with the way this species in known to produce (D. Rubinoff, pers. comm.). It was previously suggested that parasitized eggs are black and non-parasitized eggs are light green in color (Campora and Lee, 2009). We are convinced that the black color in many cases is not proof of parasitization and is probably just an indication that they are near hatching as the eggs shell is transparent and the developing larvae become darkly pigmented just prior to hatching. The plants were sparsely distributed throughout tower karst (Figure 13), from the edge of the limestone cliff line that typifies the northern half of Guam to approximately 100 m inland. The second occurrence of *H. octocula marianensis* was discovered on DoD land at the northern most point of Guam's limestone plateau (AAFB-NWF). On the transect AAFB-NWF 3, near vegetation point AAFB-NWF 3E, seven chrysalides and 40 eggs of *H. octocula marianensis* were found on *P. pedunculata* (Appendix C - Figures

14A, 14B). Eggs again were both green and black and were linearly distributed on the lower surface of the leaves near the margins. These were the only two occurrences of butterfly candidate species discovered throughout the dry season transects.

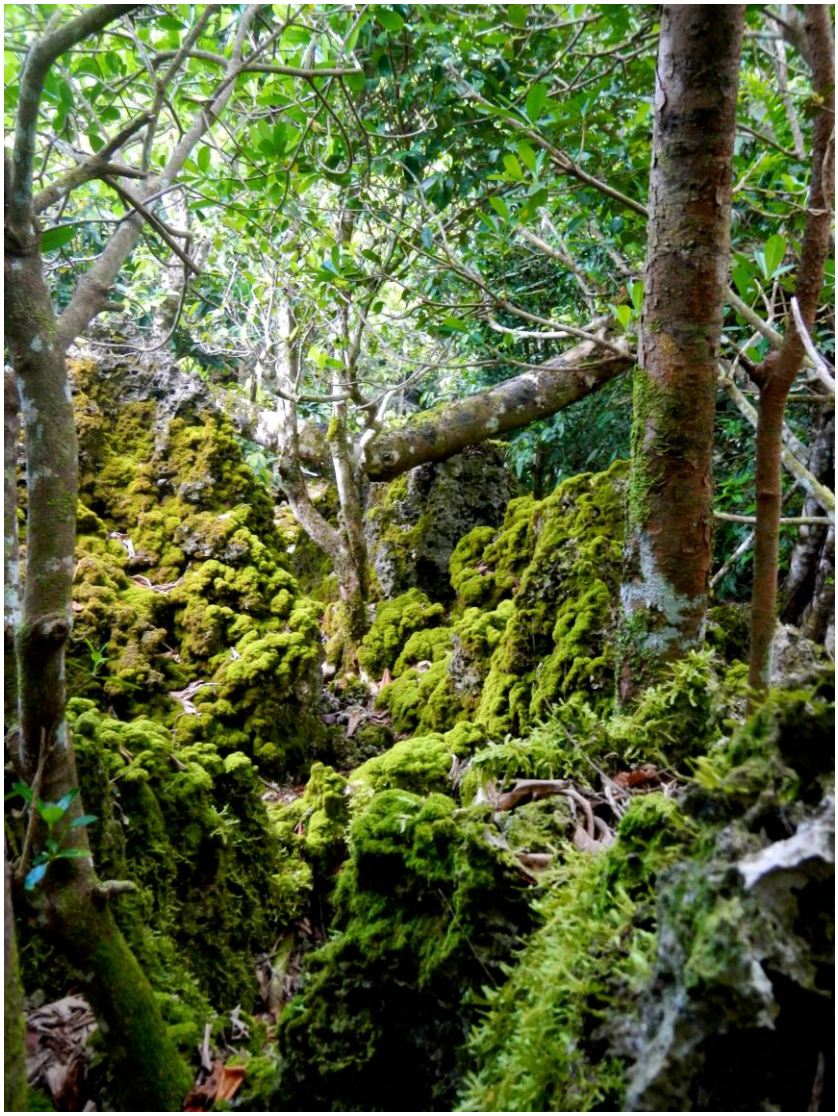


Figure 13. Tower karst topography.

Numerous trees of the *V. egistina* host plant, *M. thompsonii*, were discovered in primary and secondary limestone forests throughout the survey areas (Appendix C - Figures 2A, 2B, 3A, 3B, 7A, 7B, 9A, 9B, 10A, 10B, 11A, 11B, 12A, 12B, 14A, 14B, 15A, 15B, 16A, 16B) but no evidence of any life stage of *V. egistina* was found on any tree surveyed.

Three populations of one species of federal candidate tree snail species were found on one of the 47 transects. A colony of 10 individuals of *P. radiolata* was documented in a one person-hour search on March 28th, 2013 on NBGAH transect AH 5, near vegetation station AH 5A (Appendix C - Figures 6A, 6B),. Two other populations of *P. radiolata* were also identified along the same transect near vegetation station AH 5B (Appendix C - Figures 6A, 6B). The second population consisted of five individuals observed in a one person-hour search and individuals were found on leaves less than five meters high on a large *A. reticulata* tree, approximately 15 meters tall. Both of the populations above were found within 20 meters of a small freshwater stream. The third population of *P. radiolata* was discovered within the survey area, but was found off of the official transect line by approximately 30 meters as the field team exited the survey area. Sixty eight individuals were observed on *M. citrifolia* trees in a one person-hour search and this population was no less than 50 meters from a freshwater source. No other colonies of candidate tree snail species were observed along any of the dry season transects

3.2 Transect Floral Descriptions with Focus on Known Candidate Species

Throughout the transects, data of the trees and shrubs at the beginning, end and at 250 meter vegetation stops were recorded for all transects (Appendix D). In total, 234 vegetation points were recorded for the 47 transects and show the lands surveyed were generally primary or secondary limestone forest with large, arborescent trees.

3.3 Wet Season Targeted Search

Wet season target searches were conducted from 7/1/2013 to 8/2/2013 at various locations throughout Guam previously reported to have candidate species. A total of 29 locations were visited over 22 days and evidence of all candidate species were found, except for *V. egistina,* despite the numerous *M. thompsonii* observed during dry season transects.

AAFB: On AAFB, dry season transects AAFB 1 to AAFB four were revisited, along the northern cliff line, to observe the distribution of *H. octocula marianensis* host plants, *E. calcareum* and *P. pedunculata*.

Over two days, this area was searched and more than 90 eggs of *H. octocula marianensis* were observed on *E. calcareum*. These eggs, and others in this report below, are commonly assumed to be *H. octocula marianensis* due to characteristic species specific oviposition leaf location, low egg number and lack of parental guarding compared to *H. anomala* which lays a sheet of a large number of eggs and guards them till hatching (D. Rubinoff, pers. comm.). Taragüe basin (AAFB) was also visited and at least 145 *P. radiolata* were discovered in the basin. At a targeted revisit of AAFB-NWF, transects AAFB-NWF 3 to AAFB-NWF 5 (Appendix C - Figures 14A, 14B), one adult *H. octocula marianensis* was observed and more than 60 eggs of the same species were documented. Seventeen chrysalides of *Hypolimnas* sp. were also observed over the three days of targeted searches at AAFB-NWF.

NBGAH: NBGAH was revisited during the wet season targeted searches. The dry season transect AH 5 (Appendix C - Figures 6A, 6B) was revisited and 54 *P. radiolata* were identified over three separate one person-hour searches. Orote point, NGBAH was visited to conduct a targeted search because both *P. radiolata* (Hopper and Smith, 1992) and *H. octocula marianensis* (Schreiner and Nafus, 1996) have been previously reported from the area. During the targeted search of Orote Point, 15 *H. bolina* larvae and numerous chrysalides were observed near large patches of *P. pedunculata* and *E. calcareum*. More than 50 larvae of *H. bolina* were also observed at Orote Point and many of them occupying the host plants for *H. octocula marianensis.* This is the first documented occurrence of *H. bolina* occupying *E. calcareum* or *P. pedunculata* These, and other, larvae were identified using a combination of known species specific larval characteristics (head color) that are informative in larger larvae and confirmed by genetic analysis of larval molts found with them. No partulids were found at Orote Point. Near Orote Point, Gab Gab Beach was also searched for candidate species, but none were found.

NBGTS: Pugua Point and Haputo Beach (NGBTS) were also searched during the wet season and within the Haputo Ecological Reserve Area (HERA). At Pugua Point, one adult *H. octocula marianensis* was observed as were 57 eggs of the same species on *E. calcareum* and multiple *Hypolimnas* sp. chrysalides. During a one person-hour search for snails at Pugua, 63 *partulids* were observed, many of them *S. fragilis*. It was not always possible to distinguish *S. fragilis* from *P. radiolata* in the upper canopy, so

partulids were collectively counted. However, geotagged photographs of 19 *S. fragilis* were taken after the timed search. Haputo Beach (NGBTS) was visited twice and on 7/3/2013, more than 95 *P. radiolata* were documented as were the butterfly host plants, *E. calcareum* and *P. pedunculata*, but no evidence of *H. octocula marianensis* was observed. On the second visit to Haputo Beach, on 8/1/2013, at least 95 *P. radiolata* and 93 *P. gibba* were documented (Appendix C - Figures 11A, 11B). It should be noted that juvenile *P. radiolata* often look similar to *S. fragilis*, but genetic data allowed for the correction of any misidentifications made in the field.

Non-DoD Lands: In order to gain a larger sample size for the genetic component of the project, multiple areas outside of DoD property were targeted. One area, Route 15, was part of the initial candidate species survey area and was revisited during the wet season on 7/8/2013. The targeted area was between transects RT 3A and RT 5A and two adult *H. octocula marianensis* butterflies were observed, as well as 106 eggs of the same species on *E. calcareum* and *P. pedunculata* (Appendix C - 15A, 15B). Multiple chrysalides of *Hypolimnas* sp. were also observed during the targeted search. On 7/15/2013, Hagåtña Springs, Hagåtña River and Asan Beach Memorial Park were all visited to conduct targeted searches. At Hagåtña Springs, 11 *P. radiolata* were documented during a timed search, but many other individuals were observed subsequently in that location away from the area previously searched; at Hagåtña River, at least 17 *P. radiolata* were documented; at Asan Beach Memorial Park, 119 *P. radiolata* were documented during a one person-hour search, with many others observed in that general location outside of the timed search period. On 7/16/2013, Pigo Cemetery, Namo River and Sella Bay were visited. Pigo Cemetery was found to have four *P. radiolata*, Namo River had 10 *P. radiolata*, and at Sella Bay, eight *P. radiolata* were observed. Ritidian Point was the site of a targeted search on 8/17/2013 and 20 *P. radiolata* were documented (but many more observed) as well as one egg of *H. octocula marianensis* on *E. calcareum*. *Hypolimnas* sp. chrysalides were also observed during the search. At the Pagat Cave Area on 7/18/2013, four eggs of *H. octocula marianensis* were recorded on *E. calcareum*. The Lost Pond area was visited on 7/20/2013 and 118 *P. radiolata* were recorded along with five *S. fragilis*, an adult *H. octocula marianensis*, a larva on *E. calcareum* and five eggs of the same species on *E. calcareum* and *P.*

pedunculata. Along the 1,000 steps trail in Yigo on 7/23/2013, two *Hypolimnas* sp. chrysalides were observed on *P. pedunculata* and on the same day at the Ylig River, 22 *P. radiolata* were observed. At Fua Bay on 7/25/2013, 74 *P. radiolata* were observed and on 7/26/2013 at Cetti Bay, 30 *P. radiolata* were documented.

3.4 Partulid Home Plants

Observations of plant species occupied by snails indicate a broad diversity of home plants, including native and introduced species (Table 1). Partulids were documented on 27 species of plants, including five introduced species. At least three of the introduced plant species (e.g. *Alocasia macrorrhizos*, *Syngonium angustatum, Cocos nucifera*) were commonly occupied by partulids in some locations.

Table 1. Native and Non-Native Plant Species Observed with Partulids

Species	Species Status on Guam	Species	Species Status on Guam
Aglaia mariannensis	Native	*Melanolepis multiglandulosa*	Native
Alocasia macrorrhizos	Introduced	*Merrilliodendron megacarpum*	Native
Annona reticulata	Introduced	*Morinda citrifolia*	Native
Asplenium nidus	Native	*Ochrosia oppositifolia*	Native
Cocos nucifera	Introduced	*Ochrosia mariannensis*	Native
Cycas micronesica	Native	*Pandanus dubius*	Native
Ficus sp.	Native and Introduced spp.	*Piper guahamense*	Native
Flagellaria indica	Native	*Procris pedunculata*	Native
Glochidion marianum	Native	*Pteris tripartita*	Native
Guamia mariannae	Native	*Spathodea campanulata*	Introduced
Hernandia sonora	Native	*Syngonium angustatum*	Introduced
Hibiscus tiliaceus	Native	*Thelypteris opulenta*	Native
Ixora triantha	Native	*Thespesia populnea*	Native
Mammea odorata	Native		

3.5 Genetics for Butterflies

Refinement of DNA extraction, PCR protocols and sequencing was conducted on vacated eggs, frass, larval molt shells, chrysalides and wing clips of *H. octocula marianensis* in the laboratory with mixed results. Some sample types are more amenable to DNA preservation, subsequent extraction and PCR amplification than others. For example, we had 100% success in isolating high quality DNA from the few butterfly wing clips obtained, whereas that from chrysalides and larval molts were about 50% successful

and egg shells and frass never yielded amplifiable DNA. It is suspected that some of these materials contain more DNA and/or preserve it better and all samples are likely subject to degradation over time prior to our collection. Tissue from a total of three butterfly wing clips, two eggs, five larval molts, one frass and 51 chrysalides was collected and DNA was extracted. PCR amplification was successful for half of them. All adult wing material amplified well and produced clean DNA sequences. Out of the 51 chrysalides collected, only 19 of them amplified and 11 of those produced identifiable DNA sequences, none that matched *H. octocula marianensis*. The three COI sequences produced from *H. octocula marianensis* adults were identical in spite of their being collected from three separated locations (RT 15, NWF and Lost Pond) indicating little population structure among these mobile insects and a possible indication of recent population bottlenecks limiting genetic diversity for this species on Guam.

3.6 Genetics for Tree Snails

Refinement of DNA extraction and PCR protocols was conducted on FTA™ preserved mucus trails in the laboratory with excellent results of near 100% success in isolating high quality DNA from FTA™ preserved mucus trails. We collected, DNA extracted and PCR amplified a total of 86 individual snails of up to three species (mostly *P. radiolata*) from 16 isolated populations around the island of Guam for genetic identification and genetic population analyses. Five individuals collected at Lost Pond (2) and Pugua Point (3) were identified in the field as being *S. fragilis* and this was confirmed after sequencing. The COI sequences from them were identical. A minimum of three individuals of *P. radiolata* from each surveyed population were sequenced and aligned to each other. Although there was a very low degree of genetic heterogeneity among all surveyed populations (mostly in the silent third codon position) indicating some degree of populational genetic diversity, there was no discernible colony specific/geographic patterns. This is an indication that this species either retains limited ability to move between colonies, or that they have not been isolated long enough to accrue the amount of genetic differences that would distinguish subpopulations. This indicates a lack of genetic diversity throughout the island which makes these species less resilient evolutionarily and more prone to extinction pressures.

3.7 Introduced Snail Predators and Ungulates

During all field surveys all participants made constant efforts to note signs of, or the presence of, introduced species known to be detrimental to candidate species. We noted high amounts of habitat destruction as well as large amounts of fresh ungulate scat throughout all areas of all transect lengths (mostly pig and deer). The only areas where this was not observed were where the jagged tower karst formations were presumably extreme enough to exclude all ungulate activity. These formations stretch from the limestone cliff line inland about 100 meters and, as previously stated, contain the largest amount of butterfly host vegetation. Known tree snail predators (snails and flatworms) were intermittently found during most transects but never in high enough numbers to make a correlation between their presence and that of candidate snail species.

3.8 General Survey Results

The surveys in this study found populations of four of the five candidate species on DoD land and the contracted survey areas, indicating the importance of these areas as habitat. The dry season transect surveys identified two areas (RT 15 & AAFB-NWF) with evidence of the butterfly candidate species *H. octocula marianensis* and one area (NBGAH) with three populations of the tree snail candidate species *P. radiolata*. The wet season targeted surveys added two additional locations on AAFB for *H. octocula marianensis* and NBGTS. The targeted searches also added additional populations of the snail *P. radiolata* at Tarague Basin (AAFB) and two locations at NBGTS in addition to the remaining two candidate snails species populations at NBGTS found on the dry season transects. No evidence of the candidate species *V. egistina* was found in any location during any phase of the study. From both dry and wet season components of this study, it is evident that all five federal candidate species are in relatively low abundance on surveyed areas of Guam and *V. egistina* may already be extirpated from the island.

4.0 DISCUSSION

V. egistina

Many transects and surveys revealed occasional *M. thompsonii* trees (Appendix C), suggesting that this purported host for *V. egistina* is still fairly abundant across the survey area. The relative abundance of this host plant suggests that the butterfly has disappeared for reasons not related to host plant availability. Possibly, introduced predators or parasitoids may be responsible for the decline of this species, though the reasons *V. egistina* would have been particularly vulnerable to such introductions is unclear. To date, no eggs or larvae have been documented on *M. thompsonii* from either Guam or Rota and only adults were observed in a previous study (Schreiner and Nafus, 1996).

H. octocula marianensis

In contrast to *M. thompsonii*, the host plants for *H. octocula marianensis, P. pedunculata, E. calcareum*, were quite rare on survey transects and only observed growing along cliff edges and severe tower karst. This disjunctive distribution of the host plants for *H. octocula marianensis* has been suggested to be a result of invasive pig and deer feeding on these herbaceous plants, although this has been not quantified here or in previous studies (HDR, 2012; Appendix B). It is interesting that these plants only occur in areas that ungulates cannot reach, mainly tower karst at the cliff line or in basins and bays that may be inaccessible to pigs. In addition to the consumption of host plants by ungulates, *H. anomila* larvae, a close relative of *H. octocula marianensis* and a locally abundant taxon on Guam, were found feeding on the host plants of *H. octocula marianensis* at Orote Point. This occurrence documents that *H. anomila* and *H. octocula marianensis* are in direct competition for resources and may be yet another reason for the potential decline of the species.

S. fragilis

S. fragilis, was previously observed in several forested locations throughout Guam, (Appendix A; Hopper and Smith, 1992; Smith *et al.*, 2008; USFWS, 2012), and reported at limited locations on Rota (Smith and

Hopper, 1994; Smith, 2008a; Smith *et al*, 2008; Kerr, 2013). This species was not observed along any transect surveyed in the dry field season. However, *S. fragilis* was recorded during the wet season at Pugua Point (HERA, NBGTS) and Lost Pond (Hilaan) during targeted searches. Although it was thought some snails from other locations were also *S. fragilis*, DNA samples from such individuals indicated these were actually juvenile *P. radiolata*. Similarly, attempts to confirm recently reported sightings of *S. fragilis* at Tarague Basin by HDR (2012), were unsuccessful. The survey team visited the exact location documented in that report, but only observed *P. radiolata*. Some *P. radiolata* have very similar color patterns as *S. fragilis*, particularly as juveniles (Hopper & Smith, 1992). It may be that the HDR (2012) report misidentified juvenile *P. radiolata* as *S. fragilis*, including the reference photograph in the report. Our results confirm the occurrence of *S. fragilis* at Pugua point, which was thought to be its only remaining Guam population (Smith *et al*, 2008). The discovery of this species, albeit in limited numbers, at Lost Pond extends its range, but not nearly to its former extent. Based on this and other recent surveys, the limited distribution of *S. fragilis* on Guam is apparent, and indicates that steps must be taken to conserve this species.

Results of genetic analyses indicate that the two colonies of *S. fragilis* we were able to sample show no genetic heterogeneity which is indicative of a small population that has recently undergone a population bottleneck and is isolated from other colonies. This is most likely the case as these are the only colonies we encountered. Even if other populations exist on Guam, they are equally isolated and distant from each other and are at extreme risk of extirpation due to these factors and should be given a greater protection and recovery efforts.

P. gibba

P. gibba was also not observed along any transect surveyed in the dry field season, but is known to be restricted to forest habitats of the Marianas, as are other tree-dwelling partulids (Appendix A). On Guam, it is only currently known from Haputo (Smith *et al*., 2008). During the wet season targeted searches, a single population of at least 93 *P. gibba* was recorded from Haputo Beach (NBGTS). This population was

confined to the southern edge of the basin directly behind the beach strand vegetation, and most individuals were found on either *C. nucifera*, *Ochrosia oppositifolia*, *Pteris tripartita* or *A. macrorrhizos*. *P. gibba* has the broadest distribution throughout the Mariana Islands; its historic range includes Aguiguan, Alamagan, Anatahan, Guam, Pagan, Rota, Saipan, Sarigan, and Tinian (Kondo, 1970; Kurozumi, 1994). However, it is in decline throughout this range, and is reported to have disappeared from Aguiguan & Tinian (Smith, 2008a). This species is also likely gone from Anatahan due to its recent massive volcanic eruption and extensive habitat damage by goats and pigs (Bourquin, 2003). Preliminary genetic data (Hadfield, 2010) indicate populations from Saipan, Pagan, and Sarigan have species-level genetic divergence. This suggests the possibility that Guam's *P. gibba* population may represent a separate species, given its genetic isolation from other islands. Hence, Guam *P. gibba* are in small numbers at a single location on DoD land, and require immediate conservation measures to prevent their extinction.

Partula radiolata

P. radiolata, found at NBGAH, was the only candidate tree snail species observed during surveys conducted in the dry season. Furthermore, this is the first record of this species at this location (Crampton, 1925; Hopper & Smith, 1992). It's occurrence at this location supports previous observations that natural populations of *P. gibba* and *P. radiolata* occur near freshwater sources (Hopper & Smith, 1992). Transect AH 5 on NBGAH was the only transect near a freshwater source. Two of the three NBGAH populations were found within 20 meters of a small freshwater stream, but the third, and largest, was at least 50 meters from this freshwater source.

The wet season targeted searches provided much more information about the current distribution of populations of *P. radiolata* throughout the island of Guam, further supporting the importance of moisture to these organisms and confirming previous reports of their distribution (Hopper & Smith, 1992). Many of the population localities found were either near rivers (e.g. the Namo and Ylig Rivers), or in areas

where the freshwater lens is near the surface of the soil (e.g. Pugua Point and Lost Pond). As with *P. gibba*, *P. radiolata* was also found in coconut forests, but also has an extended range into scrub forests and limestone forests, especially those dominated by *O. oppositifolia*. This species was found on a large variety of plant species, including non-native plants, as observed in previous studies (Hopper & Smith, 1992; Smith *et al.*, 2008). A sizable population of *P. radiolata* was found on *A. macrorrizos* at NGBTS adjacent to the patch of *A. macrorrizos* containing *P. gibba* described above. Although *A. macrorrhizos* is not native to Guam, surveyors found *P. radiolata* on plants that had been clear-cut to expose a cultural archeological site. Future activities in Haputo should follow established review procedures and ensure coordination with NBG natural and cultural resources personnel to avoid the potential for inadvertent impacts to the resources within the area.

Clearly, *P. radiolata* is currently the most widespread partulid snail on Guam, and has been for at least 20 years (Hopper & Smith, 1992). Comparisons of COI sequences of individuals from all populations of *P. radiolata* sampled exhibit small amounts of genetic diversity indicative of some degree of health across the island. These observations indicate that at this time, *P. radiolata* is of relatively lesser concern than *P. gibba* and *S. fragilis*. However, our targeted searches showed this species was absent from several locations from which Hopper & Smith (1992) recorded, including Fonte B, Umatac Salonga, and Orote Point. Though broadly distributed on Guam, local *P. radiolata* populations are still disappearing.

5.0 CONCLUSIONS and RECOMENDATIONS

5.1 General

Given the results of the present study, and the body of knowledge currently available, the general recommendations are for ungulate control measures, studies on the basic biology of candidate species, and less emphasis on additional surveys on lands previously surveyed.

The primary, overall recommendation for the conservation of all candidate species in this survey is foundational: remove all feral ungulates and take measures to prevent their reintroduction. Traces of pig

and deer (e.g., scat) were found on virtually all survey areas, including the HERA, where all three candidate snail species occur, as well as *H. octocula marianensis* and both of its host plants. Ungulates not only graze upon the host plant species, but cause profound changes to the understory of forest habitats, which in turn affect tree snail and butterfly populations (Smith *et al*, 2008; Smith, 2013). Not only does ungulate activity inhibit native plant growth, but affects the composition of soil, and microclimate features such as humidity. Ungulate removal from Sarigan in 1997, resulted in substantial increases in tree density and native species in its forests (Williams, 2008) in less than 10 years, and healthy populations of tree snails (Smith, 2008b). Ungulates need to be aggressively hunted and trapped, particularly on DoD lands where access can be controlled, and effective ungulate barriers need to be erected. The eradication of pig and deer from sites that contain candidate species, as well as those that previously contained them, will serve both to enhance conditions for candidate species populations already present, and eventually provide suitable habitat for later reintroduction. We are aware of the success of the DoD sponsored ungulate control program in Hawaii that would be a good model for Guam (M. Burt, pers. comm.).

The secondary overall recommendation is to conduct comprehensive studies on the basic biology of all the candidate species. Relatively little is known about the life histories of the snails and butterflies in question, and much needs to be learned before their conservation can be effectively addressed. We have very little knowledge about basic biological requirements, reproductive output, survival rates, longevity, predation risks, activity patterns, feeding behavior, and seasonal patterns of abundance. Recommendations for such specific studies on butterfly and snail candidate species (as well as butterfly host plants) are described in the sections below.

The third overall recommendation is to focus additional surveys on locations that have not yet been adequately surveyed. Surveys are needed to examine locations that are isolated and physically difficult to access on Guam, or determine the presence and status of populations of candidate species on other Mariana Islands. However, conducting repetitive exploratory surveys in the same locations on Guam at the expense of the primary and secondary general recommendations above could divert resources away

from where they are needed most. Removal and exclusion of ungulates, studying of these species basic biology, which includes the monitoring of known populations, and searching in new places likely to harbor additional populations should be a higher priority due to the urgency that their declining numbers presents.

5.2 Butterflies

H. octocula marianensis and *V. egistina* are the two rarest butterflies on Guam and possibly throughout the entire Marianas and *V. egistina* has not been recorded on Guam since the 1970's and it was last collected from Rota in 1995 (Nafus, 1993; Schreiner and Nafus, 1996; Campora and Lee, 2009) and according to a recent issue of the Federal Register (2013) it is "apparently extirpated from Guam, the species is now restricted to Rota within a single population located in an officially conserved area, but threats to the species or its host plant are not managed." Its host plant, *M. thompsonii* is a common component of the limestone forest and does not seem to be a reason for the recent rarity of *V. egistina*, but non-specific nymphalid parasitoids may have played a role in the decrease and possible extirpation of this species on Guam (Nafus, 1993).

In order to produce an appropriate management plan for *V. egistina*, more information about it and its host plant is needed. Efforts to observe *V. egistina* on Rota where it mostly likely still occurs, should be made as a sighting of it has not been reported since 1995. If found, it will be necessary to document all life stages and determine what plants *V. egistina* are associated with. These data are necessary prior to establishing a management/recovery plan for the candidate species

H. octocula marianensis is extremely limited in distribution on Guam, although detailed searches of pristine habitat for its host plants, *P. pedunculata* or *E. calcareum* (see above), can yield considerable amounts of eggs, some larvae, and rarely, an adult butterfly. The single largest threat to the host plants is ungulate herbivory and a large area in the limestone forest that can be made free of ungulates is necessary to ensure that a suitable habitat for the host plants is maintained. A captive breeding program coupled

with efforts to cultivate the host plant should be undertaken while they can still be found in relatively accessible areas on Guam.

The two host plants grow best in full shade and although they occur on limestone, no obvious difference between growing plants in limestone rich soil or standard soil could be seen (J. Benedict, pers. obs.). The host plants can be grown from cuttings, or sections of the stem removed from a plant and placed in soil and watered frequently. Both species produce rooting systems from nodes on the photosynthetic stems, which make transplanting host plant material easy because each branch can become established as an independent plant. Also, they are erect herbs or subshrubs that do not exceed 2.5 m in height and cultivation of these plants could be done in a controlled area such as a greenhouse or a fenced area, which would allow for more controlled rearing efforts for the butterfly (Stone, 1970).

In combination with rearing efforts of *H. octocula marianensis* and its two host plants, more information on the native parasitoids that prey on the butterfly is needed. In particular it would be important to know which parasitoids are currently attacking the candidate species. Schreiner and Nafus (1996) documented that native parasitoids *Telenomus* sp. and *Ooencyrtus* sp. were found parasitizing eggs, but Nafus (1993) reported many other native and exotic predators and parasitoids of *H. anomala* and *H. bolina* that may also attack *H. octocula marianensis* (See Nafus 1993, Table 1). The effects of parasitoids as well as the degradation of hospitable habitat for host plants of *H. octocula marianensis* should be further studied and continually monitored to understand their role in the degradation of the species on Guam.

The results of our genetic inquiry with *H. octocula marianensis* support observations that these butterflies are mobile through time and will move to areas where host plants persist. This also lends credence to any efforts to conserve and propagate host plant species that they may find and utilize.

5.3 Tree Snails

The three species of partulid tree snails, *S. fragilis, P. radiolata* and *P. gibba,* were all identified on transects or targeted searches of the current study. Our results confirmed earlier observations that *P. radiolata* is both the most widespread and common partulid snail on Guam (Hopper & Smith, 1992), and

co-occurred with the other two partulids, often on the same leaf or frond. *S. fragilis* was found only at two locations: Pugua Point and Lost Pond (Hilaan), but in very small numbers at the latter location. The least common partulid, *P. gibba,* was found as a single population (~100 individuals) over a relatively small area at Haputo Beach, and is of highest concern. Both Haputo Beach and Pugua Point are part of the HERA. Hence, the HERA represents an area that requires immediate attention in order to conserve the rarest partulid species on Guam. Recommendations for the candidate snail species are enumerated below in order of priority, and include measures address habitat quality and better understand their biology.

A) Restrict access to and closely monitor the Haputo Beach population of *P. gibba.*

The potential for both anthropogenic and animal impacts on *P. gibba* were observed at Haputo Beach during the survey. The relatively small area at Haputo containing the remaining *P. gibba* is approximately 60m long, and no more than 20 meters wide. This zone should be delineated and fenced off to prevent any intrusion into their habitat and damage to these snails' home plants, by both humans and animals. Although most recreational visitors to Haputo only frequent the beach, it's necessary to err on the side of caution and protect this habitat. This should be done immediately, given the alarmingly small number of *P. gibba* remaining. Regular assessment of *P. gibba* numbers at this location is vital to conserving this species. *P. gibba* populations can fluctuate dramatically over a few months (Smith, 2008a; Smith *et al.*, 2008), so it is necessary to monitor this population monthly consisting of population census and looking for signs of vegetation changes, the presence of predators and signs of ungulate disturbance .

B) Eradicate ungulates from HERA (NBGTS).

Ungulate disturbances must be addressed to ensure the forest habitat is maintained in the areas the tree snails currently occupy (see general recommendations above). Direct evidence of the benefits for *P. gibba* populations were shown in a 2006 survey of Sarigan Island, less than 10 years after the eradication of all ungulates in 1997. Several *P. gibba* populations, on Sarigan recovered dramatically in that time (Smith, 2008a; Smith *et al.*, 2008). Hence, ungulate removal should be pursued, particularly in locations where

access and ingress can be controlled. The best location for this would be the area within HERA at NGBTS, given that all three snail species occur there, including the only remaining Guam population of *P. gibba* (Smith *et al.,* 2008) and largest known population of *S. fragilis.* All ungulates from Pugua Point to Haputo Beach must be removed and their future ingress cut off in order to improve the quality of habitat the candidate snail species presently occupy (Smith *et al.,* 2008). Both Haputo Beach and Pugua Point are isolated to the north and south, at sea level, by sheer rock coastal cliffs, and are in basins surrounded by relatively steep slopes. Ungulates should be eradicated by hunting and trapping, and an exclosure fence at the cliffline level should be erected along the length of the HERA. If needed, access to hikers could still be granted via a gate. This would stop forest habitat destruction by ungulates, improve the condition of the habitat, and would ensure these populations are not lost due to habitat destruction. These measures would also benefit populations of the butterfly candidate species, *H. octocula*, whose eggs, adults, and host plants were observed at the HERA during the wet season surveys.

C) Eradicate ungulates from Tarague Basin (AAFB).

In combination with maintaining the HERA and their respective partulid populations, it is recommended other suitable habitats for the tree snails be established and made ungulate-free, to assist in conservation efforts of these federal candidate species. From our surveys of DoD land on Guam, Tarague Basin, which presently hosts a small population of *P. radiolata*, would be a suitable area to create an ungulate free habitat for the tree snails.

Tarague Basin was reported by Crampton in 1925 to have had all three candidate snail species present. The present study as well as previous studies, indicate that this area is still occupied by *P. radiolata* and may be a suitable habitat for the other two species if ungulates are removed from the area (Crampton, 1925; HDR, 2012). Tree snail species have suffered a similar fate in the Hawaiian Islands where conservation efforts have been conducted for over a decade. Successful reintroductions of tree snails, after habitat restoration in an ungulate excluded area, are currently being undertaken in Hawaii (B. Holland, pers. comm.). As suggested by Smith *et al.* (2008), the removal of ungulates that allow the return of

densely forested areas is the best management plan for the conservation of the tree snails as well as butterflies.

D) Conduct studies on the basic biology the candidate snail species.

There is little understanding of the basic biology and life histories of the partulid candidate species that occur on Guam. This information is necessary to craft management plans to conserve these snails and prevent their extinction. Research must be conducted on all three partulids, to determine important life history traits. Very little is known or has been published about their longevity, growth rates, reproductive patterns, fecundity, diet, home plant preferences, and daily activity patterns. Although there are general statements about what these snails eat, there are no published studies on their diet or preferences of home plant. Crampton (1925) states the diet of Mariana partulids is decaying plant material and fungus on the ground at night or in the rain, and that they only remain on the underside of leaves during daytime to rest. However, he does not cite any published research or data for these observations, nor is it clear which species they are based upon. During our surveys, we only occasionally observed live partulids on the ground, even during the rain. Smith (2008b) and Smith *et al*. (2008), provide size frequency distributions of *P. gibba* from Sarigan and Guam, as well as *P. radiolata* and *S. fragilis* on Guam. However, there are no long-term studies of size frequencies of any populations, nor are there studies on individual growth rates, fecundity, and longevity. If we hope to conserve and manage these species, observational studies in the lab and field must be conducted to determine relevant life history traits.

E) Conduct studies on partulid predator/prey dynamics.

Predation rates and sources of predation must be assessed in order to minimize their impact when possible and effectively manage partulid snail populations on Guam. During our survey, the presence of the New Guinea flatworm (*P. manokwari*) was sometimes noted, even where tree snails were not. A recent study (Sugiura & Yamaura, 2009) demonstrated that these flatworms will follow chemical cues of tree snails and attack them in trees. Direct observations (C. Fiedler, pers. obs.) of flatworm predation on *P. radiolata*

confirm this. It is necessary to further characterize the impact of the flatworm, by assessing their activity patterns, habitat and dietary preferences, distribution and reproductive capacity.

There are also other sources of partulid predation, evidence of which was observed during the survey. Damage to both living and dead shells was noted for all three species, suggesting predation efforts by rats, crabs, and perhaps pigs (Smith, 2008b). Ants were also observed in and around both newly dead and living snails during the survey. The relative impact of different predators on candidate snail species is unknown and whether it varies according to location and snail species. Predation can be studied by examining vacated shells, in addition to direct observational studies. Empty partulid shells can be found on the ground, under plants, shrubs and trees inhabited by living snails. Examination of these shells, in addition to obtaining basic shell morphometrics, may yield information on sources of predation and growth patterns. Regular surveys of newly dead shells can provide direct data on predation rates in the field.

F) Assess the size and distribution of the *S. fragilis* population at Pugua Point.

Given the limited distribution and numbers of *S. fragilis* observed in this survey, and a relatively recent study (Smith *et al.*, 2008), it is necessary to determine the status of this candidate species. Our genetic results indicate that the *S. fragilis* we were able to sample shows no genetic heterogeneity, which is indicative of a small population that has recently undergone a population bottleneck and is isolated from other colonies. Such populations are at extreme risk of extirpation due to these factors. Hopper and Smith (1992) reported *S. fragilis* from seven locations on Guam, including Haputo (see map in that reference). Smith *et al.* (2008) reported *S. fragilis* at only one location, Pugua Point, and concluded this was the only remaining population on Guam. Our survey data confirmed the presence of many *S. fragilis* at Pugua Point, perhaps over a larger area than reported by Smith *et al.* (2008). The discovery of an additional population at Lost Pond in this survey is encouraging, but the numbers of *S. fragilis* observed there were very small. During the wet season, we visited three other sites reported by Hopper & Smith (1992) to have *S. fragilis* (Ylig River, Anigua Cemetery, and Fonte B), but failed to find this species. Hence, the

population at Pugua Point may be the best situation for conservation of this species on Guam and should be assessed thoroughly.

G) Conduct additional surveys for candidate snail species at specific locations.

In order to properly assess populations of all three snail species, it is necessary to know where they occur. However, such surveys should be conducted in places with the best chance of finding additional populations. Our survey results confirmed the overall pattern of Guam partulid snails most recently reported (Hopper & Smith, 1992; Smith & Hopper, 1994; Smith *et al.,* 2008), with some exceptions, notably the decline of *S. fragilis*. The present survey showed that *P. radiolata* currently has the broadest distribution, and in large numbers at some locations. For *P. gibba,* additional populations on Guam are unlikely, and surveys of other islands would be more fruitful. For *S. fragilis*, there are a few locations on Guam that should be revisited, such as Sella Bay & the Talofofo River, where they were previously reported to occur (Hopper & Smith, 1992), as well as the island of Rota, where they may still occur (Kerr, 2013). We highly recommend that surveys be conducted at the Naval Ordinance Annex, in and around Fena Reservoir (not included in the 6,077 acre proposed survey area, therefore it was not included the present study) for candidate snail species as only one survey of this area is known (Smith *et al.,* 2008). That study confirmed the presence of *P. radiolata* in a limited search area. The presence of *S. fragilis* at Naval Ordinance Annex is suspected there (B. Tibbatts, Guam DAWR, pers. comm.). Hence, a detailed survey of likely habitat around this location is necessary.

H) Conduct captive rearing research on all three species.

Captive rearing of candidate tree snail species is recommended, as both a stopgap and a way to closely examine the biology of these animals. Reportedly, many partulids can be successfully maintained and propagated in controlled environments, including species from Guam (Gouveia et al, 2011; Tonge & Bloxam, 2007). In 1994, the Zoological Society of London began coordinating captive breeding efforts of endangered Partula. Currently, 25 species, including *P. gibba*, are held and bred at 15 collaborating

institutions worldwide (ZSL, 2013). Captive populations of *P. gibba* obtained from Saipan are being held at three institutions and their numbers are increasing, with a combined total of over 2000 snails as of 2012 (Pearce-Kelly, pers. comm.). Captive *P. radiolata* were also held for breeding by at least two institutions, but did not survive (Pearce-Kelly, 2010). Captive rearing has provided important information about the basic biology of partulid species (Gouveia *et al.*, 2011), and should be a component of their conservation on Guam. Successful captive rearing of candidate partulid species will also allow researchers to propagate these snails for later reintroduction to recovered habitats, if necessary. In the event of a major typhoon or degradation of habitat, laboratory populations would serve as a contingency for their conservation.

I) Maintain the genetic heterogeneity that still exists in extant populations by protecting each colony as separate units in order to preserve any present diversity and promote greater heterogeneity as insurance against extinction in the future. Collect genetic data from as many additional populations as possible of candidate species on Guam to inform management decisions as well as from populations on other islands to explore the possibilities of introducing additional heterogeneity in the future as further insurance against local extinction.

6.0 LITERATURE CITED

Bourquin, O. 2003. Invertebrate survey - Anatahan, Northern Mariana Islands. *CNMI Division of Fish & Wildlife Services Technical Report* #10: 61-86.

Campora, C. and S. Lee. 2009. Survey for the Mariana eight spot butterfly, *Hypolimnas octocula marianensis* (Lepidoptera: Nymphalidae), in the Pagat Route 15 area of Yigo.

Cowie, R.H. 1992. Evolution and extinction of Partulidae, endemic Pacific island land snails. Philosophical Transactions of the Royal Society, London B 335:167–191.

Crampton, H.E. 1925. Studies on the variation, distribution, and evolution of the genus *Partula*: The species of the Mariana Islands, Guam and Saipan. Carnegie Inst. Washington Publ. 228A:1–116.

Federal Register. 2013. Federal Register/Vol. 78, No. 226/Friday, November 22, 2013/Proposed Rules/p. 70135

Folmer, O., M. Black, W. Hoeh, R. Lutz, and R. Vrijenhoek. 1994. DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metazoan invertebrates. *Mol Mar Biol Biotechnol*. 3(5): 294-299.

Gouveia, A.R., P. Pearce-Kelly, D.L.J. Quicke & S.R. Leathe. 2011. Effects of Different Calcium Concentrations Supplemented on the Diet of *Partula gibba* on their Morphometric Growth Parameters, Weight and Reproduction Success, *Malacologia* 54(1-2): 139-146

Hadfield, M.G. 2010. Pagan Island Tree-Snail Surveys: a report to the U.S. Fish & Wldlife Service.

Hopper, D. R. and B. D. Smith. 1992. Status of tree snails (Gastropoda: Partulidae) on Guam, with a resurvey of sites studied by H.E. Crampton in 1920. *Pacific Science* 46: 77-85.

Kerr, A. M. 2013. The partulid tree snails of the Mariana Islands, Micronesia. *UOG Marine Lab Tech Rep* 152: 1-21

Kondo, Y. 1970. Some aspects of Mariana Islands Partulidae (Mollusca, Pulmonata). *Occasional Papers of Bernice P. Bishop Museum* 24: 73–90.

Koscinski, D., L.A. Crawford, H.A., Keller and N. Keyghobadi. 2011. Effects of different methods of non-lethal tissue sampling on butterflies. *Ecol. Entomol.* **36**: 301–308.

Kurozumi, T. 1994. Land molluscs from the northern Mariana Islands, Micronesia. *Natural History Research, Special Issue* 1: 113–119.

Lee, T, J.B. Burch, T. Coote, P. Pearce-Kelly, C. Hickman, J-Y. Meyer & D. Ó. Foighil. 2009. Moorean tree snail survival revisited: a multi-island genealogical perspective. *BMC Evolutionary Biology* 2009, **9**:204.

Nafus, D.M. 1993. Movement of introduced biological control agents onto non-target butterflies, *Hypolimnas* spp. (Lepidoptera: Nymphalidae). *Environ. Entomol*. 22: 265-272.

Pearce-Kelly, P. 2010. Partula snail EEP Annual Report 2007–2008, unpaginated in D. de Man, W. van Lint, A. Gam & Henke (eds). *EAZA Yearbook 2007–2008*. European Association of Zoos and Aquaria, Amsterdam.

Regnier, C., O. Gargomin, G. Faulkner and N. Puillandre. 2011. Foot mucus stored on FTA cards is a reliable and non-invasive source of DNA for genetics studies in molluscs. *Conservation Genet. Resour.* 3:377-382

Smith, B.D. 2013. Taxonomic inventories and assessmens of terrestrial snails on the islandsof Tinian and Aguiguan in the Commonwealth of the NOrthern Mariana islands. Univeristy of Guam Marine Laboratory Technical Report 154: 1-32.

Smith, B.D. 2008a. Seven decades of disruption, decline, and extinction of land snails in Aguiguan, Mariana Islands. Report to the Division of Fish and Wildlife Commonwealth of the Northern Mariana Islands Saipan, CNMI. *University of Guam Marine Laboratory Miscellaneous Report* 116: 1–21.

Smith, B.D. 2008b. Preliminary Assessment of Endemic Arboreal Snails in Three Forest Types in Sarigan, with Notes on Ground-dwelling Species. *CNMI Division of Fish & Wildlife Services Technical Report* #14-8: 1-23.

Smith, B.D., and D.R. Hopper. 1994. The Partulidae of the Mariana Islands: Continued threats and declines. *Hawaiian Shell News* 42(June):10–11.

Smith, B.D., R.D. Cooper-Nurse and A. M. Gawel. 2008. Survey of Endangered Tree Snails on Navy-Owned Lands in Guam. Prepared for the U.S. Navy by Marine Laboratory, University of Guam, Mangilao.

Smith, B.D. & R.H. Randall. 2007. Assessment of endangered tree snails on department of defense lands in Guam.

Schreiner, I and D. M. Nafus. B. 1996. Survey of rare butterflies in the Mariana Islands.

Schreiner, I. and D. Nafus. 1997. Butterflies of Micronesia. Agricultural Experiment Station, College of Agriculture and Life Sciences, University of Guam.

Stone, B.C. 1970. The Flora of Guam. *Micronesica*. 6: 1-659.

Sugiura, S. & Y. Yamaura. 2009. Potential impacts of the invasive flatworm *Platydemus manokwari* on arboreal snails. *Biol Invasions*. 11:737–742

Tonge, S. & Q. Bloxam. 1990. A review of the captive-breeding programme for Polynesian tree snails *Partula* species. *International Zoo Yearbook*, 30: 51–59.

Williams, L.L. 2008. Sarigan Forest Surveys 1999, 2000 and 2006. *CNMI Division of Fish & Wildlife Services Technical Report* #14-2: 1-25

ESA-USFWS. 2013. U.S. Fish and Wildlife Service Endangered Species Act Listing Workplan, FY13 - FY18 MDL packages and other court setlement agreements.

FWS. 2011. Candidate Species Fact Sheet - U.S. Fish and Wildlife Service. *www.fws.gov/endangered/esa-library/pdf/candidate_species.pdf*

HDR 2012 (DRAFT). Threatened and Endangered Species and Migratory Birds Monitoring report. Naval Support Activity Anderson, Guam. Prepared for HDR by Globetek Group Inc.

USFWS. 2012. U.S. Fish and Wildlife Service Species Assessment and Listing Priority Assignment Form

USFWS. 2013. USFWS Endangered Species Act Listing Workplan.

ZSL (Zoological Society of London). 2013. *Polynesia: Partula Snail*. http://www.zsl.org/conservation/regions/americas/snail-wars-in-the-pacific,45,AR.html [Accessed 4 October 2013].

7.0 LIST OF PARTICIPANTS AND PREPARERS

University Faculty and Staff

John Benedict, Ph.D., UoG - Project Coordinator, Botanical/GIS Specialist
Frank Camacho, Ph.D., UoG - Snail Team Co-Leader
George Fiedler, Ph.D., UoG - Butterfly Team Co-Leader
William Haines, Ph.D., UHM - Butterfly Team Visiting Specialist
Brenden Holland, Ph.D., UHM - Snail Team Visiting Specialist
Alex Kerr, Ph.D., UoG - Snail Team Co-Leader
Maria Kottermaier, UoG - GIS Specialist
Dan Lindstrom, Ph.D., UoG - Principal Investigator, Genetics Team Leader
Aubrey Moore, Ph.D., UoG - Butterfly Team Co-Leader
John Peterson, Ph.D., UoG - Assistant Vice President of Research
Edwin Reyes, M.A., UoG - Program Manager
Dan Rubinoff, Ph.D., UHM - Butterfly Team Visiting Specialist
Ruth Sakuma, UoG - Budget and procurement
David Sischo, Ph.D., UHM - Snail Team Visiting Specialist

Post-Graduate Research Associate I (Field Technicians)

Rob Ady, UoG - B.A. Biology
Julie Duay, UoG - M.S. Biology

Undergraduate Research Assistant II (Botany/GIS & Genetics Techs)

Patrick Mantanona, UoG - Biology Major
Sherri Mantanona, UoG - Biology Major
Michael Natuel, UoG - Biology Major
Steve Pillman, UoG - Biology Major
Megan Volsteadt, UoG - Biology Major

[This page intentionally left blank.]

APPENDIX A

Micronesian Tree Snail Literature Review.

[This page intentionally left blank.]

Partulid tree snails (Partulidae: Stylommatophora) of the Mariana Islands, Micronesia

ALEXANDER M. KERR[1,2]

[1] *Marine Laboratory, University of Guam, Mangilao GU 96923 USA.*

[2] *Corresponding author: alexander.kerr@aya.yale.edu*

Running title: MARIANA ISLAND PARTULIDAE

Abstract. This paper provides a systematic review, extended descriptions and illustrations of the six species of Partulidae recorded from the Mariana Islands. Five species of *Partula* have been described from the archipelago, *P. gibba* Férussac, 1821 is the most widely distributed, but in strong decline on most islands; *P. radiolata* (Pfeiffer, 1846), is endemic to the island of Guam, where it is declining rapidly; *P. salifana* Crampton, 1925, another Guam endemic is extinct, as is *P. langfordi* Kondo, 1970, only collected from Aguiguan. The fifth species, *Partula desolata* Bauman & Kerr, 2013, is known only from archaeological material from Rota. A sixth Marianas partulid, *Samoana fragilis* (Férussac, 1821), is known from Guam and Rota, but is likely declining, as well.

Sumåria. Hu eksplika yan na'fanmalitråtu gi este na papit nu i todu i seis na klåsen Partulidae ni mañasaga gi iya Marianas. Guaha sinku na klåsen *Partula*: *P. gibba* mañasaga siha gi meggai na isla, lao na'dididide pa'go gi meggaiña isla siha; *P. radiolata* mañasaga ha' siha gi iya Guahan yan chinaddek i mana'didide-ña; Guahan ha' i sinagå-ña *P. salifana*, lokkue', lao mafñas esta; yan mafñas *P. langfordi* gi iya Aguiguan, lokkue'. Siña ha' masodda' i karakot siha i mina'sinko yan minafñas na klåsi, *P. desolata*, gi amkoko' na pigo gi iya Rota. I mina'seis na klåsen Partulidae, *S. fragilis*, mañasaga siha gi iya Guam yan Rota, lao na'dididide' ha' pa'go, lokkue.

Introduction

The purpose of this report is to provide a review of the land snails from the Partulidae Pilsbry, 1900 inhabiting the Mariana Islands of western Micronesia. While the systematics of this fauna is uncontroversial, at least absent a detailed molecular phylogeographic analysis, there nevertheless exists no single account of these animals' descriptions, taxonomic history, geographic distribution and biology. Given the current worry over their decline and subsequent increasing interest in their conservation, I assemble this review of these rare animals.

Geographical setting

The Mariana Islands (Fig. 1) are a north-south oriented, arc-shaped archipelago of small (10 to 540 km^2) islands in the western tropical Pacific Ocean (13° to 20° N, 142° to 144° W), approximately 2400 km east of the Philippines. Of the 14 main islands, seven are currently inhabited by people, most quite sparsely. The climate is tropical maritime with marked wet and drier seasons, influenced by the Asian monsoons and frequent typhoons, especially between June and November.

The Mariana archipelago formed by the volcanism resulting from the tectonic subduction of the Pacific plate under the Philippine plate. The largest and southernmost islands (Saipan, Tinian, Rota, Guam) are the oldest (ca. 40 my), volcanically quiescent, and of volcanic rocks or tectonically uplifted limestone. The islands to the north are much younger (to 5 my) and volcanically active, and entirely of volcanic composition. As a result of this geologic history, terrestrial habitats in the Mariana Islands include two main types of forests, typified by different communities of plants. Limestone forest is a

forest type found only rarely worldwide. The limestone forests unique to the Mariana Islands are found in the southern and older, Mariana Islands with tectonically uplifted limestone members. Ravine forests, by contrast are found on the volcanic soils of more islands in the archipelago, and as the name implies tend to be restricted to ravines and river basins. The more exposed areas are usually of savanna and covered in tall grasses. Guam and Saipan also possess minor, but significant areas of mangrove and seagrass, as well as estuarine areas receiving significant terrigenous input. The tallest mountains of Rota are just high enough to possess patches of another habitat, cloud forest, a forest type more extensive in the highest island of the neighbouring Caroline archipelago, Pohnpei. The geographic distribution and areal extent of terrestrial habitats across the Mariana archipelago largely influence the distribution and species richness of terrestrial organisms, particularly small, hydrophilic forms, such as land snails.

The Chamorro, the indigenous inhabitants of the Mariana archipelago, arrived *circa* 4000 – 3500 BCE (Athens et al. 2004). Of the 14 "main", i.e. largest, islands, only seven are currently inhabited, some quite sparsely. Still, most other islands show evidence of previous occupation (Russell 1998). European colonisation of the archipelago began in the mid-17th century by Spain, who conceded the southernmost island of Guam to the United States as a territory in 1898. After this time, the northern islands lay briefly in German (1899-1914), then Japanese hands (1914-1945), until they also came under United States administration, eventually as the Commonwealth of the Northern Mariana Islands.

The land snails of the Mariana Archipelago

Land snails belong to two main evolutionary *cum* taxonomic groups, the clade Caenogastropoda (formerly a taxonomic superorder), a large group of primarily marine snails that all retain the ancestral gills of their marine gastropod cousins, and the informal group Pulmonata (formerly a taxonomic order), that is, the lung-bearing snails. The latter group includes the subject of this treatise, the Partulidae. The shell-less slugs are also all members of the air-breathing pulmonates, but several evolutionary disparate groups have independently evolved to become slugs through the partial or complete loss of their shell. The slugs of the oceanic Pacific islands are few, and all are recent introductions (Cowie 2001).

The land snails of the Indo-west Pacific are not at all well documented. In the Mariana Islands, there are about 117 known distinct species (Bauman 1996b) distributed in 19 families and 38 genera. Of these, at least 11 (9.4%) have been introduced (Cowie 2000), some in all probability prehistorically by the islands' first human inhabitants (Christensen & Weisler 2013). Of the native forms, probably close to two dozen still require formal description (Bauman 1996a). Many of the species recorded from the Marianas have only been collected from the southern islands, Saipan, Tinian, Rota and, most often, Guam. The fauna of the northern islands remains the least known (Kurozumi 1994).

In the Chamorro language, land snails in general are called *akaleha'*. Land snails appear not to have been used as food or otherwise in material culture, given their absence from the archaeological record and oral culture, although *Partula* were trade items elsewhere in Oceania (Lee et al. 2007; Ó Foighil et al. 2011). The only known use for

land snails in the Mariana Islands appears to be a relatively recent development: Partulid snails, particularly the more colourful forms of *Partula gibba*, were sewn together into purses and jewelry for commercial sale to tourists, especially following World War II. This practice is of uncertain origin, but one that appears to have originated before 1940 and continued into at least the 1950's, then ceased as the Marianas largely transitioned to a market economy by the early 1960's, and certainly before partulids became rarer on heavily human-populated islands later in the 20th century.

The land snails from the Mariana Islands were first described and reported by Jean-René Constant Quoy and Joseph Paul Gaimard (Quoy & Gaimard 1833), the surgeons *cum* naturalists aboard the French naval vessel *Uranie,* Captain L. Freycinet commanding, which stopped on Guam in April of 1819 during its circumnavigation of the world during the years 1817 to 1820, and later aboard the *Astrolabe,* Captain Jules Dumont d'Urville commanding, which circumnavigated the world in 1826 to 1829. Many other new descriptions of Marianas snails came through the vast collections of the amateur naturalist and 'Prince of Collectors' Hugh Cuming (Dance 1980), many described by Ludwig K. G. Pfieffer (e.g., Pfieffer 1857). The next substantial addition to the fauna was by J. F. Quadras and O. F. von Möllendorff (1894a-b), who added several dozen species and varieties to the tally of endemic forms. Important work in the 20th century includes that of Henry E. Crampton (1925), H. Barrington Baker (1938, 1940-1941), as well as C. Montague Cooke, Jr. and Yoshio Kondo (e.g., Cooke & Kondo 1960; Kondo 1968, 1970) beginning in the 1960s, Alan Solem (1982) in the 1980s, and later, David R. Hopper and Barry D. Smith (1992), Taiji Kurozumi (1994) and Scott Bauman (1996a-b). The most recent and authoritative checklists for land snails from the Mariana Islands are

Smith (2003) for the Assimineidae (a group encompassing *circa* one-third of the fauna) and Bauman (1996a-b), who provided an annotated list of all Marianas species then known.

Current declines

Across the Pacific, there is an on-going and unprecedented rate of extinctions documented for many native snail species (Cowie 1992; Lydeard et al. 2004). Sadly, the same holds true for the snail fauna of the Mariana Islands, where the numbers of nearly all species have declined precipitously during the latter half of the 20th century (Hopper and Smith, 1992; Bauman 1996b). Many species have not been seen alive in half a century, some in fact not since the publication of their original descriptions. The cause of the declines in the Marianas are primarily due to habitat destruction and the, at best, naiive introductions of generalist predators, such as the gastropods *Gonaxis* spp. and *Euglandina rosea* (Férussac, 1821) to control yet another invasive gastropod, the giant african snail *Lissachatina fulica* (Bowdich, 1822). In unparalleled biological irony these predators, as well as their endemic prey, have themselves now fallen prey to another introduced generalist molluscan predator, the bipaliid flatworm *Platydemus manokwari* De Beauchamp, 1962. The worm appears to have eliminated *Gonaxis* and *Euglandina*. In over three decades of collecting, workers have not seen a living specimen of these species (Hopper and Smith, 1992; Bauman 1996b; J. Starmer, pers. comm.; A.M.K., unpubl.).

Other factors may also have contributed to the loss of native snails in the Marianas. Paramount among these is habitat destruction and fragmentation, and perhaps

habitat degradation via invasion of exotic plants. Hopper & Smith (1992) found that 14 of 34 (41.2%) of Crampton's (1925) partulid collecting sites had since been converted to residential or industrial areas and no longer hosted snails. On the island of Tinian, the loss of most native forest from military activity may explain the absence of partulids there. Recent volcanic eruptions on the islands of Pagan and Anatahan have eliminated most of the islands' potential snail habitat. Additionally, feral ungulates on Pagan have greatly modified potential snail habitat by removing the understorey and exposing snails to desiccation and trampling under-hoof (A.M.K. pers. obs.). By contrast, on Sarigan, where ungulates have been removed, the forest understorey is closed, undisturbed, and native snails are abundant (Smith 2008b). The decline of *Partula gibba* on Guam may also have been abetted by their systematic and large-scale collection following World War II for the commercial manufacture of purses and jewelry. Photographs from this era show women sewing together shells at long tables covered with boxes full of fresh empty shells (Kerr 2013). Other factors have perhaps been less important in partulid declines. Pesticide spraying has usually been restricted to agricultural or residential areas, rather than in native forest, the primary habitat of native snails. Crampton (1925) found no shells of partulids evincing predation by rats. The large varanid lizard *Varanus indicus* Daudin, 1802 potentially eats snails opportunistically, but has coexisted with abundant partulids in the Marianas for at least a millennium (Cota 2008) absent ill effect.

The upshot is that the forests of the southern Marianas are becoming nearly devoid of most native snail species, including on the southern-most islands the iconic and once prolific Partulidae. Declines of partulids have been of the order that the two Marianas *Partula* having the most restricted distributions, *P. salifana* and *P. langfordi*,

are now undoubtedly extinct (Hopper & Smith 1992; Smith 2008a), and even *P. gibba* no longer occurs in vast areas of its former broad range (Bauman 1996; Smith 2008b). The faded, pocked and empty shells of these and other snails now litter the forest floors and crunch underfoot.

The Partulidae of the Mariana Islands

The tropical, largely arboreal snail family Partulidae consists of about 130 species in three genera, all endemic to single islands or a few adjacent islands on the western Pacific Plate. The smallest genus *Eua* Pilsbury & Cooke, 1934, of four species, is found only in Samoa and Tonga. The genus *Samoana* Pilsbury, 1909, of about 23 species, has an interesting, disjunct distribution. Most species of Partulidae inhabit single or a few adjacent islands occur from Samoa to the Marquesas Islands in Polynesia, while a single species occurs nearly 1500 km to the north-east in the southern Mariana Islands. The largest genus *Partula* Férussac, 1821 is also the most widely distributed, with about 100 described species, ranging from the Society Islands, French Polynesia, where species richness was highest, originally at 61 species, to the Palauan Archipelago in westernmost Micronesia with just three species. About 1300 km northeast of Palau lie the Mariana Islands, also in Micronesia, with five endemic species.

The first *Partula* described from the Mariana Islands, *P. gibba* Férussac, 1821, is the most widely distributed in the archipelago. Another species, *P. radiolata* (Pfeiffer, 1846), is endemic to, and still widely distributed within, the largest and southernmost island of Guam. A third species, *P. salifana* Crampton, 1925, was discovered in the forests surrounding the summit of Mt. Alifan of Guam. The fourth species, *P. langfordi*

Kondo, 1970, is restricted to the tiny island of Aguiguan. A fifth Marianas partulid *P. fragilis* Férussac, 1821 was transferred to *Samoana* by Kondo (1968). Adult shells of a sixth conchologically distinct form from the Marianas, *P. desolata* Bauman & Kerr, 2013, were collected from unconsolidated prehistoric (500 - 1000 YBP) deposits on the island of Rota, Commonwealth of the Northern Mariana Islands. This apparently long extinct species has also been figured and briefly discussed by Bauman (1996a) as *P.* c.f./aff. *gibba*.

Two instances of taxonomic confusion have arisen in the early literature regarding the disposition of the Mariana Island's *Partula*. The first concerns the type locality and range of *P. guamensis* Pfieffer, 1821 as recorded in the original description. Despite this and its suggestive specific epithet, the species does not occur on Guam, but is endemic to the island of Pohnpei, Federated States of Micronesia, a fact only ascertained several decades later by Hartman (1885). A recent account of the status of this species is provided by Pelep & Hadfield (2011). Second, *P. radiolata* had been reported in its original description (Pfeiffer 1846) as an endemic of the island of New Ireland in the Bismarck Archipelago, Papua New Guinea. This inaccuracy was soon noticed and corrected by some authors (e.g., Reeve 1851), but was also perpetuated by several others, e.g., Hartman (1881), and most recently by Parkinson et al. (1987).

Biology of the Marianas Partulidae

Cowie (1992) reviews general aspects of the life history, ecology and genetics of the Partulidae Pacific-wide, including some information on the partulids of the Mariana Islands. Crampton (1925) provides much information on the ecology and size

distributions of Partulidae in the Marianas. Hopper & Smith (1992) give habitat information Much of what follows is gleaned from these sources, as well as personal observation.

Like most partulids, the Marianas species are arboreal and prefer the cooler, shaded and moist forest understorey. They are found most often on leaves and are active day and night, especially when it is wet, as after a rain or in humid closed-canopy or riverine forest. Where they occur, they are found on nearly any species of large-leaved plants, whether native or introduced. The three remaining extant species, *P. gibba*, *P. radiolata* and *S. fragilis* may be seen in beach backstrand vegetation, generally dominated by the trees *Hernandia* spp. and *Cordia* spp., or in riverine forest where *Hibiscus tiliaceus* L. is predominant. The now extinct *P. salifana* was restricted to upland native forest in Guam's southern volcanic highlands. No work has been done on possible habitat partitioning or interspecific competition amongst Mariana partulids. Species appear to often co-occur on Guam (Crampton 1925). Studies of Moorean snails also indicate considerable overlap in habitat, with differences perhaps attributable to diet or environmental tolerances (Murray et al. 1982 in Cowie 1992).

The diets of Mariana partulids are uncertain. Crampton (1925) writes that the *Partula* are fungivorous and "apparently ... subsist upon the mycelia of fungi...." They indeed graze the surface of living and decaying leaves and branches, suggesting a diet of fungus or, perhaps, microalgae. Carnivory has been reported for a Samoan partulid (Cooke 1928), but this behaviour is unknown amongst any other species (Cowie 1992). Other Pacific partulids are reported to be herbivorous, feeding on fresh and decaying vegetation (Murray et al. 1982 in Cowie 1992).

Members of the Partulidae, like nearly all pulmonate snails, are simultaneous hermaphrodites. The degree of self-fertilisation varies widely between partulids, but *P. gibba* appears to be exclusively self-fertilising (Johnson et al. 1977 in Cowie 1992). Like other Partulidae, Marianas species are ovoviviparous, usually brooding two to eight young in calcareous egg capsules in a special chamber. The egg shell is calcareous and opaque in most *Partula*, but is thin and clear in *P. radiolata* (Crampton 1925). In all partulids, the egg shell is resorbed by the parent before birth. While most partulids attain reproductive maturity after the development of a complete shell, one with a fully formed and flared peristome, gravid *S. fragilis* are often found lacking a fully formed aperture (Crampton 1925). The lifespans of Mariana partulids are unknown. However, the Moorean *P. taeniolata* begins reproduction at around one year and lives to more than five years (Murray & Clarke 1984 in Cowie 1992).

Systematics

Below is a systematic account of the Mariana Partulidae. Species are given alphabetically by genus, then chronologically by species. Following the species' full scientific name, taxonomic authority and date, is included an abbreviated synonymy. Scientific names are in italics, which by convention consists first of the genus name, always capitalized, the specific epithet, which is not, followed by the name of the person who first scientifically described the species, a comma, and the publication date of the description. Higher taxonomy generally follows Bouchet and Rocroi (2005), except when contraindicated by Bruere et al. (2010, 2012). Each species' description includes

reference to figures illustrating the shell from, when possible, apical, apertural and basal views, and when available, the live animal.

No English common names are included here, since none exist. As well, these species lack species-specific Chamorro names. Following each scientific name is a brief description of notable and diagnostic aspects of the animal's morphology, color, diurnal activity pattern, habitat, depth, and lifestyle followed by its geographic distribution and occurrence in the archipelago, and finally, information on the specimen shown in the figures.

Clade Stylommatophora *sensu* Bouchet & Rocroi (2005)

Family Partulidae Pilsbry, 1900

Genus *Partula* Férussac, 1821

Type species: *Helix faba* Gmelin, 1791 via suppression of *Limax faba* Martyn, 1784 (see ICZN 1957). Type locality: Raiatea, Society Islands, French Polynesia.

Partula gibba Férussac, 1821

(Figs. A-B)

Partula gibba Férussac, 1821; *Helix gibba*, Quoy & Gaimard (1833); *Bulimus gibbus*, Pfieffer (1848); *Partula mastersi* Pfeiffer, 1857; *Partula bicolor* Pease, 1872; *Partula gibba bicolor* Pilsbry, 1909-1910.

Description: Shell dextral or, quite rarely, sinistral, conic-ovate, perforate, pellucid. Spire acute, 4 to 4½ whorls, the last gibbous. Sculpture of spiral striae, crossed by weak longitudinal growth striae; suture slightly adpressed, various shades of white or brown. Aperture oblong-ovate, subquadrangular; peristome reflexed, broadly dilated, white. Background color variable, chestnut brown to whitish-yellow; also purple. Adult length 14 to 18 mm, width 10 to 14 mm. (Description from Smith et al. 2008b)

Biology: Ovoviviparous, self-fertilising simultaneous hermpaphrodite. Once the most commonly encountered *Partula* on Guam.

Range: *Partula gibba* is the most widely distributed partulid in the Mariana Islands, occurring on Guam, Rota, Aguiguan, Tinian, Saipan, Anatahan, Sarigan, Alamagan, and Pagan (Kurozumi 1994; Smith et al. 2008b). Still common on some northern islands, such as Pagan and Sarigan.

Photos: D. Sischo, primary forest, Rota, 2010, no scale bar.

***Partula langfordi* Kondo, 1970**

(Fig. C)

Description: Much smaller and with whorls less convex than *P. gibba*. Dextral shell described by Kondo (1970) as ovate-conic and moderately thin, a spire of five, slightly convex whorls, and an obtuse apex, aperture oblong-ovate with a white peristome thickened and expanded, background color buff superimposed by maroon. A band on whorls two and three also maroon. The band begins at whorl one and a half as a faint brown marking one-third the width of the whorl and gradually widens to one-half width of the whorl deepening to maroon at whorl three. The band expands to three-fourths

width of whorl four and dissipates into a vague blend of buff-maroon at the beginning of whorl five to the end of the shell. The holotype has a length of 14.0 mm, a diameter of 9 mm, and a aperture length of 8 mm. (Description from Kondo 1970).

Biology: Hermaphroditic. Ovoviviparous. *P. langfordi* prefers cool, shaded forest (Smith 2008a). Likely extinct.

Range: An endemic of Aguiguan. A survey conducted there in 1995 found no live *P. langfordi* and only fresh, dead shells (B. Smith, pers. comm. in Bauman 1996b), while a survey in 2006, also found no live animals, but only old, degraded shells. This is compelling evidence that the species on this very small island is extinct (Smith 2008a).

Photo: Y. Kondo, Aguiguan, 1952, holotype?, no scale bar, fig. 2 in Kondo (1970).

***Partula radiolata* (Pfeiffer, 1846)**

(Fig. D)

Bulimus (*Partula*) *radiolatus* Pfeiffer, 1846; *Partula radiolata rushi* Pilsbry, 1909-1910.

Description: Shell dextral, oblong-tapering, subperforate, thin. Spire obtuse, whorls typically 5, slightly convex, the last about equal to the spire. Sculpture of faint, impressed lines. Aperture obliquely oval; peristome simple, thin, white, expanded, the right margin somewhat straightened, columellar margin dilated above, spreading above the umbilicus. Background color pale straw with darker axial rays and brown lines. Adult length 13 to 18.5 mm, width 8 to 12 mm. (Description from Smith et al. 2008.)

Biology: Ovoviviparous. The most commonly encountered *Partula* on Guam. Found in bushes on the undersides of leaves.

Range: Endemic to Guam. Crampton (1925).indicates that the species been erroneously reported to occur on the island of New Ireland in the Bismarck Archipelago by Pfeiffer (1846), Hartman (1881), and Parkinson et al. (1987).

Photo: A. M. Gawel, on *Alocasia macrorrhiza* leaf, Guam, 2010, no scale bar.

Partula salifana Crampton, 1925

(Fig. E-F)

Description: Shell dextral, ovate-conic, thick and heavy. Umbilicus open, slightly flattened. Spire somewhat protracted, whorls 5 to 5¼, slightly impressed below the suture. Sculpture of spiral striae on embryonic whorls becoming weaker on postembryonic whorls. Aperture elongate, interior purplish and shining, peristome expanded and flattened, gradually narrowing as it approaches contact with body whorl, color variable from white to yellowish brown or purple. Background color is a rich chestnut-brown or seal-brown to yellowish or olive; the apex color is often purple as a result of decortication. Adult length 17 to 19 mm, width 10.5 to 11.7 mm. (Description from Crampton 1925.)

Biology: Ovoviviparous. Probably extinct.

Range: *Partula salifana* is the most geographically restricted of the partulids in the Mariana Islands. It was known only from the summit of Mount Alifan and two adjacent peaks on the southwest coast of Guam.

Photo: M. and J. Coltro, *P. salifana*, on bushes after rain, Mt. Alifan, Guam, collected by E. Hailey, 1946, scale bar = 5 mm, © M. and J. Coltro (www.femorale.com) with permission.

Partula desolata Bauman & Kerr, 2013

(Fig. G)

Partula sp. cf./aff. *gibba*, Bauman (1996b).

Description: Shells 17-19 mm in height, dextral, spire conical, whorls nearly flat, numerous prosoclinic growth striae, fine appressed spiral striae, suture disinct, emarginate, aperture slightly oblique, auriculate, peristome thick, flattened, polished, parietal callus, undenticulate, umbilicus deep, partially eclipsed by reflexed columellar margin. Similar shells are not mentioned in Crampton's (1925) monograph on variation in Partulidae of Saipan or Guam, or Kondo's (1970) analysis of *Partula* on Aguiguan.

Biology: Known only from a few subfossil specimens in association with other still extant native snails, including *P. gibba*. Uncalibrated radiocarbon dates of presumably anthropogenic charcoal associated with some shells ca. 400 years old (Bauman 1996b; Steadman 1999). This species apparently went extinct during late prehistoric times.

Range: Four shells of this distinctive *Partula* were collected from archaeologic test pits in caves on both the northern and southern coasts of Rota (Bauman 1996b).

Photo: S. Bauman, subfossil, cave deposits, Rota, 1995, scale bar = 5 mm.

Samoana fragilis (Férussac, 1821)

(Fig. H)

Partula fragilis Férussac, 1821; *Partula quadrasi* Möllendorff, 1894.

Description: Shell dextral, ovate-conic, narrowly and half-covered perforate, fragile, pellucid. Spire conic, apex somewhat obtuse; whorls typically four, slightly convex, separated by adpressed, marginated suture; last whorl distinctly convex, nearly

tumid. Sculpture of delicate spiral striae intersected by transverse growth striae. Aperture oblique, oval; peristome thin, well expanded, columella dilated above, recurved, forming distinct angle with parietal wall. Background color buff; narrow darker maculations and whitish banding due to viscera visible through the shell. Adult length 12 to 16 mm, width 10 to 12 mm. (Description from Smith et al. 2008.)

Biology: Usually in the northern half of Guam in limestone forest. Unique among Mariana Islands partulids, the eggs are large (4.2 mm × 3.3 mm) and encapsulated by a calcareous shell. Further, *S. fragilis* reaches sexual maturity before growing a reflexed peristome, a trait not reported for any other partulid species (Crampton 1925).

Range: The only species of *Samoana* to occur outside of southeastern Polynesia. Reported from Guam and Rota in the Mariana Islands (Kondo 1970; D. Sischo, pers. comm.).

Photo: A. M. Gawel, Ritidian, Guam, 2007, no scale bar. The lectotype and paratype are figured in Zilch (1962).

Acknowledgements

For identifications, permission to use figures, loan of specimens, obscure literature, and sage advice, we are indebted to Scott Bauman (Florida Museum of Natural History), Carl Christensen (Bernice P. Bishop Museum, Hawaii), Marcus and José Coltro (Femorale.com, Brazil), Ann Marie Gawel (U.S. Fish and Wildlife Service), Dave Hopper (U.S. Fish and Wildlife Service), Regina Kawamoto (Bernice P. Bishop Museum, Hawaii), Dave Sischo (University of Hawaii), and Barry Smith (University of Guam).

Literature Cited

Athens, J.S., M.F. Dega & J.V. Ward. 2004. Austronesian colonisation of the Mariana Islands: The palaeoenvironmetal evidence. *Bulletin of the Indo-Pacific Prehistory Association* 24 21-30.

Baker, H. B. 1938. Zonitid snails from Pacific islands-part 1. 1. Southern genera of Microcystinae. Bernice P. Bishop Museum Bulletin 158: 1-102, pls. 1-20.

Baker, H. B. 1940. Zonitid snails from Pacific islands-part 2. 2. Hawaiian genera of Microcystinae. Bernice P. Bishop Museum Bulletin 165: 105-201, pls. 21-42.

Baker, H. B. 1941. Zonitid snails from Pacific islands-parts 3 and 4. 3. Genera other than Microcystinae. 4. Distribution and indexes. Bernice P. Bishop Museum Bulletin 166: 205-370, pls. 43-65.

Bauman S. 1996a. Diversity and decline of land snails on Rota, Mariana Islands. *American Malacological Bulletin* 12: 13–27.

Bauman S. 1996b. *Diversity and Decline of Land Snails on Rota, Mariana Islands*. Masters Thesis, University of Guam.

Bauman, S. and A.M. Kerr. 2013. *Partula desolata* sp. nov. (Pulmonata: Partulidae), an extinct land snail from Rota, Mariana Islands, Micronesia. *Micronesia* 2013-05: 1-12.

Bouchet, P. & Rocroi, J.-P. 2005. Classification and nomenclator of gastropod families. *Malacologia* 47: 1-397.

Breure, A. S. H., D.S.J. Groenenberg and M. Schilthuizen. 2010. New insights in the phylogenetic relations within the Orthalicoidea (Gastropoda: Stylommatophora) based on 28S sequence data. *Basteria* 74: 25-31.

Breure, A. S. H. and P. Romero. 2012. Support and surprises: molecular phylogeny of the land snail superfamily Orhalicoidea using a three-locus gene analysis with a divergence time analysis and ancestral area reconstruction (Gastropoda: Stylommatophora). *Archiv für Molluskenkunde* 141: 1-20.

Cooke, C. M. 1928. Food habits of Partula zebrina Gould. *Bulletin of the Bernice P. Bishop Museum* 47: 5-12.

Cooke, C, M., Jr., and Y . Kondo. 1960. Revision of Tornatellinidae and Achatinellidae (Gastropoda, Pulmonata). *Bernice P. Bishop Museum Bulletin* 221: 1-303.

Cota, M. 2008. Varanus indicus and its presence on the Mariana Islands: Natural geographic distribution vs. introduction. *Biawak* 2: 18-27.

Cowie, R. H. 1992. Evolution and extinction of Partulidae, endemic Pacific island land snails. *Philosophical Transactions of the Royal Society, London B* 335: 167-191.

Cowie, R. H. 2000. Non-indigenous land and freshwater molluscs in the islands of the Pacific: conservation impacts and threats. Pages 143-172 in G. Sherley (ed.), *Invasive species in the Pacific: A Technical Review and Draft Regional Strategy*. South Pacific Regional Environmental Programme, Apia, Samoa.

Crampton H. E. 1925. *Studies on the variation, distribution and evolution of the genus Partula. The species of the Mariana Islands, Guam and Saipan*. Publication 228a, Carnegie Institution of Washington.

Christensen, C. C. & M. I. Weisler. 2013. Land Snails from Archaeological Sites in the Marshall Islands, with Remarks on Prehistoric Translocations in Tropical Oceania. *Pacific Science* 67: 81-104.

Dance, S. P. 1980. Hugh Cuming (1791-1865), Prince of collectors. *Journal of the Society for the Bibliography of Natural History* 9: 477-501.

Hartman, W. D. 1881. Observations on the Species of the Genus *Partula* Fér., with a Bibliographical Catalogue of all the Species. *Bulletin of the Museum of Comparative Zoology* 9:171-196.

Hartman, W. D. 1885. Descriptions of new species of Partula and a synonymic catalogue of the genus. *Proceedings of the Academy of Natural Sciences of Philadelphia* 1885: 203-223.

Hopper, D. R. and B. D. Smith. 1992. Status of tree snails (Gastropoda: Partulidae) on Guam, with a resurvey of sites studied by H.E. Crampton in 1920. *Pacific Science* 46: 77-85.

Kerr, A. M. 2013. Land snails (akaleha') of the Mariana Islands. *Guampedia: The Encyclopedia of Guam*. http://guampedia.com/land-snails-akaleha-of-the-mariana-islands/ [Accessed 14 September 2013]

Kondo, Y. 1968. Partulidae: preview of anatomical revision. *Nautilus* 81: 73-77.

Kondo, Y. 1970. Some aspects of Mariana Islands Partulidae (Mollusca, Pulmonata). *Occasional Papers of Bernice P. Bishop Museum* 24: 73-90.

Kurozumi, T. 1994. Land molluscs from the northern Mariana Islands, Micronesia. *Natural History Research, Special Issue* 1: 113–119.

Lee, T., J. B. Burch, T. Coote, B. Fontaine, O. Gargominy, P. Pearce-Kelly & D. Ó Foighil. 2007. Prehistoric inter-archipelago trading of Polynesian tree snails leaves a conservation legacy. *Proceedings of the Royal Society B Biological Sciences* 1627: 2907-2914.

Lydeard, C., Cowie, R.H., Ponder, W.F., Bogan, A.E., Bouchet, P., Clark, S.A., Cummings, K.S., Frest, T.J., Gargominy, O., Herbert, D.G., Hershler, R., Perez, K.E., Roth, B., Seddon, M., Strong, E.E., & Thompson, F.G. 2004. The global decline of nonmarine mollusks. *Bioscience* 54: 321–330.

Mead, A. R. 1961. *The Giant African Snail: A Problem in Economic Malacology*. University of Chicago Press. 257 pp.

Ó Foighil, D., Lee, T. and Slapcinsky. 2011. Prehistoric anthropogenic introduction of partulid tree snails in Papua New Guinean archipelagoes. *Journal of Biogeography* 38: 1625-1632.

Pemberton, C. E. 1954. *Invertebrate Consultants Committee for the Pacific. Report for 1949-1954.* The Pacific Science Board, National Academy of Sciences-National Research Council, Washington, D.C.

Pelep, P. O. & M. G. Hadfield. 2011. The status of the endemic snails of the genus *Partula* (Gastropoda: Partulidae) on Pohnpei, Federated States of Micronesia. *Micronesica* 41: 253-262.

Pfeiffer, L. 1848. *Monographia Heliceorum Viventium*. Volume 2. Lipsiae: F. A. Brockhaus. 594 pp.

Pfeiffer, L. 1857. Descriptions of thirty-one new species of land-shells, from Mr. Cuming's collection. *Proceedings of the Zoological Society of London* 25: 107-113.

Parkinson, B., J. Hemmen, and K. Groh. 1987. *Tropical landshells of the world*. Verlag Christa Hemmen, Wiesbaden. 279 pp.

Pilsbry, H. A. and C. M. Cooke, Jr., 1934. Partulidae of Tonga and related forms. *Bishop Museum Occasional Papers* 10: 3-21.

Pilsbry, H. A. 1900. On the zoological position of *Partula* and *Achatinella*. *Proceedings of the Academy of Natural Sciences, Philadelphia* 1900: 561-567.

Quadras, J. F. & O. F. Möllendorf. 1894a. Diagnoses specierum novarum a J. F. Quadras in insulis Mariannis collectarum scripserunt. *Nachrichtsblatt der Deutschen Malakozoologischen Gesellschaft* 26: 13-22.

Quadras, J. F. & O. F. Möllendorf. 1894b. Diagnoses specierum novarum a J. F. Quadras in insulis Mariannis collectarum scripserunt. *Nachrichtsblatt der Deutschen Malakozoologischen Gesellschaft* 26: 33-42.

Quoy, J. R. C. & Gaimard, J. P. 1833. *Voyage de découvertes de l'Astrolabe pendant les années 1826, 1827, 1828-1829 sous le commandement de M. J. Dumont-D'Urville. Zoologie: Mollusca. Volume 3*. Paris.

Reeve, L. A. 1851. Conchologia Iconica. Volume VI. Reeve and Benham, London.

Russell, S. 1998. Gani revisited: A historical overview of the Mariana archipelago's northern islands. *Pacific Studies* 21: 83-105.

Smith, B.D. 2003. Prosobranch gastropods of Guam. *Micronesica* 35/36: 245–271.

Smith, B.D. 2008a. Seven Decades of Disruption, Decline, and Extinction of Land Snails in Aguiguan, Mariana Islands. Report to the Division of Fish and Wildlife Commonwealth of the Northern Mariana Islands Saipan, CNMI. University of *Guam Marine Laboratory Miscellaneous Report* 116: 1-21.

Smith, B.D. 2008b. Preliminary assessment of endemic arboreal snails in three forest types in Sarigan, with notes on ground-dwelling species, pp. 8-1 to 8-18 plus 2 pl. in G. Martin (ed.) Wildlife and Vegetation Surveys of Sarigan Island April 13-25, 2006. *CNMI Division of Fish and Wildlife Technical Report* 14: 1-1 -- 12-6.

Smith, B.D., R. Cooper-Nurse, & A.M. Gawel. 2008. Survey of Endangered Tree Snails on Navy-Owned Lands in Guam. *University of Guam Marine Laboratory Technical Report* 125: 1-22.

Solem, A. 1982. *Endodontoid land snails from Pacific Islands (Mollusca: Pulmonata: Sigmurethra). Part II. Families Punctidae and Charopidae, Zoogeography.* Field Museum of Natural History, Chicago.

Steadman, D.W. 1999. The prehistory of vertebrates, especially birds, on Tinian Aguiguan, and Rota, Northern Mariana Islands. *Micronesica* 31: 319-345.

Zilch, A. 1962. Die Typen und typoide des Natur-Museums Senckenberg, 26: Mollusca, Achatinellacea. *Archiv Für Molluskenkunde* 91: 77-94.

Figure 1. Map of the Mariana Islands with islands mentioned in the text labeled

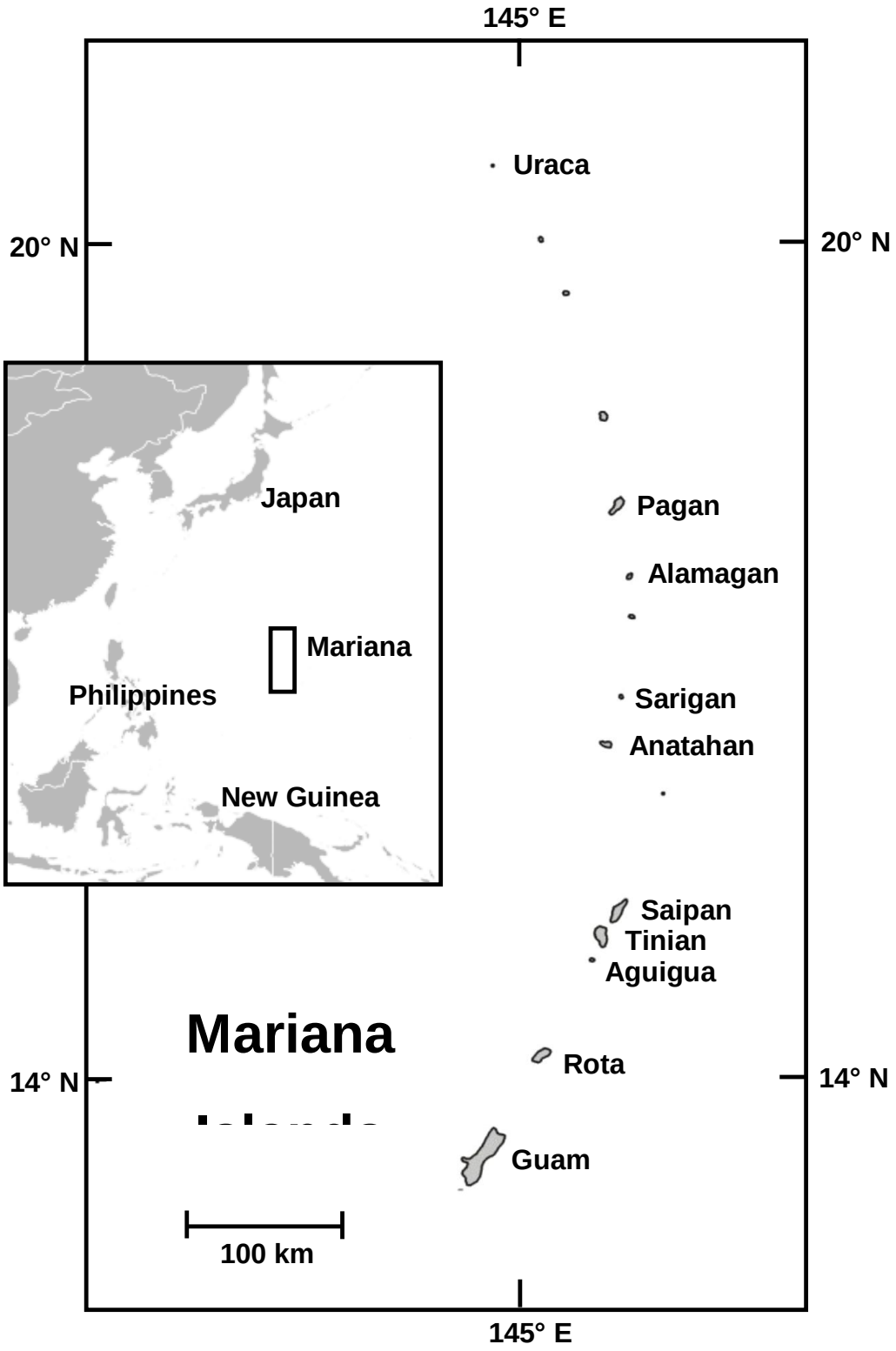


Plate I

Figure A. *Partula gibba* Férussac, 1821, live animal, approx size, 2 cm.

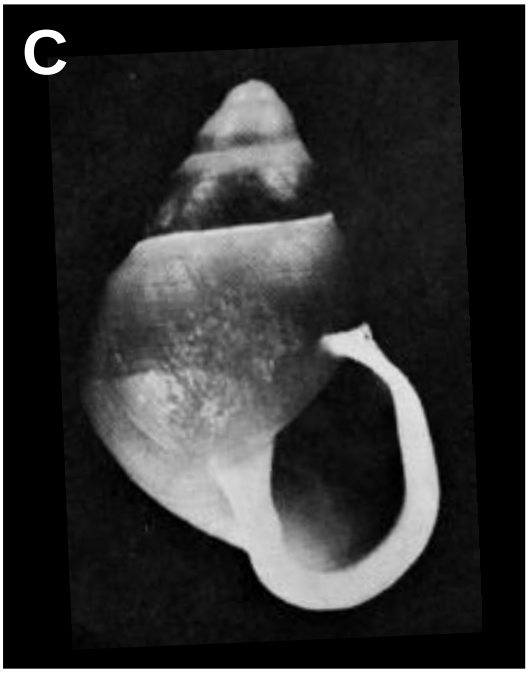
Figure B. *Partula gibba* Férussac, 1821, live animal, approx size, 2 cm.

Figure C. *Partula langfordi* Kondo, 1970, shell, apertural view, approx. size, 1.6 cm.

Figure D. *Partula radiolata* (Pfeiffer, 1846) , live animal, approx size, 1.7 cm.


A


B


C


D

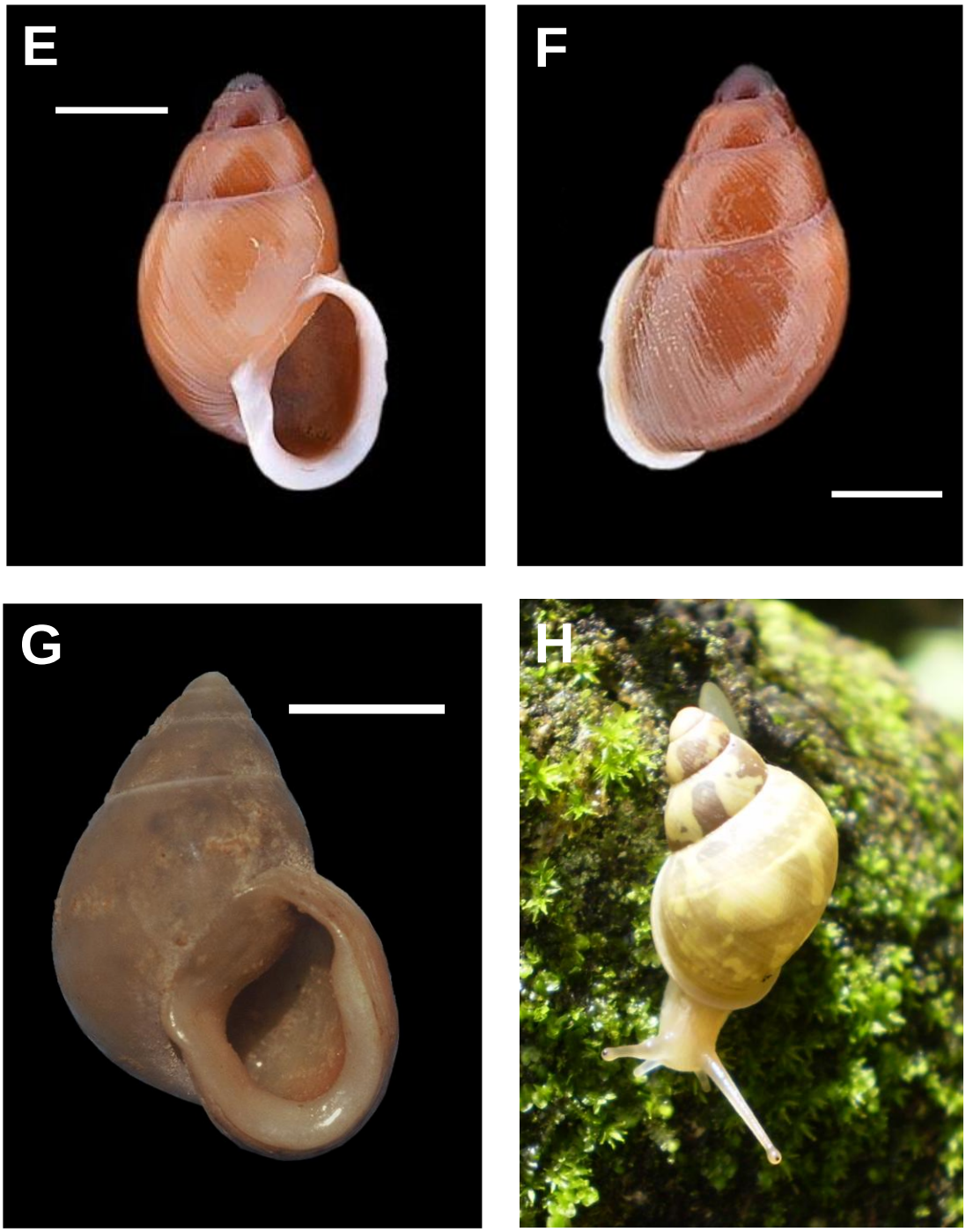
Plate II

Figure E. *Partula salifana* Crampton, 1925, shell, apertural view, scale bar = 5 mm.

Figure F. *Partula salifana* Crampton, 1925, shell, adapertural view, scale bar = 5 mm.

Figure G. *Partula desolata* Bauman & Kerr, 2013, shell, apertural view, scale = 5 mm.

Figure H. *Samoana fragilis* (Férussac, 1821), live specimen, approx. size, 1.6 cm.


E
F
G
H

[This page intentionally left blank.]

APPENDIX B

Candidate Butterfly Species Literature Review

[This page intentionally left blank.]

The Mariana Eight Spot Butterfly, *Hypolimnas octocula marianensis* and the Mariana Wandering Butterfly, *Vagrens egistina*, of the Mariana Islands, Micronesia

AUBREY MOORE

Abstract. *Hypolimnas octocula marianensis* Fruhstorfer 1912, commonly referred to as the Mariana eight spot butterfly or the Mariana forest flicker, is a subspecies of nymphalid butterfly recorded only from the islands of Guam and Saipan in the Mariana Islands. Because of its rarity and limited distribution, this subspecies became a candidate for listing under the United States Endangered Species Act in 1997. The objective of this article is to review what is currently known about this rare subspecies.

Taxonomy

Hypolimnas octocula is one of four species of nymphalid butterflies inhabiting the Mariana Islands including *H. bolina, H. anomola*, and *Vagrans egistina. H. bolina* and *H. anomola* are common. However, *V. egistina* is very rare, not having been observed since the 1970s (Schreiner and Nafus, 1997). As with H. *octocula marianensis*, *V. egistina* became a candidate for listing under the United States Endangered Species Act in 1997.

The subspecies *Hypolimnas octocula marianensis* was described by Fruhstorfer (1912). The parent species, *Hypolimnas octocula* was described under the name *Diadema octocula* by Butler in 1869. In addition to *H. o. marianensis*, there are several other subspecies occupying islands of Palau, Vanuatu, New Caledonia and the Loyalties, Fiji, Tonga, and Samoa (Samson 1986).

Samson (1986) revised the *Hypolimnas octocula* complex. He split the group into two species, *H. octocula and H. arakalulk. In H. arakalulk*, he placed only two subspecies, both from Micronesia: *H. arakalulk mari*anensis from the Marianas and *H. arakalulk arak*alulk for Palau. However, in this article I will use *Hypolimnas octocula marianensis* as the valid name.

This scientific name for the Mariana eight spot butterfly is often misspelled (Table 1). The most egregious error occurs in a U.S. National Park Service document (Haysmith et al., 2005), available online, where the authors misspelled

all three components of the trinomial, "*Hypolymnus octucula mariannensis*", and used this name in the caption for a photograph of a butterfly taken on Rota, which is outside the known range for *H. o. marianensis*. The butterfly in the image is clearly a female *H. bolina*, a common species in the Marianas. This misidentified image was reused in a fact sheet on the Marianas eight spot butterfly published as part of the Guam Military Buildup Draft Environmental Impact Statement (Volume 9, Chapter 2).

A valid scientific name can be considered to be a key which unlocks the global information base for a taxon. Information associated with misspelled or otherwise invalid names may be inaccessible or overlooked. This is especially true for information stored in databases which use valid scientific names as unique identifers. A recent attempt to use databases to assess the relationship between rare species and invasive species illustrates this problem. Roberts et al. (2013) have developed an innovative strategy were they use bibliographic database queries to extract information to be used in a massive literature review aimed at assessing the relationships between invasive species and threatened species. To extract information on threatened species, they used a query based on scientific names from lists provided by the U. S. Fish and Wildlife Service. Unfortunately, the name currently listed for *H. o. marianensis* is misspelled (*H. o. mariannensis*). So it is likely that only literature keyed to this particular misspelling of the scientific name will be identified for the review, and literature which uses the valid scientific name,

synonyms, or other misspellings will be ignored.

Observations and Distribution

Here I attempt to list all known observation and collection records for *H. o. marianensis*.

Both *H. o. marianensis* and its synonym, *H. o. arakalulk* (misspelled as "arakaluk"), are listed by the Global Biodiversity Information Facility (GBIF). There are currently no occurrence records available for this subspecies, although there are records for other subspecies of *H. octocula*.

Type Specimens - Saipan (n=2)

According to Samson (1986), locations of the type specimens for *H. o. marianensis* are unknown. He examined a neotype and an alloneotype, both collected on Saipan:

Neotype, male, Museum Paris, Saypan (Mariannes), M. A. Marche, 200-83 (BM); Neallotype, female, Saipan, Mariana Isl., July 30, 1920 (AMNH).

These are the only Saipan collection records I was able to find. There are no specimens of *H. o. marianensis* in the Northern Marianas Islands insect collection housed at the Northern Marianas College on Saipan (Schreiner and Nafus (1996)).

Swezey Collection -October 17, 1936 - Guam (n=1)

Swezey (1942) collected a single female *H. o. marianensis* during his 1936

entomological survey of Guam. The collection data are reported as "Piti, from hibiscus at residence, Oct. 17, Swezey". This specimen is in the Bishop Museum collection.

Some authors infer from the fact that Swezey collected only a single specimen of *H. o. octocula* that this subspecies was rare in 1936. However, this may not be the case. Swezey's mission on Guam was an agricultural pest survey (Swezey and Association, 1942; IMMS, 1943) and presumably he did not spend much time and effort collecting in karst habitats inhabited by *H. o. marianensis* and its host plants. The single adult specimen he collected was caught opportunistically while feeding on Hibiscus nectar at Swezey's temporary residence in Piti (Samson, 1986)

Muniappan Collection -15 and 20 August, 1975 - Guam (n=3)

As reported by Samson (1986), Muniappan reared 3 butterfies from "larvae collected on limestone forest plant, Procris sp. at Hilaan Point, 15 and 20 August, 1975". Specimens are in the University of Guam insect collection.

Schreiner and Nafus Surveys -1995 - Saipan (n=0), Rota (n=0), Guam (n > 6)

Schreiner and Nafus (1996) surveyed for *H. o. marianensis* on Saipan, Rota and Guam during 1995. Early in the survey they discovered that the larvae fed upon *Elatostema calcareum* (tupun ayuyu) in addition to the previously known larval host plant, *Procris pendunculata*. Both are forest herbs in the family

Urticaceae growing on karst limestone. For each site where the plants were found, 200 stems of *Procris* and 200 stems of *Elatostema* were searched, or as many as were available.

Table 1: Synonymy for *Hypolimnas octocula marianensis* Fruhstorfer 1912.

Name	References	Status
Hypolimnas octocula marianensis	Fruhstorfer (1912); Swezey (1942); Schreiner and Nafus (1997); Wiles et al. (1999); DAWR (2005); NAVFAC (2010); US Navy (2012); Anonymous (2012a)	valid name
Hypolimnasarakalulk marianensis	DAWR (2005)	genus and sp. epithet concatonated
Hypolimnasarakalulk marianesis	DAWR (2005)	genus and sp. epithet concatenated and mispelled subsp. epithet
Hypolimnas arakalulk marianensis	DAWR (2005)	synonym
Hypolimnas arakalulk marianensis	Anonymous (2013a,b)	mispelled sp. epithet
Hypolimnas octucual marianensis	US Navy (2012)	mispelled species epithet
Hypolimnas octucual marianensis	US Navy (2012)	mispelled sp. epithet
Hypolimnas octucual marianensis	US National Park Service (2005); NAVFAC (2010); US Navy (2012); U.S. Fish and Wildlife Service (2012); USAF (2006)	mispelled sp. epithet and subsp. epithet
Hypolimnas octucual marianensis	Schreiner and Nafus (1996); Hawly and Castro (2008); NAVFAC (2010); US Navy (2012); Anonymous (2012a,b); Roberts et al. (2013)	mispelled subsp. epithet
Hypolimnus octocula mariannesis	US Navy (2012)	mispelled genus and subsp. epithet
Hypolymnus octicula	US Navy (2010b,a)	mispelled genus and sp. epithet; subsp. epithet missing
Hypolymnus octucula mariannensis	Haysmith et al. (2005)	mispelled genus, sp. epithet and subsp. epithet
Hypolimnas octocula mariannesis	Schreiner and Nafus (1996)	mispelled subsp. epithet
Hypolimnas octocula mariannenis	NAVFAC (2010)	mispelled subsp. epithet
Hypolimnus oculata var. mariannensis	USAF (2006)	subsp. epithet mispelled and referred to as a var.

- Saipan

H. octocula was not found on Saipan. *Procris* was located along the base of the cliff line going around from Suicide Cliff to Kalebrera Cave. Several large

stands were located. However no sign of adult or larvae could be found. No specimens were found in the fairly extensive collection of butterflies in the Northern Mariana Islands Insect Collection.

- Rota

Although no butterflies of this species have ever been collected on Rota, Schreiner and Nafus searched several sites, as Rota has not been collected as extensively as Guam and Saipan. *Elatostema* was abundant behind the Japanese gun on the way up to the Sabana, and at similar cliff-backed sites at that altitude and slightly higher. *Procris* occurred at some of these locations. Although chewing of the plants was noted, this appeared to be caused by the green caterpillar of a noctuid moth. No evidence of *H. octocula* was found.

- Guam

On Guam, a number of sites along the northern half of Guam were searched. *Procris* and occasionally *Elatostema* occur on the windward side in patches in limestone forest in a narrow band about 200 ft above sea level. Both *Elatostema* and *Procris* occurred on the leeward side in forests perhaps 100-200 ft. above sea level. At all locations where the host plants were found at least one of the stages of *H. o. marianensis* was also found. The most butterflies seen in one day at a suitable location was six. They found no eggs at most sites, but up to 71 at one site which

was undergoing a small outbreak. Eggs and larvae were more abundant on *Elatostema* on the leeward side. Schreiner and Nafus did not search patches of host plants which are thought to occur in patches of limestone forest on the Southern mountains.

One site, below the University of Guam, was surveyed intensively for one year. See the Biology section below for results from observations at this site. Schreiner and Nafus (1996) do not clearly indicate the total number of adult *H. o. marianensis* observed during their surveys. In a table of adult butterfly sightings, they list a total of 6 sightings: 3 individuals at Spanish Steps, Orote on 29-JUN-1995, 2 individuals at Tweed's Cave on 24-JUL1995, and 1 individual at Lower Pagat on 2-AUG-1995. However, this table does not include any sightings at the site near the University of Guam campus in Mangilao and elsewhere in their report, they state that "The most butterflies seen in one day at a suitable location *was six."*

Muniappan Collection -2001 - Guam (n=1)

A specimen of an adult *H. o. marianensis* specimen in the University of *Guam insect collection is labeled: "Hilaan Pt., Guam, Sep 7 2001, Muniappan".*

Bob Okoniewsky Sighting -April, 2008 - Guam (n=1)

Bob Okoniewsky emailed excellent images of an adult *H. octocula marianensis* to me in April, 2008. This individual accidentally few into the

passenger compartment of his vehicle as he was driving on Andersen Air Force Base, Yigo, Guam.

Hawly and Castro Survey - June - October, 2008 -Tinian (n=0)

Hawly and Castro (2008) surveyed Tinian for *H. o. marianensis*, even though the subspecies has never been reported from this island. They located populations of *Elatostema calcareum* at four locations and monitored these plants for all *H. o. marianensis* life stages Each identifed host plant site was visually scanned for life cycle stages (eggs, caterpillar, chrysalis, and imagoes/adults) by one or two observers for up to two weeks at various time of the day. At Japanese Cave site-2, 2 caterpillars and 4 chrysalises of *Hypolimnas bolina* were found feeding and pupating on *E. calcareum*, the chrysalises were reared in the lab for confirmation.

Two butterfly bait traps (lip type obtained from BioQuip.com) were set at each host plant site for up to two weeks. The butterfly bait traps were re-baited every three days with locally obtained mashed, rotting bananas, a liberal dose of raw cane sugar, and a dash of water. The bait was prepared on the afternoon prior to the morning of use and typically became well fermented prior to being placed in the field. The traps were positioned within 5 meters of a host plant cluster and at approximately 3-4 meters above the ground.

After 4,806 documented minutes (approx. 80 hours) of visual searching and

1,848 documented trap hours (approx. 77 days) during the months of September and October, 2008 no life cycle stage of either species was observed.

Vegetation Survey 1 -2008 - Guam (n=1)

A military contractor reported a sighting of an adult *H. o. marianensis* while doing vegetation surveys in the Pagat area of Yigo, Guam (Duenas 2010).

Vegetation Survey 2 -2009 - Guam (n=0)

In a vegetation survey in at Andersen Air Force Base (AAFB) in which "the specific task was to document the presence of host plants for butterfly species that are candidates for the Endangered Species Act, no *H. o. marianensis* butterflies were observed (TEC Inc. (2010)).

Andersen Air Force Base Butterfly Survey, Sept. 28 -Oct. 2, 2009 and Jan. 25, 2010 - Jan. 31, 2010 -Guam (n=0)

A survey for the Mariana Eight-Spot Butterfly, *H. o. marianensis*, was conducted on three Department of Defense parcels on Guam: Andersen Air Force Base (AAFB), Andersen South and Navy Barrigada during late 2009 and early 2010(AECOM Inc., 2010).

The survey used two methods: timed counts and baited traps. Timed counts were conducted along linear transects within each of the three parcels. At every 30 meters two scientists would stand back-to-back and enumerate observations of all butterfly species within a 5-minute period. The areas investigated along the

transect consisted of 20 m diameter circle plots. The biologists communicated with each other frequently throughout the survey period so as not to count the same individual butterfly twice. A total of five transects were studied. Three transects were located on AAFB and one transect was located on Andersen South and Navy Barrigada. [The report refers to figures which show the locations of the transects. However, these figures are missing from the Natural Resources Survey Report (NAVFAC, 2010).]

Two baited traps were placed on each transect during daylight hours. The bait consisted of a mixture of mashed ripe bananas, apple cider, sugar, and yeast. At the end of the trapping period, which lasted approximately 6 hours, the traps were checked, and captured butterflies were noted and then released.

There were no observations of *H. o. marianensis* during this survey. Presence or absence of host plants was not reported.

Campora Survey - Pagat -2010, Guam (n=1)

A survey for all life stages of the Mariana Eight-Spot Butterfy, *H. o. marianensis*, and its two host plants along three transects in the Route 15 -Pagat Village area of Yigo, Guam from July 15 to July 24, 2009 (NAVFAC Pacifc, 2010).

Transects were first surveyed over their entire length for host plants. Once the most probable areas of butterfly habitat (i.e. areas with a high density of host

plants) were identified, efforts were then focused on those sites. This consisted of searching host plants for eggs, larvae, and pupae, monitoring the understory and upper forest canopy for adults, and monitoring bait pans. A digital camera (Canon 30D) was used to capture images of host plants and all butterfly life stages. Field binoculars were used to identify adult butterflies from long distances. Bait pans consisted of aluminum pie tins and were suspended approximately five to six feet from the ground. Banana and pieces of fish were used as bait. Bananas were prepared one day in advance by mashing and mixing with cane sugar and water and leaving at room temperature in a sealed bag for 24 hours. Fish pieces were obtained from a local market and placed in bait stations on the same day of purchase. Three bait pans were used in each area of butterfly habitat for a period of two days.

A single adult male *H. o. marianensis* was observed and photographed at the same location on consecutive days on a transect near the Route 15 North transect near the Yigo race track.

A total of 7 *Hypolimnas* larva were found at 5 different locations on both *E. calcareum* and *P. pedunculata*. Hypolimnas eggs were found only on *E. calca*reum, with a total of 19 eggs at 5 diferent locations. One viable *Hypolimna*s chrysalis was found on *E. calcareum*, and three empty *Hypolimnas* chrysalides were found on P. *pedunculata*. These immatures were probably *H. o. marianensis*. However, this could not be definitely confirmed in the feld. *H. octocula* eggs and caterpillars are

very similar to those of *H. bolina* and *H. anomola* which are common on Guam. Note that *H. bolina* has been observed to feed on *E. calcareum* (Hawly and Castro, 2008).

All of the 19 eggs where black, indicating that they were parasitized.

UH (Rubinof) Surveys -2011 and 2012 - Guam (n=?)

Reports for these surveys are currently unavailable.

Biology

Most of what is known about the biology of *H. o. marianensis* comes from Schreiner and Nafus (1996), an unpublished report of rare butterfly surveys on Guam, Saipan and Rota. During these surveys, they found *H. o. marianensis* only on Guam, at several sites. One site, below the University of Guam was surveyed for one year. Butterflies were most abundant between December and February. These months include the end of the rainy season and the beginning of the dry season on Guam. Population levels were very low in July and August, the beginning of the rainy season.

Larval Host Plants and Feeding Habits

Early in their surveys, Schreiner and Nafus found that larvae fed upon *Elatostema calcareum* (tupun ayuyu) in addition to the previously known host, *Procris pedunculata*. Both are forest herbs in the family Urticaceae growing on

karst limestone. Schreiner and Nafus (1996) noted a tight association in occurrence of the butterfly and its host plants: "At all locations where the host plants were found at least one of the stages of *H. octocula* was also found."

"In Guam, a number of sites along the northern half of Guam have been searched. *Procris* and occasionally *Elatostema* occur on the windward side in patches in limestone forest in a narrow band about 200 ft above sea level. Both *Elatostema* and *Procris* occurred on the leeward side in forests perhaps 100-200 ft. above sea level. At all locations where the host plants were found at least one of the stages of *H. octocula* was also found. The most butterflies seen in one day at a suitable location was six. We found no eggs at most sites, but up to 71 at one site which was undergoing a small outbreak. Eggs and larvae were more abundant on *Elatostema* on the leeward side. Still to be searched are patches of these plants which are thought to occur in patches of limestone forest on the Southern mountains."

Life Cycle

Schreiner and Nafus (1996) provide developmental times for eggs and six instars of *H. o. marianensis* caterpillars (Table 2). The length of time spent as a pupa and longevity of adults is unknown.

Stage Specific Survivorship

Schreiner and Nafus (1996) made repeated observations of individuals in the field until they changed to the next life stage or disappeared (Table 2). They used recovery rates as lower bound estimates of stage specific survivorship. Only 10 per cent of individuals observed as eggs where recovered as first instar caterpillars. Schreiner and Nafus attribute this low rate to egg predation by ants and egg parasitism by hymenopterans (see below). Recovery rates for larval instars two to five ranged from 44 to 88 per cent. However, the recovery rate for sixth instar caterpillars was only 29 per cent. Schreiner and Nafus attribute this low rate to the dispersal of the large sixth instar caterpillars when they are searching for food or a cryptic location for pupation.

Predation and Parasitism

In their year-long study of the *H. o. mariane*nsis population near the University of Guam campus in Mangilao, Schreiner and Nafus found that egg predation, probably by ants, and egg parasites killed the majority of eggs. Parasitized eggs were brought to the laboratory and reared. Except for two eggs which produced *Ooencyrtus* sp., all the eggs were parasitized by a *Telenomus* sp. In contrast to the Mangilao site, however, eggs recovered from other sites did produce *Ooencyrtus* sp. They suspected that these were the same native species of wasps observed attacking *H. anomala* and *H. bolina* eggs. No egg, larval or pupal

parasites which are known to have been introduced for biological control purposes were recovered.

Table 2: Field observations of *H. o. marianensis.* development at a site near the University of Guam campus during 1995. Data from Schreiner and Nafus (1996).

Stage	Days Spent in Stage	No. Found	No. Found after Hatching or Moulting to Next Stage	Percent Recovered
egg	6	445	45	10
1st instar	2.4 ± 0.6	47	21	44
2nd instar	2.0 ± 0.7	37	21	57
3rd instar	2.5 ± 0.8	36	32	88
4th instar	2.9 ± 0.8	46	30	65

The Guam Comprehensive Wildlife Conservation Strategy (DAWR, 2005) lists "predation of caterpillar by an ichneumonid wasp" as a threat to *H. o. marianensis*. I was unable to find any other reference for *H. o. marianensis* caterpillars being attacked by ichneumon wasps, which are parasitoids, not predators.

Conservation

When planning an effective conservation strategy, one must first collect enough information about the threatened taxon to understand and prioritize risks to be mitigated. Unfortunately, except for Schreiner and Nafus's yearlong study of a population of *H. o. marianensis* near the University of Guam Schreiner and Nafus (1996), our knowledge of this rare butterfly is limited to data from accidental

sightings plus presence/absence surveys with some observations on association with the two known host plants.

The Guam Department of Agriculture Division of Aquatic and Wildlife Resources and the United States Fish and Wildlife Service have independently developed published threat assessments and conservation recommendations for *H. o. marianensis* Both are brief enough to be quoted here.

> Threat Assessment and Recommendations from the Guam Comprehensive Wildlife Conservation Strategy (GCWCS)
> (Quoted verbatim from DAWR (2005))
> Threats:
> Habitat loss for the host plants by introduced plant species, and predation of caterpillar by an ichneumonid wasp, are believed to be causes of this species rarity.
> Action Plan: Habitat degradation and loss: Identify and map occurrences of *Procris pedunculata*. Reduce impacts of ungulates and invasive plants in limestone forests areas where *Procris* occurs. Small or extirpated population: Conduct monthly surveys at the Hilaan Point to observe seasonal activity for this butterfly species, and cultivate caterpillars of this species and rear them to adult stage in a parasite and predation free enclosure for propagation. Release reared in the lab adults in limestone habitats

where the host plant is abundant and especially in conservation areas Guam.

The GCWCS action plan for *H. o. marianensis* has not been implemented. Threat Assessment and Recommendations from the U.S. Fish and Wildlife Service (USFWS) Species Assessment and Listing Priority Assignment Form (Quoted verbatim from Anonymous (2012a))

Summary of Threats :

Based on our evaluation of predation and parasitism we conclude there is sufficient information to develop a proposed rule for this species due to the threat of predation by ants and parasitism by small wasps. The likely extirpation of this species from Saipan and its reduction to low numbers on Guam makes it vulnerable to random demographic and environmental events. We find that this species is warranted for listing throughout all of its range, and, therefore, find that it is unnecessary to analyze whether it is threatened or endangered in a significant portion of its range. ...

Recommended Conservation Measures :

- Develop and implement monitoring surveys for the Mariana eight spot butterfly.
- Conduct parasite control.
- Conduct ant control.

The USFWS recommendation for conserving *H. o. marianensis* by controlling parasites and ants may not produce positive results. There is currently no evidence that larvae or pupae are being parasitized and it is probable that the two known egg parasitoids are native parasitic wasps Schreiner and Nafus (1996) which have coevolved with *H. o. marianensis*. *H. o. marianensis* immature are attacked by alien ant species, but closely related butterfly species on Guam are abundant despite attacks from these same ants.

Although reasons for the scarcity of *H. o. marianensis* are not fully understood, there seems to be a consensus among entomologists that have studied this butterfly that the subspecies is rare because its host plants are heavily grazed by introduced deer and pigs, which have high populations in most of Guam's limestone forest areas. There is a tight association between occurrence of *H. o. marianensis* and its host plants. Schreiner and Nafus (1996) reported "At all locations where the host plants were found at least one of the stages of *H. o. marianensis* was also found." Recent surveys have shown that Eight-spot butterflies are rarely observed except in close proximity to host plants.

The loss of *E. calcareum* and *Procris pedunculata* in many areas of Guam due to heavy deer and pig feeding has been linked to the rarity of the butterfly *H. o. marianensis*, which is endemic to Guam and Saipan (Wiles et al., 1999).

Browsing damage to native forests can he extensive, causing significant changes in forest structure and species composition. The objectives of current deer

management programs in the Marianas are not compatible with the conservation of native ecosystems and recovery of endangered species. Recommendations are made to reduce deer densities dramatically through intensive continuous harvest over large areas of each island and to eradicate deer from sites of significant ecological value Wiles et al. (1999).

Host plants (*Procris pedunculata* and *Elatostema calcareum*) for larvae of the candidate Mariana eight spot butterfly, *Hypolimnas octocula marianensis*, are found in the limestone forest of Andersen Air Force Base. Deer browse has limited occurrence of these plant species to pinnacle karst and cliff edges that are inaccessible to deer. Anonymous (2012b).

Exclusion of ungulates and repopulation of limestone forest conservation areas with larval host plants may present the most promising conservation measure.

References

AECOM Inc. Butterfly Survey Report: Andersen Air Force Base, Andersen South, Navy Barrigada included in Appendix E of the Natural Resource Survey Report in Support of the Environmental Impact Statement for the Marine Corps Relocation Initiative to Various Locations . Technical report, 2010.

Anonymous. U . S . Fish and Wildlife Service Species Assessment: *Hypolimnas octocula mariannensis*. Technical report, US Fish and Wildlife Service, 2012a.

URL http://ecos.fws.gov/docs/ candidate/assessments/2013/r1/I0R7I01.pdf

Anonymous. Draft Joint Marianas Andersen Air Force Base Ungulate Management Plan. Technical report, 2012b.

URL http://sablan.house.gov/sites/sablan.house.gov/files/documents/ 16.AFBUngulateManagementPlan 25July 2012.pdf

Anonymous. Global Names Index, 2013a.

URL http://gni.globalnames.org/datasources/30? page=423&search term=ns:HYP*

Anonymous. uBio, 2013b.

URL http://www.ubio.org/portal/index.php?client= ubio&category=w&startPage=1&search=Hypolimnas.

DAWR. Guam Comprehensive Wildlife Conservation Strategy (GCWCS). Technical report, Division of Aquatic and Wildlife Resources, Guam Department of Agriculture, 2005.

URL http://www.guamdawr.org/Conservation/gcwcs2/

Camacho & Associates Inc. Duenas. Vegetation Survey of Various DOD and Non-DOD Lands: included in Appendix D of Natural Resource Survey Report in Support of the Environmental Impact Statement for the Marine Corps Relocation Initiative to Various Locations on Guam: Final. Technical Report June, 2010.

Fruhstorfer. No Title. Seitz Gross Schmetterlinge der Erde, 9:554-555, 1912.

Hawly, N.B. and Antonio Castro. Report to FWS: Candidate butterfly survey, Tinian, 2008. 2008.

Haysmith, L.F., F.L. Klasner, S.H. Stephens, and G.H. Dicus. Pacifc Island Network vital signs monitoring plan. Natural Resource Report NPS/PACN/NRR-2006/003. Technical report, National Park Service, Fort Collins, Colorado, 2005.

URL http://science.nature.nps.gov/ im/monitor/plans/PACN MonitoringPlan.pdf

A. D. IMMS. The Insects of Guam. Nature, 152(3845):55, July 1943. ISSN 0028-0836. doi: 10.1038/152055a0.

URL http://www.nature.com/doifinder/10.1038/152055a0

NAVFAC. Natural Resource Survey Report in Support of the Environmental Impact Statement for the Marine Corps Relocation Initiative to Various Locations on Guam. Technical report, 2010.

URL http://guaminsects.net/doc/misc/101223finalGuamNaturalResourcesSurvey c.pdf

NAVFAC Pacifc. Survey for the Mariana eight spot butterfy, *Hypolimnas octocula marianensis* (Lepidoptera: Nymphalidae), in the Pagat Route 15 area of Yigo Village, Guam: included in Appendix E of Natural Resource Survey Report in Support of the Environmental Impact Stat. Technical Report August, Pearl Harbor, HI, 2010.

Roberts, P.D., H. Diaz-Soltero, D.J. Hemming, M.J. Parr, N.H. Wakefeld, and H.J. Wright. What is the evidence that invasive species are a significant contributor to the decline or loss of threatened species? A systematic review map. Environmental Evidence, 2(1):5, 2013. ISSN 2047-2382. doi: 10.1186/2047-2382-2-5.

URL http://www. environmentalevidencejournal.org/content/2/1/5.

Samson, C. The *Hypolimnas octocula* Complex, with Notes on *H. inopinata* (Lepidoptera: Nymphalidae). Tyo to Ga, 37(1):15-43, 1986.

URL http://ci.nii.ac.jp/els/110007707621. pdf?id=ART0009513673&type=pdf&lang=en&host=cinii&order no=&ppv type=0&lang sw= &no=1352161642&cp=.

Schreiner, I. and D. Nafus. Survey of rare butterflies in the Mariana Islands. page 10, 1996.

URL http://guaminsects.myspecies.info/sites/guaminsects.myspecies. info/files/SchreinerandNafus1995.pdf

Schreiner, I. and D.M. Nafus. Butterflies of Micronesia. Agricultural Experiment Station, College of Agriculture and Life Sciences, University of Guam, 1997.

URL http://guaminsects.myspecies.info/sites/guaminsects.myspecies.info/ files/ButterfliesOfMicronesia.pdf

Swezey, O.H. Butterflies of Guam. Bernice P. Bishop Museum, Honolulu, 1942.

Swezey, O.H. and Hawaiian Sugar Planters' Association. Insects of Guam I. Number no. 172 in Bernice P. Bishop Museum bulletin. Bernice P. Bishop Museum, 1942.

URL http://books. google.com/books?id=ftcrAAAAMAAJ

TEC Inc. Guam Vegetation Surveys in Support of the Military Buildup EIS at Various Locations on Guam: included in Appendix D of Natural Resource

Survey Report in Support of the Environmental Impact Statement for the Marine Corps Relocation Initiative to Various Lo. Technical Report April, 2010.

U.S. Fish and Wildlife Service. Federal Register 77: 225. Technical report, 2012. URL www.gpo. gov/fdsys/pkg/FR-2012-11-21/pdf/2012-28050.pdf

US National Park Service. Draft Reconnaissance Survey: Significant Natural Areas and Cultural Sites: Island of Rota, Commonwealth of the Northern Mariana Islands, 2005. URL http://www. botany.hawaii.edu/basch/uhnpscesu/htms/parkrota/

US Navy. Haputo Ecological Reserve Area General Management Plan, Naval Base Guam. Technical report, 2010a.

US Navy. Orote Peninsula Ecological Reserve Area General Management Plan, Naval Base Guam. Technical report, 2010b.

US Navy. Final Joint Region Marianas Integrated Natural Resources Management Plan: Guam, Tinian, Farallon de Medinilla. Technical Report September, Joint Region Marianas, 2012.

USAF. Final Environmental Impact Statement: Establishment and Operation of an Intelligence, Surveillance, Reconnaissance, and Strike Capability, Andersen Air Force Base, Guam. Technical report, 2006.

G. J. Wiles, D. W. Buden, and D. J. Worthington. History of introduction, population status, and management of Philippine deer (*Cervus mariannus*) on Micronesian Islands. Mammalia, 63(2): 194-215, 1999.

APPENDIX C

Transect Atlas of GIS/Satellite and Vegetation of All Areas Surveyed.

Figure 1A. The Transects Surveyed on Andersen AFB (AA 1 - AA 4)

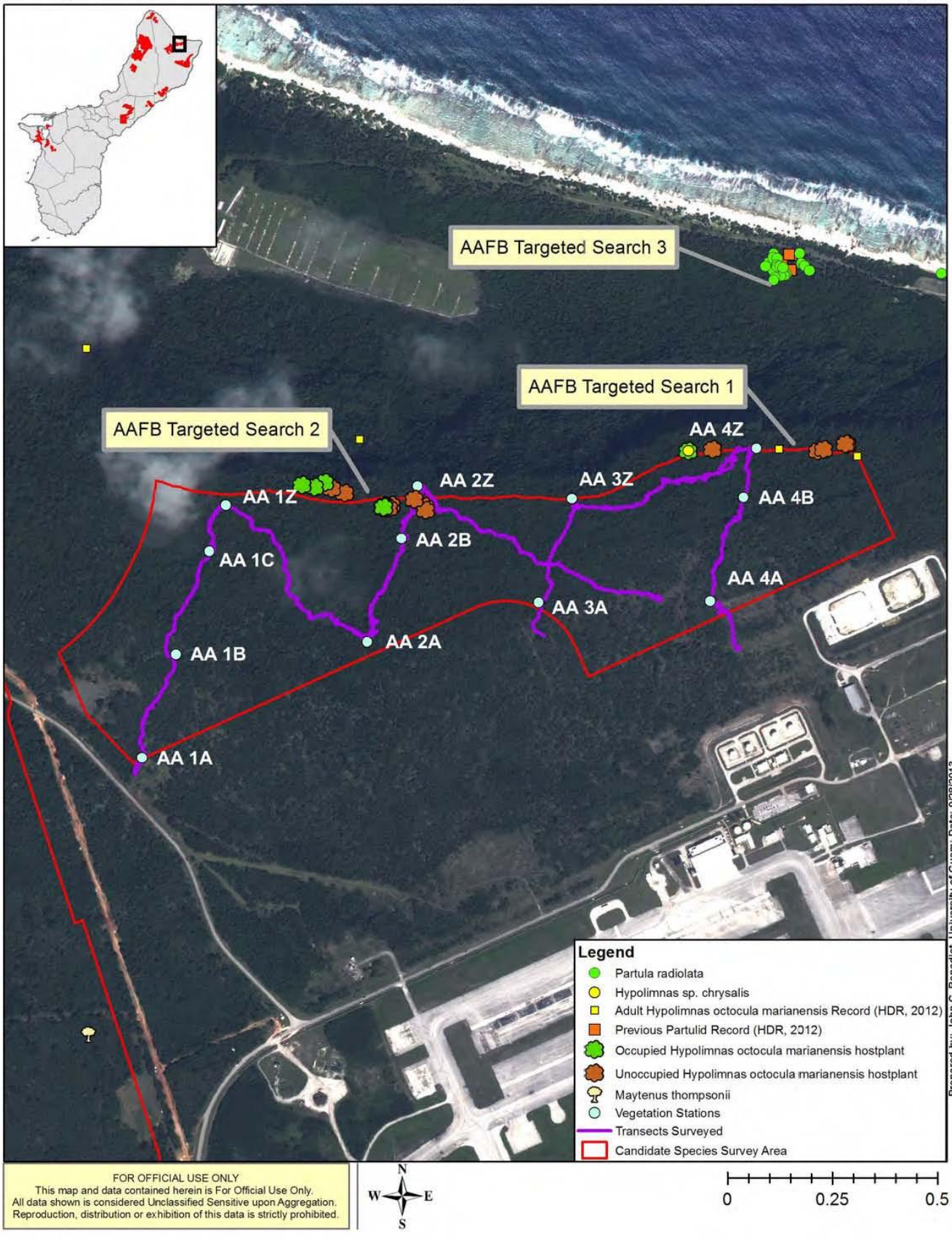


Figure 1B. The Transects Surveyed on Andersen AFB (AA 1 - AA 4)

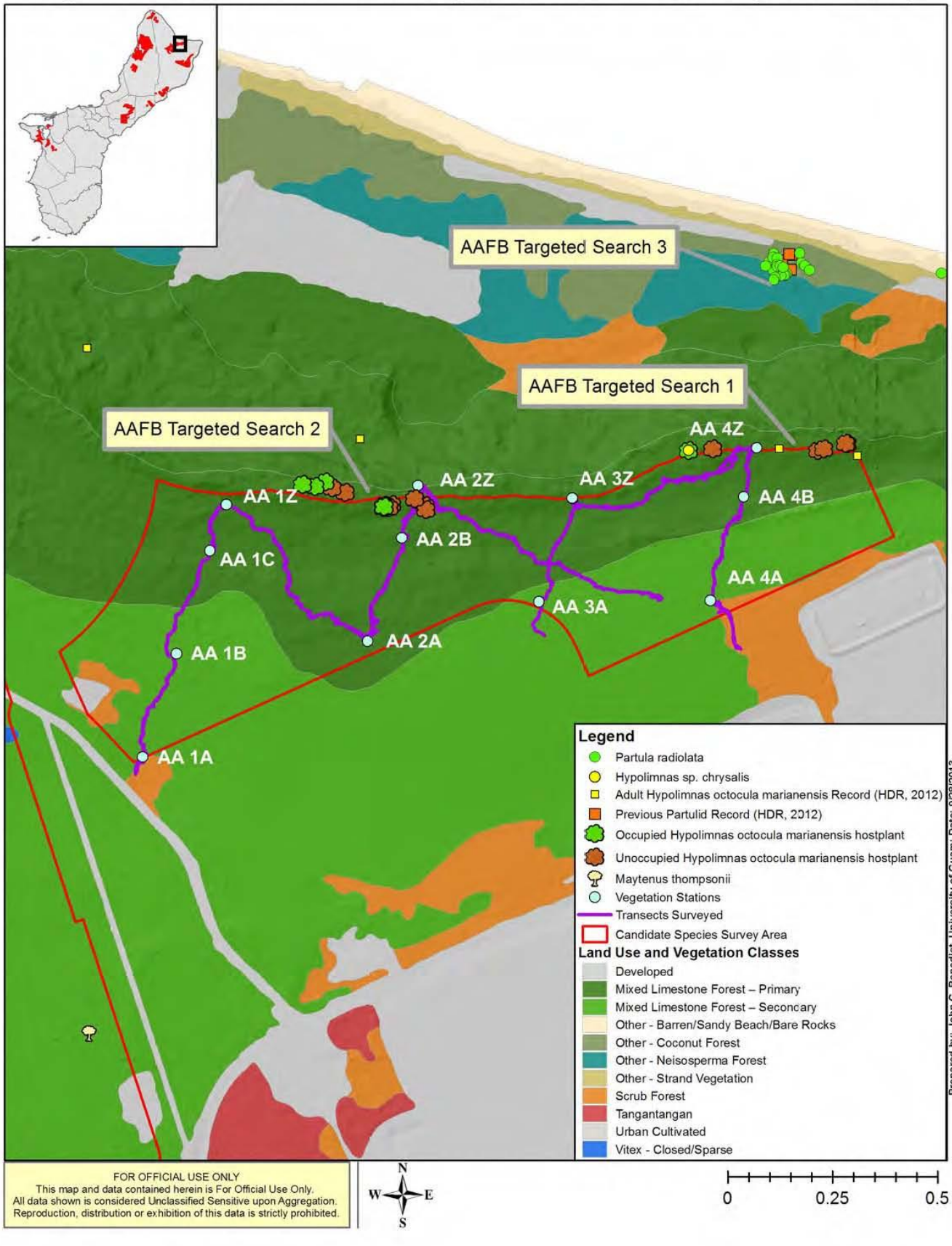


Figure 2A. The Transects Surveyed on Andersen AFB (AA 5 - AA 7)

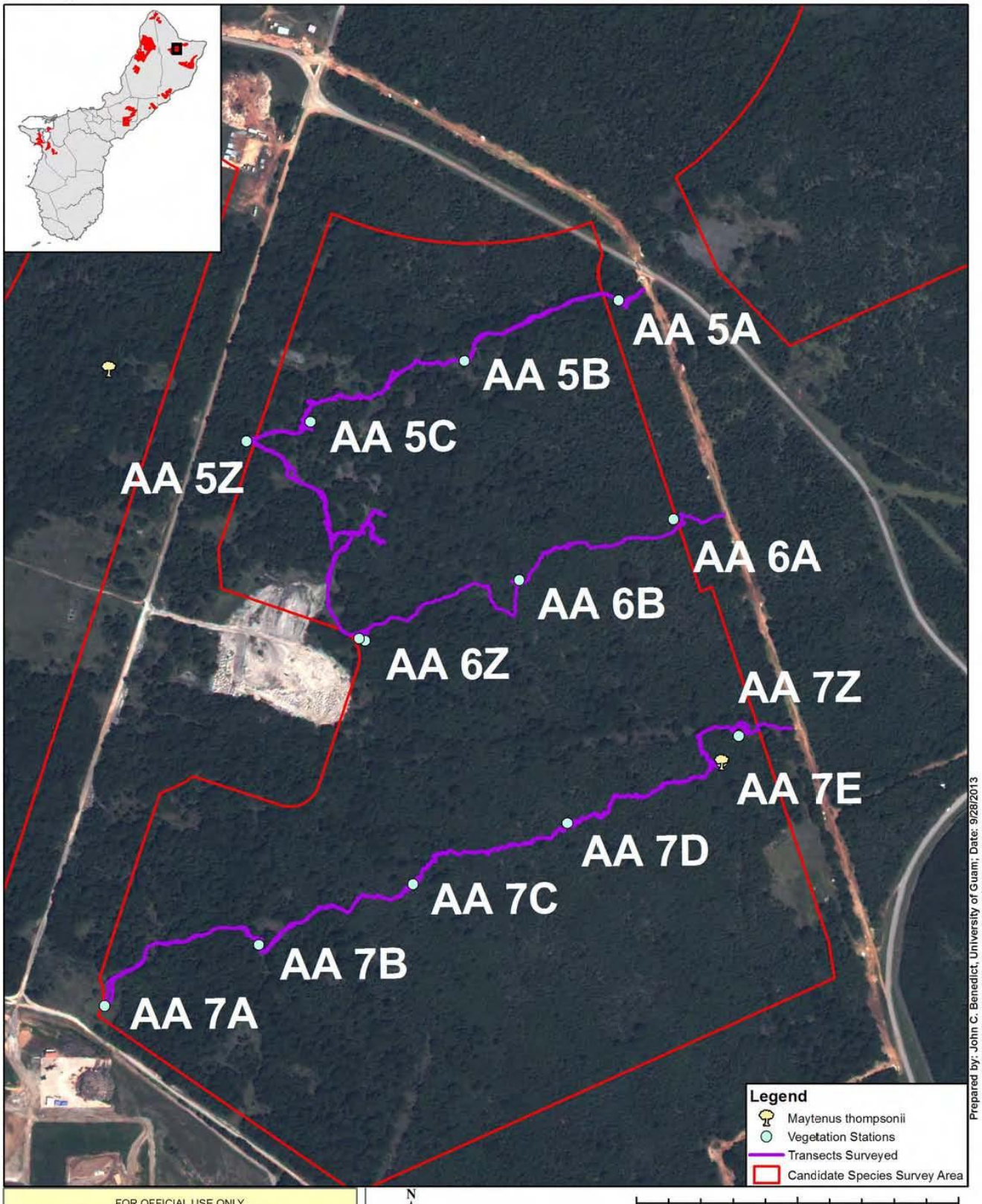


Figure 2B. The Transects Surveyed on Andersen AFB (AA 5 - AA 7)

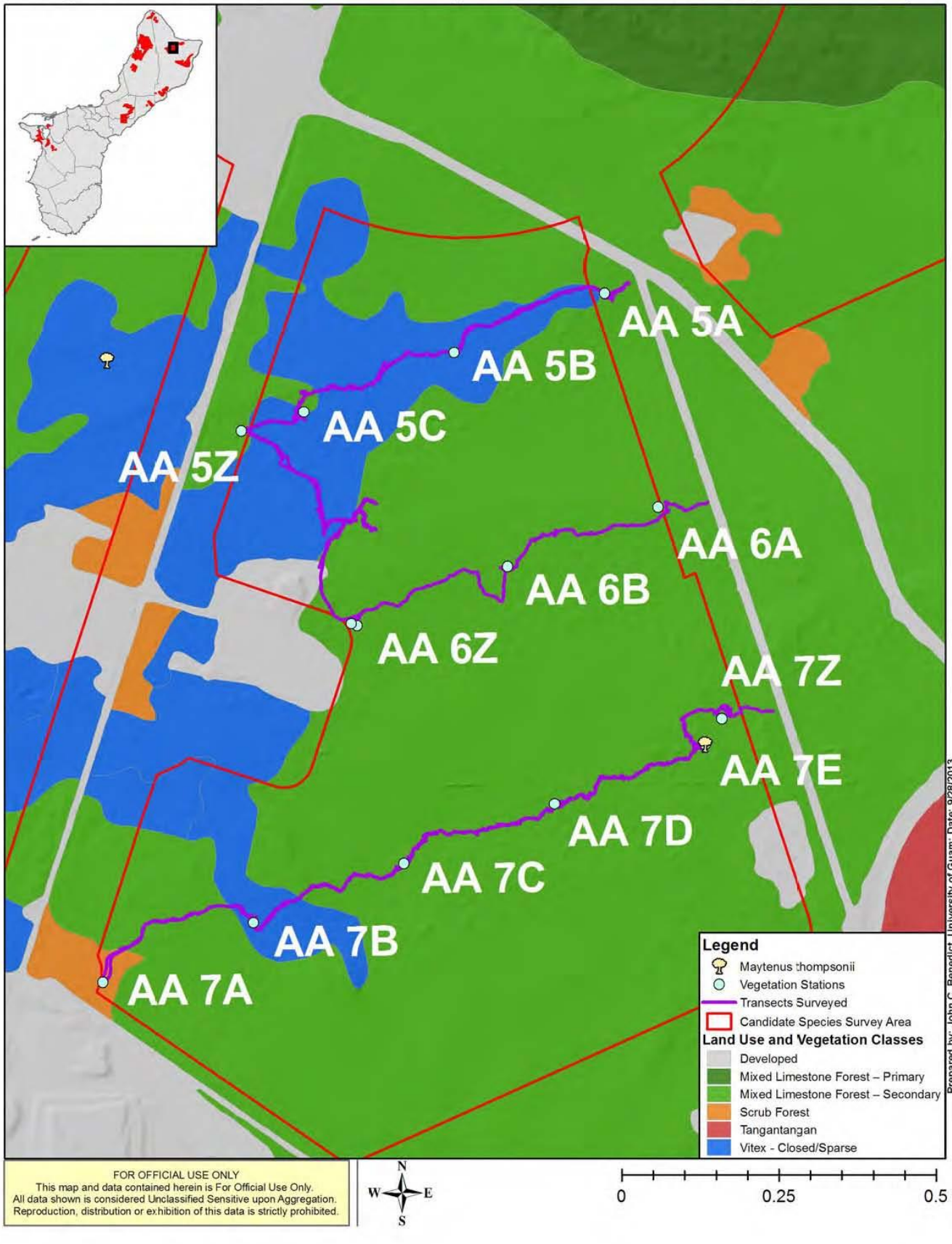


Figure 3A. The Transects Surveyed on Andersen AFB (AA 8 - AA 11)

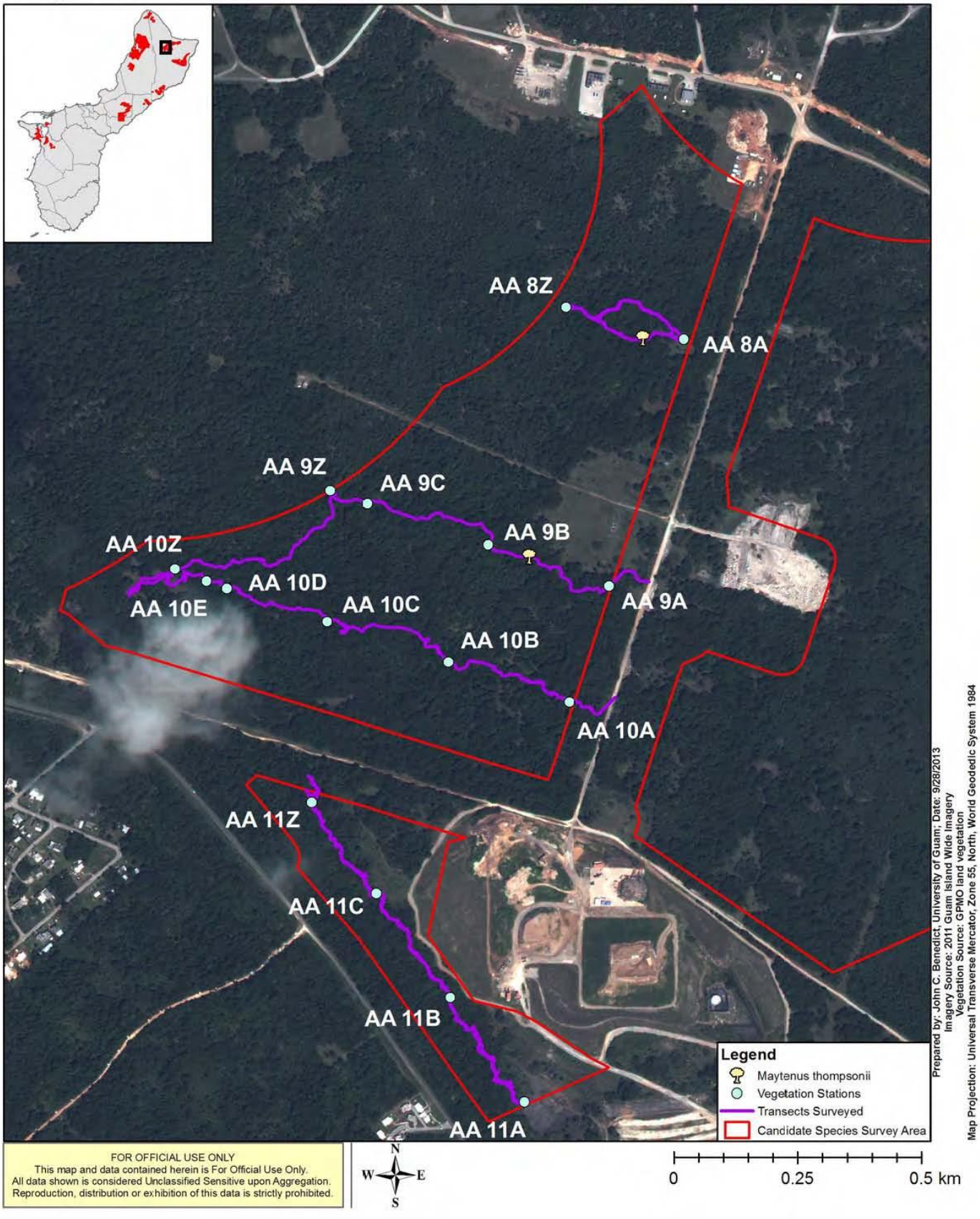


Figure 3B. The Transects Surveyed on Andersen AFB (AA 8 - AA 11)

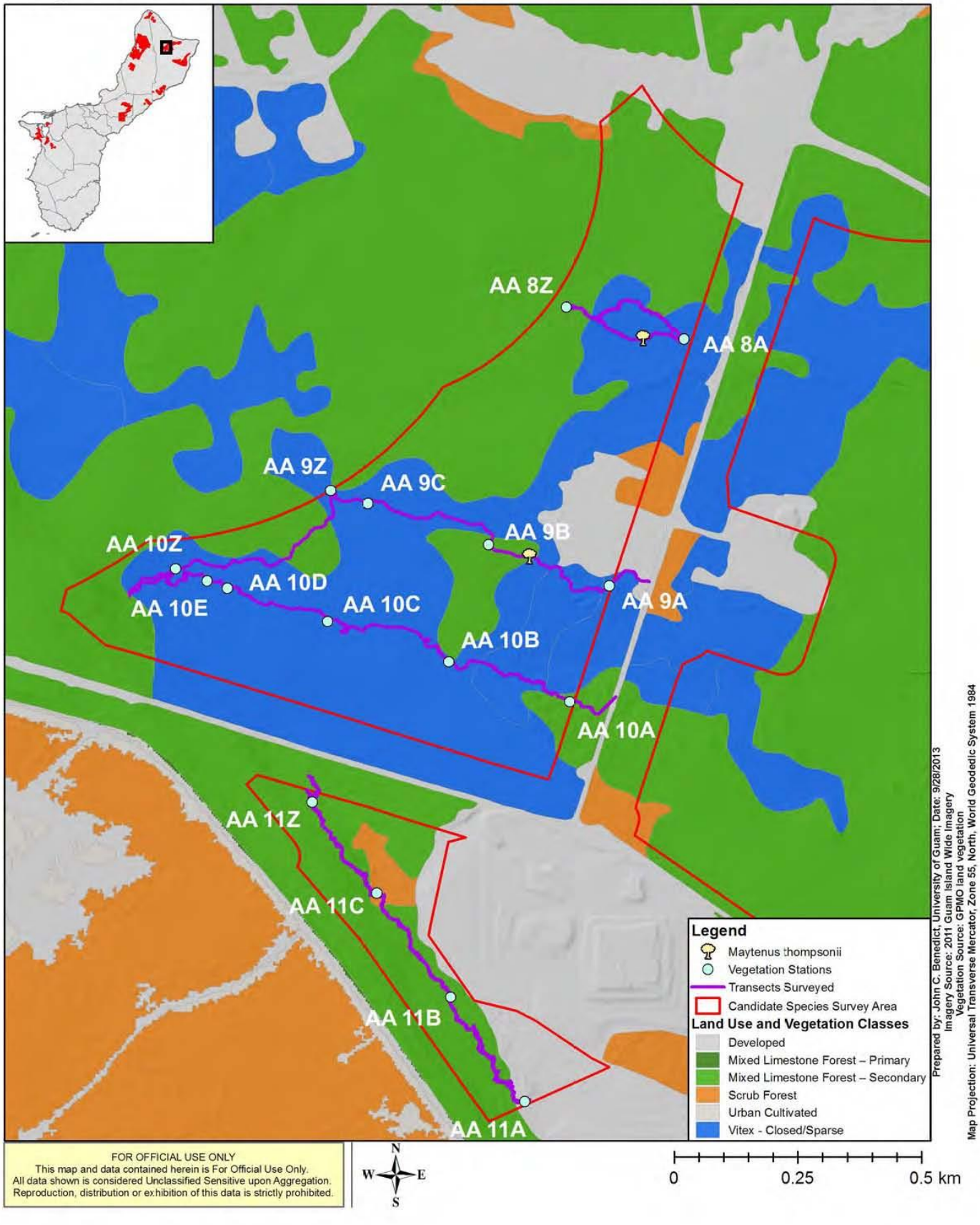


Figure 4A. The Transects Surveyed on Apra Harbor (AH 1)

Figure 4B. The Transects Surveyed on Apra Harbor (AH 1)

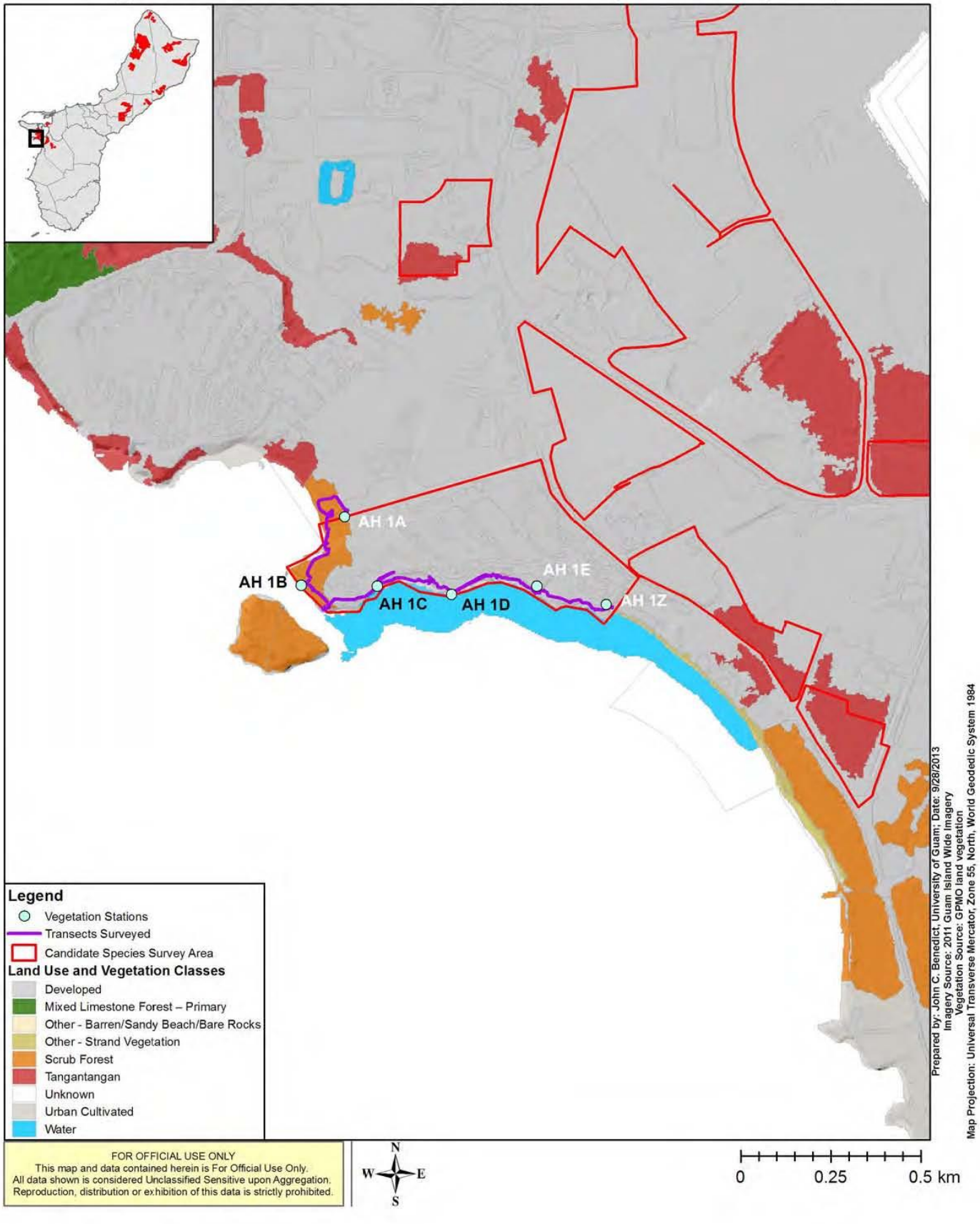


Figure 5A. The Transects Surveyed on Apra Harbor (AH 2 - AH 4)

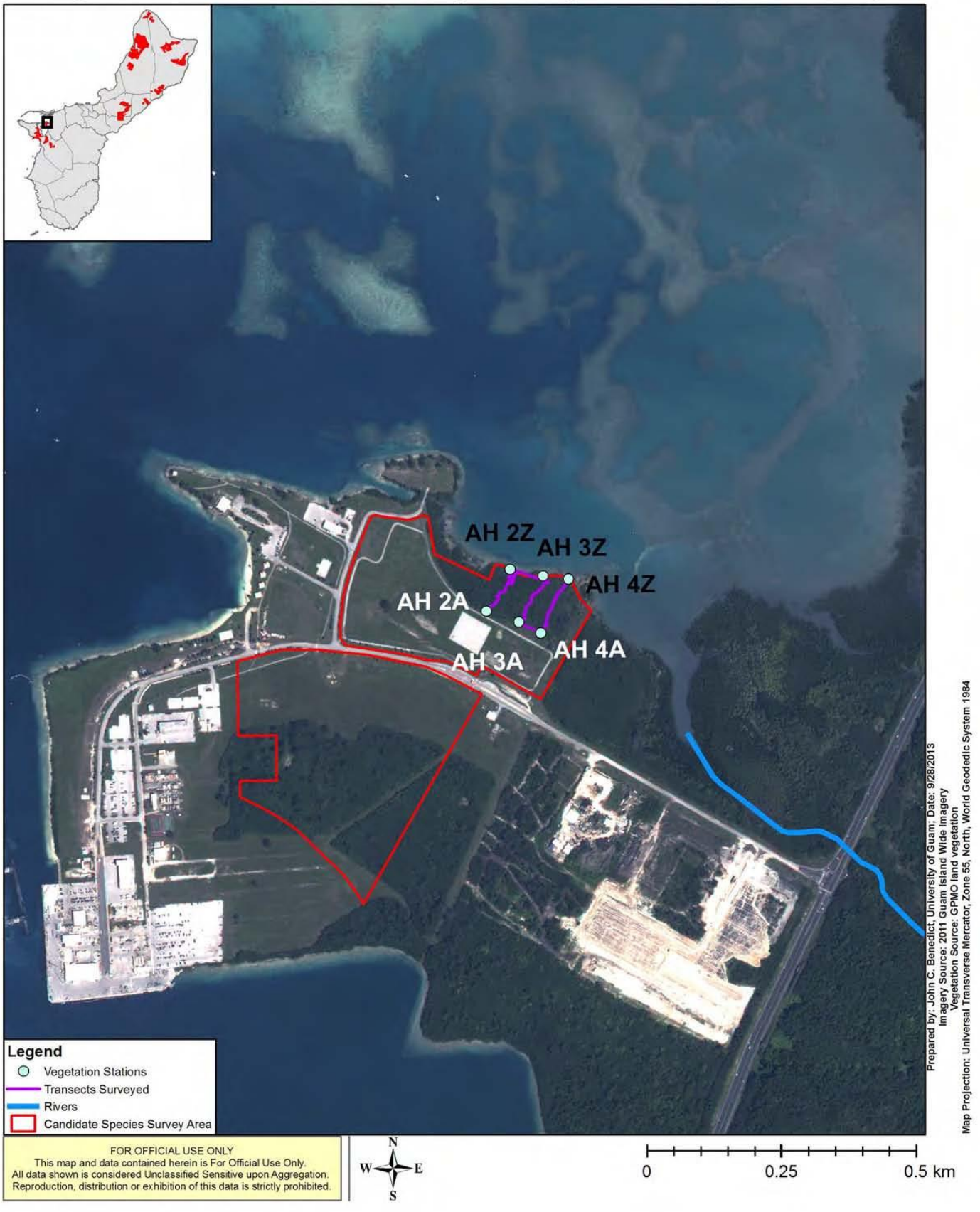


Figure 5B. The Transects Surveyed on Apra Harbor (AH 2 - AH 4)

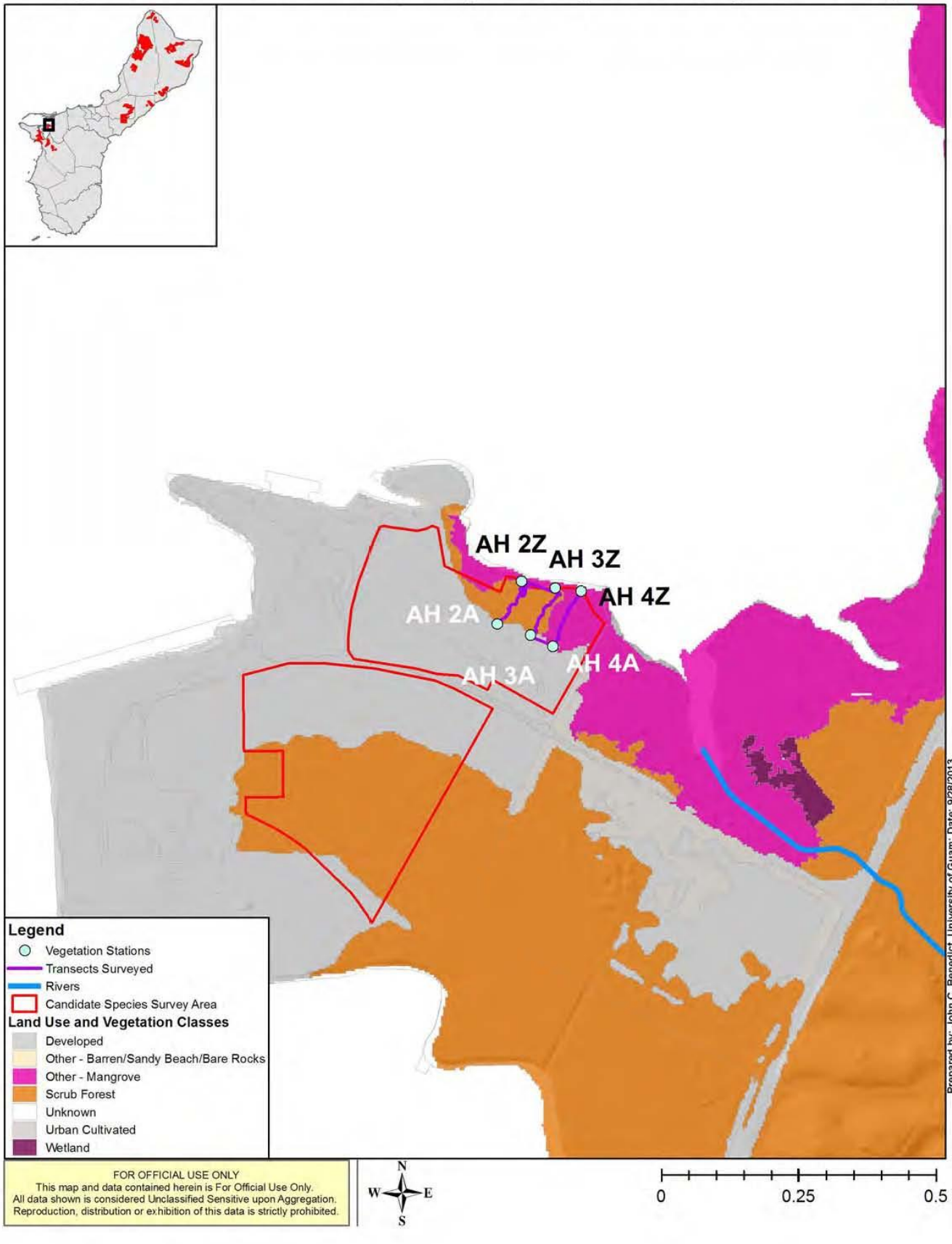


Figure 6A. The Transects Surveyed on Apra Harbor (AH 5)

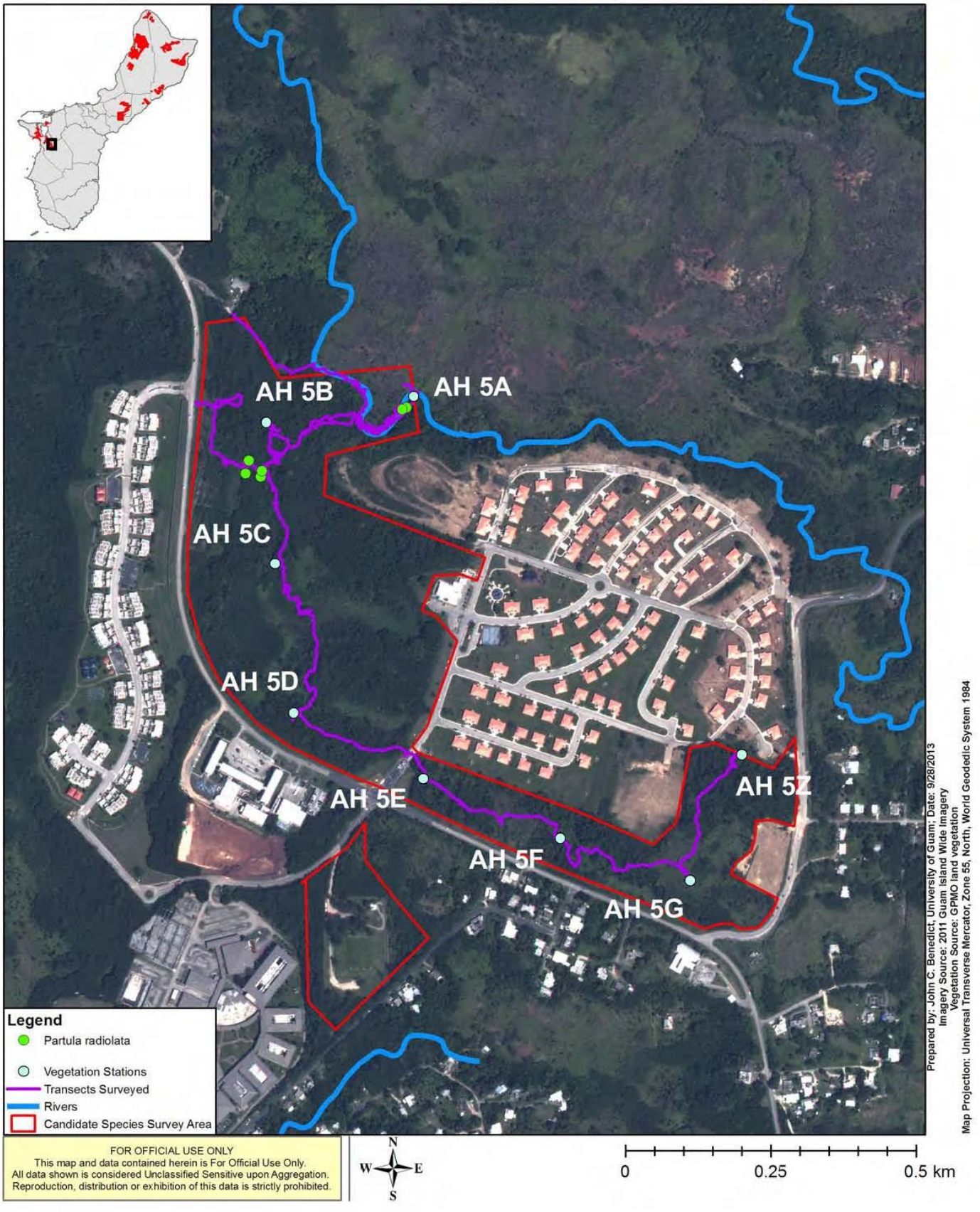


Figure 6B. The Transects Surveyed on Apra Harbor (AH 5)

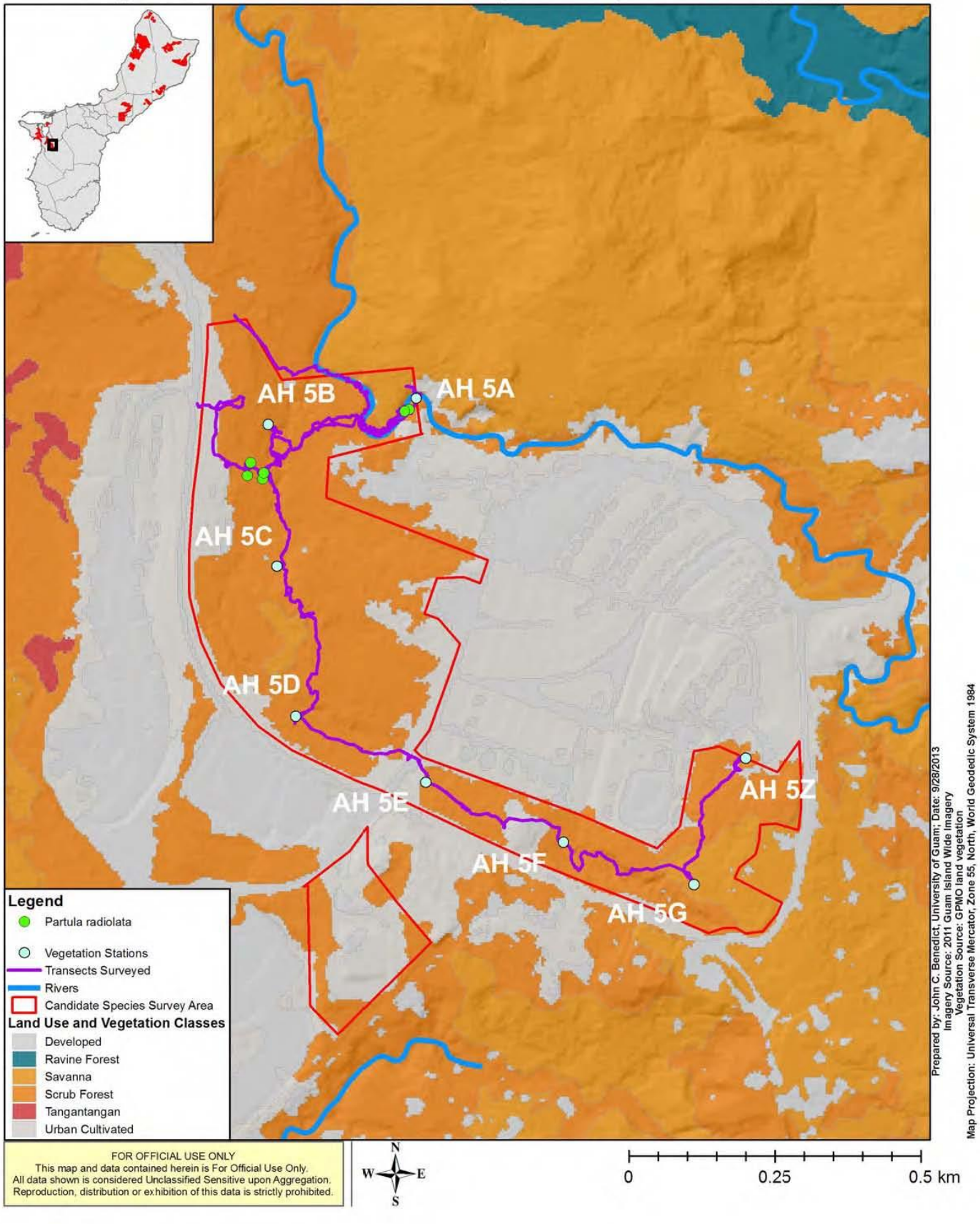


Figure 7A. The Transects Surveyed on Barrigada (BA 1 – BA 2)

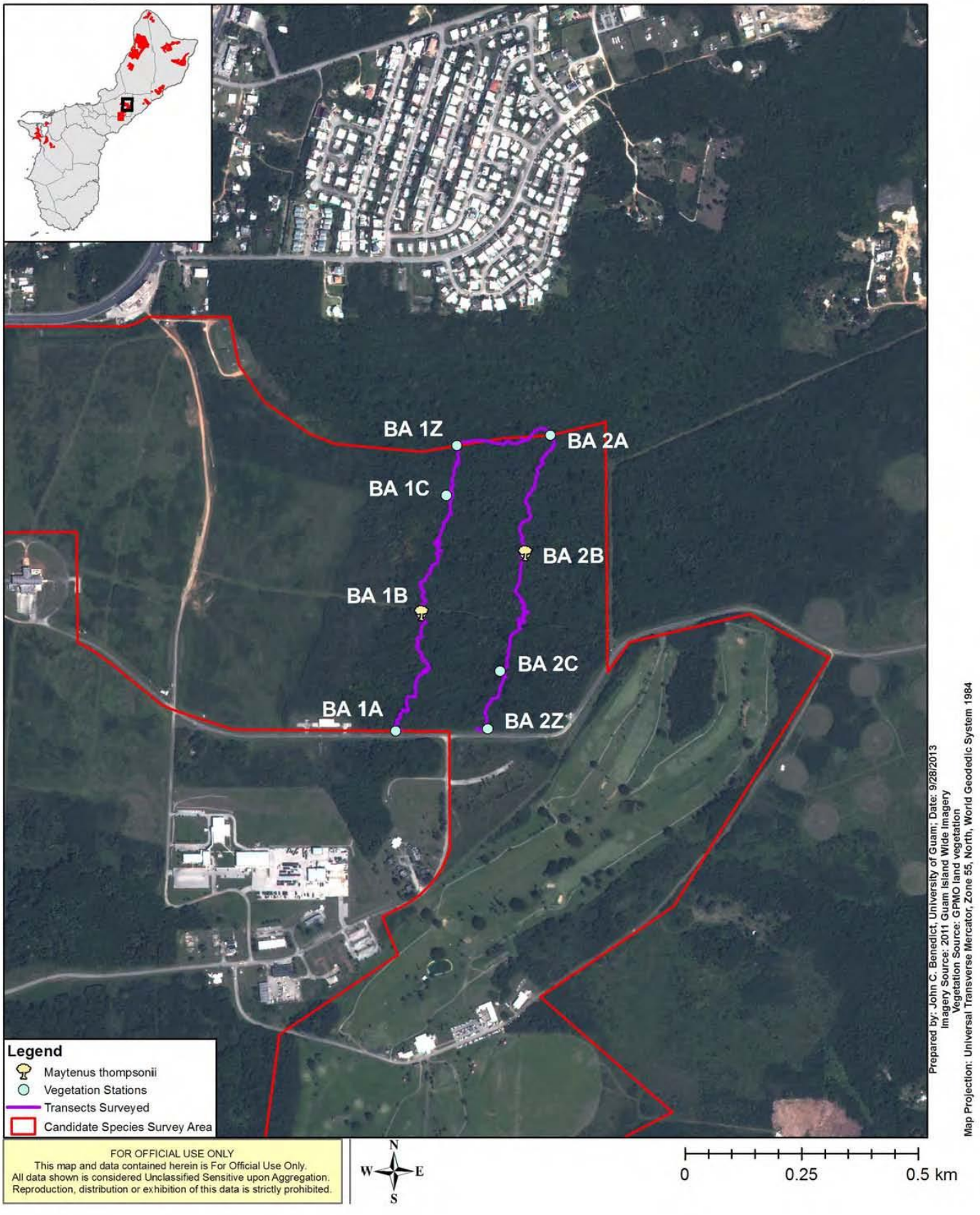


Figure 7B. The Transects Surveyed on Barrigada (BA 1 – BA 2)

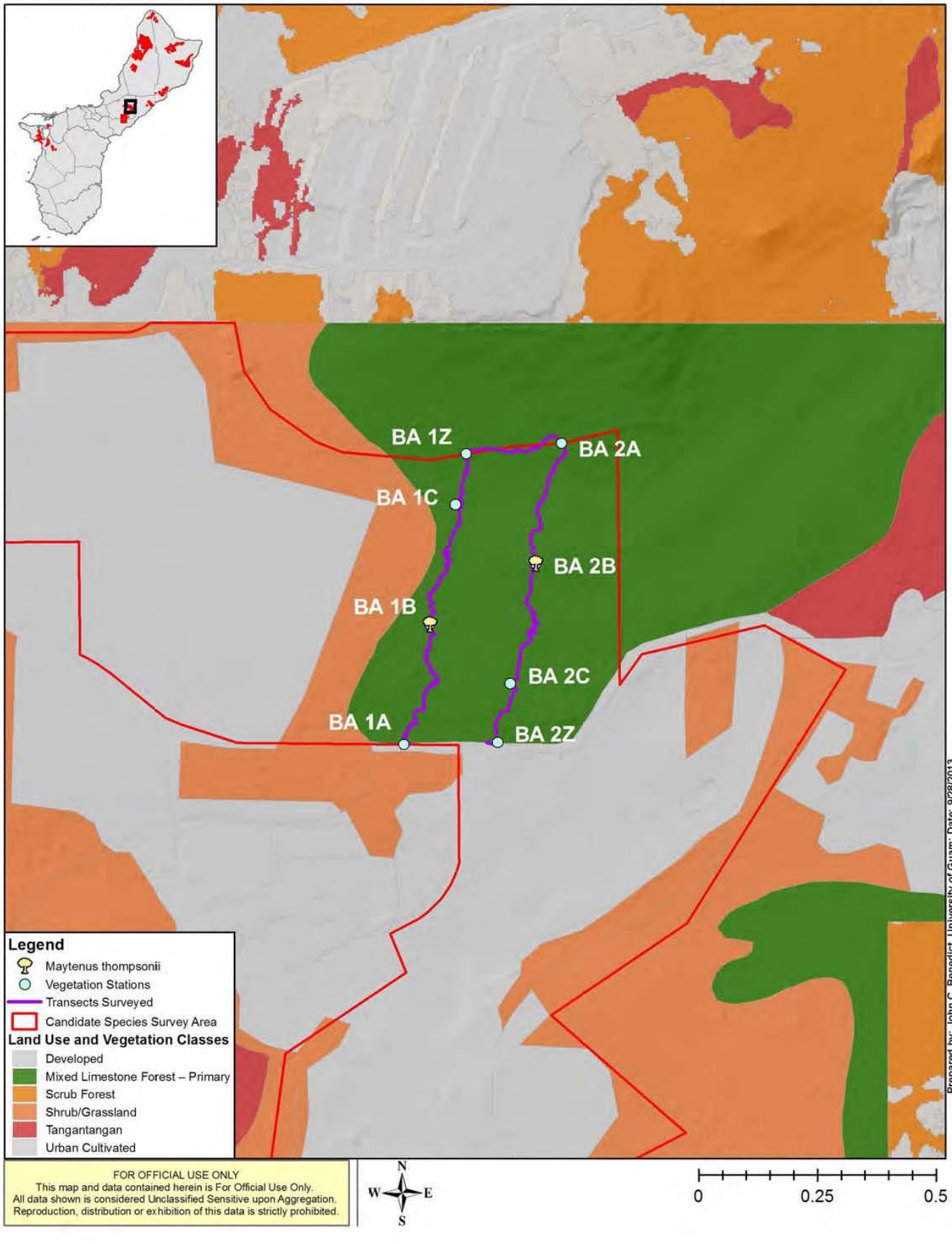


Figure 8A. The Transects Surveyed on Barrigada (BA 3 – BA 4)

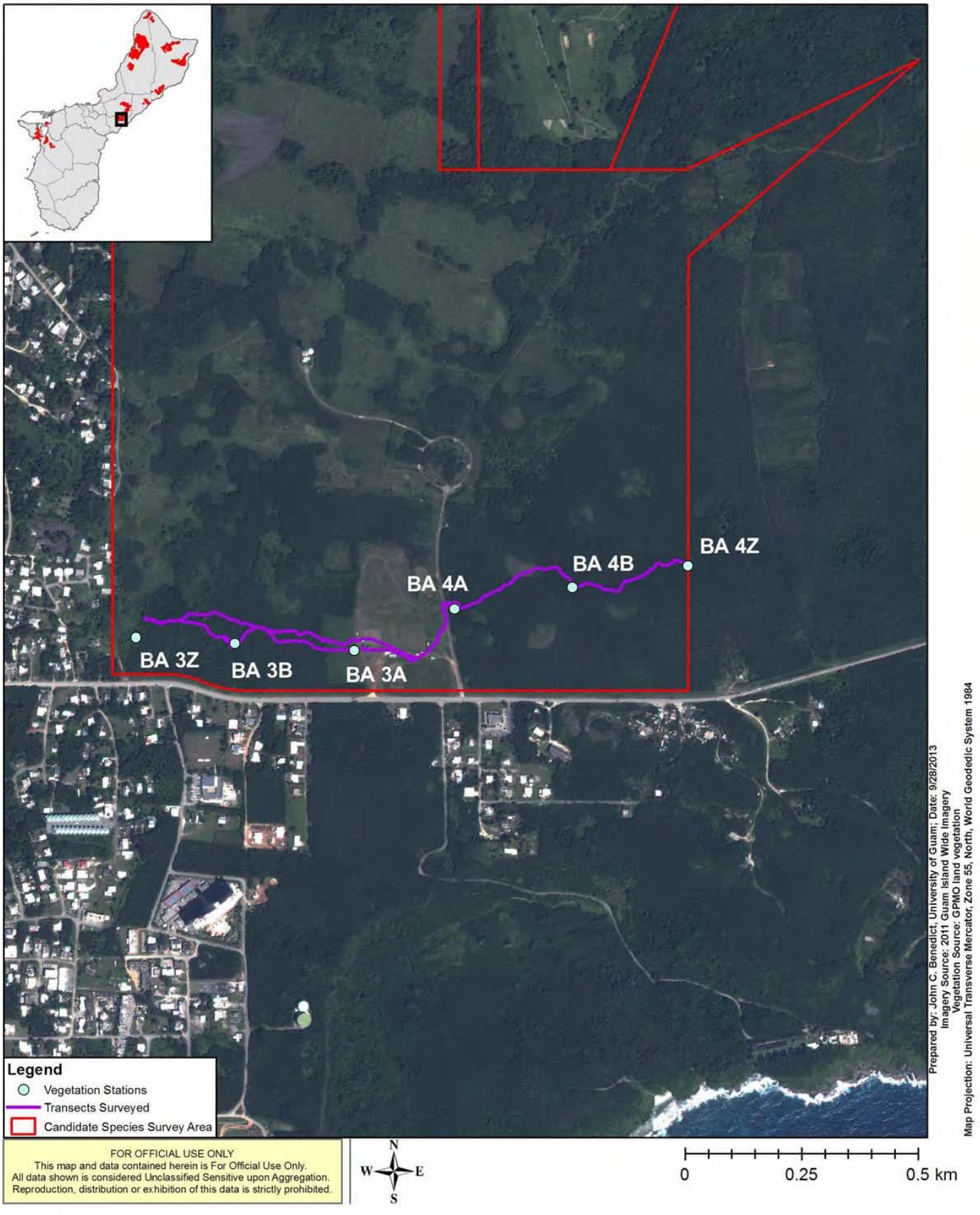


Figure 8B. The Transects Surveyed on Barrigada (BA 3 – BA 4)

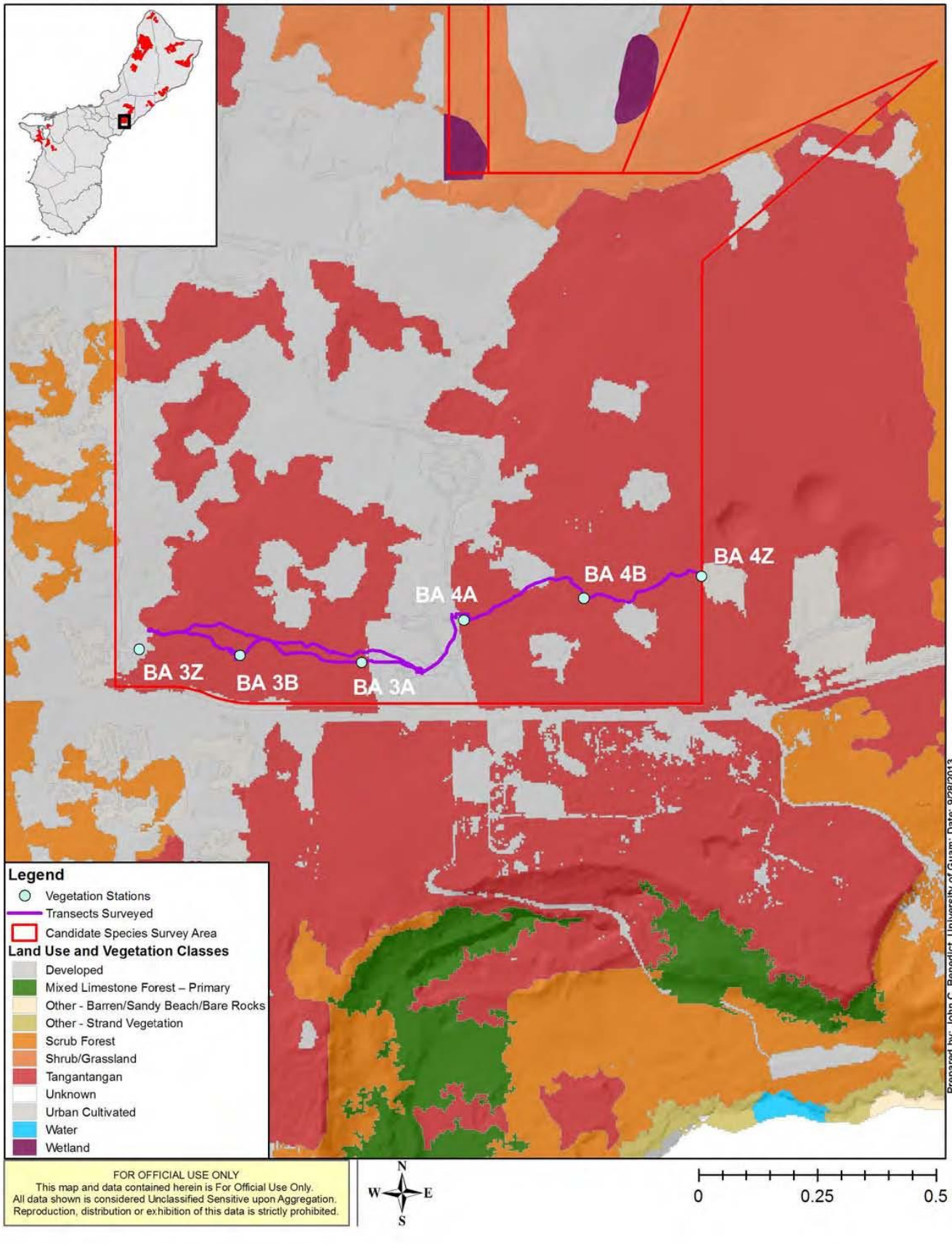


Figure 9A. The Transects Surveyed on Finegayan (FG 1)

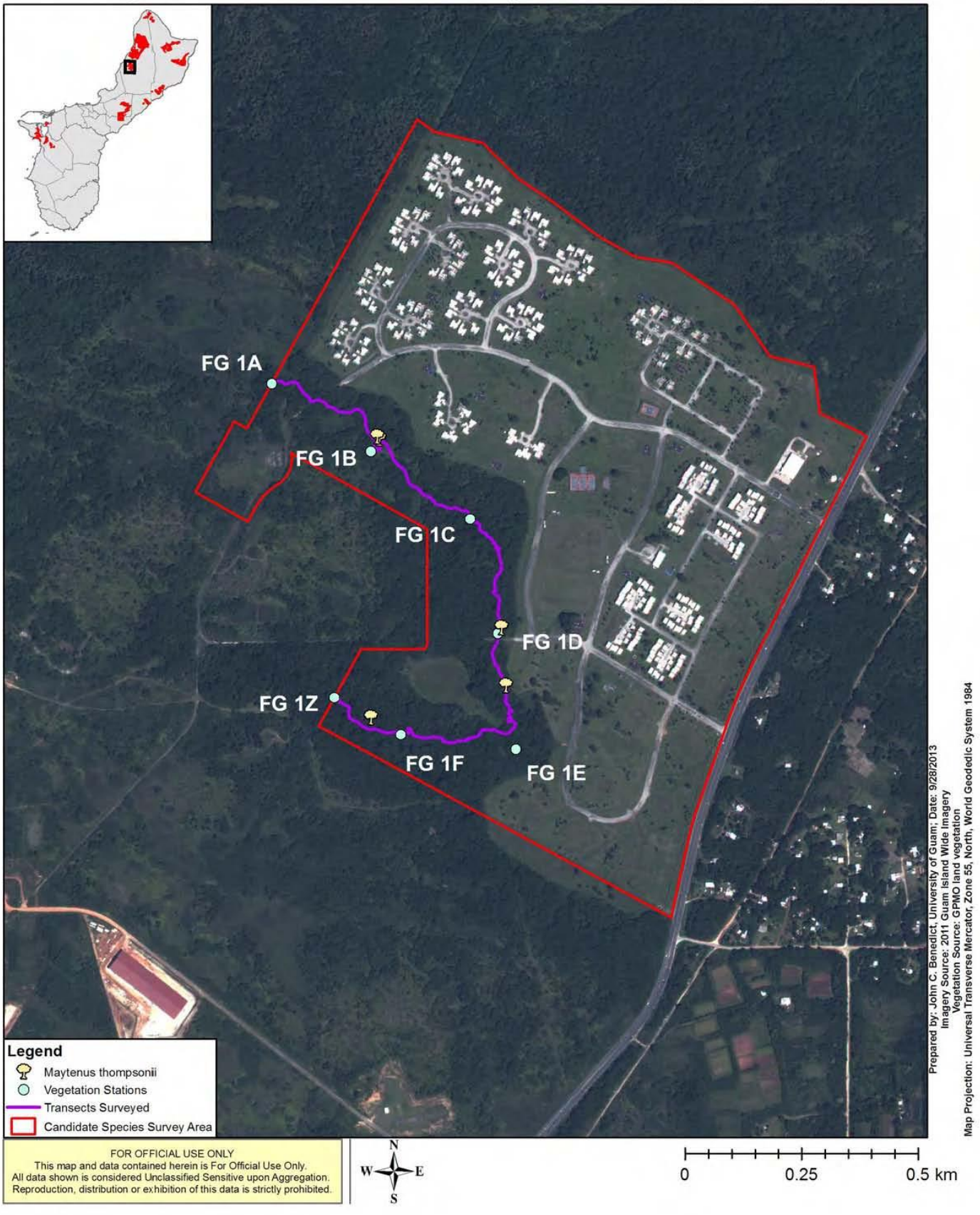


Figure 9B. The Transects Surveyed on Finegayan (FG 1)

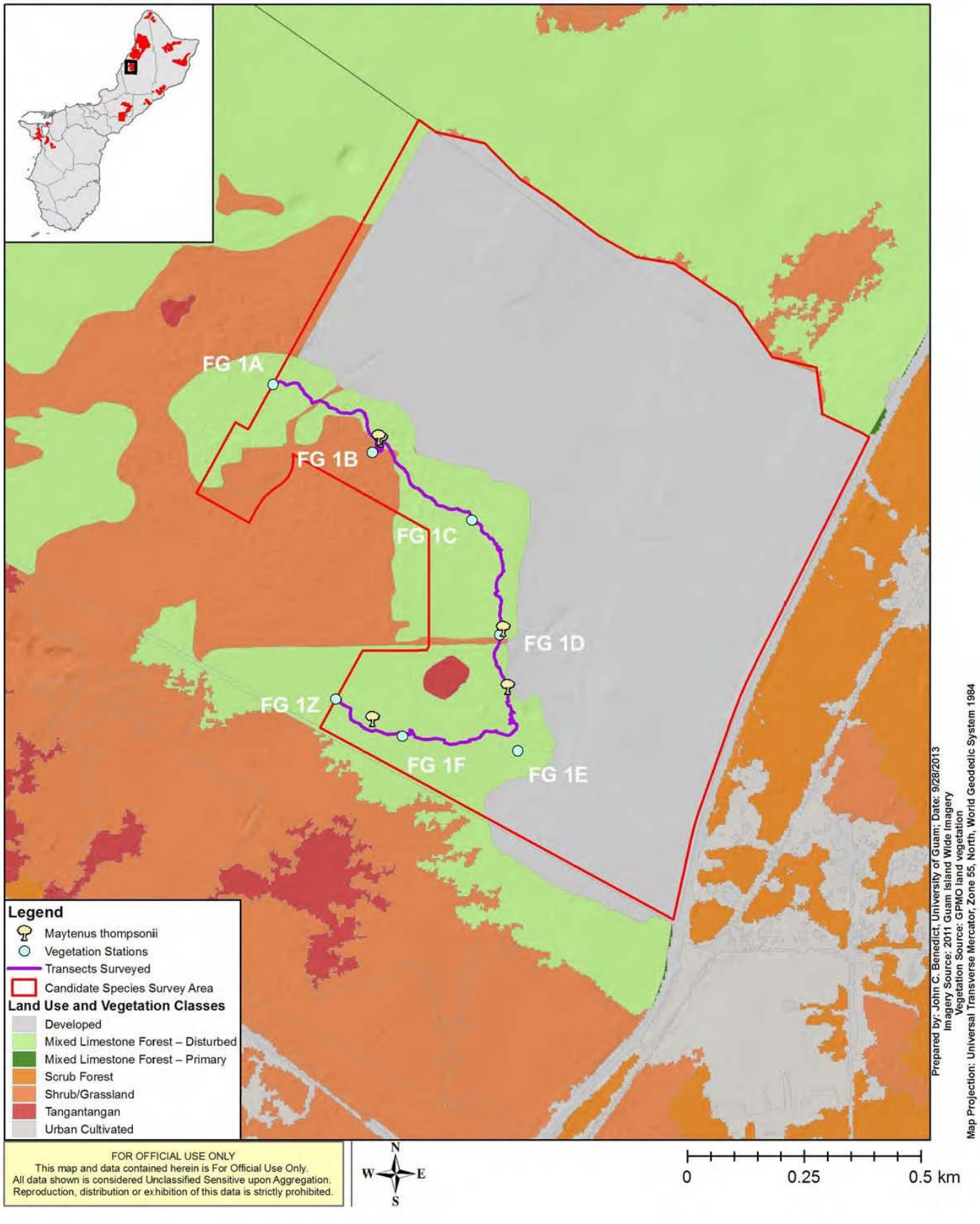


Figure 10A. The Transects Surveyed on Finegayan (FG 2 - FG 5)

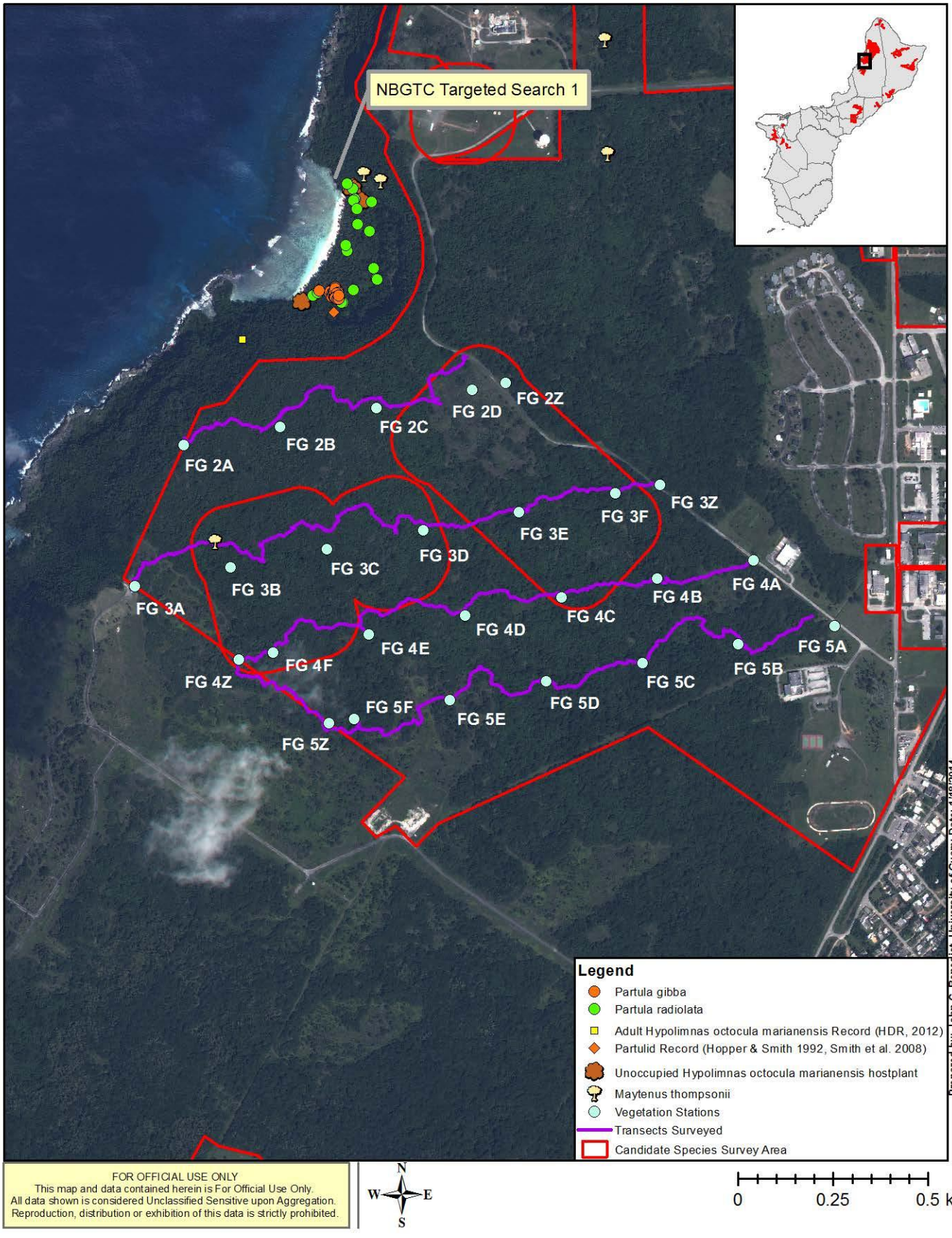


Figure 10B. The Transects Surveyed on Finegayan (FG 2 - FG 5)

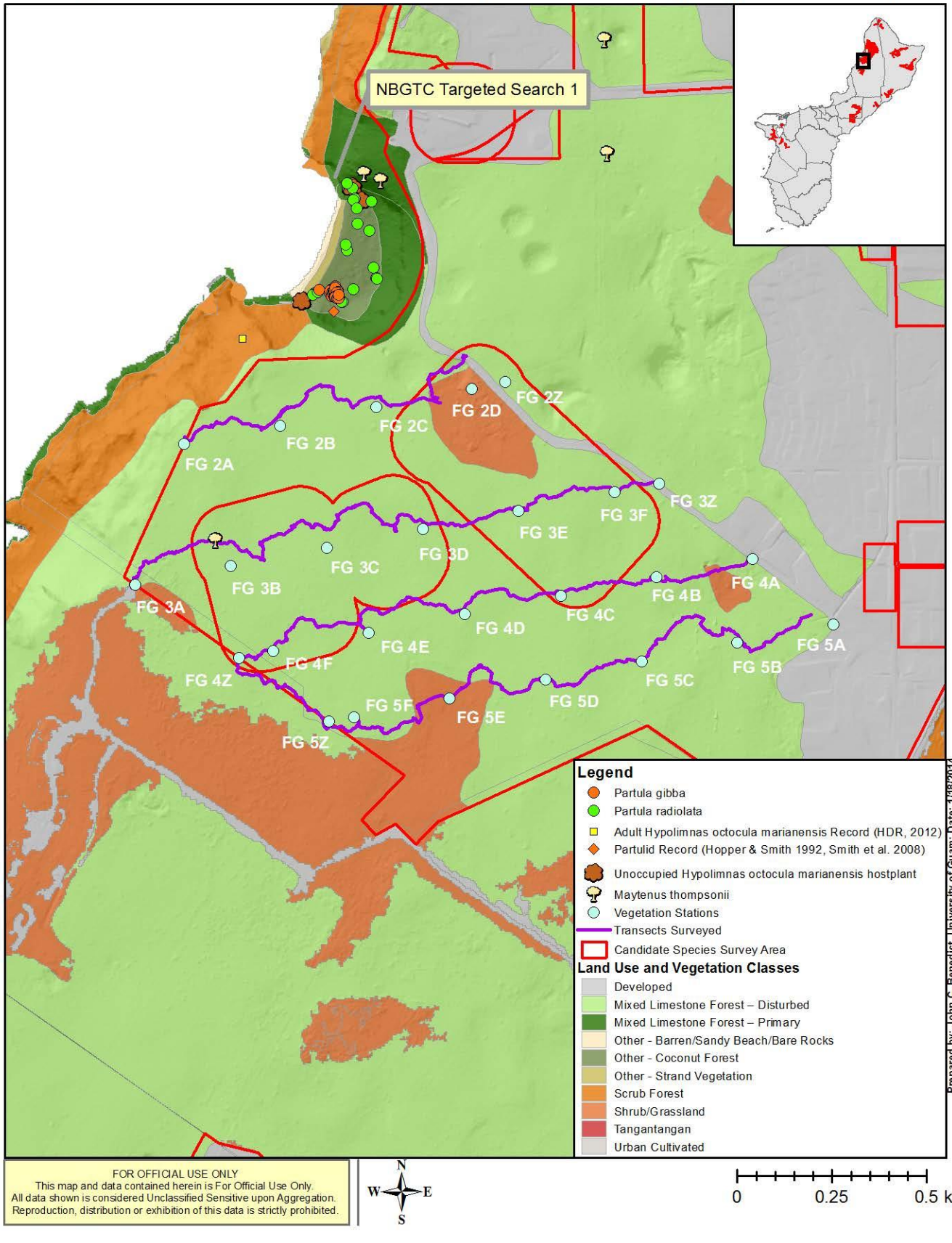


Figure 11A. The Transects Surveyed on Finegayan (FG 6 - FG 9)

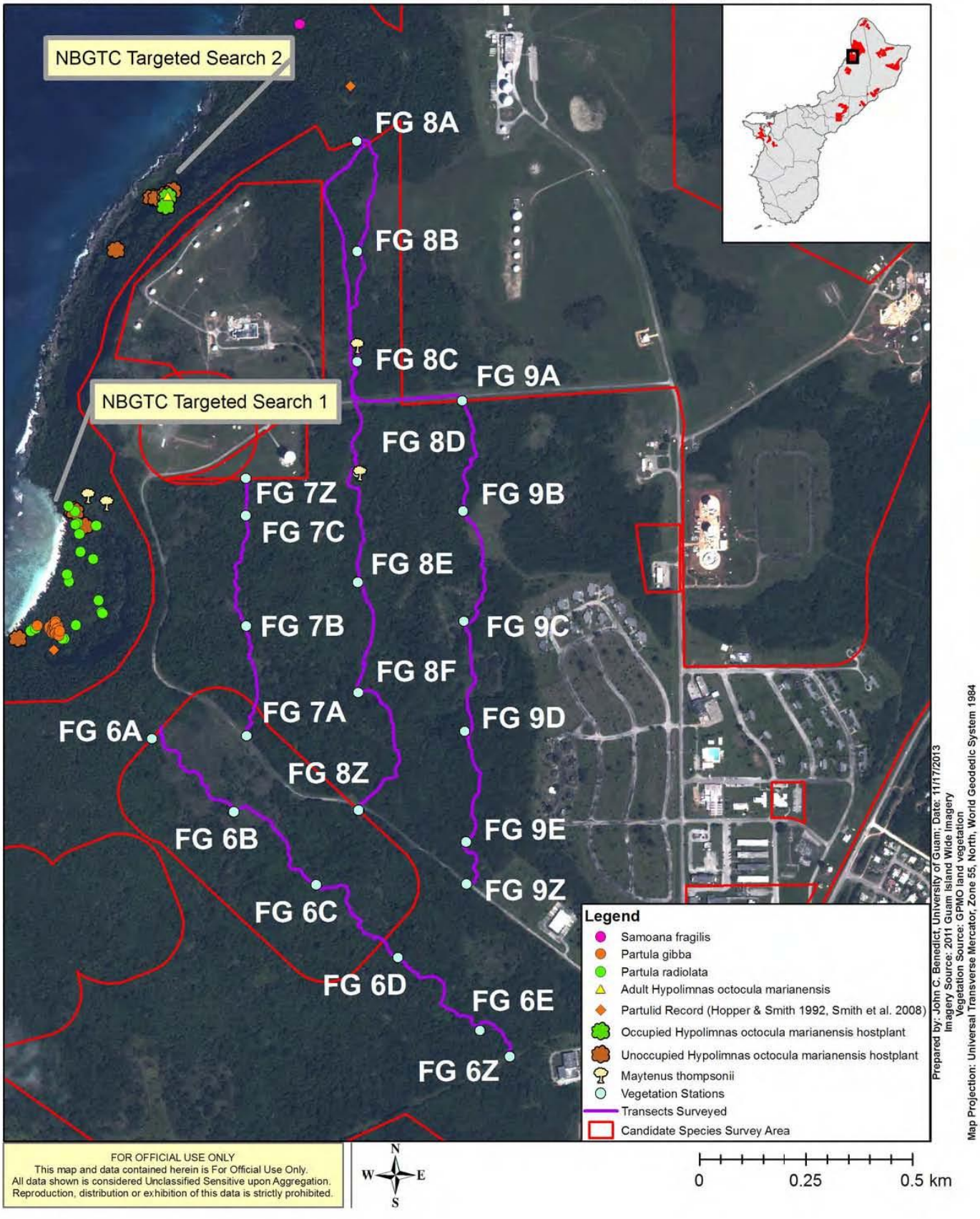


Figure 11B. The Transects Surveyed on Finegayan (FG 6 - FG 9)

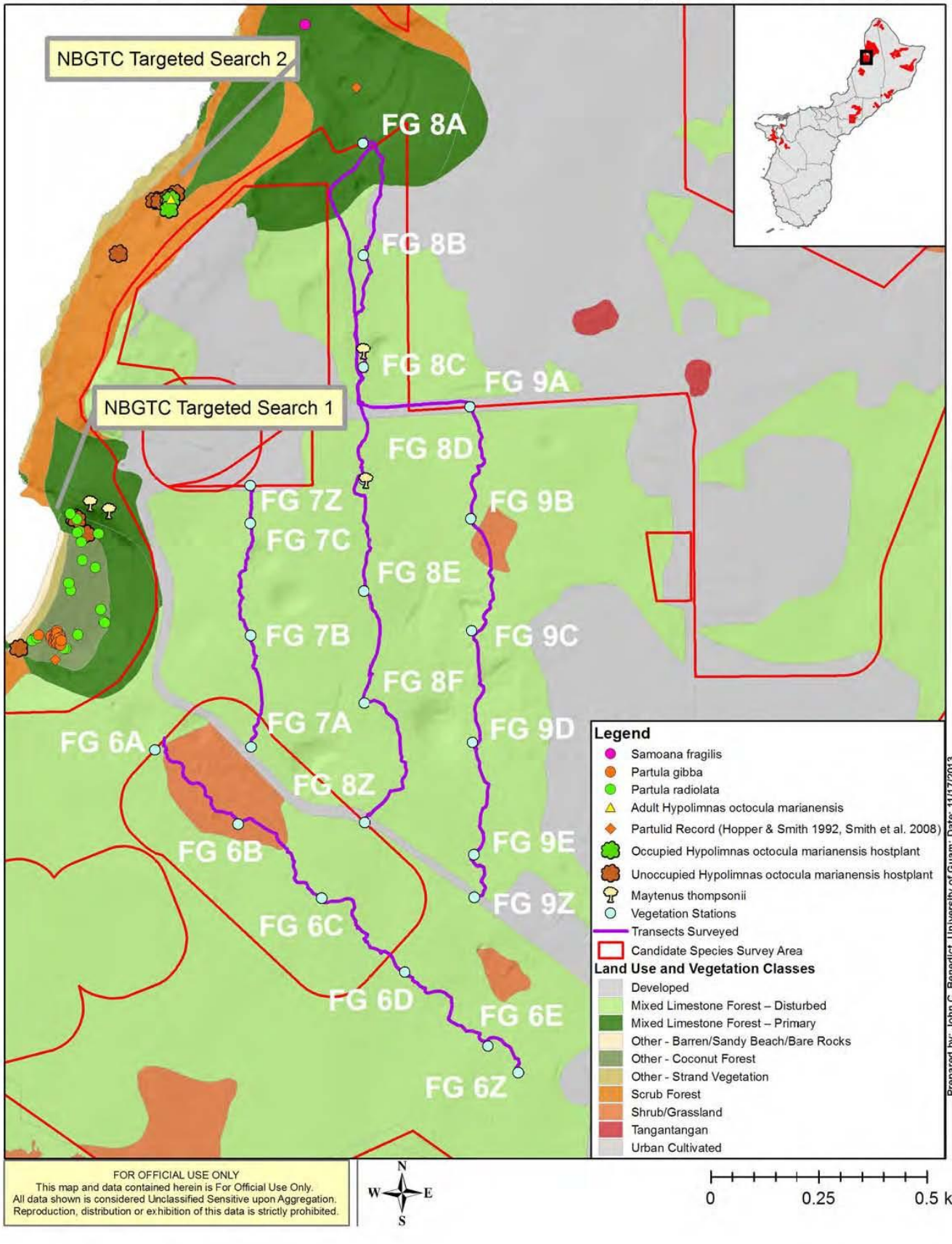


Figure 12A. The Transects Surveyed on Finegayan (FG 10 - FG 15)

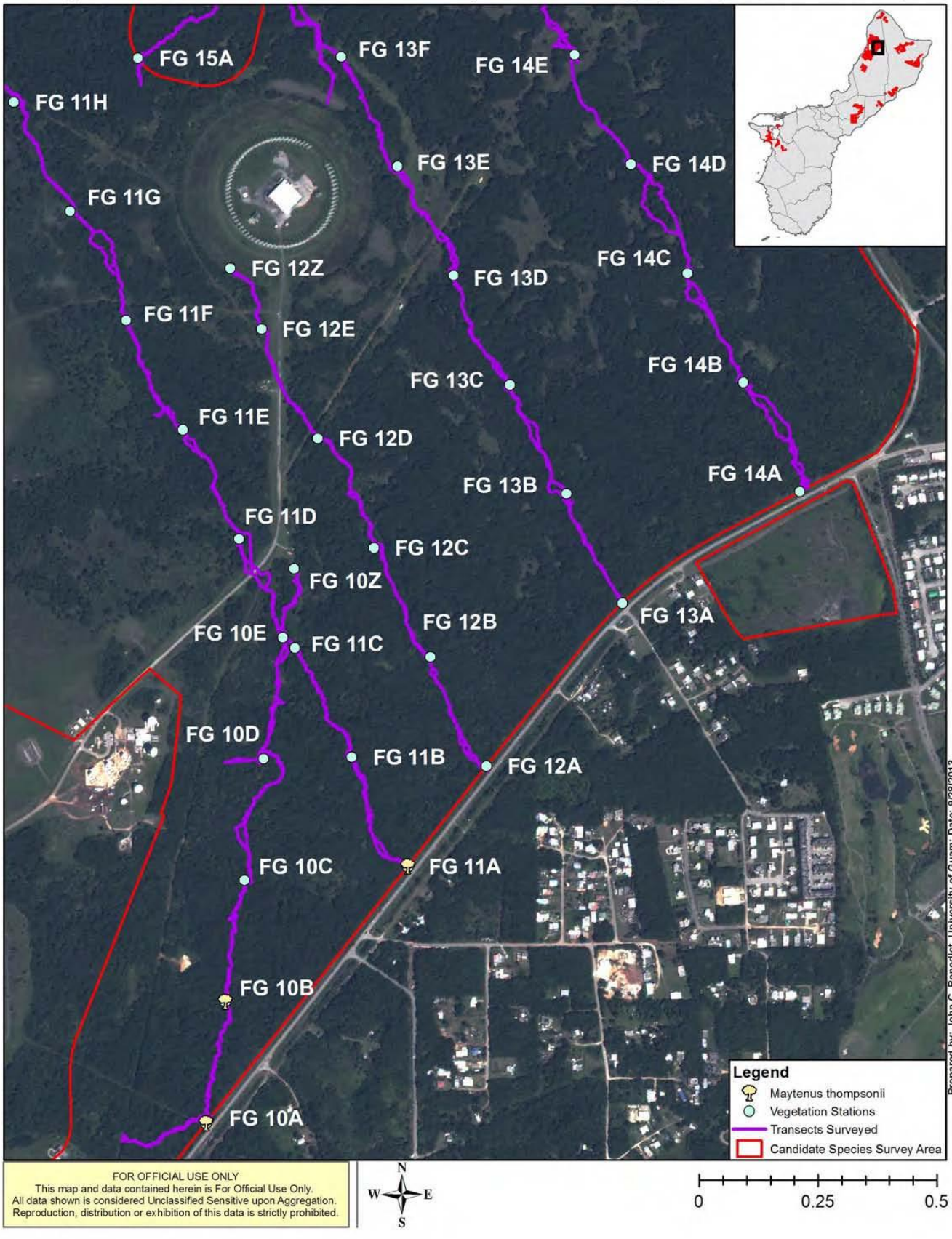


Figure 12B. The Transects Surveyed on Finegayan (FG 10 - FG 15)

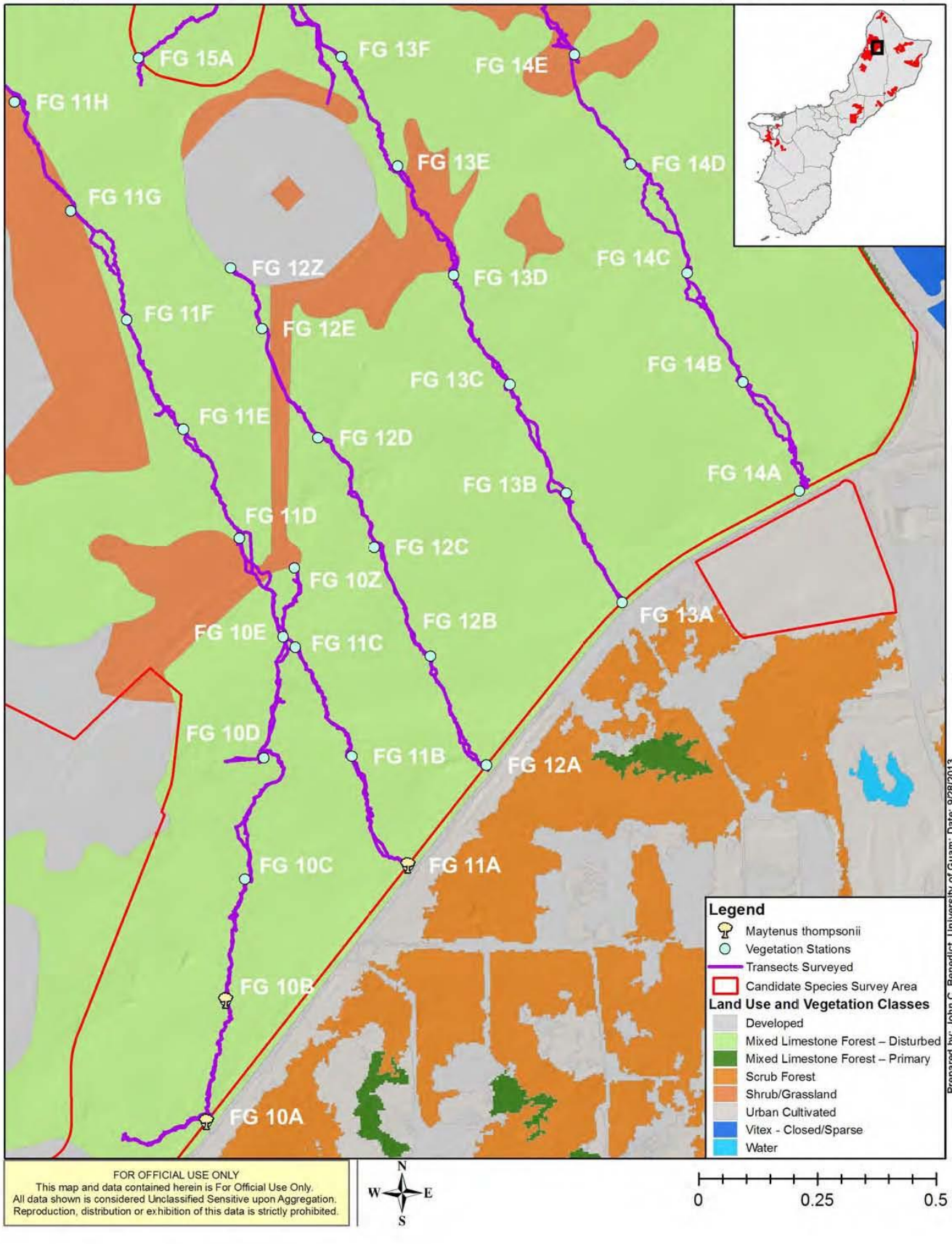


Figure 13A. The Transects Surveyed on Finegayan (FG 11 - FG 17)

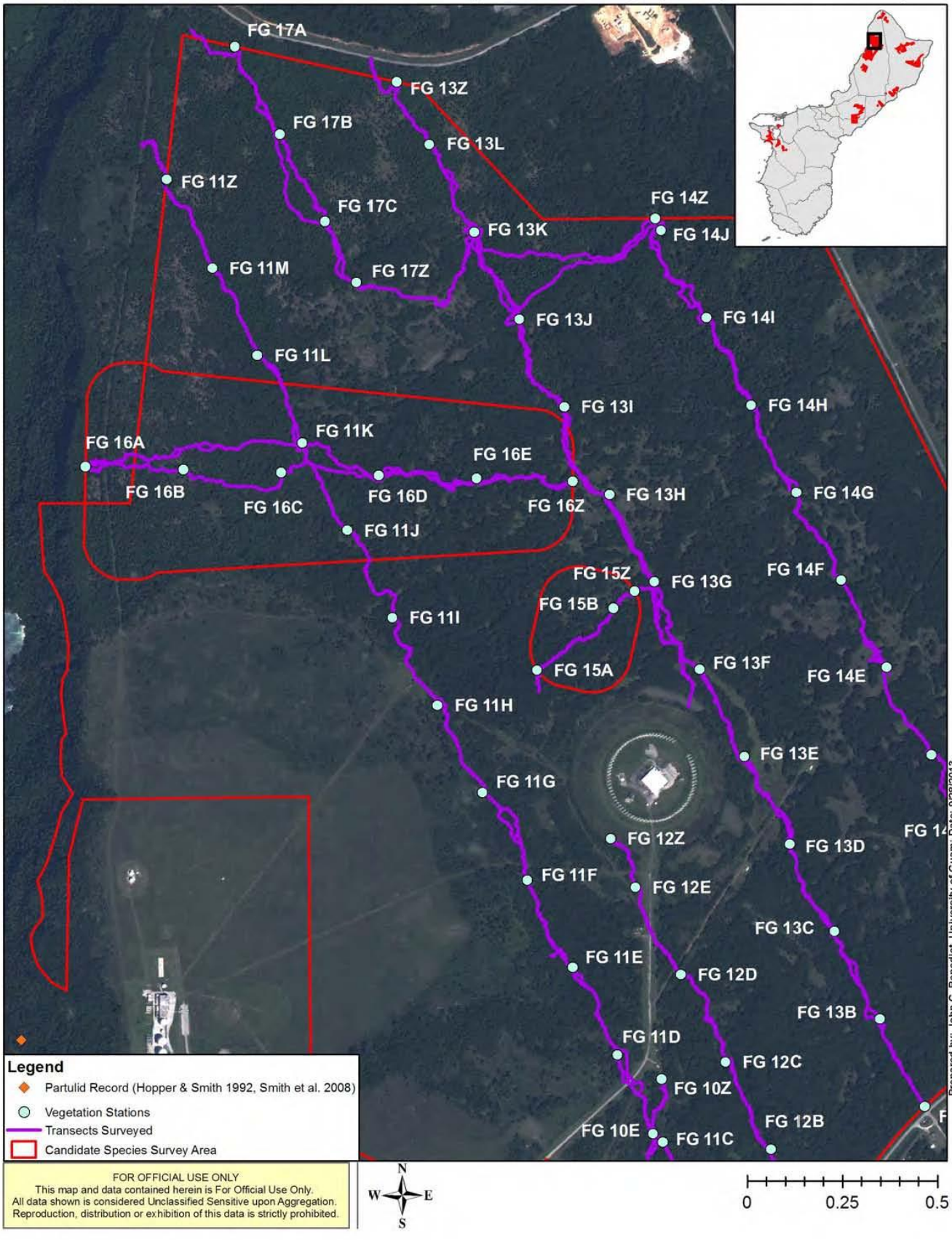


Figure 13B. The Transects Surveyed on Finegayan (FG 11 - FG 17)

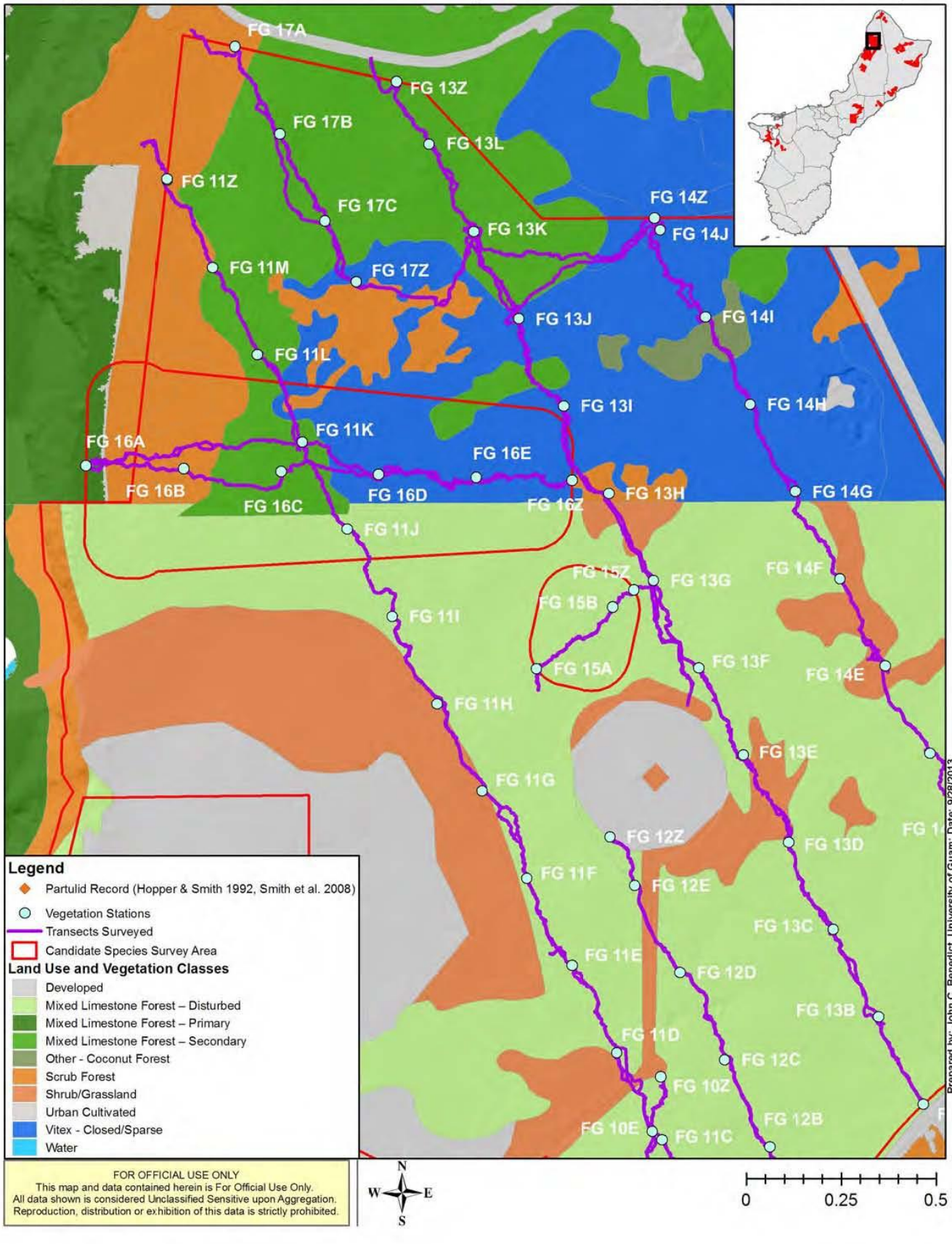


Figure 14A. The Transects Surveyed on Northwest Field (NW 1 - NW 5)

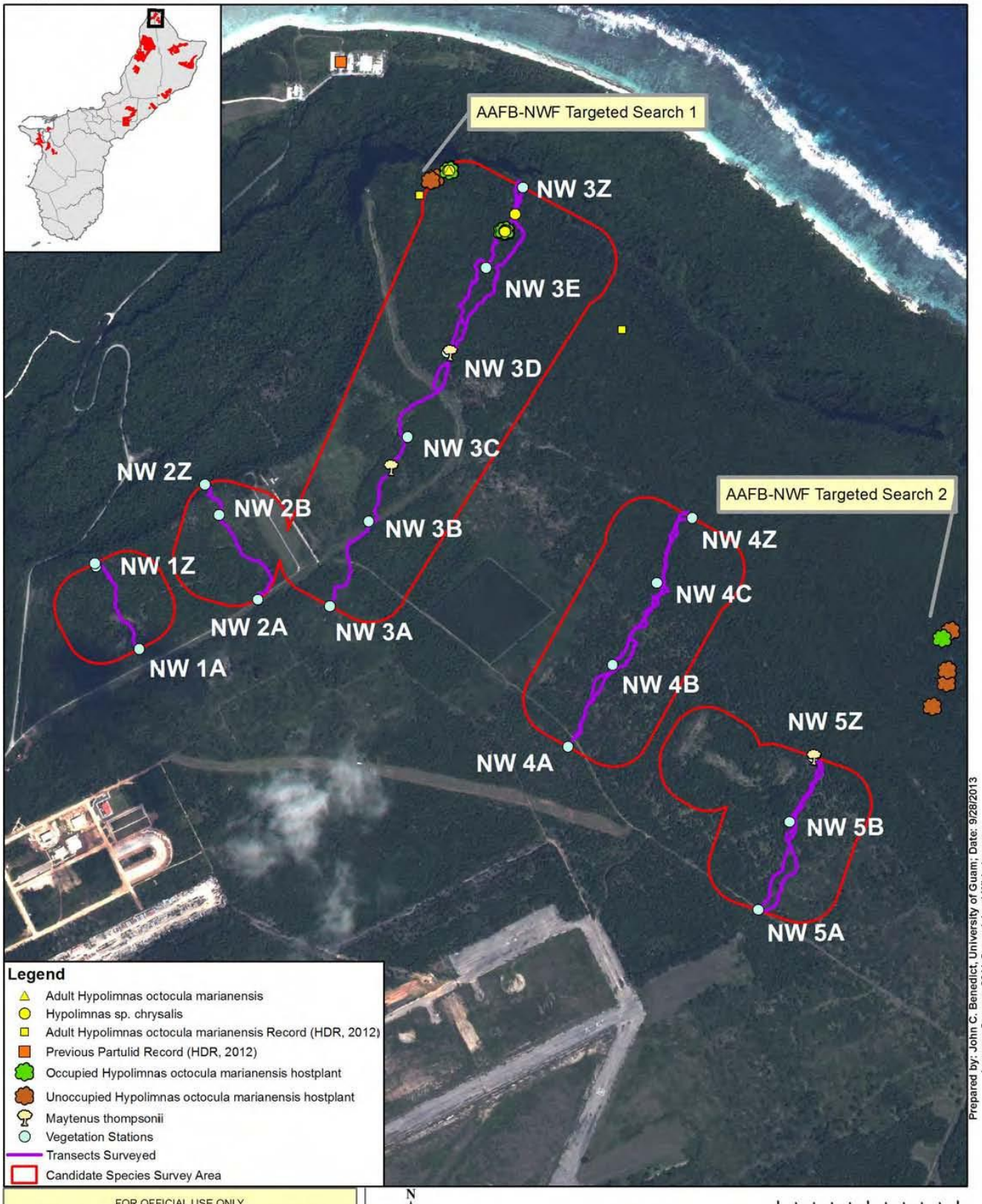


Figure 14B. The Transects Surveyed on Northwest Field (NW 1 - NW 5)

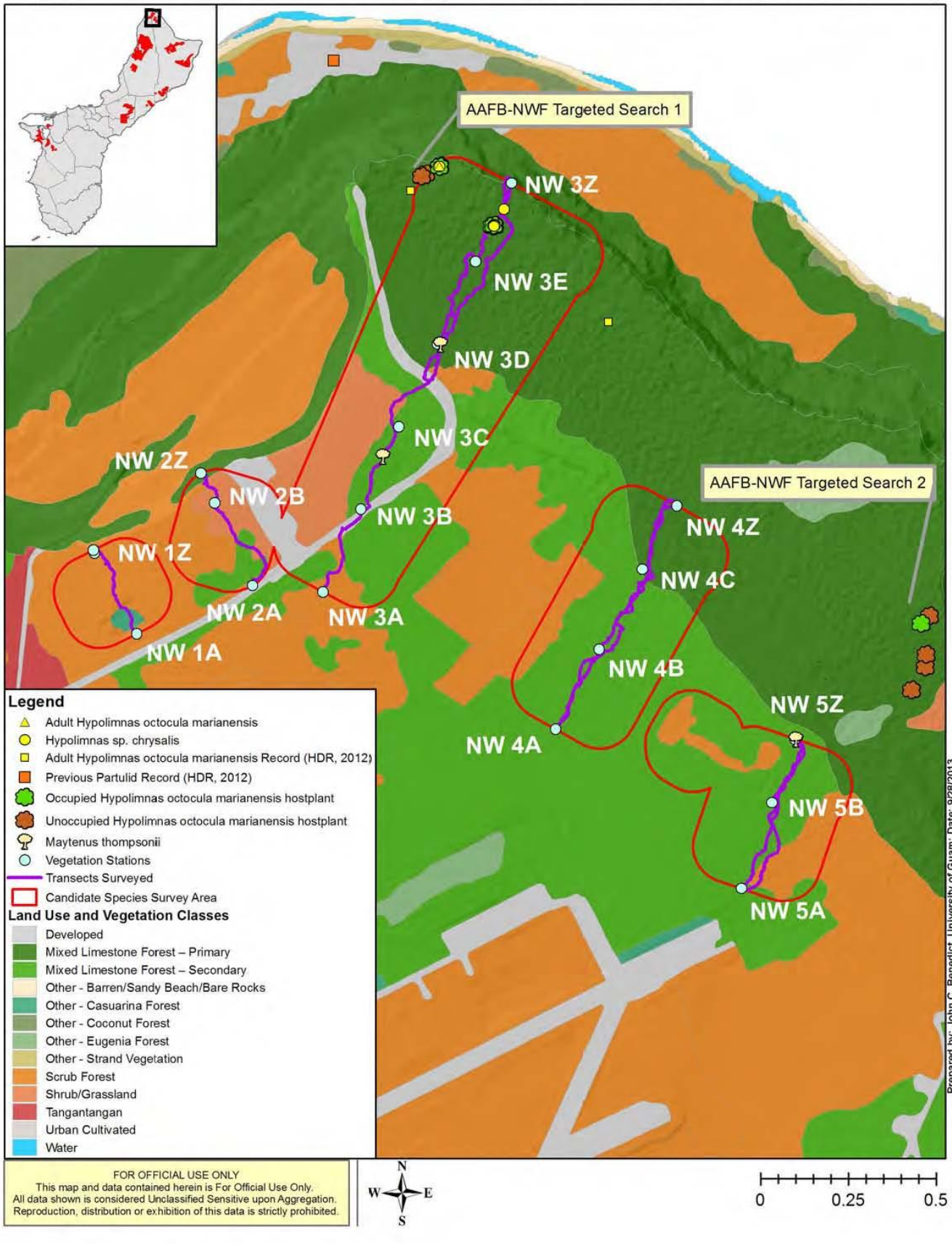


Figure 15A. The Transects Surveyed on Route 15 (RT 1 – RT 3 & RT 5)

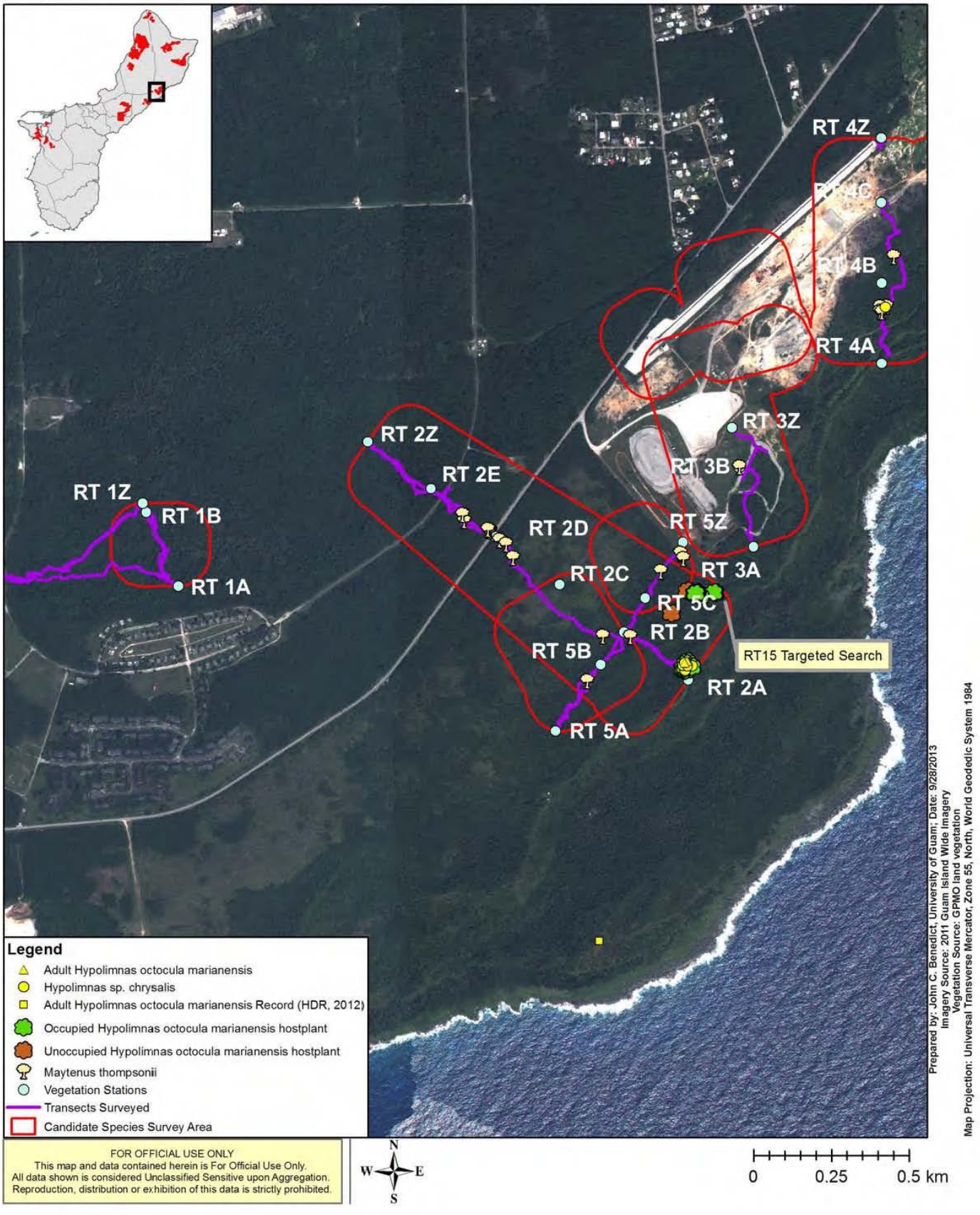


Figure 15B. The Transects Surveyed on Route 15 (RT 1 – RT 3 & RT 5)

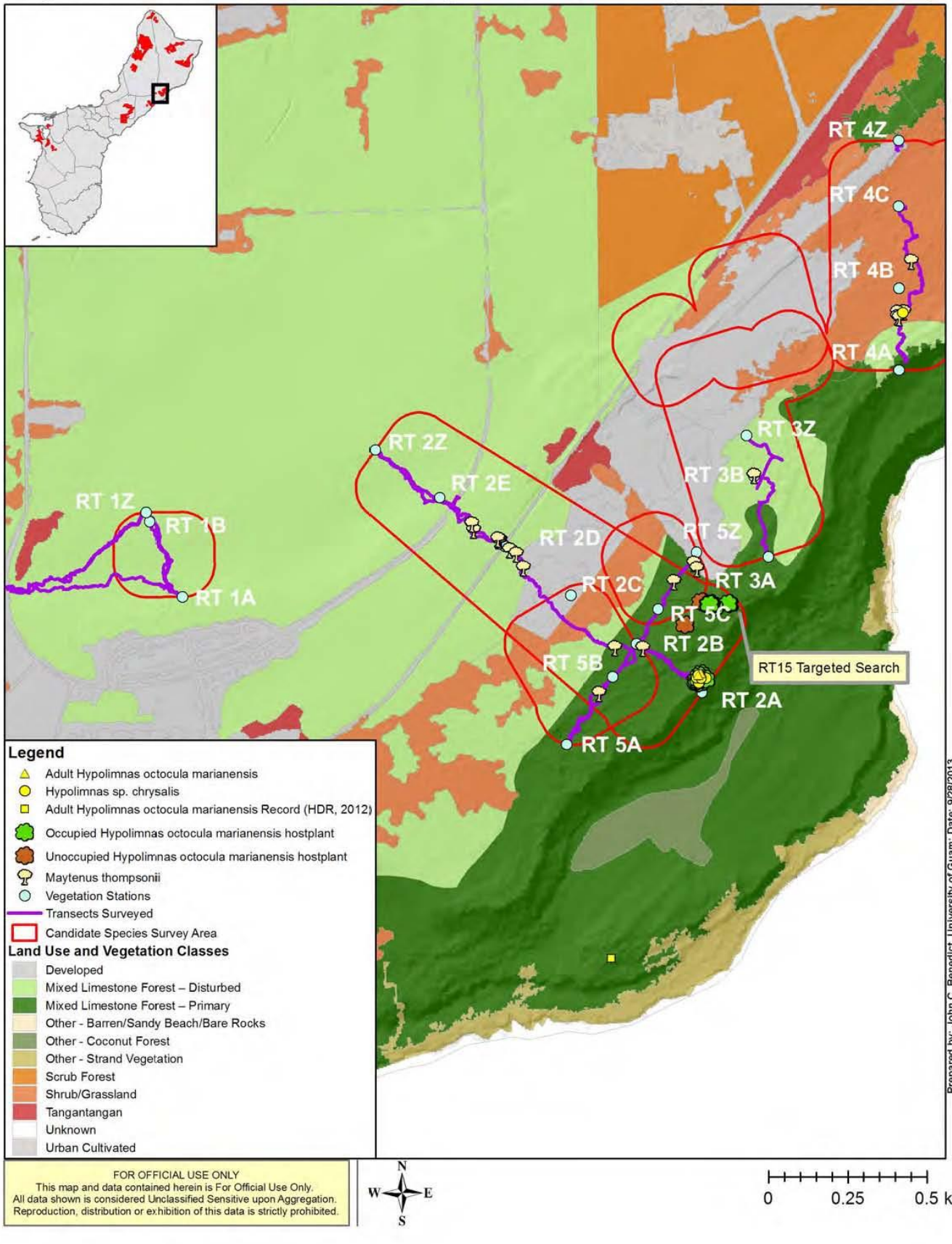


Figure 16A. The Transects Surveyed on Route 15 (RT 4)

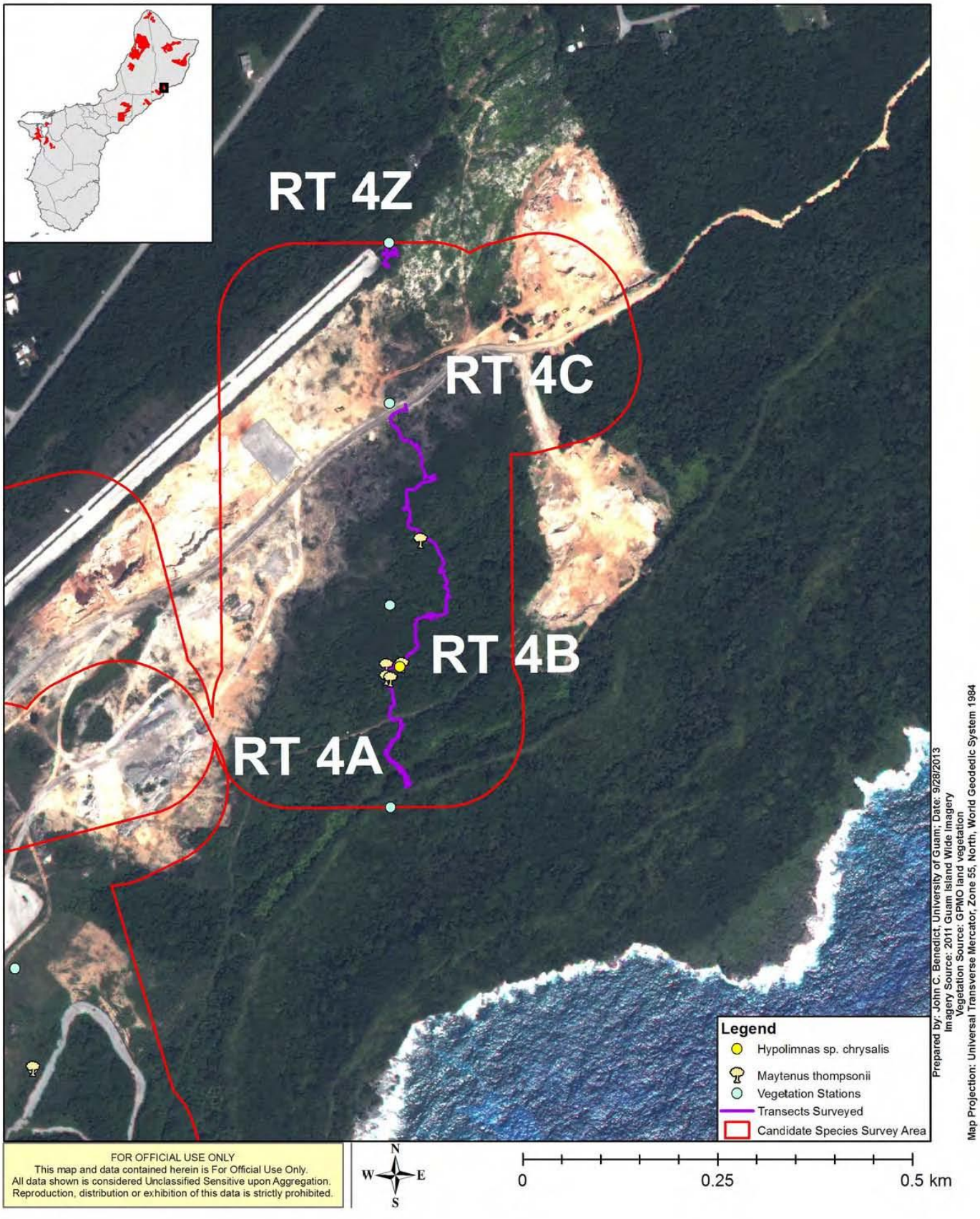
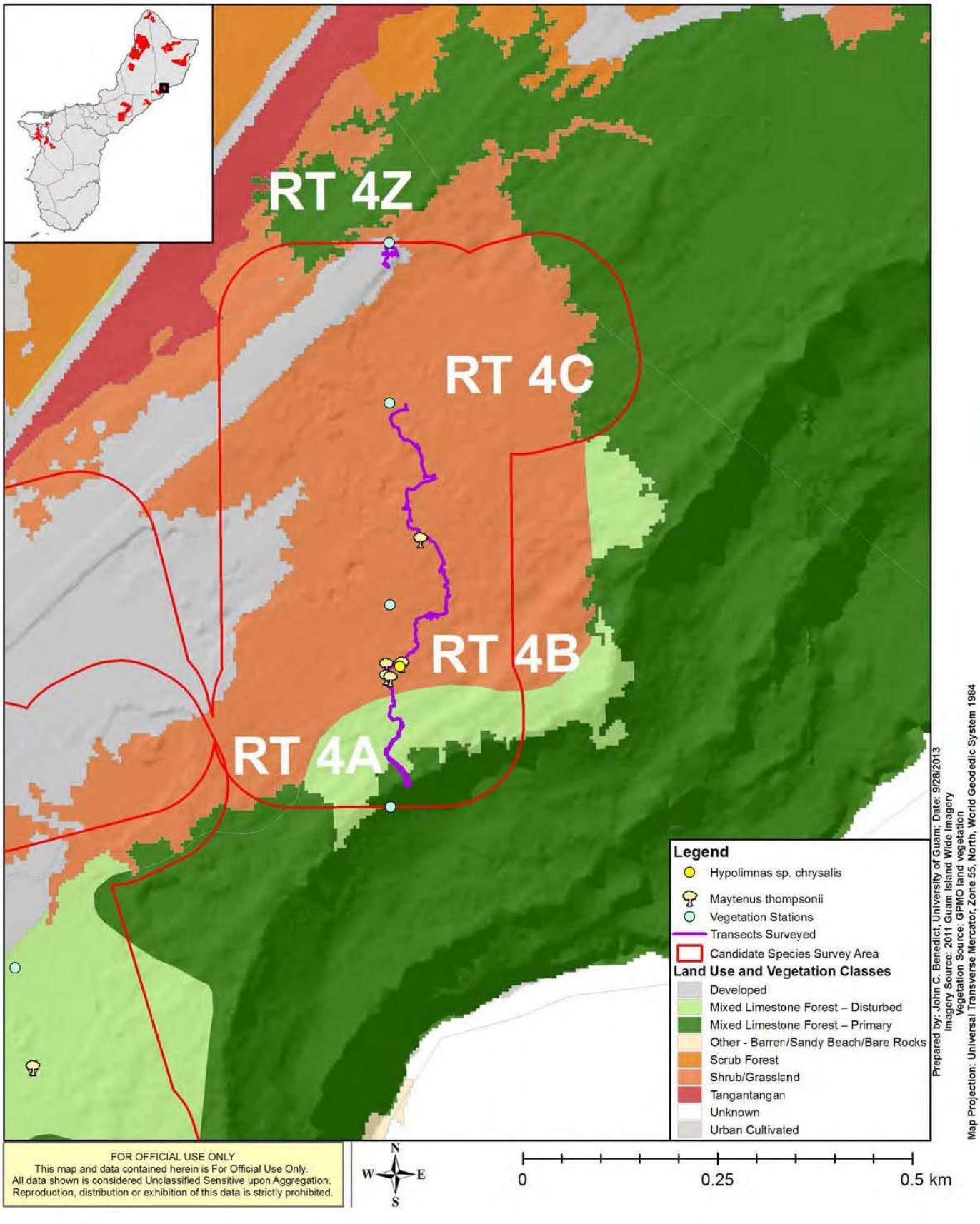


Figure 16B. The Transects Surveyed on Route 15 (RT 4)



[This page intentionally left blank.]

APPENDIX D

Transect Flora Vegetation Station List

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
AAFB	AA1A	4/15/2013	13.59028881730	144.90756826100	Scrub Forest	*Cestrum diurnum, Guamia mariannae, Hibiscus tiliaceus, Triphasia trifolia, Wikstroemia indica.*
AAFB	AA1B	4/15/2013	13.59243524550	144.90828865100	Mixed Limestone Forest - Secondary	*Cycas micronesica, Guamia mariannae, Hibiscus tiliaceus, Pandanus tectorius.*
AAFB	AA1C	4/15/2013	13.59458167320	144.90900905200	Mixed Limestone Forest - Primary	*Aglaia mariannensis, Cycas micronesica, Ficus* sp., *Guamia mariannae.*
AAFB	AA1Z	4/15/2013	13.59554015240	144.90935545000	Mixed Limestone Forest - Primary	*Aglaia mariannensis, Cycas micronesica, Ficus* sp., *Guamia mariannae.*
AAFB	AA2A	4/15/2013	13.59269635160	144.91238695500	Mixed Limestone Forest - Primary	*Aglaia mariannensis, Cestrum diurnum, Cycas micronesica, Elaeocarpus joga, Guamia mariannae, Pandanus tectorius.*
AAFB	AA2B	4/15/2013	13.59484277280	144.91310739400	Mixed Limestone Forest - Primary	*Aglaia mariannensis, Cycas micronesica, Ficus* sp., *Guamia mariannae.*
AAFB	AA2Z	4/15/2013	13.59593321310	144.91345858000	Mixed Limestone Forest - Primary	*Aglaia mariannensis, Cycas micronesica, Ficus* sp., *Guamia mariannae*, ***Procris pendunculata***.
AAFB	AA3A	4/12/2013	13.59351602970	144.91604633200	Mixed Limestone Forest - Secondary	*Aglaia mariannensis, Cestrum diurnum, Guamia mariannae.*
AAFB	AA3Z	4/12/2013	13.59567393200	144.91676078200	Mixed Limestone Forest - Primary	*Cycas micronesica, Guamia mariannae, Ochrosia oppositifolia.*
AAFB	AA4A	4/12/2013	13.59354667410	144.91971262900	Mixed Limestone Forest - Secondary	*Aglaia mariannensis, Cestrum diurnum, Guamia mariannae, Premna obtusifolia, Wikstroemia indica.*
AAFB	AA4B	4/12/2013	13.59569308380	144.92043313900	Mixed Limestone Forest - Primary	*Aglaia mariannensis, Guamia mariannae, Premna obtusifolia.*
AAFB	AA4Z	4/12/2013	13.59671118070	144.92071165900	Mixed Limestone Forest - Primary	*Aglaia mariannensis, Cycas micronesica, Ficus* sp., *Guamia mariannae, Intsia bijuga.*
AAFB	AA5A	4/16/2013	13.59080544340	144.90499250000	Mixed Limestone Forest - Secondary	*Aglaia mariannensis, Guamia mariannae, Hibiscus tiliaceus, Premna obtusifolia.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
AAFB	AA5B	4/16/2013	13.58998094260	144.90284229700	Vitex - Closed/Sparse	*Hibiscus tiliaceus, Pandanus tectorius, Vitex parviflora, Wikstroemia indica.*
AAFB	AA5C	4/16/2013	13.58915642530	144.90069211100	Vitex - Closed/Sparse	*Aglaia mariannensis, Cocos nucifera, Hibiscus tiliaceus, Premna obtusifolia, Vitex parviflora, Wikstroemia indica.*
AAFB	AA5Z	4/16/2013	13.58889676650	144.89980289800	Mixed Limestone Forest - Secondary	*Guamia mariannae, Hibiscus tiliaceus, Morinda citrifolia, Pandanus tectorius, Vitex parviflora.*
AAFB	AA6A	4/16/2013	13.58783476060	144.90575657100	Mixed Limestone Forest - Secondary	*Aglaia mariannensis, Guamia mariannae, Hibiscus tiliaceus, Premna obtusifolia.*
AAFB	AA6B	4/16/2013	13.58701026970	144.90360638900	Mixed Limestone Forest - Secondary	*Guamia mariannae, Hibiscus tiliaceus, Pandanus tectorius, Premna obtusifolia, Wikstroemia indica.*
AAFB	AA6Z	4/16/2013	13.58621980040	144.90137104700	Mixed Limestone Forest - Secondary	*Guamia mariannae, Hibiscus tiliaceus, Leucaena leucocephala, Pandanus tectorius, Vitex parviflora.*
AAFB	AA7A	4/15/2013	13.58124050810	144.89782184600	Scrub Forest	*Guamia mariannae, Hibiscus tiliaceus, Pandanus tectorius, Vitex parviflora.*
AAFB	AA7B	4/15/2013	13.58206503880	144.89997195000	Vitex - Closed/Sparse	*Guamia mariannae, Pandanus tectorius, Triphasia trifolia, Vitex parviflora, Wikstroemia indica.*
AAFB	AA7C	4/15/2013	13.58288955310	144.90212207200	Mixed Limestone Forest - Secondary	*Aglaia mariannensis, Cestrum diurnum, Guamia mariannae, Hibiscus tiliaceus, Ochrosia oppositifolia.*
AAFB	AA7D	4/15/2013	13.58371405090	144.90427221200	Mixed Limestone Forest - Secondary	*Caesalpinia major, Cestrum diurnum, Guamia mariannae, Hibiscus tiliaceus, Pandanus tectorius.*
AAFB	AA7E	4/15/2013	13.58453853230	144.90642236800	Mixed Limestone Forest - Secondary	*Aglaia mariannensis, Cestrum diurnum, Guamia mariannae, Hibiscus tiliaceus,* ***Maytenus thompsonii****.*
AAFB	AA7Z	4/15/2013	13.58490141950	144.90666226800	Mixed Limestone Forest - Secondary	*Aglaia mariannensis, Cestrum diurnum, Guamia mariannae, Hibiscus tiliaceus, Pandanus tectorius, Wikstroemia indica.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
AAFB	AA8A	4/17/2013	13.58985490810	144.89862586600	Vitex - Closed/Sparse	*Cestrum diurnum, Pandanus tectorius, Vitex parviflora,* ***Maytenus thompsonii****.*
AAFB	AA8Z	4/17/2013	13.59041076360	144.89649441200	Mixed Limestone Forest - Secondary	*Cycas micronesica, Guamia mariannae, Hibiscus tiliaceus.*
AAFB	AA9A	4/16/2013	13.58550380570	144.89727097800	Vitex - Closed/Sparse	*Guamia mariannae, Pandanus tectorius, Vitex parviflora.*
AAFB	AA9B	4/16/2013	13.58623024230	144.89508417900	Mixed Limestone Forest - Secondary	*Aglaia mariannensis, Guamia mariannae,* ***Maytenus thompsonii****, Pandanus tectorius, Vitex parviflora.*
AAFB	AA9C	4/16/2013	13.58695665760	144.89289736900	Vitex - Closed/Sparse	*Aglaia mariannensis, Guamia mariannae, Hibiscus tiliaceus, Pandanus tectorius, Vitex parviflora.*
AAFB	AA9Z	4/16/2013	13.58718435460	144.89221189200	Vitex - Closed/Sparse	*Hibiscus tiliaceus, Pandanus tectorius, Vitex parviflora, Wikstroemia indica.*
AAFB	AA10A	4/16/2013	13.58345530770	144.89655006600	Mixed Limestone Forest - Secondary	*Ficus* sp.*, Guamia mariannae, Hibiscus tiliaceus, Ochrosia oppositifolia, Pandanus tectorius.*
AAFB	AA10B	4/16/2013	13.58416331390	144.89435697900	Vitex - Closed/Sparse	*Guamia mariannae, Ochrosia oppositifolia, Pandanus tectorius, Premna obtusifolia, Vitex parviflora.*
AAFB	AA10C	4/16/2013	13.58487129880	144.89216388200	Vitex - Closed/Sparse	*Hibiscus tiliaceus, Pandanus tectorius, Vitex parviflora.*
AAFB	AA10D	4/16/2013	13.58545967390	144.89034123700	Vitex - Closed/Sparse	*Hibiscus tiliaceus, Pandanus tectorius, Vitex parviflora.*
AAFB	AA10E	4/16/2013	13.58559518110	144.88997650300	Vitex - Closed/Sparse	*Elaeocarpus joga, Hibiscus tiliaceus, Pandanus tectorius, Vitex parviflora.*
AAFB	AA10Z	4/16/2013	13.58580502200	144.88940112400	Vitex - Closed/Sparse	*Hibiscus tiliaceus, Pandanus tectorius, Vitex parviflora, Wikstroemia indica.*
AAFB	AA11A	4/17/2013	13.57641701120	144.89573791100	Developed	*Cocos nucifera, Hibiscus tiliaceus, Leucaena leucocephala, Nephrolepis hirsutula, Verbena jamaicensis.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
AAFB	AA11B	4/17/2013	13.57825413400	144.89439389600	Mixed Limestone Forest - Secondary	*Averrhoa bilimbi, Guamia mariannae, Hibiscus tiliaceus, Leucaena leucocephala, Morinda citrifolia, Pandanus dubius, Pandanus tectorius, Triphasia trifolia, Vitex parviflora.*
AAFB	AA11C	4/17/2013	13.58009124620	144.89304985900	Scrub Forest	*Hibiscus tiliaceus, Morinda citrifolia, Pandanus dubius, Pandanus tectorius, Verbena jamaicensis, Vitex parviflora.*
AAFB	AA11Z	4/17/2013	13.58169243190	144.89187840300	Mixed Limestone Forest - Secondary	*Averrhoa bilimbi, Guamia mariannae, Hibiscus tiliaceus, Morinda citrifolia, Ochrosia oppositifolia, Nephrolepis hirsutula, Pandanus dubius, Pandanus tectorius, Triphasia trifolia, Vitex parviflora.*
NBGAH	AH1A	3/28/2013	13.41686649000	144.64867524400	Scrub Forest	*Casuarina equisetifolia, Colubrina asiatica, Leucaena leucocephala, Morinda citrifolia.*
NBGAH	AH1B	3/28/2013	13.41520904200	144.64758914200	Scrub Forest	*Leucaena leucocephala, Morinda citrifolia.*
NBGAH	AH1C	3/28/2013	13.41518738290	144.64947720500	Developed	*Barringtonia asiatica,Bikkia tetrandra, Carica papay, Casuarina equisetifolia, Cocos nucifera, Colubrina asiatica, Cordia subcordata, Hernandia sonara, Leucaena leucocephala, Morinda citrifolia Musa* sp., *Pandanus tectorius, Scaevola taccada, Thespesia populnea.*
NBGAH	AH1D	3/28/2013	13.41498813820	144.65133440300	Developed	*Barringtonia asiatica, Bikkia tetrandra, Carica papaya, Casuarina equisetifolia, Cocos nucifera, Colubrina asiatica, Cordia subcordata, Hernandia sonara, Leucaena leucocephala, Musa* sp., *Pandanus tectorius, Scaevola taccada, Thespesia populnea.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
NBGAH	AH1E	3/28/2013	13.41518713480	144.65345530600	Developed	*Barringtonia asiatica, Bikkia tetrandra, Carica papaya, Casuarina equisetifolia, Cocos nucifera, Colubrina asiatica, Cordia subcordata, Hernandia sonara, Leucaena leucocephala, Musa* sp., *Pandanus tectorius, Scaevola taccada, Thespesia populnea.*
NBGAH	AH1Z	3/28/2013	13.41474180080	144.65519374200	Developed	*Barringtonia asiatica, Carica papaya, Casuarina equisetifolia, Cocos nucifera, Colubrina asiatica, Cordia subcordata, Hernandia sonara, Leucaena leucocephala, Musa* sp., *Pandanus tectorius, Scaevola taccada, Thespesia populnea.*
NBGAH	AH2A	3/27/2013	13.44358764760	144.67450820200	Developed	*Casuarina equisetifolia, Colubrina asiatica, Hibiscus tiliaceus, Leucaena leucocephala, Morinda citrifolia, Polypodium punctatum, Scaevola taccada.*
NBGAH	AH2Z	3/27/2013	13.44426112490	144.67490226900	Other - Mangrove	*Cocos nucifera, Hibiscus tiliaceus, Ipomea pes-caprae sub*sp. *Brasiliensis, Leucaena leucocephala, Scaevola taccada.*
NBGAH	AH3A	3/27/2013	13.44341338180	144.67505333600	Developed	*Cocos nucifera, Hibiscus tiliaceus, Ipomoea sp., Leucaena leucocephala, Morinda citrifolia, Scaevola taccada.*
NBGAH	AH3Z	3/27/2013	13.44415996550	144.67545800500	Other - Mangrove	*Cocos nucifera, Hibiscus tiliaceus, Ipomoea sp., Leucaena leucocephala, Morinda citrifolia, Scaevola taccada.*
NBGAH	AH4A	3/27/2013	13.44323144650	144.67541535700	Developed	*Acrostichum aureum, Cocos nucifera, Hibiscus tiliaceus, Ipomea pes-caprae sub*sp. *Brasiliensis, Leucaena leucocephala, Morinda citrifolia, Scaevola taccada.*
NBGAH	AH4Z	3/27/2013	13.44410743740	144.67588499400	Other - Mangrove	*Acrostichum aureum, Cocos nucifera, Hibiscus tiliaceus, Ipomea pes-caprae sub*sp. *Brasiliensis, Leucaena leucocephala, Pandanus dubius, Pandanus tectorius, Scaevola taccada.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
NBGAH	AH5A	3/28/2013	13.40647357490	144.68223768900	Scrub Forest	*Areca catechu, Casuarina equisetifolia, Catalpa longissima, Flaqellaria indica, Hibiscus tiliaceus, Miscanthus floridulus, Morinda citrifolia, Pandanus tectorius, Polypodium punctatum, Scaevola taccada, Vitex parviflora.*
NBGAH	AH5B	3/28/2013	13.40608731610	144.67996426700	Scrub Forest	*Annona reticulata, Glochidion marianum, Pandanus tectorius.*
NBGAH	AH5C	3/28/2013	13.40396614790	144.68009367400	Scrub Forest	*Hibiscus tiliaceus, Pandanus tectorius, Spathodea campanulata.*
NBGAH	AH5D	3/28/2013	13.40172577720	144.68038816600	Scrub Forest	*Hibiscus tiliaceus, Pandanus tectorius.*
NBGAH	AH5E	3/29/2013	13.40073879210	144.68238238300	Scrub Forest	*Areca catechu, Casuarina equisetifolia, Colubrina asiatica, Leucaena leucocephala.*
NBGAH	AH5F	3/29/2013	13.39984328580	144.68450066900	Scrub Forest	*Areca catechu, Casuarina equisetifolia, Colubrina asiatica.*
NBGAH	AH5G	3/29/2013	13.39921345820	144.68650874200	Savanna	*Casuarina equisetifolia, Cocos nucifera, Jasminum multiflorum, Leucaena leucocephala, Miscanthus floridulus.*
NBGAH	AH5Z	3/29/2013	13.40110050340	144.68730500200	Urban Cultivated	*Bambusa vulgaris, Casuarina equisetifolia, Cocos nucifera, Colubrina asiatica, Spathodea campanulata, Vitex parviflora.*
NBGB	BA1A	4/4/2013	13.47624727710	144.82372851100	Developed	*Colubrina asiatica, Flaqellaria indica, Hibiscus tiliaceus, Leucaena leucocephala, Miscanthus floridulus, Premna obtusifolia.*
NBGB	BA1B	4/4/2013	13.47845558030	144.82421499600	Mixed Limestone Forest - Primary	*Annona reticulata, Cocos nucifera, Flaqellaria indica, Leucaena leucocephala,* ***Maytenus thompsonii****, Triphasia trifolia, Vitex parviflora.*
NBGB	BA1C	4/4/2013	13.48066388360	144.82470148600	Mixed Limestone Forest - Primary	*Flaqellaria indica, Guamia mariannae, Hibiscus tiliaceus, Leucaena leucocephala, Ochrosia oppositifolia, Pandanus tectorius.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
NBGB	BA1Z	4/4/2013	13.48159001720	144.82490551600	Mixed Limestone Forest - Primary	*Flaqellaria indica, Hibiscus tiliaceus, Ochrosia oppositifolia, Triphasia trifolia, Vitex parviflora.*
NBGB	BA2A	4/4/2013	13.48178415570	144.82670547600	Mixed Limestone Forest - Primary	*Flaqellaria indica, Guamia mariannae, Hibiscus tiliaceus, Ochrosia oppositifolia.*
NBGB	BA2B	4/4/2013	13.47957585330	144.82621896500	Mixed Limestone Forest - Primary	*Ficus* sp., *Flaqellaria indica, Guamia mariannae, Hibiscus tiliaceus,* ***Maytenus thompsonii****, Ochrosia oppositifolia, Pandanus tectorius, Triphasia trifolia.*
NBGB	BA2C	4/4/2013	13.47736755110	144.82573246100	Mixed Limestone Forest - Primary	*Adenanthera pavonina, Flaqellaria indica, Hibiscus tiliaceus, Ochrosia oppositifolia, Pandanus tectorius, Triphasia trifolia.*
NBGB	BA2Z	4/4/2013	13.47628629610	144.82549425500	Mixed Limestone Forest - Primary	*Flaqellaria indica, Hibiscus tiliaceus, Leucaena leucocephala.*
NBGB	BA3A	4/4/2013	13.45034804640	144.81202174500	Tangantangan	*Leucaena leucocephala.*
NBGB	BA3B	4/4/2013	13.45048196570	144.80971778000	Tangantangan	*Leucaena leucocephala, Morinda citrifolia.*
NBGB	BA3Z	4/4/2013	13.45059237670	144.80781797700	Developed	*Flaqellaria indica, Hibiscus tiliaceus, Leucaena leucocephala.*
NBGB	BA4A	4/4/2013	13.45112388790	144.81394571200	Tangantangan	*Leucaena leucocephala, Panicum maximum.*
NBGB	BA4B	4/4/2013	13.45153204560	144.81621576700	Tangantangan	*Annona reticulata, Averrhoa bilimbi, Flaqellaria indica, Leucaena leucocephala, Morinda citrifolia.*
NBGB	BA4Z	4/4/2013	13.45193351070	144.81844871500	Developed	*Annona reticulata, Averrhoa bilimbi, Flaqellaria indica, Leucaena leucocephala.*
NBGTS	FG1A	3/29/2013	13.55224407560	144.82548207800	Mixed Limestone Forest - Disturbed	*Annona reticulata, Carica papaya, Flaqellaria indica, Hibiscus tiliaceus, Miscanthus floridulus, Morinda citrifolia, Pandanus dubius, Pandanus tectorius, Piper guahamense, Premna obtusifolia, Triphasia trifolia, Vitex parviflora.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
NBGTS	FG1B	3/29/2013	13.55097595200	144.82739296500	Shrub/Grassland	*Aglaia mariannensis, Annona reticulata, Artocarpus mariannensis, Carica papaya, Elaeocarpus joga, Eugenia* sp., *Flaqellaria indica, Hibiscus tiliaceus,* ***Maytenus thompsonii****, Miscanthus floridulus, Morinda citrifolia, Ochrosia oppositifolia, Pandanus dubius, Pandanus tectorius, Piper guahamense, Premna obtusifolia, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG1C	3/29/2013	13.54970781060	144.82930383200	Mixed Limestone Forest - Disturbed	*Annona reticulata, Flaqellaria indica, Hibiscus tiliaceus, Miscanthus floridulus, Morinda citrifolia, Pandanus dubius, Pandanus tectorius, Piper guahamense, Premna obtusifolia, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG1D	3/29/2013	13.54756562540	144.82984399800	Mixed Limestone Forest - Disturbed	*Annona reticulata, Cassia alata, Eugenia* sp., *Flaqellaria indica, Hibiscus tiliaceus, Intsia bijuga,* ***Maytenus thompsonii****, Morinda citrifoli, Ochrosia oppositifolia, Pandanus dubius, Pandanus tectorius, Piper guahamense, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG1E	3/29/2013	13.54539739460	144.83018890500	Mixed Limestone Forest - Disturbed	*Cassia alata, Hibiscus tiliaceus, Peltophorum pterocarpum.*
NBGTS	FG1F	3/29/2013	13.54566936850	144.82797154200	Mixed Limestone Forest - Disturbed	*Artocarpus mariannensis, Cassia alata, Cycas micronesica, Elaeocarpus joga, Flaqellaria indica, Guamia mariannae, Morinda citrifolia, Ochrosia oppositifolia, Pandanus dubius, Pandanus tectorius, Piper guahamense, Vitex parviflora.*
NBGTS	FG1Z	3/29/2013	13.54635845180	144.82668757900	Mixed Limestone Forest - Disturbed	

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
NBGTS	FG2A	3/30/2013	13.57302567920	144.82779595600	Mixed Limestone Forest - Disturbed	*Annona reticulata, Eugenia* sp., *Ficus* sp., *Guamia mariannae, Ochrosia oppositifolia, Piper guahamense, Thespesia populnea, Triphasia trifolia.*
NBGTS	FG2B	3/30/2013	13.57345109570	144.83006387400	Mixed Limestone Forest - Disturbed	*Annona reticulata, Artocarpus mariannensis, Cestrum diurnum, Ficus* sp., *Flaqellaria indica, Guamia mariannae, Morinda citrifolia, Ochrosia oppositifolia, Pandanus tectorius, Piper guahamense, Triphasia trifolia.*
NBGTS	FG2C	3/30/2013	13.57387649270	144.83233180400	Mixed Limestone Forest - Disturbed	*Cestrum diurnum, Ficus* sp., *Guamia mariannae, Morinda citrifolia, Ochrosia oppositifolia, Pandanus dubius, Pandanus tectorius, Piper guahamense.*
NBGTS	FG2D	3/30/2013	13.57430187030	144.83459974400	Shrub/Grassland	*Annona reticulata, Ficus* sp., *Hibiscus tiliaceus, Leucaena leucocephala, Ochrosia oppositifolia, Pandanus tectorius, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG2Z	3/30/2013	13.57430679760	144.83539286200	Mixed Limestone Forest - Disturbed	*Annona reticulata, Ficus* sp., *Hibiscus tiliaceus, Leucaena leucocephala, Morinda citrifolia, Ochrosia oppositifolia, Pandanus tectorius, Triphasia trifolia.*
NBGTS	FG3A	3/30/2013	13.56979510010	144.82663394400	Mixed Limestone Forest - Disturbed	*Annona reticulata, Bambusa vulgaris, Clerodendrum quadriloculare, Hibiscus tiliaceus, Miscanthus floridulus, Pandanus tectorius.*
NBGTS	FG3B	3/30/2013	13.57022052230	144.82890182900	Mixed Limestone Forest - Disturbed	*Annona reticulata, Flaqellaria indica, Hibiscus tiliaceus,* ***Maytenus thompsonii****, Morinda citrifolia, Vitex parviflora.*
NBGTS	FG3C	3/30/2013	13.57064592510	144.83116972500	Mixed Limestone Forest - Disturbed	*Hibiscus tiliaceus, Morinda citrifolia, Ochrosia oppositifolia, Pandanus dubius, Pandanus tectorius, Vitex parviflora.*
NBGTS	FG3D	3/30/2013	13.57107130850	144.83343763200	Mixed Limestone Forest - Disturbed	*Annona reticulata, Elaeocarpus joga, Ochrosia oppositifolia.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
NBGTS	FG3E	3/30/2013	13.57149667240	144.83570555000	Mixed Limestone Forest - Disturbed	*Cestrum diurnum, Hibiscus tiliaceus, Pandanus tectorius, Pennisetum* sp., *Wikstroemia indica.*
NBGTS	FG3F	3/30/2013	13.57192201690	144.83797347900	Mixed Limestone Forest - Disturbed	*Eugenia* sp., *Jasminum multiflorum, Ochrosia oppositifolia.*
NBGTS	FG3Z	3/30/2013	13.57211885980	144.83902308100	Developed	*Aglaia mariannensis, Elaeocarpus joga, Guamia mariannae, Jasminum multiflorum, Ochrosia oppositifolia, Pandanus tectorius, Piper guahamense, Vitex parviflora.*
NBGTS	FG4A	4/1/2013	13.57039266200	144.84123833100	Developed	*Cocos nucifera, Hibiscus tiliaceus.*
NBGTS	FG4B	4/1/2013	13.56996734850	144.83897040600	Mixed Limestone Forest - Disturbed	*Guamia mariannae, Hibiscus tiliaceus, Ochrosia oppositifolia, Pandanus tectorius.*
NBGTS	FG4C	4/1/2013	13.56954201550	144.83670249100	Mixed Limestone Forest - Disturbed	*Aglaia mariannensis, Eugenia* sp., *Hibiscus tiliaceus, Morinda citrifolia, Ochrosia oppositifolia, Pandanus tectorius.*
NBGTS	FG4D	4/1/2013	13.56911666310	144.83443458800	Mixed Limestone Forest - Disturbed	*Hibiscus tiliaceus, Ochrosia oppositifolia, Pandanus tectorius, Vitex parviflora.*
NBGTS	FG4E	4/1/2013	13.56869129130	144.83216669600	Mixed Limestone Forest - Disturbed	*Guamia mariannae, Hibiscus tiliaceus, Morinda citrifolia, Pandanus tectorius, Triphasia trifolia.*
NBGTS	FG4F	4/1/2013	13.56826590000	144.82989881500	Mixed Limestone Forest - Disturbed	*Cocos nucifera, Hibiscus tiliaceus, Pandanus tectorius, Vitex parviflora, Wikstroemia indica.*
NBGTS	FG4Z	4/1/2013	13.56811368060	144.82908731800	Mixed Limestone Forest - Disturbed	*Cocos nucifera, Hibiscus tiliaceus, Morinda citrifolia, Ochrosia oppositifolia, Pandanus tectorius.*
NBGTS	FG5A	4/1/2013	13.56888438060	144.84314555000	Developed	*Cocos nucifera, Hibiscus tiliaceus, Pandanus tectorius.*
NBGTS	FG5B	4/1/2013	13.56845908600	144.84087763200	Mixed Limestone Forest - Disturbed	*Eugenia* sp., *Guamia mariannae, Hibiscus tiliaceus, Pandanus tectorius.*
NBGTS	FG5C	4/1/2013	13.56803377200	144.83860972600	Mixed Limestone Forest - Disturbed	*Hibiscus tiliaceus, Ochrosia oppositifolia, Pandanus tectorius, Triphasia trifolia, Vitex parviflora.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
NBGTS	FG5D	4/1/2013	13.56760843850	144.83634183000	Mixed Limestone Forest - Disturbed	*Eugenia* sp., *Guamia mariannae, Hibiscus tiliaces, Ochrosia oppositifolia, Pandanus tectorius, Triphasia trifolia.*
NBGTS	FG5E	4/1/2013	13.56718308560	144.83407394600	Shrub/Grassland	*Hibiscus tiliaceus, Pandanus tectorius, Vitex parviflora.*
NBGTS	FG5F	4/1/2013	13.56675771330	144.83180607300	Mixed Limestone Forest - Disturbed	*Aglaia mariannensis, Ochrosia oppositifolia, Pandanus tectorius, Triphasia trifolia.*
NBGTS	FG5Z	4/1/2013	13.56664869050	144.83122483600	Mixed Limestone Forest - Disturbed	*Hibiscus tiliaceus, Ochrosia oppositifolia, Pandanus tectorius, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG6A	4/1/2013	13.57425303630	144.83339901700	Mixed Limestone Forest - Disturbed	*Aglaia mariannensis, Annona reticulata, Eugenia* sp., *Ficus* sp., *Ochrosia oppositifolia, Pandanus tectorius, Triphasia trifolia.*
NBGTS	FG6B	4/1/2013	13.57275796010	144.83513017400	Shrub/Grassland	*Cestrum diurnum, Hibiscus tiliaceus, Ochrosia oppositifolia, Pandanus tectorius, Pennisetum* sp., *Vitex parviflora, Wikstroemia indica.*
NBGTS	FG6C	4/1/2013	13.57126286860	144.83686131100	Mixed Limestone Forest - Disturbed	*Aglaia mariannensis, Eugenia* sp., *Ficus* sp., *Guamia mariannae, Ochrosia oppositifolia, Pandanus tectorius, Piper guahamense, Triphasia trifolia.*
NBGTS	FG6D	4/1/2013	13.56976776160	144.83859242600	Mixed Limestone Forest - Disturbed	*Aglaia mariannensis, Annona reticulata, Ficus* sp., *Guamia mariannae, Hibiscus tiliaceus, Ochrosia oppositifolia, Pandanus tectorius, Triphasia trifolia.*
NBGTS	FG6E	4/1/2013	13.56827263920	144.84032352000	Mixed Limestone Forest - Disturbed	*Aglaia mariannensis, Cestrum diurnum, Flaqellaria indica, Guamia mariannae, Ochrosia oppositifolia, Pandanus dubius, Pandanus tectorius, Premna obtusifolia, Thespesia populnea, Triphasia trifolia, Vitex parviflora.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
NBGTS	FG6Z	4/1/2013	13.56773618970	144.84094462600	Mixed Limestone Forest - Disturbed	*Aglaia mariannensis, Eugenia* sp., *Guamia mariannae, Hibiscus tiliaceus, Morinda citrifolia, Ochrosia oppositifolia, Pandanus dubius, Pandanus tectorius, Pennisetum* sp., *Triphasia trifolia, Vitex parviflora.*
NBGTS	FG7A	4/9/2013	13.57445055850	144.83539251600	Mixed Limestone Forest - Disturbed	*Hibiscus tiliaceus, Vitex parviflora.*
NBGTS	FG7B	4/9/2013	13.57656583460	144.83538742900	Mixed Limestone Forest - Disturbed	*Eugenia* sp., *Guamia mariannae, Hibiscus tiliaceus, Ochrosia oppositifolia, Pandanus tectorius, Triphasia trifolia, Vitex parviflora, Wikstroemia indica.*
NBGTS	FG7C	4/9/2013	13.57882487130	144.83538199200	Mixed Limestone Forest - Disturbed	*Aglaia mariannensis, Eugenia* sp., *Guamia mariannae, Hibiscus tiliaceus, Ochrosia oppositifolia, Pandanus tectorius.*
NBGTS	FG7Z	4/9/2013	13.57958337460	144.83538016600	Developed	*Eugenia* sp., *Guamia mariannae, Hibiscus tiliaceus, Ochrosia oppositifolia, Pandanus tectorius, Piper guahamense, Triphasia trifolia, Verbena jamaicensis, Vitex parviflora, Wikstroemia indica.*
NBGTS	FG8A	4/3/2013	13.58649415910	144.83772474000	Mixed Limestone Forest - Primary	*Aglaia mariannensis, Annona reticulata, Artocarpus altilis, Cycas micronesica, Eugenia* sp., *Guamia mariannae, Ochrosia oppositifolia.*
NBGTS	FG8B	4/3/2013	13.58423512030	144.83773016600	Mixed Limestone Forest - Disturbed	*Annona reticulata, Eugenia* sp., *Ficus* sp., *Guamia mariannae, Hibiscus tiliaceus, Ochrosia oppositifolia, Pandanus tectorius, Triphasia trifolia.*
NBGTS	FG8C	4/3/2013	13.58197608120	144.83773558900	Mixed Limestone Forest - Disturbed	*Aglaia mariannensis, Artocarpus altilis, Cocos nucifera, Guamia mariannae, Hibiscus tiliaceus, Leucaena leucocephala,* ***Maytenus thompsonii****, Morinda citrifolia, Ochrosia oppositifolia, Pandanus tectorius, Triphasia trifolia.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
NBGTS	FG8D	4/3/2013	13.57971704170	144.83774100800	Mixed Limestone Forest - Disturbed	*Aglaia mariannensis, Annona reticulata, Eugenia* sp., *Ficus* sp., *Guamia mariannae,* ***Maytenus thompsonii****, Morinda citrifolia, Pandanus tectorius, Premna obtusifolia, Triphasia trifolia, Verbena jamaicensis.*
NBGTS	FG8E	4/3/2013	13.57745800180	144.83774642300	Mixed Limestone Forest - Disturbed	*Artocarpus altilis, Eugenia* sp., *Guamia mariannae, Hibiscus tiliaceus, Ochrosia oppositifolia, Pandanus tectorius.*
NBGTS	FG8F	4/3/2013	13.57519896150	144.83775183500	Mixed Limestone Forest - Disturbed	*Eugenia* sp., *Hibiscus tiliaceus, Ochrosia oppositifolia, Pandanus tectorius, Premna obtusifolia, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG8G	4/3/2013	13.57293992080	144.83775724400	Developed	*Eugenia* sp., *Guamia mariannae, Ochrosia oppositifolia, Pandanus tectorius, Premna obtusifolia, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG8Z	4/3/2013	13.57279239770	144.83775759700	Developed	*Hibiscus tiliaceus, Pandanus tectorius, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG9A	4/3/2013	13.58117648390	144.83994578300	Developed	*Artocarpus altilis, Hibiscus tiliaceus, Pandanus tectorius, Piper guahamense, Premna obtusifolia.*
NBGTS	FG9B	4/3/2013	13.57891751840	144.83996563500	Mixed Limestone Forest - Disturbed	*Guamia mariannae, Hibiscus tiliaceus, Ochrosia oppositifolia, Pandanus tectorius, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG9C	4/3/2013	13.57665855240	144.83998548400	Mixed Limestone Forest - Disturbed	*Casuarina equisetifolia, Hibiscus tiliaceus, Morinda citrifolia, Pandanus tectorius, Vitex parviflora.*
NBGTS	FG9D	4/3/2013	13.57439958600	144.84000533000	Mixed Limestone Forest - Disturbed	*Guamia mariannae, Hibiscus tiliaceus, Morinda citrifolia, Pandanus tectorius, Vitex parviflora.*
NBGTS	FG9E	4/3/2013	13.57214061920	144.84002517100	Mixed Limestone Forest - Disturbed	*Guamia mariannae, Hibiscus tiliaceus, Ochrosia oppositifolia, Pandanus tectorius, Piper guahamense, Vitex parviflora.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
NBGTS	FG9Z	4/3/2013	13.57127882510	144.84003274000	Developed	*Guamia mariannae, Hibiscus tiliaceus, Leucaena leucocephala, Pandanus tectorius, Premna obtusifolia, Vitex parviflora.*
NBGTS	FG10A	4/6/2013	13.57654452100	144.85103494800	Mixed Limestone Forest - Disturbed	*Flaqellaria indica, Guamia mariannae, Hibiscus tiliaceus, Leucaena leucocephala,* ***Maytenus thompsonii****, Ochrosia oppositifolia, Polypodium punctatum, Vitex parviflora.*
NBGTS	FG10B	4/6/2013	13.57877511710	144.85140041500	Mixed Limestone Forest - Disturbed	*Cocos nucifera, Guamia mariannae, Hibiscus tiliaceus, Leucaena leucocephala,* ***Maytenus thompsonii****, Ochrosia oppositifolia, Pandanus tectorius, Polypodium punctatum, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG10C	4/6/2013	13.58100571330	144.85176588500	Mixed Limestone Forest - Disturbed	*Aglaia mariannensis, Eugenia* sp., *Flaqellaria indica, Guamia mariannae, Morinda citrifolia, Ochrosia oppositifolia, Pandanus dubius, Pandanus tectorius, Piper guahamense, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG10D	4/6/2013	13.58323630960	144.85213135900	Mixed Limestone Forest - Disturbed	*Aglaia mariannensis, Flaqellaria indica, Guamia mariannae, Hibiscus tiliaceus, Ochrosia oppositifolia, Pandanus tectorius, Polypodium punctatum, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG10E	4/6/2013	13.58546690610	144.85249683600	Mixed Limestone Forest - Disturbed	*Hibiscus tiliaceus, Morinda citrifolia, Pandanus tectorius, Vitex parviflora.*
NBGTS	FG10Z	4/6/2013	13.58672674590	144.85270325900	Mixed Limestone Forest - Disturbed	*Hibiscus tiliaceus, Leucaena leucocephala, Morinda citrifolia, Pandanus tectorius, Vitex parviflora.*
NBGTS	FG11A	4/6/2013	13.58126196200	144.85485141300	Mixed Limestone Forest - Disturbed	*Eugenia* sp., *Hibiscus tiliaceus,* ***Maytenus thompsonii****, Nephrolepis hirsutula, Pandanus tectorius, Triphasia trifolia, Vitex parviflora.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
NBGTS	FG11B	4/6/2013	13.58326739610	144.85378824900	Mixed Limestone Forest - Disturbed	*Aglaia mariannensis, Eugenia* sp., *Flaqellaria indica, Guamia mariannae, Hibiscus tiliaceus, Jasminum multiflorum, Ochrosia oppositifolia, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG11C	4/6/2013	13.58527282270	144.85272506400	Mixed Limestone Forest - Disturbed	*Bambusa vulgaris, Cocos nucifera, Hibiscus tiliaceus, Morinda citrifolia, Nephrolepis hirsutula, Pandanus tectorius, Vitex parviflora.*
NBGTS	FG11D	4/6/2013	13.58727824180	144.85166186000	Mixed Limestone Forest - Disturbed	*Hibiscus tiliaceus, Morinda citrifolia, Nephrolepis hirsutula, Verbena jamaicensis, Vitex parviflora.*
NBGTS	FG11E	4/9/2013	13.58928365340	144.85059863600	Mixed Limestone Forest - Disturbed	*Flaqellaria indica, Hibiscus tiliaceus, Morinda citrifolia, Nephrolepis hirsutula, Pandanus tectorius, Piper guahamense, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG11F	4/9/2013	13.59128905750	144.84953539200	Mixed Limestone Forest - Disturbed	*Cocos nucifera, Guamia mariannae, Hibiscus tiliaceus, Nephrolepis hirsutula, Pandanus tectorius, Piper guahamense, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG11G	4/9/2013	13.59329445410	144.84847212800	Shrub/Grassland	*Hibiscus tiliaceus, Leucaena leucocephala, Morinda citrifolia, Piper guahamense.*
NBGTS	FG11H	4/9/2013	13.59529984320	144.84740884400	Shrub/Grassland	*Flaqellaria indica, Guamia mariannae, Hibiscus tiliaceus, Leucaena leucocephala, Ochrosia oppositifolia, Pandanus tectorius, Vitex parviflora.*
NBGTS	FG11I	4/9/2013	13.59730522480	144.84634554100	Mixed Limestone Forest - Disturbed	*Guamia mariannae, Hibiscus tiliaceus, Pandanus tectorius, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG11J	4/9/2013	13.59931059890	144.84528221800	Mixed Limestone Forest - Disturbed	*Eugenia* sp., *Guamia mariannae, Hibiscus tiliaceus, Pandanus tectorius, Triphasia trifolia, Verbena jamaicensis, Vitex parviflora.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
NBGTS	FG11K	4/8/2013	13.60131596550	144.84421887500	Mixed Limestone Forest - Secondary	*Cestrum diurnum, Cycas micronesica, Guamia mariannae, Hibiscus tiliaceus, Morinda citrifolia, Ochrosia oppositifolia, Pandanus tectorius, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG11L	4/8/2013	13.60332132460	144.84315551200	Mixed Limestone Forest - Secondary	*Guamia mariannae, Hibiscus tiliaceus, Ochrosia oppositifolia, Piper guahamense, Vitex parviflora.*
NBGTS	FG11M	4/8/2013	13.60532667620	144.84209212900	Mixed Limestone Forest - Secondary	*Aglaia mariannensis, Cestrum diurnum, Cycas micronesica, Guamia mariannae, Ochrosia oppositifolia, Pandanus tectorius, Piper guahamense.*
NBGTS	FG11Z	4/8/2013	13.60733202030	144.84102872600	Scrub Forest	*Aglaia mariannensis, Eugenia* sp., *Guamia mariannae, Hibiscus tiliaceus, Ochrosia oppositifolia.*
NBGTS	FG12A	4/6/2013	13.58310429990	144.85634193400	Mixed Limestone Forest - Disturbed	*Flaqellaria indica, Guamia mariannae, Hibiscus tiliaceus, Leucaena leucocephala, Nephrolepis hirsutula, Pandanus tectorius, Vitex parviflora.*
NBGTS	FG12B	4/6/2013	13.58510974070	144.85527877000	Mixed Limestone Forest - Disturbed	*Hibiscus tiliaceus, Nephrolepis hirsutula, Pandanus tectorius, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG12C	4/6/2013	13.58711517400	144.85421558600	Mixed Limestone Forest - Disturbed	*Cestrum diurnum, Hibiscus tiliaceus, Morinda citrifolia, Nephrolepis hirsutula, Pandanus tectorius, Piper guahamense, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG12D	4/6/2013	13.58912059980	144.85315238300	Mixed Limestone Forest - Disturbed	*Cocos nucifera, Flaqellaria indica, Hibiscus tiliaceus, Morinda citrifolia, Nephrolepis hirsutula, Pandanus tectorius, Piper guahamense, Vitex parviflora.*
NBGTS	FG12E	4/6/2013	13.59112601820	144.85208916000	Mixed Limestone Forest - Disturbed	*Flaqellaria indica, Hibiscus tiliaceus, Leucaena leucocephala, Morinda citrifolia, Nephrolepis hirsutula, Vitex parviflora.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
NBGTS	FG12Z	4/6/2013	13.59224125020	144.85149788100	Developed	*Leucaena leucocephala, Morinda citrifolia, Nephrolepis hirsutula, Pandanus tectorius, Spathodea campanulata.*
NBGTS	FG13A	4/10/2013	13.58609775650	144.85891160300	Mixed Limestone Forest - Disturbed	*Elaeocarpus joga, Flaqellaria indica, Leucaena leucocephala, Morinda citrifolia, Nephrolepis hirsutula, Pandanus tectorius, Spathodea campanulata, Vitex parviflora.*
NBGTS	FG13B	4/10/2013	13.58810320900	144.85784844100	Mixed Limestone Forest - Disturbed	*Elaeocarpus joga, Guamia mariannae, Ochrosia oppositifolia, Pandanus tectorius, Piper guahamense, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG13C	4/10/2013	13.59010865410	144.85678526100	Mixed Limestone Forest - Disturbed	*Guamia mariannae, Hibiscus tiliaceus, Pandanus tectorius, Vitex parviflora.*
NBGTS	FG13D	4/10/2013	13.59211409170	144.85572206000	Mixed Limestone Forest - Disturbed	*Hibiscus tiliaceus, Morinda citrifolia, Pandanus tectorius, Vitex parviflora.*
NBGTS	FG13E	4/10/2013	13.59411952180	144.85465883900	Mixed Limestone Forest - Disturbed	*Hibiscus tiliaceus, Pandanus tectorius, Vitex parviflora.*
NBGTS	FG13F	4/10/2013	13.59612494440	144.85359559900	Mixed Limestone Forest - Disturbed	*Hibiscus tiliaceus, Pandanus tectorius, Vitex parviflora.*
NBGTS	FG13G	4/10/2013	13.59813035950	144.85253233900	Mixed Limestone Forest - Disturbed	*Hibiscus tiliaceus, Nephrolepis hirsutula, Pandanus tectorius, Vitex parviflora.*
NBGTS	FG13H	4/11/2013	13.60013576710	144.85146905900	Scrub Forest	*Hibiscus tiliaceus, Nephrolepis hirsutula, Pandanus tectorius, Vitex parviflora.*
NBGTS	FG13I	4/11/2013	13.60214116720	144.85040575900	Vitex - Closed/Sparse	*Hibiscus tiliaceus, Pandanus tectorius, Vitex parviflora.*
NBGTS	FG13J	4/11/2013	13.60414655980	144.84934243900	Vitex - Closed/Sparse	*Guamia mariannae, Hibiscus tiliaceus, Ochrosia oppositifolia, Pandanus tectorius, Vitex parviflora.*
NBGTS	FG13K	4/11/2013	13.60615194490	144.84827910000	Mixed Limestone Forest - Secondary	*Cestrum diurnum, Cycas micronesica, Eugenia* sp., *Hibiscus tiliaceus, Ochrosia oppositifolia, Pandanus tectorius, Premna obtusifolia.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
NBGTS	FG13L	4/12/2013	13.60815732250	144.84721574100	Mixed Limestone Forest - Secondary	*Aglaia mariannensis, Cycas micronesica, Guamia mariannae, Ochrosia oppositifolia, Piper guahamense.*
NBGTS	FG13Z	4/12/2013	13.60960141400	144.84644999100	Mixed Limestone Forest - Secondary	*Aglaia mariannensis, Cycas micronesica, Guamia mariannae, Ochrosia oppositifolia, Pandanus tectorius.*
NBGTS	FG14A	4/10/2013	13.58814371740	144.86226220300	Mixed Limestone Forest - Disturbed	*Cocos nucifera, Flaqellaria indica, Guamia mariannae, Hibiscus tiliaceus, Pandanus tectorius, Spathodea campanulata, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG14B	4/10/2013	13.59014918680	144.86119905600	Mixed Limestone Forest - Disturbed	*Guamia mariannae, Hibiscus tiliaceus, Pandanus tectorius, Piper guahamense, Vitex parviflora.*
NBGTS	FG14C	4/10/2013	13.59215464870	144.86013589000	Mixed Limestone Forest - Disturbed	*Pandanus tectorius, Vitex parviflora.*
NBGTS	FG14D	4/10/2013	13.59416010310	144.85907270300	Mixed Limestone Forest - Disturbed	*Guamia mariannae, Hibiscus tiliaceus, Pandanus tectorius, guahamense, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG14E	4/10/2013	13.59616555000	144.85800949700	Mixed Limestone Forest - Disturbed	*Cocos nucifera, Hibiscus tiliaceus, Nephrolepis hirsutula, Vitex parviflora.*
NBGTS	FG14F	4/11/2013	13.59817098950	144.85694627100	Shrub/Grassland	*Cassia alata, Pandanus tectorius, Verbena jamaicensis, Vitex parviflora.*
NBGTS	FG14G	4/11/2013	13.60017642140	144.85588302500	Vitex - Closed/Sparse	*Hibiscus tiliaceus, Morinda citrifolia, Nephrolepis hirsutula, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG14H	4/11/2013	13.60218184590	144.85481975900	Vitex - Closed/Sparse	*Pandanus tectorius, Piper guahamense, Vitex parviflora.*
NBGTS	FG14I	4/11/2013	13.60418726280	144.85375647300	Vitex - Closed/Sparse	*Cocos nucifera, Guamia mariannae, Ochrosia oppositifolia, Pandanus tectorius, Piper guahamense, Vitex parviflora.*
NBGTS	FG14J	4/11/2013	13.60619267230	144.85269316800	Vitex - Closed/Sparse	*Cassia alata, Guamia mariannae, Pandanus tectorius, Piper guahamense, Triphasia trifolia, Vitex parviflora.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
NBGTS	FG14Z	4/11/2013	13.60646601970	144.85254823200	Vitex - Closed/Sparse	*Cassia alata, Cocos nucifera, Guamia mariannae, Ochrosia oppositifolia, Pandanus tectorius, Vitex parviflora.*
NBGTS	FG15A	4/10/2013	13.59610683340	144.84975922500	Mixed Limestone Forest - Disturbed	*Guamia mariannae, Hibiscus tiliaceus, Ochrosia oppositifolia, Pandanus tectorius, Piper guahamense, Vitex parviflora.*
NBGTS	FG15B	4/10/2013	13.59752199280	144.85155941100	Mixed Limestone Forest - Disturbed	*Pandanus tectorius, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG15Z	4/10/2013	13.59792126050	144.85206731500	Mixed Limestone Forest - Disturbed	*Hibiscus tiliaceus, Nephrolepis hirsutula, Pandanus tectorius, Vitex parviflora.*
NBGTS	FG16A	4/8/2013	13.60077548480	144.83910088000	Mixed Limestone Forest - Primary	*Annona reticulata, Cycas micronesica, Eugenia* sp., *Guamia mariannae, Hibiscus tiliaceus, Tabernaemontana rotensiss, Triphasia trifolia.*
NBGTS	FG16B	4/8/2013	13.60070794310	144.84140936500	Scrub Forest	*Cassia alata, Cestrum diurnum, Cycas micronesica, Guamia mariannae, Hibiscus tiliaceus, Ochrosia oppositifolia, Piper guahamense, Premna obtusifolia, Triphasia trifolia.*
NBGTS	FG16C	4/8/2013	13.60064037990	144.84371785200	Mixed Limestone Forest - Secondary	*Cestrum diurnum, Guamia mariannae, Hibiscus tiliaceus, Ochrosia oppositifolia, Pandanus tectorius, Piper guahamense, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG16D	4/8/2013	13.60057279500	144.84602634100	Vitex - Closed/Sparse	*Cocos nucifera, Guamia mariannae, Hibiscus tiliaceus, Pandanus tectorius, Triphasia trifolia, Verbena jamaicensis, Vitex parviflora.*
NBGTS	FG16E	4/8/2013	13.60050518850	144.84833483200	Vitex - Closed/Sparse	*Cestrum diurnum, Eugenia* sp., *Hibiscus tiliaceus, Nephrolepis hirsutula, Pandanus tectorius, Triphasia trifolia, Vitex parviflora.*
NBGTS	FG16Z	4/12/2013	13.60043877300	144.85060193900	Scrub Forest	*Guamia mariannae, Ochrosia oppositifolia, Pandanus tectorius, Piper guahamense, Triphasia trifolia.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
NBGTS	FG17A	4/12/2013	13.61040918540	144.84262763300	Scrub Forest	*Aglaia mariannensis, Guamia mariannae, Pandanus tectorius.*
NBGTS	FG17B	4/12/2013	13.60840383500	144.84369104100	Mixed Limestone Forest - Secondary	*Aglaia mariannensis, Cestrum diurnum, Cycas micronesica, Eugenia* sp., *Guamia mariannae, Hibiscus tiliaceus, Ochrosia oppositifolia.*
NBGTS	FG17C	4/12/2013	13.60639847710	144.84475442900	Mixed Limestone Forest - Secondary	*Hibiscus tiliaceus, Nephrolepis hirsutula, Vitex parviflora.*
NBGTS	FG17Z	4/8/2013	13.60499308060	144.84549965900	Vitex - Closed/Sparse	*Nephrolepis hirsutula, Pandanus tectorius, Triphasia trifolia, Verbena jamaicensis, Vitex parviflora.*
AAFB-NWF	NW1A	4/2/2013	13.63906071860	144.85615257000	Scrub Forest	*Casuarina equisetifolia, Hibiscus tiliaceus, Morinda citrifolia, Ochrosia oppositifolia, Triphasia trifolia.*
AAFB-NWF	NW1Z	4/2/2013	13.64106237780	144.85508175000	Scrub Forest	*Cycas micronesica, Guamia mariannae, Ochrosia oppositifolia, Ochrosia mariannensis, Pandanus tectorius, Triphasia trifolia.*
AAFB-NWF	NW2A	4/2/2013	13.64025698370	144.85911652300	Developed	*Aglaia mariannensis, Guamia mariannae, Leucaena leucocephala, Pandanus tectorius, Premna obtusifolia, Triphasia trifolia, Verbena jamaicensis.*
AAFB-NWF	NW2B	4/2/2013	13.64230517490	144.85814202000	Shrub/Grassland	*Morinda citrifolia, Ochrosia mariannensis, Pandanus tectorius, Triphasia trifolia.*
AAFB-NWF	NW2Z	4/2/2013	13.64304199050	144.85779144700	Mixed Limestone Forest - Primary	*Morinda citrifolia, Ochrosia mariannensis, Pandanus tectorius, Tabernaemontana rotensiss, Triphasia trifolia, Verbena jamaicensis.*
AAFB-NWF	NW3A	4/2/2013	13.64010099550	144.86090500200	Scrub Forest	*Hibiscus tiliaceus, Leucaena leucocephala, Ochrosia oppositifolia, Ochrosia mariannensis, Pandanus tectorius, Triphasia trifolia, Verbena jamaicensis.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
AAFB-NWF	NW3B	4/2/2013	13.64214922370	144.86187943300	Mixed Limestone Forest - Secondary	*Eugenia* sp., *Hibiscus tiliaceus, Leucaena leucocephala, Ochrosia oppositifolia, Ochrosia mariannensis, Triphasia trifolia, Verbena jamaicensis.*
AAFB-NWF	NW3C	4/2/2013	13.64419745030	144.86285387800	Mixed Limestone Forest - Secondary	*Cynometra ramiflora, Eugenia* sp., *Guamia mariannae,* ***Maytenus thompsonii****, Ochrosia oppositifolia, Ochrosia mariannensis, Premna obtusifolia, Triphasia trifolia.*
AAFB-NWF	NW3D	4/2/2013	13.64624567510	144.86382833800	Mixed Limestone Forest - Primary	*Aglaia mariannensis, Cynometra ramiflora, Eugenia* sp., *Guamia mariannae, Hibiscus tiliaceus,* ***Maytenus thompsonii****, Ochrosia mariannensis, Triphasia trifolia.*
AAFB-NWF	NW3E	4/2/2013	13.64829389830	144.86480281300	Mixed Limestone Forest - Primary	*Aglaia mariannensis, Cycas micronesica, Eugenia* sp., *Ficus* sp., *Guamia mariannae, Hibiscus tiliaceus,* ***Maytenus thompsonii****, Ochrosia mariannensis,* ***Procris pendunculata****.*
AAFB-NWF	NW3Z	4/2/2013	13.65023576620	144.86572670200	Mixed Limestone Forest - Primary	*Aglaia mariannensis, Eugenia* sp., *Ficus* sp., *Guamia mariannae, Ochrosia mariannensis, Triphasia trifolia.*
AAFB-NWF	NW4A	4/3/2013	13.63669196180	144.86685068600	Mixed Limestone Forest - Secondary	*Aglaia mariannensis, Cestrum diurnum, Eugenia* sp., *Guamia mariannae, Hibiscus tiliaceus, Ochrosia oppositifolia, Pandanus tectorius, Triphasia trifolia.*
AAFB-NWF	NW4B	4/3/2013	13.63867366210	144.86795966500	Mixed Limestone Forest - Secondary	*Aglaia mariannensis, Cestrum diurnum, Guamia mariannae, Ochrosia oppositifolia, Premna obtusifolia, Triphasia trifolia.*
AAFB-NWF	NW4C	4/3/2013	13.64065535980	144.86906866100	Mixed Limestone Forest - Primary	*Aglaia mariannensis, Cynometra ramiflora, Eugenia* sp., *Guamia mariannae, Ochrosia oppositifolia.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
AAFB-NWF	NW4Z	4/3/2013	13.64223599750	144.86995322900	Mixed Limestone Forest - Primary	*Aglaia mariannensis, Cestrum diurnum, Cycas micronesica, Eugenia* sp., *Ficus* sp., *Guamia mariannae, Pandanus tectorius, Wikstroemia indica.*
AAFB-NWF	NW5A	4/3/2013	13.63273945710	144.87159240300	Mixed Limestone Forest - Secondary	*Eugenia* sp., *Leucaena leucocephala, Pandanus tectorius, Premna obtusifolia, Triphasia trifolia, Verbena jamaicensis, Wikstroemia indica.*
AAFB-NWF	NW5B	4/3/2013	13.63486405390	144.87237749200	Mixed Limestone Forest - Secondary	*Aglaia mariannensis, Cestrum diurnum, Eugenia* sp., *Guamia mariannae, Hibiscus tiliaceus, Ochrosia oppositifolia, Triphasia trifolia, Wikstroemia indica.*
AAFB-NWF	NW5Z	4/3/2013	13.63644866230	144.87296305000	Mixed Limestone Forest - Secondary	*Aglaia mariannensis, Cestrum diurnum, Cycas micronesica, Guamia mariannae,* ***Maytenus thompsonii****, Ochrosia oppositifolia, Premna obtusifolia, Wikstroemia indica.*
Non-DoD	RT1A	4/17/2013	13.50256483190	144.87116417300	Mixed Limestone Forest - Disturbed	*Aglaia mariannensis, Averrhoa bilimbi, Cocos nucifera, Flaqellaria indica, Guamia mariannae, Hibiscus tiliaceus, Jasminum multiflorum, Ochrosia oppositifolia, Pandanus tectorius, Piper guahamense, Triphasia trifolia, Vitex parviflora.*
Non-DoD	RT1B	4/17/2013	13.50463885620	144.87024901100	Mixed Limestone Forest - Disturbed	*Aglaia mariannensis, Averrhoa bilimbi, Flaqellaria indica, Guamia mariannae, Hibiscus tiliaceus, Jasminum multiflorum, Ochrosia oppositifolia, Pandanus tectorius, Piper guahamense, Triphasia trifolia, Vitex parviflora.*
Non-DoD	RT1Z	4/17/2013	13.50489618040	144.87013546600	Mixed Limestone Forest - Disturbed	*Aglaia mariannensis, Averrhoa bilimbi, Flaqellaria indica, Guamia mariannae, Hibiscus tiliaceus, Leucaena leucocephala, Ochrosia oppositifolia, Pandanus tectorius, Piper guahamense, Triphasia trifolia.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
Non-DoD	RT2A	3/26/2013	13.49993531450	144.88589944600	Mixed Limestone Forest - Primary	*Aglaia mariannensis, Ficus* sp., *Guamia mariannae, Heritiera longipetiolata, Macaranga thompsonii, Premna obtusifolia,* ***Procris pendunculata****.*
Non-DoD	RT2B	3/26/2013	13.50127638970	144.88404161000	Mixed Limestone Forest - Primary	*Aglaia mariannensis, Carica papaya, Cycas micronesica, Eugenia* sp., *Ficus* sp., *Flaqellaria indica, Guamia mariannae, Hibiscus tiliaceus, Intsia bijuga, Leucaena leucocephala, Macaranga thompsonii,* ***Maytenus thompsonii****, Miscanthus floridulus, Ochrosia oppositifolia, Nephrolepis hirsutula, Ochrosia mariannensis, Pandanus tectorius, Premna obtusifolia, Psidium guajava, Psychotria mariana, Scaevola taccada, Triphasia trifolia.*
Non-DoD	RT2C	3/26/2013	13.50261744790	144.88218375300	Developed	*Aglaia mariannensis, Annona reticulata, Carica papaya, Cycas micronesica, Cynometra ramiflora, Eugenia* sp., *Ficus* sp., *Flaqellaria indica, Guamia mariannae, Hibiscus tiliaceus, Macaranga thompsonii, Miscanthus floridulus, Ochrosia oppositifolia, Nephrolepis hirsutula, Ochrosia mariannensis, Pandanus tectorius, Premna obtusifolia, Psidium guajava, Psychotria mariana, Scaevola taccada, Triphasia trifolia.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
Non-DoD	RT2D	3/26/2013	13.50395848920	144.88032587700	Mixed Limestone Forest - Disturbed	*Aglaia mariannensis, Annona reticulata, Carica papaya, Cycas micronesica, Eugenia* sp., *Flaqellaria indica, Guamia mariannae, Hibiscus tiliaceus, Macaranga thompsonii,* ***Maytenus thompsonii****, Miscanthus floridulus, Ochrosia oppositifolia, Nephrolepis hirsutula, Ochrosia mariannensis, Pandanus tectorius, Premna obtusifolia, Psidium guajava, Psychotria mariana, Scaevola taccada, Triphasia trifolia.*
Non-DoD	RT2E	3/27/2013	13.50529951350	144.87846798100	Mixed Limestone Forest - Disturbed	*Aglaia mariannensis, Averrhoa bilimbi, Carica papaya, Elaeocarpus joga, Eugenia* sp., *Ficus* sp., *Flaqellaria indica, Hibiscus tiliaceus, Leucaena leucocephala, Pandanus dubius, Pandanus tectorius, Piper guahamense, Premna obtusifolia, Spathodea campanulata, Triphasia trifolia.*
Non-DoD	RT2Z	3/27/2013	13.50661638000	144.87664351200	Mixed Limestone Forest - Disturbed	*Aglaia mariannensis, Averrhoa bilimbi, Elaeocarpus joga, Eugenia* sp., *Ficus* sp., *Flaqellaria indica, Ochrosia oppositifolia, Pandanus dubius, Pandanus tectorius, Triphasia trifolia.*
Non-DoD	RT3A	3/27/2013	13.50367011620	144.88778583200	Mixed Limestone Forest - Primary	*Aglaia mariannensis, Cycas micronesica, Eugenia* sp., *Ficus* sp., *Flaqellaria indica, Guamia mariannae, Leucaena leucocephala, Macaranga thompsonii, Ochrosia oppositifolia, Ochrosia mariannensis, Triphasia trifolia, Vitex parviflora.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
Non-DoD	RT3B	3/27/2013	13.50589299340	144.88737390900	Mixed Limestone Forest - Disturbed	*Carica papaya, Cestrum diurnum, Cycas micronesica, Cynometra ramiflora, Eugenia* sp., *Ficus* sp., *Flaqellaria indica, Guamia mariannae, Intsia bijuga, Macaranga thompsonii, **Maytenus thompsonii***, *Morinda citrifolia, Ochrosia oppositifolia, Premna obtusifolia, Ricinus communis, Triphasia trifolia, Vitex parviflora.*
Non-DoD	RT3Z	3/27/2013	13.50701667540	144.88716567500	Mixed Limestone Forest - Disturbed	*Aglaia mariannensis, Cynometra ramiflora, Elaeocarpus joga, Eugenia* sp., *Ficus* sp., *Guamia mariannae, Leucaena leucocephala, Miscanthus floridulus, Morinda citrifolia, Ochrosia oppositifolia, Pennisetum* sp., *Ricinus communis, Triphasia trifolia, Vitex parviflora.*
Non-DoD	RT4A	3/25/2013	13.50881840850	144.89149029600	Mixed Limestone Forest - Primary	*Aglaia mariannensis, Caesalpinia major, Casuarina equisetifolia, Cocos nucifera, Flaqellaria indica, Guamia mariannae, Hibiscus tiliaceus, Intsia bijuga, Leucaena leucocephala, Morinda citrifolia, Ochrosia oppositifolia, Pandanus dubius, Pandanus tectorius, Triphasia trifolia.*
Non-DoD	RT4B	3/25/2013	13.51107753150	144.89148352000	Shrub/Grassland	*Aglaia mariannensis, Annona muricata, Caesalpinia major, Carica papaya, Casuarina equisetifolia, Cocos nucifera, Flaqellaria indica, Guamia mariannae, Hibiscus tiliaceus, Intsia bijuga, Leucaena leucocephala, Macaranga thompsonii, **Maytenus thompsonii**, Morinda citrifolia, Ochrosia oppositifolia, Ochrosia mariannensis, Pandanus dubius, Pandanus tectorius, Piper guahamense, Premna obtusifolia, Psychotria mariana, Triphasia trifolia, Vitex parviflora.*

Area	Transect Point	Day	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)	Vegetation Recorded
Non-DoD	RT4C	3/25/2013	13.51333665420	144.89147674000	Shrub/Grassland	*Carica papaya, Euphorbia pulcherrima, Ficus* sp., *Hernandia sonara, Leucaena leucocephala, Nephrolepis hirsutula, Passiflora* sp., *Pipturus argenteus, Platycerium grande.*
Non-DoD	RT4Z	3/26/2013	13.51513847760	144.89147133000	Developed	*Aglaia mariannensis, Cynometra ramiflora, Eugenia* sp., *Ficus* sp., *Guamia mariannae, Pandanus tectorius, Premna obtusifolia.*
Non-DoD	RT5A	3/26/2013	13.49850069270	144.88206672200	Mixed Limestone Forest - Primary	*Aglaia mariannensis, Cycas micronesica, Cynometra ramiflora, Eugenia* sp., *Ficus* sp., *Guamia mariannae, Pandanus tectorius, Premna obtusifolia.*
Non-DoD	RT5B	3/26/2013	13.50036904730	144.88336453000	Mixed Limestone Forest - Primary	*Eugenia* sp., *Flaqellaria indica, Jasminum multiflorum,* ***Maytenus thompsonii****, Ochrosia oppositifolia.*
Non-DoD	RT5Z	3/26/2013	13.50223739790	144.88466235800	Mixed Limestone Forest - Primary	*Cynometra ramiflora, Eugenia* sp., *Ficus* sp., *Guamia mariannae, Hibiscus tiliaceus, Lantana camara var. aculeata, Leucaena leucocephala,* ***Maytenus thompsonii****, Pandanus dubius, Pandanus tectorius, Triphasia trifolia.*

* Host plant seen along transect, nearest this vegetation stop

[This page intentionally left blank.]

APPENDIX E

Federal Candidate Species Occurrence List

Table 1. Occurrences of *Samoana fragilis* on DoD lands on Guam

Date	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
7/11/13	NBGTS	Pugua Point	*Samoana fragilis* & *Partula radiolata*	First man-hour search at Pugua Point (12 min; 10 m radius); 63 total partulids spotted; 39 snails observed on *Merrilliodendron megacarpum*, 19 on *Annona reticulata*, & 5 on *Guamia mariannae*. At least 3 were *Samoana fragilis*.	13.588894	144.836521	Mixed Limestone Forest - Primary

Table 2. Occurrences of *Partula radiolata* on DoD lands on Guam

Date	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
3/28/13	NBGAH	AH 5	*Partula radiolata*	10 total *Partula radiolata* observed in man-hour search.	13.406311	144.682129	Scrub Forest
3/28/13	NBGAH	AH 5	*Partula radiolata*	5 *Partula radiolata* observed in man-hour search.	13.405273	144.679871	Scrub Forest
3/28/13	NBGAH	AH 5	*Partula radiolata*	68 *Partula radiolata* observed in man-hour search.	13.405518	144.679688	Scrub Forest
7/3/13	NBGTS	Haputo Beach	*Partula radiolata*	At least 5 snails on *Hibiscus tiliaceus*; plant not fully accessible.	13.578908	144.83178	Mixed Limestone Forest - Primary
7/3/13	NBGTS	Haputo Beach	*Partula radiolata*	During first man-hour search (length of search = 10 min), 5 *P. radiolata* were recorded: 2 on *Pandanus dubius*, 2 on *Procris pedunculata*, and 1 on *Ixora triantha*.	13.57902	144.831645	Mixed Limestone Forest - Primary
7/3/13	NBGTS	Haputo Beach	*Partula radiolata*	During second man-hour search (length of search = 12 min), 82 *P. radiolata* were recorded: 60 on *Alocasia macrorrhizos*, 4 on *Cocos nucifera*, 2 on *Asplenium nidus*, 12 on *Thespesia populnea*, and 4 on a *Thelypteris opulenta*.	13.5786111	144.8322222	Mixed Limestone Forest - Primary
7/3/13	NBGTS	Haputo Beach	*Partula radiolata*	3 *Partula radiolata* on *Alocasia macrorrhizos*; each snail on a different *Alocasia macrorrhizos* within the same area.	13.5786111	144.8322222	Mixed Limestone Forest - Primary
7/3/13	NBGTS	Haputo Beach	*Partula radiolata*	1 Partula radiolata on *Melanolepis multiglandulosa*.	13.5786111	144.8322222	Mixed Limestone Forest - Primary
7/10/13	NBGAH	AH 5	*Partula radiolata*	First man-hour search at AH5-1 (12 min; 10 m radius); 11 total *Partula radiolata* spotted (10 adults; 1 juvenile); all snails observed on *Syngonium angustatum.*	13.406287	144.682061	Scrub Forest
7/10/13	NBGAH	AH 5	*Partula radiolata*	Second man-hour search at AH5-2 (12 min; 10 m radius); 9 total Partula radiolata spotted (6 adults; 3 juvenile); 7 snails observed on *Annona reticulata*, 1 on *Glochidion marianum*, & 1 on *Flagellaria indica.*	13.405364	144.679892	Scrub Forest

Date	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
7/10/13	NBGAH	AH 5	*Partula radiolata*	Third man-hour search at AH5-3 (12 min; 10 m radius); 34 total *Partula radiolata* spotted; 31 snails observed on *Morinda citrifolia*, 3 on *Spathodea campanulata.*	13.405318	144.67964	Scrub Forest
7/11/13	NBGTS	Pugua Point	*Samoana fragilis & Partula radiolata*	First man-hour search at Pugua Point (12 min; 10 m radius); 63 total partulids spotted; 39 snails observed on *Merrilliodendron megacarpum*, 19 on *Annona reticulata*, & 5 on *Guamia mariannae*. At least 3 were *Samoana fragilis*.	13.588894	144.836521	Mixed Limestone Forest - Primary
8/1/13	NBGTS	Haputo Beach 2	*Partula radiolata*	1 *Partula radiolata* on *Cocos nucifera*.	13.57867	144.831826	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula radiolata*	1 *Partula radiolata* on *Alocasia macrorrhizos*.	13.578643	144.83179	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula radiolata*	1 *Partula radiolata* on *Hernandia sonora*.	13.578449	144.831874	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula radiolata*	1 *Partula radiolata* on *Alocasia macrorrhizos*.	13.578087	144.8319	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula radiolata*	At least 5 *Partula radiolata* on *Ficus sp.*	13.577089	144.832278	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula radiolata*	2 *Partula radiolata* on *Ochrosia oppositifoila.*	13.576844	144.832336	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula radiolata*	1 *Partula radiolata* on *Piper guahamense*.	13.576819	144.832355	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula radiolata*	1 *Partula radiolata* on *Aglaia mariannensis*.	13.576819	144.832355	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula radiolata*	1 *Partula radiolata* on *Annona reticulata*.	13.576579	144.831798	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula radiolata*	1 *Partula radiolata* on *Alocasia macrorrhizos*.	13.576304	144.831553	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula radiolata*	1 *Partula radiolata* on white bractate fungus.	13.576305	144.831518	Other - Coconut Forest

Date	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
8/1/13	NBGTS	Haputo Beach 2	*Partula radiolata*	1 *Partula radiolata* on *Alocasia macrorrhizos*.	13.576431	144.831428	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula radiolata & Partula gibba.*	During first man-hour search (length of search = 12 min), 61 *P. radiolata* & 15 *P. gibba* were recorded: 51 on *Alocasia macrorrhizos*, 15 on *Pandanus dubius*, 3 on *Cocos nucifera*, and 2 on rocks.	13.576441	144.831438	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula radiolata*	1 *Partula radiolata* on *Cocos nucifera*.	13.576497	144.830879	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula radiolata*	1 *Partula radiolata* on *Asplenium nidus*.	13.576464	144.830843	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula radiolata*	1 *Partula radiolata* on *Cocos nucifera*.	13.576516	144.830952	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula radiolata & Partula gibba*	4 *Partula radiolata* and at least 4 *Partula gibba* on *Ochrosia oppositifolia*.	13.576509	144.831341	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula radiolata*	1 *Partula radiolata* on *Cocos nucifera*; 1 *Partula radiolata* on *Alocasia macrorrhizos*; 1 *Partula radiolata* on *Pteris tripartita*.	13.576463	144.831453	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula radiolata*	1 *Partula radiolata* on *Cocos nucifera*.	13.577477	144.831654	Mixed Limestone Forest - Primary
8/1/13	NBGTS	Haputo Beach 2	*Partula radiolata*	1 *Partula radiolata* on *Cocos nucifera*.	13.577618	144.831613	Mixed Limestone Forest - Primary
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	At least 5 *Partula radiolata* on *Ochrosia oppositifolia*.	13.600767	144.92163	Other - Neisosperma Forest
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	During first man-hour search (length of search = 12 min), 71 *P. radiolata* were recorded: 5 on *Ochrosia mariannensis*, 58 on *Ochrosia oppositifolia*, 5 on *Hernandia sonora*, 2 on *Cycas micronesica* & 1 on ground.	13.600767	144.92163	Other - Neisosperma Forest

Date	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	1 *Partula radiolata* on *Cycas micronesica*; 1 *Partula radiolata* on *Ochrosia oppositifolia*.	13.600348	144.92466	Other - Neisosperma Forest
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	3 *Partula radiolata* on *Ochrosia oppositifolia*.	13.600326	144.921359	Other - Neisosperma Forest
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	1 *Partula radiolata* on *Ochrosia oppositifolia*.	13.600301	144.921319	Other - Neisosperma Forest
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	1 *Partula radiolata* on *Cycas micronesica*.	13.600304	144.921296	Other - Neisosperma Forest
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	1 *Partula radiolata* on *Ochrosia oppositifolia*.	13.600299	144.921232	Other - Neisosperma Forest
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	1 *Partula radiolata* on *Ochrosia oppositifolia*.	13.600416	144.921148	Other - Neisosperma Forest
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	1 *Partula radiolata* on *Ochrosia oppositifolia*.	13.600439	144.921081	Other - Neisosperma Forest
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	3 *Partula radiolata* on *Ochrosia oppositifolia;* deer feces found on ground near base of tree.	13.6004	144.921071	Other - Neisosperma Forest
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	1 *Partula radiolata* on *Ochrosia oppositifolia*.	13.600256	144.921102	Other - Neisosperma Forest
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	1 *Partula radiolata* on *Ochrosia oppositifolia*.	13.600212	144.92108	Other - Neisosperma Forest
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	1 *Partula radiolata* on *Ochrosia oppositifolia*.	13.600574	144.920968	Other - Neisosperma Forest

Date	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	1 *Partula radiolata* on *Ochrosia oppositifolia.*	13.600752	144.921076	Other - Neisosperma Forest
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	At least 10 *Partula radiolata* on *Ochrosia oppositifolia.*	13.600675	144.92106	Other - Neisosperma Forest
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	At least 15 *Partula radiolata* on *Ochrosia mariannensis*.	13.600663	144.921146	Other - Coconut Forest
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	3 *Partula radiolata* on *Ochrosia oppositifolia*; 2 *Partula radiolata* on *Mammea odorata*.	13.600499	144.920902	Other - Coconut Forest
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	1 *Partula radiolata* on *Ochrosia oppositifolia.*	13.600522	144.92114	Other - Coconut Forest
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	*1 Partula radiolata* on *Ochrosia oppositifolia.*	13.600489	144.921147	Other - Coconut Forest
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	2 *Partula radiolata* on *Ochrosia oppositifolia.*	13.600494	144.921208	Other - Coconut Forest
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	4 *Partula radiolata* on *Ochrosia oppositifolia.*	13.600465	144.921271	Other - Coconut Forest
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	At least 5 *Partula radiolata* on *Hernandia sonora*.	13.600554	144.921667	Other - Coconut Forest
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	At least 4 *Partula radiolata* on *Ochrosia oppositifolia.*	13.600504	144.921739	Other - Coconut Forest
8/2/13	AAFB	Tarague Basin 2	*Partula radiolata*	At least 5 *Partula radiolata* on *Hernandia sonora*.	13.600406	144.921843	Other - Barren/Sandy Beach/Bare Rocks

Table 3. Occurrences of *Partula gibba* on DoD lands on Guam

Date	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
8/1/13	NBGTS	Haputo Beach 2	*Partula radiolata & P. gibba*	During first man-hour search (length of search = 12 min), 61 *P. radiolata & 15 P. gibba* were recorded: 51 on *Alocasia macrorrhizos*, 15 on *Pandanus dubius*, 3 on *Cocos nucifera*, and 2 on rocks.	13.576441	144.831438	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Cocos nucifera*.	13.576569	144.830982	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Pteris tripartita*.	13.576511	144.831235	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Ochrosia oppositifolia*.	13.576589	144.831286	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Ochrosia oppositifolia*.	13.576549	144.831247	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Alocasia macrorrhizos*.	13.576434	144.831344	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Ochrosia oppositifolia*.	13.57652	144.831304	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Ochrosia oppositifolia*.	13.576431	144.831293	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Ochrosia oppositifolia*.	13.576481	144.831342	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Ochrosia oppositifolia*.	13.57643	144.831343	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Ochrosia oppositifolia*.	13.576546	144.83136	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Alocasia macrorrhizos*.	13.576558	144.831377	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Alocasia macrorrhizos*.	13.576504	144.831432	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Cocos nucifera*.	13.576551	144.831437	Other - Coconut Forest

Date	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Alocasia macrorrhizos* .	13.576653	144.831364	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	At least 10 *Partula gibba* on *Ochrosia oppositifolia*.	13.576561	144.831329	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	At least 8 *Partula gibba* on *Ochrosia oppositifolia*.	13.57659	144.831365	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula radiolata & P. gibba*	4 *Partula radiolata* and at least 4 *Partula gibba* on *Ochrosia oppositifolia*.	13.576509	144.831341	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Alocasia macrorrhizos*.	13.576468	144.831315	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Alocasia macrorrhizos*.	13.576494	144.831351	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	4 *Partula gibba* on *Alocasia macrorrhizos*.	13.576512	144.831379	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	7 *Partula gibba* on *Pteris tripartita*.	13.576509	144.831387	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Piper guahamense* & 1 *Partula gibba* on *Alocasia macrorrhizos.*	13.576513	144.831407	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Piper guahamense*.	13.576533	144.831356	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	26 *Partula gibba* on *Cocos nucifera*.	13.57661	144.831366	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Cocos nucifera*.	13.576519	144.831438	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Alocasia macrorrhizos*.	13.576444	144.831402	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Alocasia macrorrhizos*.	13.576506	144.831404	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Alocasia macrorrhizos*.	13.576421	144.831379	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	2 *Partula gibba* on *Piper guahamense*.	13.576403	144.831346	Other - Coconut Forest

Date	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Alocasia macrorrhizos*.	13.576402	144.831381	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	4 *Partula gibba* on *Pandanus dubius*.	13.57641	144.831366	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	2 *Partula gibba* on *Alocasia macrorrhizos*.	13.576379	144.831415	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Alocasia macrorrhizos*.	13.576373	144.831446	Other - Coconut Forest
8/1/13	NBGTS	Haputo Beach 2	*Partula gibba*	1 *Partula gibba* on *Cocos nucifera*.	13.576463	144.831453	Other - Coconut Forest

Table 4. Occurrences of adult *Hypolimnas octocula marianensis* butterflies on DoD lands on Guam

Date	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
7/5/13	AAFB-NWF	NW 3 to NW 5 Part 1	*H. octocula marianensis*	1 adult spotted on tree; a wing sample was obtained.	13.650649	144.863883	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis*	1 adult spotted (passive fluttering & perching on *Procris pedunculata*); attempt to capture adult unsuccessful.	13.500459	144.885865	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis*	1 adult spotted (passive fluttering & perching on *Eugenia reinwardtiana*) - maybe the same adult observed earlier & adult wing clip.	13.50041	144.885797	Mixed Limestone Forest - Primary
7/11/13	NBGTS	Pugua Point	*H. octocula marianensis*	1 adult observed perching on *Procris pedunculata* & passive fluttering around patches; attempt to capture adult for DNA sampling was unsuccessful.	13.585367	144.833742	Scrub Forest

Table 5. Occurrences of *Hypolimnas* sp. chrysalides on DoD lands on Guam

Date	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
3/25/13	RT 15	RT 4A to 4C	*H. octocula marianensis?*	1 chrysalis on *Maytenus thompsonii*, 1 in a spider web.	13.5103905	144.8915966	Shrub/Grassland
3/26/13	RT 15	RT 15 2A to 2B	*H. octocula marianensis?*	7 on *Procris pedunculata*, 1 on a fern, 1 on a Ficus root, and 1 on *Guamia mariannae*	13.5002199	144.88582	Mixed Limestone Forest - Primary
3/26/13	RT15	RT 15 2A	*H. octocula marianensis*	1 chrysalis on *Procris pedunculata.*	13.5002019	144.8858159	Mixed Limestone Forest - Primary
3/26/13	RT15	RT 15 2A	*H. octocula marianensis*	1 chrysalis on *Procris pedunculata.*	13.5003412	144.8857493	Mixed Limestone Forest - Primary
4/2/13	AAFB-NWF	NW 3E to 3Z	*H. octocula marianensis?*	2 chrysalides on *Procris pedunculata*	13.6491983	144.865315	Mixed Limestone Forest - Primary
4/2/13	AAFB-NWF	NW 3E to 3Z	*H. octocula marianensis?*	4 chrysalides on *Procris pedunculata*	13.6495878	144.8655352	Mixed Limestone Forest - Primary
4/2/13	AAFB-NWF	NW 3E to 3Z	*H. octocula marianensis*	1 incomplete chrysalis on *Procris pedunculata.*	13.649204	144.8652765	Mixed Limestone Forest - Primary
4/2/13	AAFB-NWF	NW 3E to 3Z	*H. octocula marianensis*	1 incomplete chrysalis on *Procris pedunculata.*	13.6491867	144.8652487	Mixed Limestone Forest - Primary
4/2/13	AAFB-NWF	NW 3E to 3Z	*H. octocula marianensis*	1 incomplete chrysalis on *Procris pedunculata.*	13.6491732	144.8652526	Mixed Limestone Forest - Primary
4/2/13	AAFB-NWF	NW 3E to 3Z	*H. octocula marianensis?*	1 smooth chrysalis on *Procris pedunculata.*	13.6491656	144.8652784	Mixed Limestone Forest - Primary
7/1/13	AAFB	AA 1 to AA 4 Part 1	*H. octocula marianensis*	2 chrysalides on *Ficus sp.*; 1 chrysalis on a fern.	13.596664	144.919253	Mixed Limestone Forest - Primary
7/5/13	AAFB-NWF	NW 3 to NW 5 Part 1	*H. octocula marianensis?*	1 chrysalis present on *Eugenia sp*. chrysalis not collected; maybe chrysalis of *Euploea leucostictos*.	13.650654	144.863853	Mixed Limestone Forest - Primary
7/5/13	AAFB-NWF	NW 3 to NW 5 Part 1	*H. octocula marianensis*	3 chrysalides on Ficus sp.; maybe chrysalides of *Euploea leucostictos*.	13.650649	144.863883	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis*	1 chrysalis on *Eugenia reinwardtiana*.	13.5004	144.885833	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis*	2 chrysalides on *Guamia mariannae*.	13.5004	144.885833	Mixed Limestone Forest - Primary

Date	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis*	1 chrysalis on *Eugenia palumbis*.	13.5004	144.885833	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis*	I chrysalis on *Aglaia mariannensis*.	13.500333	144.886017	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis*	1 chrysalis on *Asplenium nidus*.	13.500333	144.885883	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis*	1 chrysalis on *Asplenium nidus*.	13.500333	144.885883	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis*	1 chrysalis on *Eugenia reinwardtiana*.	13.50041	144.885797	Mixed Limestone Forest - Primary

Table 6. Occurrences of occupied *Hypolimnas octocula marianensis* host plants on DoD lands on Guam

Date	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
3/26/13	RT15	RT 15 2A	*H. octocula marianensis*	1 patch of *Procris pedunculata*, no butterfly presence.	13.50022174	144.8858355	Mixed Limestone Forest - Primary
3/26/13	RT15	RT 15 2A	*H. octocula marianensis*	3 light green eggs on *Procris pedunculata.*	13.5002416	144.8858057	Mixed Limestone Forest - Primary
3/26/13	RT15	RT 15 2A	*H. octocula marianensis*	1 black egg on *Procris pedunculata.*	13.50026507	144.8857285	Mixed Limestone Forest - Primary
3/26/13	RT15	RT 15 2A	*H. octocula marianensis*	1 black egg on *Procris pedunculata.*	13.50025728	144.8857812	Mixed Limestone Forest - Primary
3/26/13	RT15	RT 15 2A	*H. octocula marianensis*	3 black eggs on *Procris pedunculata.*	13.50022878	144.8857658	Mixed Limestone Forest - Primary
3/26/13	RT15	RT 15 2A	*H. octocula marianensis*	4 black eggs on *Procris pedunculata.*	13.50019558	144.8857848	Mixed Limestone Forest - Primary
3/26/13	RT15	RT 15 2A	*H. octocula marianensis*	1 light green egg on *Procris pedunculata.*	13.50019827	144.8858247	Mixed Limestone Forest - Primary
3/26/13	RT15	RT 15 2A	*H. octocula marianensis*	6 black eggs on *Procris pedunculata.*	13.50024888	144.8857597	Mixed Limestone Forest - Primary
3/26/13	RT15	RT 15 2A	*H. octocula marianensis*	4 light green eggs on *Procris pedunculata.*	13.50026598	144.8857938	Mixed Limestone Forest - Primary
3/26/13	RT15	RT 15 2A	*H. octocula marianensis*	2 black eggs on *Procris pedunculata.*	13.50031017	144.8857799	Mixed Limestone Forest - Primary
3/26/13	RT15	RT 15 2A	*H. octocula marianensis*	3 light green eggs and 4 black eggs on *Procris pedunculata.*	13.500353	144.8858656	Mixed Limestone Forest - Primary
4/2/13	AAFB-NWF	NW 3E to 3Z	*H. octocula marianensis*	7 black eggs on *Procris pedunculata.*	13.6491731	144.8652705	Mixed Limestone Forest - Primary
4/2/13	AAFB-NWF	NW 3E to 3Z	*H. octocula marianensis*	10 black eggs on *Procris pedunculata.*	13.64919808	144.8652877	Mixed Limestone Forest - Primary
4/2/13	AAFB-NWF	NW 3E to 3Z	*H. octocula marianensis*	1 large patch of *Procris pedunculata.*	13.64919833	144.8652506	Mixed Limestone Forest - Primary
4/2/13	AAFB-NWF	NW 3E to 3Z	*H. octocula marianensis*	1 light green eggs and 10 black eggs on *Procris pedunculata.*	13.6491845	144.8652786	Mixed Limestone Forest - Primary
4/2/13	AAFB-NWF	NW 3E to 3Z	*H. octocula marianensis*	17 black eggs on *Procris pedunculata.*	13.64917437	144.8652556	Mixed Limestone Forest - Primary

Date	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
4/2/13	AAFB-NWF	NW 3E to 3Z	*H. octocula marianensis*	9 black eggs on *Procris pedunculata.*	13.64919137	144.8652362	Mixed Limestone Forest - Primary
4/2/13	AAFB-NWF	NW 3E to 3Z	*H. octocula marianensis*	1 white egg on *Procris pedunculata*.	13.64919758	144.8652754	Mixed Limestone Forest - Primary
7/1/13	AAFB	AA 1 to AA 4 Part 1	*H. octocula marianensis*	More than 40 eggs in 3 patches of *Elatostema calcareum.*	13.596664	144.919253	Mixed Limestone Forest - Primary
7/2/13	AAFB	AA 1 to AA 4 Part 2	*H. octocula marianensis*	6 eggs on *Elatostema calcareum*	13.595521	144.912724	Mixed Limestone Forest - Primary
7/2/13	AAFB	AA 1 to AA 4 Part 2	*H. octocula marianensis*	8 eggs on *Elatostema calcareum*	13.59548	144.912714	Mixed Limestone Forest - Primary
7/2/13	AAFB	AA 1 to AA 4 Part 2	*H. octocula marianensis*	7 eggs on 2 patches of *Elatostema calcareum.*	13.5955	144.912736	Mixed Limestone Forest - Primary
7/2/13	AAFB	AA 1 to AA 4 Part 2	*H. octocula marianensis*	3 eggs on *Elatostema calcareum*	13.596006	144.911474	Mixed Limestone Forest - Primary
7/2/13	AAFB	AA 1 to AA 4 Part 2	*H. octocula marianensis*	At least 2 eggs on *E. calcareum*, patch not fully accessible.	13.595917	144.911255	Mixed Limestone Forest - Primary
7/2/13	AAFB	AA 1 to AA 4 Part 2	*H. octocula marianensis*	26 eggs on *Elatostema calcareum; patch not fully accessible.*	13.595961	144.910989	Mixed Limestone Forest - Primary
7/5/13	AAFB-NWF	NW 3 to NW 5 Part 1	*H. octocula marianensis*	At least 57 eggs on *Elatostema calcareum*; patch not fully accessible.	13.650649	144.863883	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis*	4 eggs on1 patch of *Procris pedunculata*.	13.502392	144.886644	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis*	2 eggs on 1 patch of *Elatostema calcareum.*	13.502349	144.886108	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis*	24 eggs on 1 patch of *Procris pedunculata*.	13.50229	144.886243	Mixed Limestone Forest - Primary

Date	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis*	6 eggs on 3 patches of *Procris pedunculata*.	13.502341	144.886183	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis*	6 eggs on 2 patches of *Elatostema calcareum.*	13.502333	144.886167	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis*	12 eggs on 1 patch of *Elatostema calcareum.*	13.502336	144.886139	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis*	14 eggs on 4 patches of *Elatostema calcareum.*	13.502376	144.886086	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis*	At least 6 eggs on 2 patches of *Elatostema calcareum* (5-10 m radius), approx. 20% coverage of *Elatostema calcareum*.	13.502349	144.886108	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis*	6 eggs on 2 patches of *Elatostema calcareum.*	13.50237	144.886113	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis*	49 eggs on 1 patch of *Procris pedunculata*.	13.500459	144.885865	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis*	At least 17 eggs on 1 patch of *Procris pedunculata*.	13.5004	144.885833	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis*	6 eggs on 1 patch of *Procris pedunculata*.	13.500314	144.885824	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis*	3 eggs on 1 patch of *Procris pedunculata*.	13.500304	144.886012	Mixed Limestone Forest - Primary
7/9/13	AAFB-NWF	NW 3 to NW 5 Part 3	*H. octocula marianensis*	4 eggs on 1 patch of *Elatostema calcareum;* 3 patches unoccupied	13.639323	144.87619	Mixed Limestone Forest - Primary
7/11/13	NBGTS	Pugua Point	*H. octocula marianensis*	4 eggs on at least 5 patches of *Procris pedunculata* (patches not fully accessible).	13.585367	144.833742	Mixed Limestone Forest - Primary
7/11/13	NBGTS	Pugua Point	*H. octocula marianensis*	8 eggs on at least 5 patches of *Procris pedunculata* (patches not fully accessible); 2 out of the 8 eggs were vacated.	13.585172	144.833694	Scrub Forest

Table 7. Occurrences of unoccupied *Hypolimnas octocula marianensis* host plants on DoD lands on Guam

Day	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
4/15/13	AAFB	AA 2Z	*H. octocula marianensis* host plant	No butterfly presence on *Procris pedunculata* patch.	13.595649	144.913386	Mixed Limestone Forest - Primary
7/1/13	AAFB	AA 1 to AA 4 Part 1	*H. octocula marianensis* host plant	No butterfly presence on *Elatostema calcareum* patch.	13.596806	144.922641	Mixed Limestone Forest - Primary
7/1/13	AAFB	AA 1 to AA 4 Part 1	*H. octocula marianensis* host plant	No butterfly presence on 2 *Elatostema calcareum* patches.	13.596813	144.92261	Mixed Limestone Forest - Primary
7/1/13	AAFB	AA 1 to AA 4 Part 2	*H. octocula marianensis* host plant	No butterfly presence on *Elatostema calcareum* patch.	13.596662	144.922022	Mixed Limestone Forest - Primary
7/1/13	AAFB	AA 1 to AA 4 Part 2	*H. octocula marianensis* host plant	No butterfly presence on *Elatostema calcareum* patch.	13.596694	144.922146	Mixed Limestone Forest - Primary
7/1/13	AAFB	AA 1 to AA 4 Part 2	*H. octocula marianensis* host plant	No butterfly presence on *Elatostema calcareum* patch.	13.596694	144.919769	Mixed Limestone Forest - Primary
7/2/13	AAFB	AA 1 to AA 4 Part 2	*H. octocula marianensis* host plant	No butterfly presence on *Elatostema calcareum* patch.	13.595435	144.913633	Mixed Limestone Forest - Primary
7/2/13	AAFB	AA 1 to AA 4 Part 2	*H. octocula marianensis* host plant	No butterfly presence on *Procris pedunculata* patch.	13.595517	144.913616	Mixed Limestone Forest - Primary
7/2/13	AAFB	AA 1 to AA 4 Part 2	*H. octocula marianensis* host plant	No butterfly presence on *Elatostema calcareum* patch.	13.595435	144.913633	Mixed Limestone Forest - Primary
7/2/13	AAFB	AA 1 to AA 4 Part 2	*H. octocula marianensis* host plant	No butterfly presence on *Elatostema calcareum* patch.	13.595664	144.913388	Mixed Limestone Forest - Primary

Day	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
7/2/13	AAFB	AA 1 to AA 4 Part 2	*H. octocula marianensis* host plant	No butterfly presence on *Elatostema calcareum* patch.	13.595544	144.9129	Mixed Limestone Forest - Primary
7/2/13	AAFB	AA 1 to AA 4 Part 2	*H. octocula marianensis* host plant	No butterfly presence on *Elatostema calcareum* patch.	13.595483	144.912791	Mixed Limestone Forest - Primary
7/2/13	AAFB	AA 1 to AA 4 Part 2	*H. octocula marianensis* host plant	No butterfly presence on *Elatostema calcareum* patch.	13.595475	144.912842	Mixed Limestone Forest - Primary
7/2/13	AAFB	AA 1 to AA 4 Part 2	*H. octocula marianensis* host plant	No butterfly presence on Elatostema calcareum patch.	13.595795	144.911899	Mixed Limestone Forest - Primary
7/2/13	AAFB	AA 1 to AA 4 Part 2	*H. octocula marianensis* host plant	No butterfly presence on Elatostema calcareum patch.	13.595885	144.911627	Mixed Limestone Forest - Primary
7/2/13	AAFB	AA 1 to AA 4 Part 2	*H. octocula marianensis* host plant	No butterfly presence on *Procris pedunculata* patch.	13.596006	144.911474	Mixed Limestone Forest - Primary
7/2/13	AAFB	AA 1 to AA 4 Part 2	*H. octocula marianensis* host plant	No butterfly presence on *Procris pedunculata* patch.	13.595917	144.911255	Mixed Limestone Forest - Primary
7/3/13	NBGTS	Haputo Beach	*H. octocula marianensis* host plant	At least 15 patches of *Elatostema calcareum* (very high frequency), too many to count; no butterfly presence. At least 5 patches of *Procris pedunculata* present; no butterfly presence.	13.578937	144.831743	Mixed Limestone Forest - Primary
7/3/13	NBGTS	Haputo Beach	*H. octocula marianensis* host plant	1 patch of *Elatostema calcareum* and 1 patch of *Procris pedunculata*; no butterfly presence.	13.578908	144.83178	Mixed Limestone Forest - Primary
7/3/13	NBGTS	Haputo Beach	*H. octocula marianensis* host plant	At least 15 patches of *Elatostema calcareum* and at least 15 patches of *Procris pedunculat*, too many to count; no butterfly presence.	13.578614	144.831962	Mixed Limestone Forest - Primary

Day	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
7/5/13	AAFB-NWF	NW 3 to NW 5 Part 1	*H. octocula marianensis* host plant	1 patch of *Elatostema calcareum*; no butterfly presence.	13.65047	144.863538	Mixed Limestone Forest - Primary
7/5/13	AAFB-NWF	NW 3 to NW 5 Part 1	*H. octocula marianensis* host plant	1 patch of *Elatostema calcareum*; no butterfly presence.	13.650673	144.863901	Mixed Limestone Forest - Primary
7/5/13	AAFB-NWF	NW 3 to NW 5 Part 1	*H. octocula marianensis* host plant	1 patch of *Procris pedunculata*; no butterfly presence.	13.650673	144.863901	Mixed Limestone Forest - Primary
7/5/13	AAFB-NWF	NW 3 to NW 5 Part 1	*H. octocula marianensis* host plant	1 patch of *Elatostema calcareum*; no butterfly presence.	13.650407	144.863431	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis* host plant	1 patch of *Elatostema calcareum;* no butterfly presence.	13.502383	144.88667	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis* host plant	1 patch of *Elatostema calcareum;* no butterfly presence.	13.502341	144.886183	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis* host plant	1 patch of *Procris pedunculata;* no butterfly presence.	13.50237	144.886113	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis* host plant	More than 10 patches of *Elatostema calcareum* present but many plants not accessible.	13.502399	144.886148	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis* host plant	More than 5 patches present of *Elatostema calcareum*and more than 5 patches present of *Procris pedunculata,* but plants not accessible.	13.502422	144.88594	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis* host plant	4 patches of *Elatostema calcareum*and 1 patch of *Procris pedunculata;* no butterfly presence.	13.50244	144.88587	Mixed Limestone Forest - Primary
7/8/13	RT 15	RT 5A to RT 3A	*H. octocula marianensis* host plant	1 patch of *Procris pedunculata*; no butterfly presence.	13.501805	144.88542	Mixed Limestone Forest - Primary

Day	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
7/9/13	AAFB-NWF	NW 3 to NW 5 Part 3	*H. octocula marianensis* host plant	1 patch of *Elatostema calcareum*; no butterfly presence.	13.638236	144.87629	Mixed Limestone Forest - Primary
7/9/13	AAFB-NWF	NW 3 to NW 5 Part 3	*H. octocula marianensis* host plant	2 patches of *Elatostema calcareum*; no butterfly presence.	13.638549	144.876314	Mixed Limestone Forest - Primary
7/9/13	AAFB-NWF	NW 3 to NW 5 Part 3	*H. octocula marianensis* host plant	1 patch of *Elatostema calcareum*; no butterfly presence.	13.639511	144.8764	Mixed Limestone Forest - Primary
7/9/13	AAFB-NWF	NW 3 to NW 5 Part 3	*H. octocula marianensis* host plant	2 patches of *Elatostema calcareum*; no butterfly presence.	13.637666	144.875937	Mixed Limestone Forest - Primary
7/11/13	NBGTS	Pugua Point	*H. octocula marianensis* host plant	At least 5 patches of *Procris pedunculata*and at least 5 patches of *Elatostema calcareum*; too many to count and patches not fully accessible.	13.585491	144.833829	Scrub Forest
7/11/13	NBGTS	Pugua Point	*H. octocula marianensis* host plant	1 patch of *Procris pedunculata*; no butterfly presence.	13.58427	144.832647	Scrub Forest
7/11/13	NBGTS	Pugua Point	*H. octocula marianensis* host plant	1 patch of *Procris pedunculata*; no butterfly presence.	13.585349	144.833397	Scrub Forest
7/11/13	NBGTS	Pugua Point	*H. octocula marianensis* host plant	At least 5 patches of *Procris pedunculata.*Too many to count and patches not fully accessible; no butterfly presence.	13.585333	144.8335	Scrub Forest
7/11/13	NBGTS	Pugua Point	*H. octocula marianensis* host plant	1 patch of *Procris pedunculata*; no butterfly presence.	13.585404	144.833692	Scrub Forest
7/30/13	NBGAH	Spanish Steps/ Orote Point	*H. octocula marianensis* host plant	15 patches of *Elatostema calcareum;* no butterfly presence.	13.4471	144.622031	Other - Coconut Forest

Day	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
7/30/13	NBGAH	Spanish Steps/ Orote Point	*H. octocula marianensis* host plant	1 patch of *Elatostema calcareum;* no butterfly presence.	13.447185	144.621809	Mixed Limestone Forest - Primary
7/30/13	NBGAH	Spanish Steps/ Orote Point	*H. octocula marianensis* host plant	1 patch of *Procris pedunculata*; no butterfly presence.	13.447402	144.621666	Mixed Limestone Forest - Primary
7/30/13	NBGAH	Spanish Steps/ Orote Point	*H. octocula marianensis* host plant	At least 15 patches of *Elatostema calcareum*; no butterfly presence.	13.447312	144.621427	Mixed Limestone Forest - Primary
7/30/13	NBGAH	Spanish Steps/ Orote Point	*H. octocula marianensis* host plant	1 patch of *Elatostema calcareum;* no butterfly presence.	13.447295	144.621468	Mixed Limestone Forest - Primary
8/1/13	NBGTS	Haputo Beach	*H. octocula marianensis* host plant	1 patch of *Elatostema calcareum*; no butterfly presence.	13.576311	144.830577	Other - Strand Vegetation

Table 8. Occurrences of *Maytenus thompsonii* on DoD lands on Guam

Date	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
3/25/13	RT 15	RT 15 4Z to 4B	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.51180117	144.8918336	Shrub/Grassland
3/25/13	RT 15	RT 15 3B to 3A	Hostplant *Maytenus thompsonii*	1 unknown butterfly chrysalis	13.51040818	144.8916192	Shrub/Grassland
3/25/13	RT 15	RT 15 3B to 3A	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.5103967	144.8914412	Shrub/Grassland
3/25/13	RT 15	RT 15 3B to 3A	Hostplant *Maytenus thompsonii*	1 re-sprouting shrub	13.51026745	144.8914401	Shrub/Grassland
3/25/13	RT 15	RT 15 3B to 3A	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.51024933	144.8914855	Shrub/Grassland
3/26/13	RT 15	RT 15 2D to 3C	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.50384473	144.8804358	Mixed Limestone Forest - Disturbed
3/26/13	RT 15	RT 15 2D to 3C	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.50373375	144.8806322	Mixed Limestone Forest - Disturbed
3/26/13	RT 15	RT 15 2D to 3C	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.50335153	144.8808275	Mixed Limestone Forest - Disturbed
3/26/13	RT 15	RT 15 2C to 3B	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.5011528	144.8834262	Mixed Limestone Forest - Disturbed
3/26/13	RT 15	RT 15 2B to 2A	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.50113528	144.8842234	Mixed Limestone Forest - Disturbed

Date	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
3/26/13	RT 15	RT 15 2B to 5B	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.49989768	144.8829712	Mixed Limestone Forest - Disturbed
3/26/13	RT 15	RT 15 5C to 5Z	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.50297502	144.8851031	Mixed Limestone Forest - Disturbed
3/26/13	RT 15	RT 15 5Z	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.50347953	144.8856662	Mixed Limestone Forest - Primary
3/26/13	RT 15	RT 15 5Z	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.5033243	144.8857555	Mixed Limestone Forest - Primary
3/26/13	RT 15	RT 15 2D to 2E	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.50411345	144.8801694	Mixed Limestone Forest - Primary
3/26/13	RT 15	RT 15 2D to 2E	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.50410188	144.8801318	Mixed Limestone Forest - Primary
3/26/13	RT 15	RT 15 2D to 2E	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.50414765	144.8801051	Mixed Limestone Forest - Primary
3/26/13	RT 15	RT 15 2D to 2E	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.50438343	144.8794168	Mixed Limestone Forest - Primary
3/26/13	RT 15	RT 15 2D to 2E	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.50455718	144.8793715	Developed
3/27/13	RT 15	RT 3B	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence; Approximate location based on vegetation location coordinates	13.50589299	144.8873739	Mixed Limestone Forest - Disturbed
3/29/13	NBGTS	FG 1B	Hostplant *Maytenus thompsonii*	4 shrubs very close proximity; no butterfly presence	13.5512133	144.8275457	Mixed Limestone Forest - Disturbed

Date	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
3/29/13	NBGTS	FG 1B	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.55125193	144.8275137	Mixed Limestone Forest - Disturbed
3/29/13	NBGTS	FG 1D	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.54767428	144.8299039	Mixed Limestone Forest - Disturbed
3/29/13	NBGTS	FG 1D to 2E	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.54659193	144.8299951	Mixed Limestone Forest - Disturbed
3/29/13	NBGTS	FG 1Z	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.54598608	144.8273928	Mixed Limestone Forest - Disturbed
3/30/13	NBGTS	FG 3B	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.57081068	144.8285415	Mixed Limestone Forest - Disturbed
3/30/13	NBGTS	HAPUTO BEACH	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.57922427	144.8320508	Mixed Limestone Forest - Primary
3/30/13	NBGTS	HAPUTO BEACH	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.57906837	144.8324432	Mixed Limestone Forest - Primary
4/2/13	AAFB-NWF	NW 3B to 3C	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.64344918	144.8624363	Mixed Limestone Forest - Secondary
4/2/13	AAFB-NWF	NW 3D	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.64622485	144.8639098	Mixed Limestone Forest - Secondary
4/2/13	AAFB-NWF	NW 3E to 3Z	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.64919288	144.8652578	Mixed Limestone Forest - Primary
4/2/13	AAFB-NWF	NW 5Z	Hostplant *Maytenus thompsonii*	1 tree; no butterfly presence	13.63643722	144.872978	Mixed Limestone Forest - Primary

Date	Area	Area Name	Candidate Species	Population Notes	Latitude (°N)	Longitude (°E)	Vegetation Class (FEIS July 2010)
4/3/13	NBGTS	FG 8D	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.57969063	144.8377857	Mixed Limestone Forest - Disturbed
4/3/13	NBGTS	FG 8C	Hostplant *Maytenus thompsonii*	2 shrubs; no butterfly presence	13.58229557	144.8377332	Mixed Limestone Forest - Disturbed
4/4/13	NBGB	BA 1B	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence; Approximate location based on vegetation location coordinates	13.47845558	144.824215	Mixed Limestone Forest - Primary
4/4/13	NBGB	BA 2B	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence; Approximate location based on vegetation location coordinates	13.47957585	144.826219	Mixed Limestone Forest - Primary
4/6/13	NBGTS	FG 10A	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence; Approximate location based on vegetation location coordinates	13.57654452	144.8510349	Mixed Limestone Forest - Disturbed
4/6/13	NBGTS	FG 10B	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence; Approximate location based on vegetation location coordinates	13.57877512	144.8514004	Mixed Limestone Forest - Disturbed
4/6/13	NBGTS	FG 11A	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence; Approximate location based on vegetation location coordinates	13.58126196	144.8548514	Mixed Limestone Forest - Disturbed
4/15/13	AAFB	AA 7A	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence; Approximate location based on vegetation location coordinates	13.58453853	144.9064224	Mixed Limestone Forest - Secondary
4/16/13	AAFB	AA 9B	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.586017	144.895817	Mixed Limestone Forest - Secondary
4/17/13	AAFB	AA 8A to 8B	Hostplant *Maytenus thompsonii*	1 shrub; no butterfly presence	13.589869	144.89788	Vitex - Closed/Sparse