Natural Resource Survey Report in Support of the Environmental Impact Statement for the Marine Corps Relocation Initiative to Various Locations on Guam

Final

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List of Acronyms and Abbreviations

AAFB	Andersen Air Force Base
ac	acre
AFB	Air Force Base
°C	Celsius
cm	centimeter
CNMI	Commonwealth of the Northern Mariana Islands
dbh	diameter at breast height
DoD	Department of Defense
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EOD	Explosive Ordnance Disposal
ERA	Ecological Reserve Area
ESA	Endangered Species Act
FAA	Federal Aviation Administration
GCWCS	Guam Comprehensive Wildlife Conservation Strategy
GDAWR	Guam Division of Aquatic and Wildlife Resources
GEDCA	Guam Economic Development and Commerce Authority
GPS	Global Positioning System
ha	hectare
HAPC	Habitat Area of Particular Concern
JGPO	Joint Guam Program Office
km	kilometer
m	meter
m^2	square meter
m/ha	meter per hectare
NAVFAC	Naval Facilities Engineering Command
NCTS	Naval Computer and Telecommunications Station
NMD	Non-metric Multidimensional Scaling
NMS	Naval Munitions Site
NR	Natural Resources
PVC	polyvinyl chloride
RH	relative humidity
sq cm	square centimeter
sq m/ha	square meter per hectare
SOGCN	Species of Greatest Conservation Need
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
VCP	variable circular plot
yr	year

1 Introduction

Under a Naval Facilities Engineering Command (NAVFAC) contract for Architect-Engineer Services for Environmental Planning to Support Strategic Forward Basing Initiatives and in support of the Marine Corps Relocation Initiative to Various Locations on Guam, the TEC Joint Venture received Task Order (TO) 0016 with subsequent modifications and TO 0007 Mod 04 for Natural Resources (NR) Surveys on Guam. The purpose of these TOs is to provide the necessary data to support the Environmental Impact Statement (EIS) for the Joint Guam Program Office actions relating to the relocation of the Marines by filling existing data gaps identified in the *Final Natural Resources Survey and Assessment Report of Guam and Certain Islands of the Northern Mariana Islands* (NAVFAC, 2007). Natural resource surveys were conducted on Department of Defense (DoD) and non-DoD lands on Guam (Figure 1-1).

This report provides a summary of the natural resource surveys performed under the TOs. The detailed survey reports developed by the TEC JV team members are found in this report's appendices.

1.1 DoD Lands and non–DoD Lands Considered

To meet the anticipated increase in personnel and to support proposed training activities, construction is planned at numerous military properties and non-DoD lands on Guam. DoD lands included the following: Andersen Air Force Base (AAFB), including AAFB Finegayan and Potts Junction; Andersen South; Air Force Barrigada; Navy Barrigada; North Finegayan; South Finegayan; Navy Main Base, including Inner Apra Harbor, Camp Covington, and Orote Point; and the Naval Munitions Site (NMS). Non-DoD lands included the Harmon Annex, Route 1 River Crossings, Route 15 Lands, Proposed Option Road A, and the former Federal Aviation Administration (FAA) Parcel. Figure 1-2 identifies the locations of these parcels on Guam.

1.2 Natural Resources Surveys

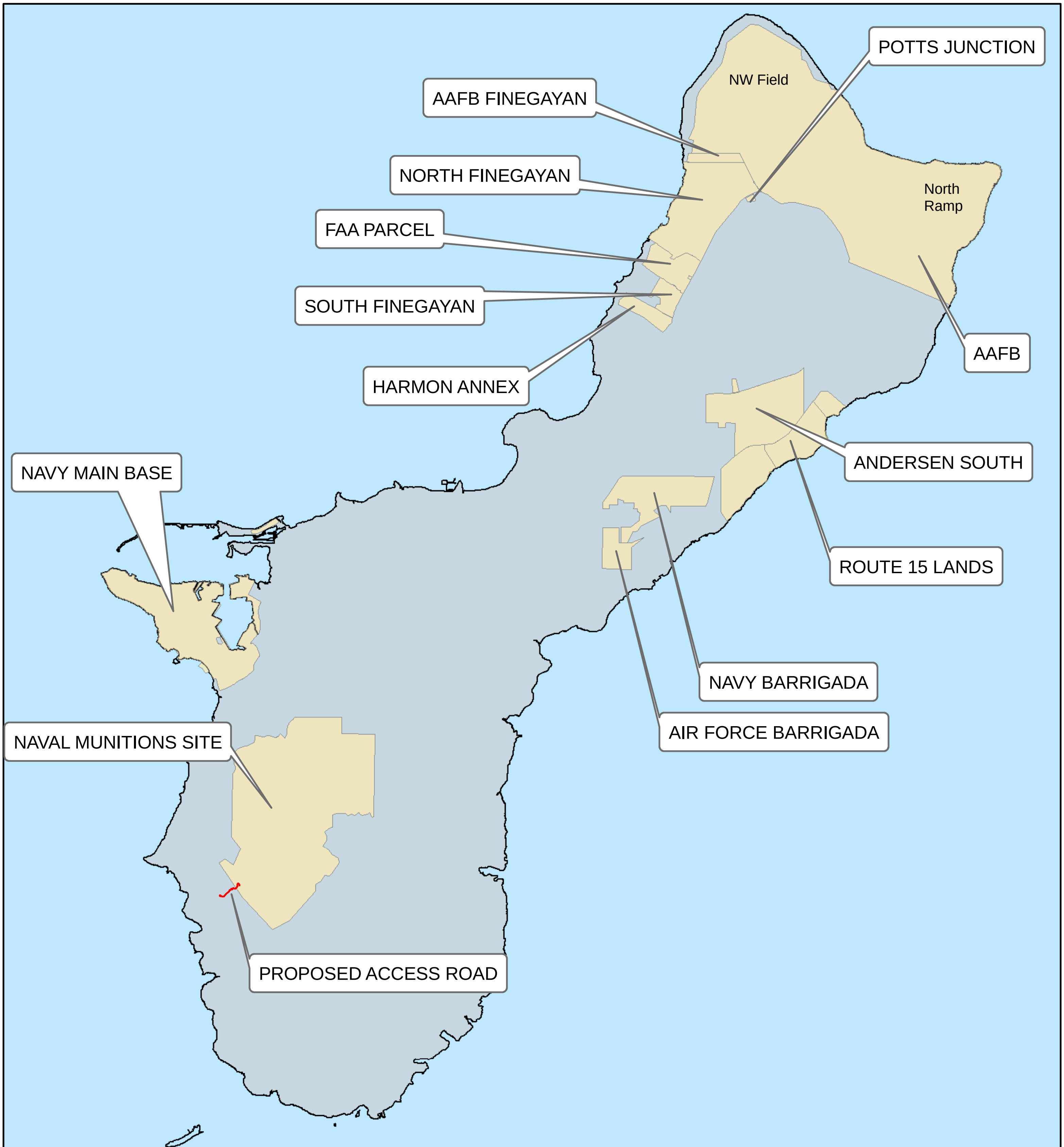
In order to assess the potential impacts to natural resources resulting from the buildup on DoD lands and non-DoD lands, a variety of natural resource surveys were conducted. These surveys included avian, butterfly, fruit bat, reptiles and amphibians (herpetofauna), marine waters, tree snail, and vegetation. Appendix A contains the descriptions of many species that were observed during the surveys. Table 1-1 identifies the surveys that were performed at each location. For each survey type a detailed technical report was prepared and these are provided in Appendices B through I.

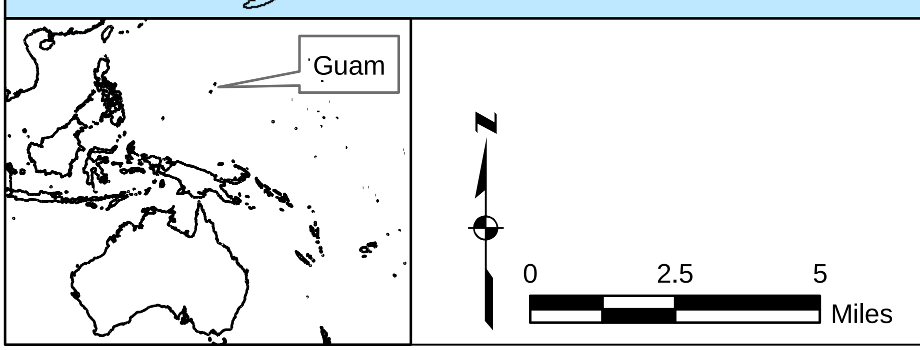
1.3 Structure of the Report

Chapter 1 is this introduction. Chapter 2 identifies the methodologies that were utilized for each survey. Survey methodologies were generally conducted in an identical manner on each parcel; although, if there was a change in methodologies, the differences are noted. Chapters 3 through 13 provide a summary of the results of the natural resources surveys that were conducted on each

Location of Guam and Northern Mariana Islands

Figure 1-1





DoD Lands & Non DoD Lands

Prepared By:

TEC Inc. Joint Venture

Prepared For:

NAVFAC

May 3, 2010	Project No.: 60133557	Figure 1-2

parcel. The detailed survey reports provided by the project team are found in Appendices B through I.

Table 1-1

Natural Resources Surveys Conducted on Each Parcel

Property	Survey						
	Avian	Butterfly	Fruit Bat	Herpeto-fauna	Marine	Tree Snail	Vegetation
Air Force							
Andersen AFB	√	√		√		√	
AAFB Finegayan	√			√			√
Potts Junction	√						√
Andersen South	√	√		√		√	√
Air Force Barrigada	√	√		√			√
Navy							
Main Base							
Inner Apra Harbor					√		
Oscar and Papa Wharves					√		
Polaris Point	√			√	√		√
Camp Covington Wetlands	√						
Orote Point	√			√			√
NMS	√			√		√	√
NORTH Finegayan	√			√		√	√
South Finegayan	√			√			√
Navy Barrigada							
Non-DoD							
NMS Proposed Access Road Option A	√			√		√	√
Former FAA Parcel	√			√		√	√
Route 15 Lands*	√		√	√		√	√
Route 1 Crossings	√			√		√	√
Harmon Annex**							

Notes: *Route 15 Valley not surveyed due to access issues.
** The Harmon Annex was not surveyed as similar habitat exists on nearby parcels.

2 Methods

In order to support the EIS analysis, a field program was conducted to collect necessary data not available through past studies. The field program gathered data on vegetation, herpetofauna, avifauna, tree snails, butterflies, fruit bats, and marine species occurring within specified DoD and non-DoD lands.

The field program was originally proposed in the Guam Natural Resource Surveys Draft Sampling Plan (AECOM, 2007) and finalized in the *Guam Natural Resource Surveys Pre-Final Sampling Plan, Revision 1* (AECOM, 2008) based on Navy comments. Field surveys for fruit bats and butterflies were performed using protocols approved by the Navy and not incorporated in the sampling plan. Field studies commenced following the approval of this document.

The data collected as part of the field program will be included in the EIS to assist in the assessment of potential impacts to the following: federally threatened, endangered, and candidate species and their habitats; species of biological or cultural significance; and to terrestrial and aquatic habitats from the development of infrastructure for proposed basing and training facilities.

A key component of the field effort was to survey several terrestrial transects on each property. Table 2-1 shows the number and length of transects that were surveyed on each parcel. The transects were placed within each parcel to provide representative converge of the various habitats and natural resources surveyed. The length of each individual transect is identified in Table 2-1 and within the various natural resource survey reports provided in the appendices.

2.1 Herpetofauna

Two separate efforts documented herpetofauna on DoD and non-DoD parcels. One effort, completed by the TEC JV biologists surveyed herpetofauna on ten parcels. The other effort, which was completed by NAVFAC Pacific biologists, surveyed herpetofauna on three parcels. A description of the methods used for each effort is provided in Subchapters 2.1.1 and 2.1.2.

2.1.1 Herptofauna Survey - Andersen AFB; Andersen South; Navy Barrigada; FAA Property; NMS; North Finegayan; Orote Point; RT15 Lands; South Finegayan; and Proposed Access Road Option A

Herpetological surveys were conducted between the February 17, 2008 and October 21, 2009 on the following locations: AAFB; Andersen South; Navy Barrigada; FAA Property; NMS; North Finegayan; Orote Point; RT15 Lands; South Finegayan; and Proposed Access Road Option A. The surveys were conducted on the 10 parcels and 53 transects. The surveys were conducted nocturnally (targeting gecko species) and diurnally (targeting skink species) to increase the possibility of encountering as many species as possible within appropriate habitats along survey transects within each parcel. Multiple transects were established to survey each parcel's habitats (e.g., forest, grassland, etc.). The surveys were performed by up to three biologists on each transect utilizing both glue-board and visual surveys, as described below. The herpetofauna survey reports that further details the methods are located in Appendix B**.**

Table 2-1

Number and Length of Terrestrial Survey Transects for Each Parcel

Site	Number of Transects	Total Transect Length (m)	Length of Individual Transects
DoD Parcels			
Andersen AFB	7	2,100	Transect 1 is approx. 183 m in length. Transects 2 and 3 are 305 m in length. Transect 4 is approx. 427 m in length. Transects 5, 6, and 7 are 400 m in length.
Andersen South	7	1,150	Transects 1 – 6 are 152 m in length. Transect 7 is 500 m in length.
Air Force Barrigada	3	550*	Transect is Approximately 5050 m in length
Main Base - Orote Point	4	375	Transects 1 and 2 are 76 m long. Transects 3 and 4 are 152 m long.
Main Base – Polaris Point	2	650*	East Transect is approximately 400 m in length. West East is approximately 250 m in length
Main Base – Camp Covington Wetlands	1	1,700*	Transect is 1,700 m in length.
NMS	11	3,795	Transect 1 is approximately 1,000 m in length. All other transect are approximately 137 m long.
Navy Barrigada	3	550	Transects 1 and 2 are 152 m in length. Transect 3 is 250 m in length.
North Finegayan	9	1,700	Transects 1-8 are 133 m in length. Transect 9 is approximately 516 m in length
South Finegayan	2	150	Transects 1 and 2 are 76 m in length
Non-DoD Parcels			
Former FAA Parcel	3	450	Transects 1 -3 are 152 m in length.
Route 15 Lands	3	1,300	Transect 1 is approximately 250 m in length. Transect 2 is approximately 550 m in length. Transect 3 is approximately 500 m in length.
Route 15 Valley**	1	500	Transect is 500 m in length
AAFB Finegayan	2	1,000	Transects are 500 m in length
NMS Proposed Access Road	No formal transects were utilized for this parcel. Surveys occurred within discontinuous forested areas.		
Notes: * Length approximated. ** Parcel not surveyed due to access issues.			

2.1.1.1 Glue-Board Surveys

Glue-board surveys were conducted to capture small, cryptic species that may be more difficult to identify from a brief encounter during a visual survey. Size of the animal, placement of the trap, habitat type, and weather all have varying effects on the probability of capturing reptiles using glue boards. On each transect, two “mouse” glue boards were set at 15 meter (m) intervals, one on the ground and one in a nearby tree; if a tree was not available, only a ground trap was used at that particular station. All glue boards were set in the shade adjacent to and approximately 1 m from the transect. If rain was heavy or persistent, trapping was aborted.

The times at which traps were set, checked, and removed on each transect were recorded. During diurnal glue-board surveys, traps were checked no more than four hours from opening, but were usually checked after two hours. If mortality rates were greater than 15 percent, traps were repositioned to a more protected location to reduce mortality. During nocturnal glue-board surveys, traps were left open for no more than 14 hours unless mortality rates were greater than 20 percent, in which case traps were closed earlier. The aim was to maintain mortality rates below 10 percent.

When checking traps, personnel returned to the beginning of the transect without disturbing the transect. Traps were checked in the same order as they were set. Humane removal of individuals from glue boards was imperative. When removed, animals were released slowly from the boards so that the glue released with minimal strain. If for some reason the glue was less yielding, a thin line of vegetable oil was applied to the attachment location.

2.1.1.2 Visual Surveys

Visual surveys were performed to identify species that might not be captured on a glue board. Visual surveys were conducted both nocturnally and diurnally. Day surveys commenced between 0800 and 1000 hours and night surveys between 1830 and 2030 hours. Search speed was set at approximately 0.5 kilometers per hour. All visual surveys were conducted by two trained biologists simultaneously, each assigned to opposite sides of a transect. If the transect was too narrow, searchers were staggered, but not further apart than 4 m.

When a species was encountered, the time, location along the transect, species, rain, and perch information were all recorded. Any unidentified individuals were captured where possible to aid in identification. In some instances, photographs were taken to verify identification and to document interesting occurrences.

2.1.2 Herptofauna Survey - AAFB Finegayan, Air Force Barrigada, and Polaris Point

Herpetofauna surveys were conducted by NAVFAC Pacific biologists on AAFB Finegayan, North Finegayan, Air Force Barrigada, and Polaris Point between August and November 2008.

Reptiles and amphibians were sampled by visual surveys on transects and glue board, trapping on the same transects. Visual surveys were performed during the morning and evening hours. Adhesive traps were placed every 15 m on the transect up to 15 traps. One trap was placed on the ground and one was stapled to the nearest tree at approximately breast height. Ground traps were placed between 0800 am and 0900 am and left out for four hours. Tree traps were placed at the same time but left overnight. Tree traps were checked in the late afternoon so that lizards could be removed before nightfall. For more information regarding this survey, refer to Appendix C.

2.2 Vegetation

Qualitative and quantitative vegetation surveys were conducted on DoD and non-DoD parcels. Descriptions of the surveys are provided below. The vegetation survey reports that further detail the methods of the surveys, the dates each parcel was surveyed, etc., are located in Appendix D.

2.2.1 Qualitative Surveys

General walk-over surveys (qualitative) were conducted from July 7 to July 9, 2009 and December 9, 2009 to January 20, 2009 at the following parcels:

- AAFB (the specific task was to document the presence of host plants for butterfly species that are candidates for listing under the Endangered Species Act (ESA).
- North Finegayan, NMS Almagosa Basin, and the proposed NMS Proposed Access Road.
- Route 15 upper plateau lands (Firing Range Option A lands being considered in the EIS).

Surveys consisted of walking transect lines in areas where the identities of specific vegetation communities were uncertain, where edges of certain mapped community types were uncertain, or in areas where specific activities are proposed (e.g., the proposed Access Road Option A and Andersen AFB, where new utility lines are proposed).

Plants specifically searched for are Federal- or Guam-listed species or are those identified in the Guam Comprehensive Wildlife Conservation Strategy as species of greatest conservation concern (GDAWR 2006). Also searched for were host plants for ESA-candidate butterfly species. Plant names referred to in the text are based on Raulerson (2006).

2.2.2 Quantitative Surveys

Two separate efforts documented herpetofauna on DoD and non-DoD parcels. One effort, completed by Navy contractor biologists, surveyed herpetofauna on ten parcels. The other effort, which was completed by NAVFAC Pacific biologists, surveyed herpetofauna on three parcels. A description of the methods used for each effort is provided in Subchapters 2.2.2.1 and 2.2.2.2.

2.2.2.1 Vegetation Survey - Andersen AFB; Andersen South; Navy Barrigada; FAA Property; NMS; North Finegayan; Orote Point; RT15 Lands; South Finegayan; and Proposed Access Road Option A

The goal of the quantitative vegetation surveys is to locate Federal- or Guam-listed species or ones identified in the Guam Comprehensive Wildlife Conservation Strategy as species of conservation concern and to characterize the habitat types through a visual walk and conducting a point-quarter survey over the entire length of each transect. Vegetation surveys were conducted using the following methods:

- Quantitative surveys were performed along several transects within each parcel. Along each transect, stations were placed at a minimum of every 50 m to identify species. At each station, quarter plots were placed, and the tree that was greater than 2 centimeters diameter at breast height (cm dbh) closest to the transect in each quarter was measured at dbh.

- Within a 5-m radius around the station plot, the presence or absence of ungulate sign (deer and pigs) was noted and vegetation was counted and identified to species for tree seedlings that were smaller than 2cm dbh.

- Ground cover was assessed with a 50-cm by 50-cm polyvinyl chloride (PVC) square grid or quadrat frame. At each station the frame was dropped in one of the cardinal directions approximately 1 m from the station center. The types of ground cover recorded were litter (dead vegetation), rock, bare soil, or live vegetation.

- All observations were recorded in a field log book or on data sheets.

Quantitative surveys were performed by Navy Contractor biologists during February, March, and April of 2008.

2.2.2.2 Vegetation Survey - AAFB Finegayan, Air Force Barrigada, and Polaris Point

In addition, vegetation surveys were conducted by NAVFAC Pacific biologists on AAFB Finegayan, Air Force Barrigada, and Polaris Point between August and November, 2008. The results of those surveys are provided in Appendix C.

2.3 Butterfly Surveys

From September 28 to October 2, 2009 and January 25 to 31, 2010, butterfly surveys were conducted on three transects at Andersen AFB, one transect on Andersen South, and one transect on Air Force Barrigada. The butterfly survey consisted of two methods: timed counts and baited traps. Descriptions of these methods are provided in the sections below. A butterfly survey report is provided in Appendix (E).

2.3.1 Timed Counts

Timed counts were conducted along linear transects within each of the three parcels. At 30-m intervals, two biologists stood back-to-back and enumerated the 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.

2.3.2 Baited Traps

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 (Photo 2-1). At the end of the trapping period, which lasted approximately six hours, the traps were checked, and captured butterflies were noted and then released.

Photo 2-1 A baited butterfly trap hanging on a survey transect.

2.4 Marine Surveys

Inner Apra Harbor is a natural embayment formed by tectonic activity along the Cabras Fault. Apra Harbor is a deep-water lagoon bounded on the north by Cabras Island and the long, curving Glass Breakwater. Two rivers — the Apalacha and Atantano — drain the volcanic mountain land to the east of Apra Harbor and empty into the inner harbor (Randall and Holloman, 1974). Although naturally formed, Inner Apra Harbor has been extensively modified by dredging, construction, and fill by the U.S. Navy since 1945 (Paulay et al., 2001). The inner harbor was dredged, changing the southernmost part of the original lagoon from a reef-choked, silty embayment into a harbor with a nearly uniform depth and mud bottom.

2.4.1 Marine Fauna and Flora Survey – Inner Apra Harbor

The specific objectives of the marine surveys were the following:

- Quantitative assessments of corals.
- Quantitative assessment of select macro-invertebrates.
- Fish census.
- Assessment of essential fish habitat (EFH).
- Assessment of endangered species (including federally listed, proposed for listing, and candidate species, as well as those similarly listed or otherwise recognized by Guam) to include abundance and preferred habitat, if any.

- A subjective evaluation of survey areas using the four criteria for Habitat Areas of Particular Concern (HAPCs):
    1. The ecological function provided by the habitat is significant.
    2. The habitat is sensitive to human-induced environmental degradation.
    3. Development activities are, or will be, stressing the habitat type.
    4. The habitat is rare.

Survey methods are summarized below and further details can be found in the marine survey report in Appendix F. Three separate marine survey efforts were conducted: Inner Apra Harbor; Oscar and Papa Wharves; and Polaris Point. Studies of the Inner Harbor occurred between May 21 and May 29, 2008. Marine surveys of Oscar and Papa Wharves occurred in March 2010. The methods for each effort are described in the following subchapters.

The general ecological condition of an approximately 145 ha area was assessed by a modified manta tow method. Two observers were towed behind a boat piloted along the 6,188-m boundary of the study area. Visibility was limited to less than 5 m because of high turbidity of the water. The locations and general surface coverage of corals were noted by the observers. Based upon these observations, three sites (Abo Cove, Transect 1, and Transect 2) were selected for benthic surveys, and five sites (Wharves S, T, U, V, and X) were selected for surveys of vertical wharf faces. A 100-m transect line was established along the 2-m isobath at Abo Cove. For Transects 1 and 2, in open areas of the harbor floor away from wharves or the shoreline, a global positioning system (GPS) tracking unit in a waterproof housing was towed by a diver swimming along the harbor floor. Lengths of the tracks were calculated with SigmaScan Pro 5.0 (SPSS, Inc., 1999). At Wharves S, V, and X, 100-m transects were established. At Wharves T and U, 50-m transects were established, because access to larger wharf areas was not granted. GPS coordinates were recorded for the ends of all transects.

Both Oscar and Papa Wharves are obstructed by large shipyard facilities that limited access to wharf faces. During the survey period, two large crane barges were moored at Oscar Wharf while a large dry dock occupies virtually all of Papa Wharf's main face. Therefore, transect lengths were limited to a 50-m stretch of wharf face at Oscar Wharf and a 50-m stretch of wharf face at the back of Papa Wharf where this wharf s with Romeo Wharf. GPS coordinates were recorded for transect locations at each wharf.

Benthic Cover - Benthic quadrats were surveyed along transects established for coral, invertebrate, and fish surveys. Six transects, each 50 m long, were established at a fixed depth (3–5 m) throughout Inner Apra Harbor. The percentage cover of algae, corals, and sponges in five 0.25-square meter (m^2) quadrats was quantified *in situ* for each transect. Macrophotographs of the representative species were taken. Voucher specimens of algae were collected to establish a reference collection of algae from Inner Apra Harbor. *In situ* cover estimates of turf algae were troubled by poor visibility and, therefore, removed from the data set prior to analysis.

Corals - Coral communities were assessed quantitatively along the transects by an observer using the point-quarter method of Cottam et al. (1953). Points were established 3 to 10 m apart on each transect. Each point served as a focus of four equal-sized quadrants arrayed around the point. Within each quadrant, the coral closest to the central point was located. This coral's identity, distance from the point, length, and width were recorded. If no corals lay within 1 m of the point, that quadrant was recorded as having no corals.

Macroinvertebrates – All conspicuous solitary epibenthic macroinvertebrates occurring within 1 m of either side of the transect lines at Abo Cove and Wharves S, T, U, V, and X were identified and enumerated by an observer swimming along the transect line. For this study, conspicuous is defined as being larger than 50 millimeters (mm) in size and as being clearly visible to an observer without the need for overturning rocks or digging into the substrate. Cryptic, microscopic, nocturnal, and highly motile species that avoid humans (e.g., crabs and shrimps) were not included within the scope of this study. Species diversity and abundance were recorded in 10-m intervals along the transect line.

Fishes – Fish were surveyed visually along transect lines. Observations were constrained by poor visibility and all species had to be counted on a single pass along the transect line. At Abo Cove, the line was deployed along the bottom as the diver observed and counted fishes. Along wharf faces, three transects were run (where possible): just below the surface (subsurface), at mid-depth (the principal transect line), and at the bottom of the wharf wall. All fishes observed 0.5 m above or below the principal transect line were counted on subsurface and mid-depth transects; at the bottom, all fishes observed 1 m to the seaward side (away from the wharf face) of the transect line were counted.

At two stations located in open areas of the harbor away from wharves or the shoreline, GPS tracking was used to census fishes. Here, one diver utilized a GPS unit set on timed-tracking mode and towed above him in a waterproof housing and recorded all benthic species observed within 1 m to either side of an imaginary line directly in front of the diver (Colin and Donaldson, in review). Observations were recorded during the course of the swim just above the bottom substrate. Pelagic species could not be observed because of poor visibility. Fishes were identified to species. Reference photographs and video were taken with an underwater digital camera or underwater digital video camera, but image quality tended to be extremely poor because of turbid conditions.

EFH - Extremely poor visibility on transects at all stations limited the ability to collect data on EFH. Underwater photographs taken along the transect line to estimate benthic structure used by different species were essentially useless. Similarly, measures of rugosity (benthic structural complexity), limited to the edge of a shallow reef at Abo Cove, were made under near-zero visibility and were fraught with error. Therefore, it was possible only to make qualitative descriptions of habitats used by fishes.

2.5 Avian Surveys

Four surveys were conducted during 2008, during the following periods: February 16-25; March 27 - April 6; June 24-28; and December 9-19. In 2009, additional surveys were conducted during July 16-19 and September 21-24. Both roadside and forest bird surveys were utilized to characterize avian communities at various sites. The avifauna survey report that further details the methods of the surveys is located in Appendix G.

In addition, surveys were conducted by NAVFAC Pacific biologists on AAFB Finegayan, Air Force Barrigada and Polaris Point between August and November 2008 (Appendix C).

2.5.1 Roadside Survey

A modified point-count methodology, in conjunction with a line transect (i.e., existing roadways) was used to enumerate bird detections (Bibby et al., 2000) for the roadside surveys. Total numbers of species detections (no direction or distance data were collected) were recorded (either by visual observations or song, or both) within one 3-minute survey period at each pre-determined station; no surveys were replicated. In order to minimize double-counting, survey stations were positioned a minimum of 150 m apart. All surveys were conducted either during the morning from sunrise to 1000 hours, or in the evening after 1700 hours.

For the Air Force Barrigada, AAFB Finegayan, and Polaris Point parcels, the roadside bird surveys methodologies varied from the avian surveys conducted on other parcels. Because the sites varied in size, the avian surveys consisted of a point count survey along each transect (count stations every 100 m on the transect) and/or, depending on the site, a roadside breeding bird type survey. Surveys started between 0600 and 0700 hours and were completed by 1100 hours. Due to the small size of the areas surveyed the number of stations at each site was fewer than 10. For the breeding bird surveys avian identification was performed along roadside survey routes. Each survey route utilized available Base roadways in areas planned for development. Sampling locations (i.e., stops) were at approximately 500-m intervals. At each stop, an 8-minute point count was conducted. During the count, every bird seen within a 0.25-mile radius or heard was recorded.

2.5.2 Forest Bird Survey

In forested habitat, bird detections were enumerated using a point-count methodology along variable-length straight-line transects (Bibby et al., 2000). Survey stations were placed a minimum of 150 m apart so as to minimize double-counting. All bird species were recorded (by either visual observations or song, or both) within one 8-minute survey. All station surveys were conducted during the morning hours from sunrise to 1000 hours. As in the roadside surveys, no surveys were replicated. Although direction and distance measurements were recorded, only relative abundance among species will be discussed.

For the Air Force Barrigada, AAFB Finegayan, and Polaris Point the forest bird surveys methodologies, varied from the avian surveys conducted on other parcels. Forest birds were surveyed using the variable circular plot (VCP) method (Scott et al. 1986). All birds seen or heard during an 8-minute count period at each station were recorded with the detection type (audio, visual, or combined detection) and the distance to the bird when first detected, estimated to the nearest meter. Observations between stations were not recorded.

2.5.3 Endangered Avian Species

Although all avian surveys recorded any ESA-listed, Guam-listed, or other species of concern, two species warranted specific survey efforts.

Mariana Swiftlet (*Aerodramus bartschi*)

During the station-count surveys for Mariana fruit bats, observers also searched for the ESA- and Guam-listed endangered Mariana swiftlet. Searches were used to determine whether this species utilized the areas for foraging, movement between foraging areas, and roosting or nesting. In addition to noting the occurrence of the swiftlets (if they occurred), all avian species heard or observed were recorded during fruit bat station-count surveys.

Mariana Common Moorhen (*Gallinula chloropus guami*)

The Camp Covington wetland on Navy Main Base was identified as a habitat requiring species-specific surveys to determine whether the ESA-listed endangered Mariana common moorhen was present. Eleven listening stations were strategically positioned around the wetland habitat. Surveys were conducted during the morning hours from sunrise to 1000 hours. Survey stations were placed a minimum of 150 m apart so as to minimize double-counting. All moorhen detections (visual or auditory) were recorded within one 8-minute survey; no surveys were replicated.

2.6 Tree Snail Surveys

Surveys for partulid tree snails were designed to locate, identify, and assess the distribution and abundance of partulid tree snails on DoD and non-DoD lands proposed for use under the EIS. Tree snail surveys occurred in 2008 and September, October, and December, 2009, and in January, 2010. Surveys targeted four species of partulid tree snail (Gastropoda: Partulidae):

- Fat Guam Partula tree snail (*Partula gibba*)
- Guam or Pacific tree snail (*Partula radiolata*)
- Mt. Alifan tree snail (*Partula salifana*)
- Fragile tree snail (*Samoana fragilis*)

Three of these tree snails (humped tree snail, Guam tree snail, and fragile tree snail) are federal candidate species for listing under the ESA (U.S. Fish and Wildlife Service [USFWS], 2010). The Government of Guam lists all four species as endangered (Guam Department of Aquatic and Wildlife Resources [GDAWR], 2006).

2.6.1 Locations

Tree-snail surveys were carried out along select transects situated at nine locations on Guam: AAFB, Andersen South, Air Force Barrigada, Former FAA parcel, Route 15 Lands, North Finegayan, South Finegayan, NMS, and Proposed Access Road Option Road A. To increase the possibility of detecting the four target species, transects were set up within habitat containing known host plants known to be used by partulid tree snails.

2.6.2 Methods

Three survey methods were used to determine the presence of tree snails at each survey location: general visual surveys, detailed visual surveys, and quadrat surveys. These methods are specifically designed to target partulid tree snails and are adapted from those utilized in previous tree snail assessments (Hopper and Smith, 1992; Smith et al., 2008). A description of each method follows.

- **General visual surveys -** General visual surveys involved up to two trained observers walking each transect searching likely tree snail habitat for the presence of snails. During the general visual survey period, observers also noted specific areas that included an abundance of known partulid host plants, and areas where detailed visual surveys would subsequently occur. Information on known partulid host plant species was obtained from Hopper and Smith (1992). Host species for the tree snails are identified as the following: *Alocasia macrorrhiza, Annona reticulata, Asplenium nidus, Barringtonia asiatica, Cocos nucifera, Cycas micronesica, Derris trifoliata, Hernandia nymphaeifolia, , Intsia bijuga, Mammea odorata, Neisosperma oppositifolia, Phymatodes scolopendria, Pandanus dubius, Piper guamensis,* and *Triphasia trifolia*

- **Detailed visual surveys** – These were conducted at locations along each transect where known partulid host plants were abundant. At each location, observers intensively examined the leaves and stems of known partulid host plants for up to 30 minutes. If live tree snails were observed, quadrat surveys (see below) were completed. Following each plant examination, leaf litter was investigated for partulid shells for up to 10 minutes. If snail shells were observed, the location and condition of the shell (e.g., weathering, fragmentation, color intensity or bleaching) that may indicate recent presence of the snails were noted. If live partulid tree snails or their empty shells were found during the detailed visual survey period, the location was recorded as supporting tree snails.

- **Quadrat surveys -** If live partulid tree snails were located within the 30-minute detailed visual survey period, four 25-m^2 quadrats were established under the densest understory, as determined by a spherical densitometer. All partulid tree snails occurring within the quadrats and to a height of 2 m were identified to species, and their shell length and height measured to the nearest 0.1 mm with sliding vernier calipers. Host plant species and vertical height of the host plant to 0.5 m were recorded for each partulid tree snail observed.

During the quadrat surveys, temperature (in degrees Celsius [°C]), relative humidity (RH), and air movement (by the Beaufort scale) were measured with miniature probes in microhabitats inhabited by partulid tree snails to quantify inhabited microhabitat features (Crampton, 1925). Temperature, humidity, and air-movement measurements were also taken in uninhabited areas to assess their suitability for supporting tree snail populations. Comparisons of data from inhabited and uninhabited forest will provide a clearer characterization of suitable microclimatic conditions suitable for tree snail survival. The tree-snail survey report that further details the methods of the surveys is located in Appendix H.

2.7 Fruit Bat Surveys

2.7.1 Survey Locations

Mariana fruit bat surveys were conducted from locations positioned in forest areas containing known Mariana fruit-bat roosting and foraging vegetation. The survey locations were situated on the east side of Route 15 in the northeast region of Guam, stretching from the Lumuna area through the Asdonlucas area south to Pagat Point. In addition NAVFAC Biologists performed surveys on North Finegayan, Orote Point and Navy Barrigada (NAVFAC, 2008). These locations were not associated with any of the designated transects used for vegetation, bird, tree snail, or herpetological surveys.

2.7.2 Methods

Station-count surveys (Utzurrum et al., 2003) were conducted to determine the presence of solitary Mariana fruit bats, locate aggregations or colonies, and assess the location of fruit bat flight paths. Surveys were carried out between 0510 and 0745 hours. Each location was surveyed four times, twice each by two trained observers. The survey locations were chosen as vantage points that provided wide and unimpeded views of potential fruit-bat habitat and flight paths. Binoculars and a spotting scope were used to detect and count fruit bats at each location.

While carrying out station-count surveys for Mariana fruit bats, the observers collected anecdotal observational data on the phenological phases (flowering and fruiting) of plants, focusing on species that may be used as food sources by Mariana fruit bats. The fruit bat survey report, which includes details of the survey methods, is provided in Appendix I.

2.8 River Crossing Investigations

Investigations occurred at the crossings of five rivers that flow under Marine Corps Drive (Route 1). All of the rivers empty into the shallow bays of Guam's western coast and ultimately the Philippine Sea. At these five crossings, the bridges require modification as some do not meet current load requirements and all are not rated for Anti-Ballistic Missile (ABM) transport. These study areas for the river crossings included terrestrial and aquatic habitats 30.5 m upstream and downstream of the bridges. The riverine habitats were also identified through snorkel surveys, in which the benthic substrate, fish, and floral populations were noted. Also, avian surveys were performed in the vicinity of the bridge locations.

3 Andersen AFB

Herpetofauna, butterfly, vegetation, avian, and tree snail surveys were conducted on Andersen AFB (AAFB). Three study areas comprise the main portion of Andersen AFB: Northwest Field, North Ramp, and the proposed utility corridors along Route 9. The locations of the transects in these three areas are shown on Figures 3-1, 3-2, and 3-3, respectively.

At AAFB, seven transects were surveyed. Two transects were set in degraded forest in the North Ramp area (Figure 3-1), with the shrub *Wickstroemia elliptica* being the dominant species, but also containing *Morinda citrifolia* and *Hibiscus tiliaceus* trees. Two transects (Figure 3-2) were located in the Northwest Field Area in native limestone forest habitat predominated by *Guamia mariannae, Aglaia mariannensis, Premna obtusifolia, Neisosperma oppositifolia*, and *Pandanus tectorius* trees. The final three transects were located within the southern portion of the facility at proposed utility corridors near the base boundary with Route 9 (hereafter referred to as the Route 9 Boundary Transects) (Figure 3-3).

Herpetofauna, vegetation, and avian surveys were also conducted on two other parcels associated with the AAFB. These parcels are AAFB Finegayan and Potts Junction (Figure 3-4).

3.1 Herpetofauna Surveys

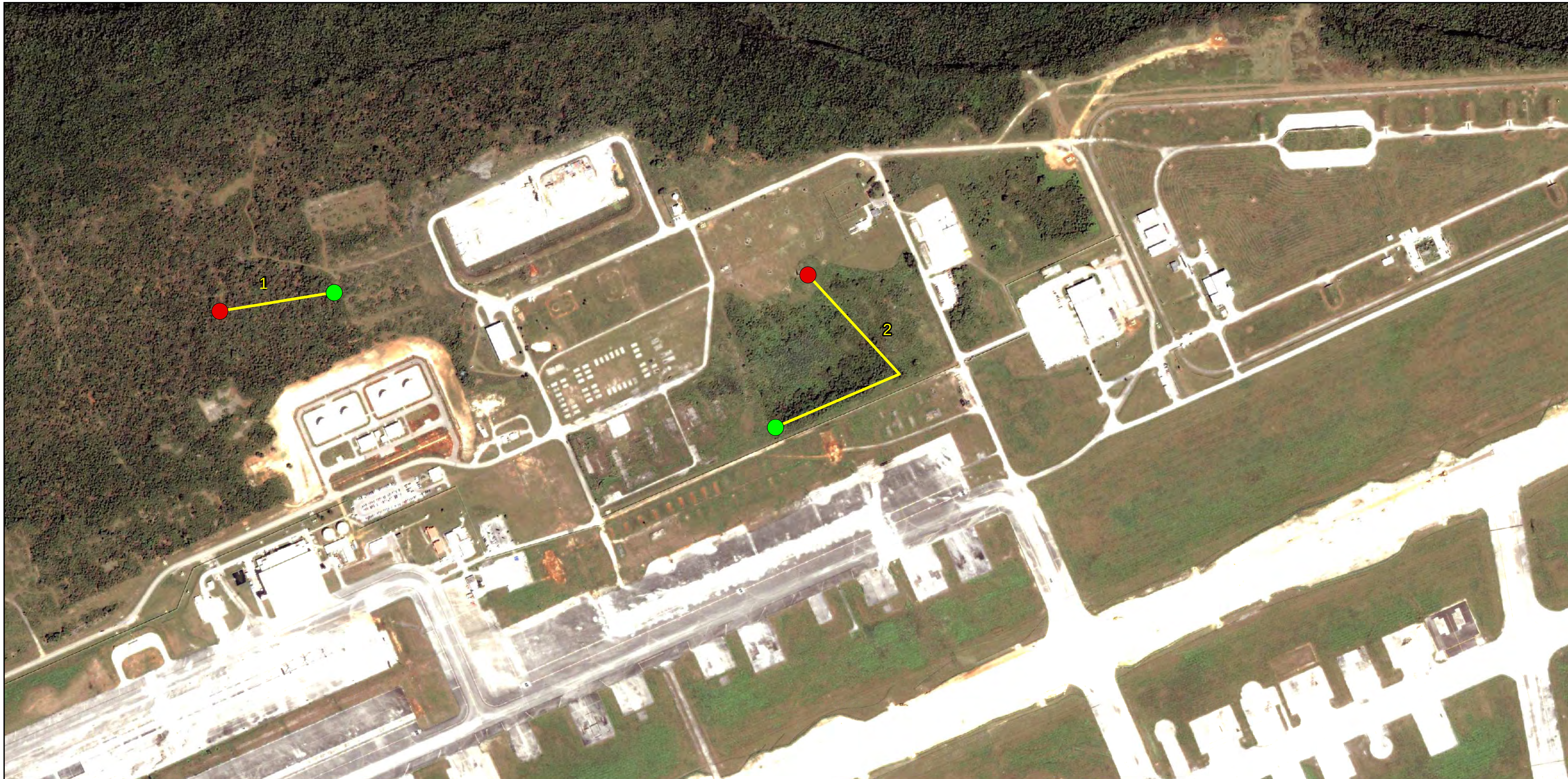
Two survey efforts identified herptofauna associated within the select areas of AAFB. Subchapter 3.1.1 identifies herptofauna observed within the Northwest Field, North Ramp, and proposed utility corridors along Route 9. Subchapter 3.1.2 identifies herptofauna observed within AAFB Finegayan.

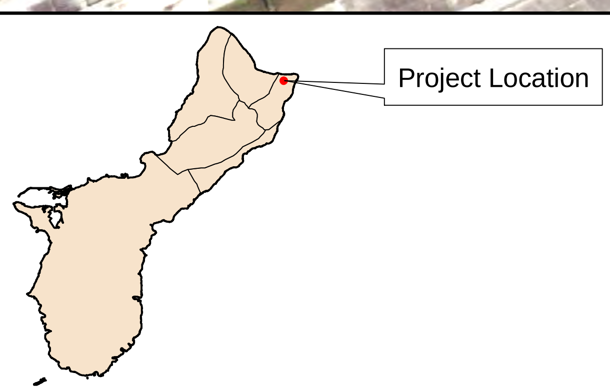
3.1.1 Herpetofauna – Northwest Field, North Ramp, and Proposed Utility Corridors

Nine herpetofauna species were captured or observed on AAFB. Table 3-1 identifies the species and their status. For more information on the herpetofauna survey and results, please refer to Appendix B.

The capture of moth skink (Photo 3-1), a Guam-listed endangered species, at AAFB is noteworthy. The distribution and abundance of this native skink on Guam is unknown, due to the variability of information presented by authors. The skink was captured on Transect 7, Station 16.

The continued widespread presence of the curious skink and the brown treesnake, as well as other introduced amphibian species, is of concern because of each species' potentially deleterious impacts to Guam's native fauna (Rodda et al., 1999, Kraus et al., 1999, Wiles et al., 2003, Christy et al., 2007a). Of particular concern is the potential of the other introduced species to serve as additional food sources for the brown treesnake (Fritts and Rodda, 1998, Christy et al., 2007a).





Beginning Transect Point

End Transect Point

Transect Lines

N

0 200 400 Feet

0 200 400 Meters

Andersen AFB North Ramp

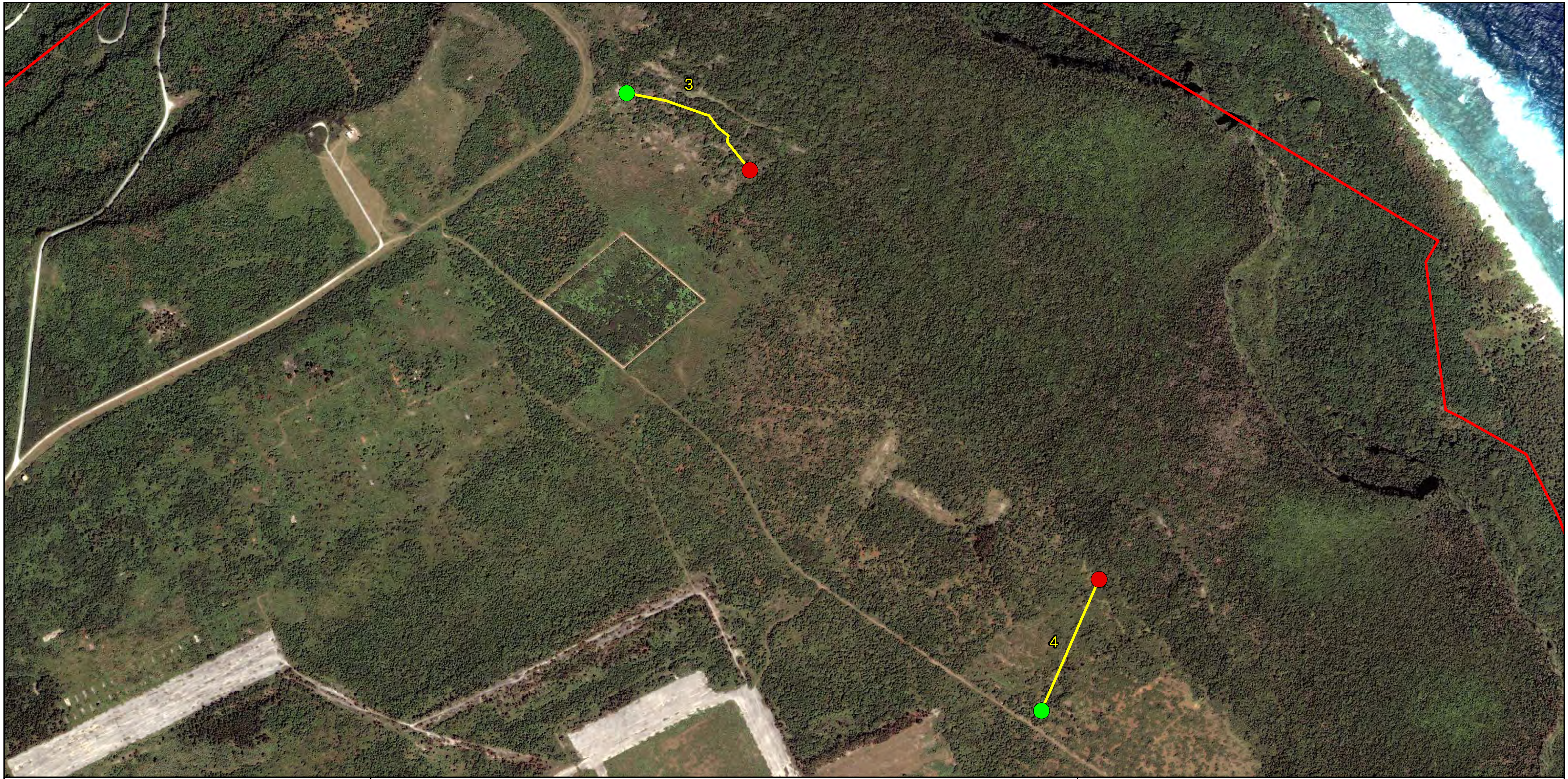
Transect Map

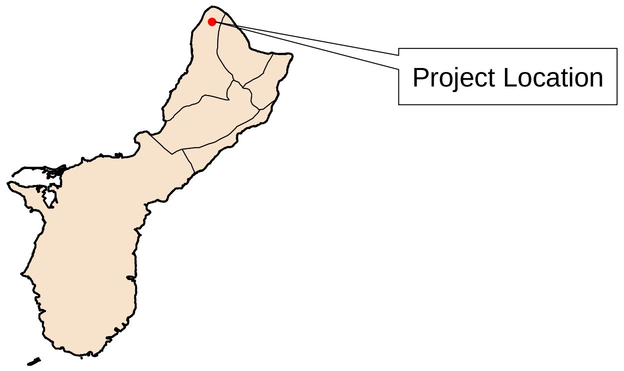
Prepared By: TEC Inc. Joint Venture

A Joint Venture of TEC Inc., AECOM TS Inc., and EDAW, Inc.

Prepared For: NAVFAC Naval Facilities Engineering Command NAVFAC PACIFIC

May 3, 2010	Project No.: 60133557	Exhibit 3-1





Beginning Transect Point

End Transect Point

Transect Lines

Installation Boundary

N

0 200 400 Meters

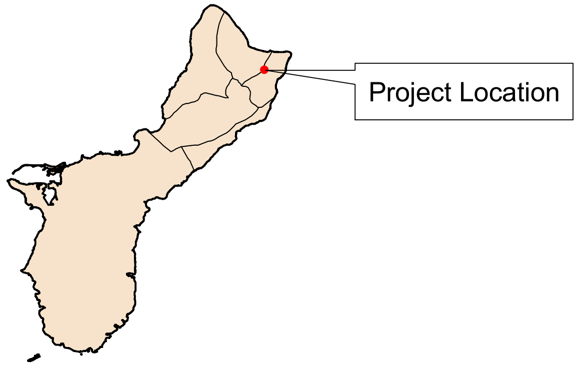
Andersen AFB Northwest Field

Transect Map

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC Naval Facilities Engineering Command

May 3, 2010	Project No.: 60133557	Figure 3-2



Beginning Transect Point

End Transect Point

Transect Lines

Installation Boundary

N

0 200 400

Meters

Andersen AFB - Utility Corridors

Transect Map

Prepared By:

TEC Inc. Joint Venture

A Joint Venture of TEC Inc., AECOM TS Inc., and EDAW, Inc.

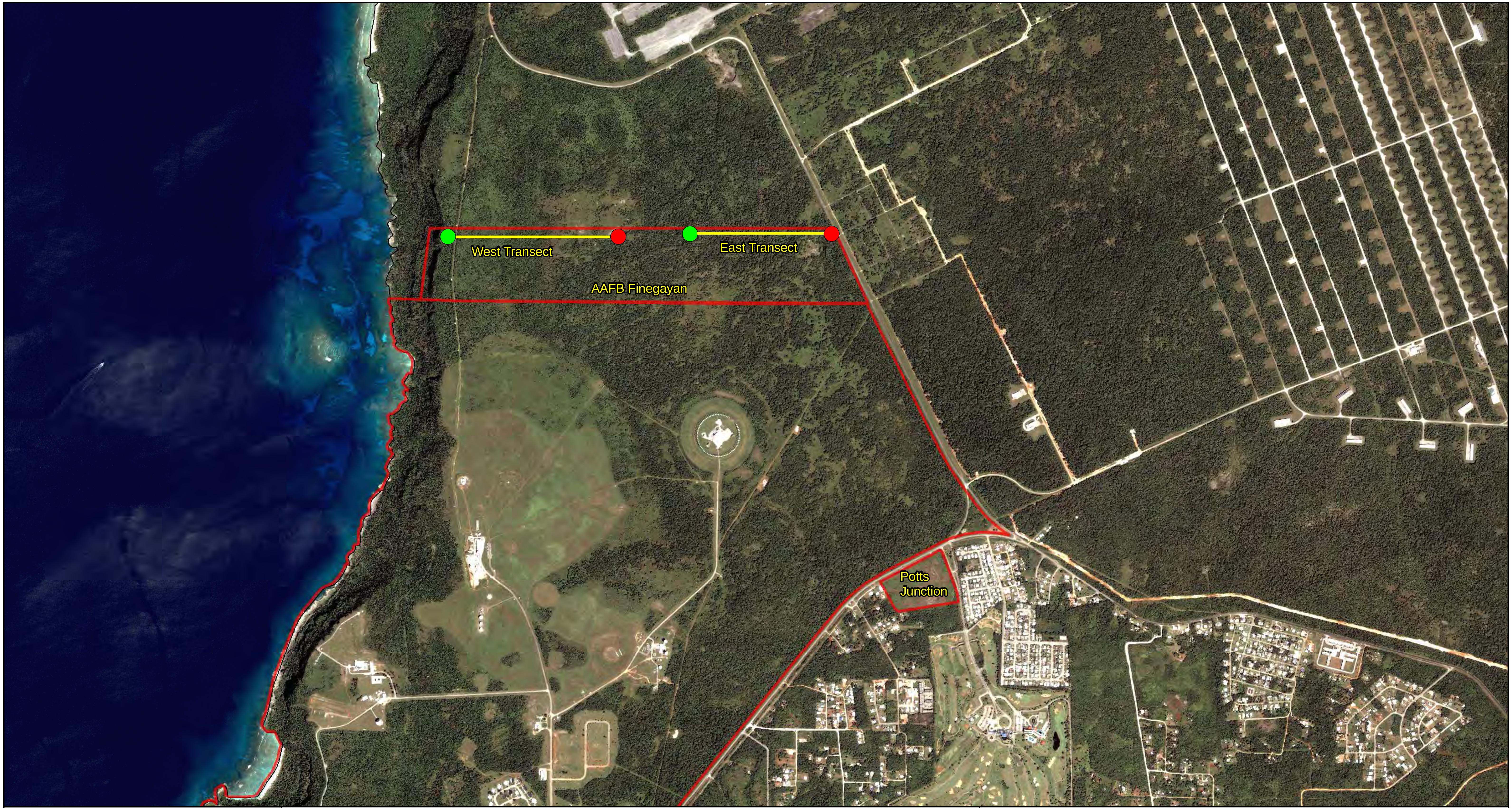
Prepared For:

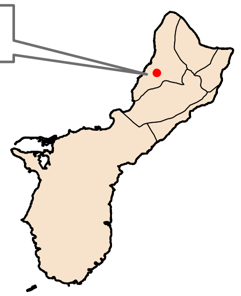
NAVFAC

Naval Facilities Engineering Command

NAVFAC PACIFIC

May 3, 2010	Project No.: 60133557	Figure 3-3





Beginning Transect Point

End Transect Point

Installation Boundary

Installation Boundary

N

0 20 40 Miles

AAFB Finegayan and Potts Junction

Transect Map

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 3-4

Table 3-1

Herpetofauna Captured or Observed on Andersen AFB

Group	Species	Status
Skinks	*Curious skink (Carlia ailanpalai*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
	Moth skink (*Lipinia noctua*)	Native*
Geckos	House gecko (*Hemidactylus frenatus*)	Introduced
	Mutilating gecko (*Gehyra mutilata*)	Native
Snakes	Brown treesnake (*Boiga irregularis*)	Introduced
	Brahminy blind snake (*Ramphotyphlops braminus*)	Introduced
Amphibians	Marine toad (*Rhinella marinus*)	Introduced
	Greenhouse frog (*Eleutherodactylus planirostris*)	Introduced
Note: *Identified in the Guam Comprehensive Wildlife Conservation Strategy (GCWCS) as Endangered/ Species of Greatest Conservation Need (SOGCN) (GDAWR, 2006).		

Photo 3-1 Moth skink, *Lipinia noctua*

3.1.2 Herptofauna – AAFB Finegayan

In 2008, the NAVFAC Pacific biologists performed herpetofauna surveys along two transects in AAFB Finegayan (Figure 3-4). The transects were identified at Transect East and Transect West. Table 3-2 identifies the herptofauna that were observed.

Table 3-2

Herpetofauna Captured or Observed on AAFB Finegayan

Group	Species	Status
Skinks	Curious skink (Carlia ailanpalai)	Introduced
	Pacific blue-tailed skink (Emoia caeruleocauda)	Native
	Moth skink (Lipinia noctua)	Native*
Geckos	House gecko (Hemidactylus frenatus)	Introduced
	Mutilating gecko (Gehyra mutilata)	Native
Snakes	Brown treesnake (*Boiga irregularis*)	Introduced
Amphibians	Marine toad (Rhinella marinus)	Introduced
Note: *Identified in the Guam Comprehensive Wildlife Conservation Strategy (GCWCS) as Endangered/ Species of Greatest Conservation Need (SOGCN) (GDAWR, 2006).		

3.2 Vegetation Survey

On the AAFB, vegetation surveys were performed within along Transects 5, 6, and 7 proposed utility corridors (Subchapter 3.2.1), the AAFB Finegayan (Subchapter 3.2.2) and the Potts Junction Property (Subchapter 3.2.3).

In addition to the qualitative survey performed as part of this work, the Air Force previously performed a more in-depth vegetation survey (Andersen AFB, 2008). The results of this study indicated that in east AAFB, the North Ramp project area consists primarily of developed land, but there are small areas of mixed herbaceous scrub and mixed limestone forest- in the northern portion of the site. The South Ramp project area consists primarily of developed land, but there are small areas of *Ochrosia mariannensis* edge and mixed herbaceous scrub habitats in the eastern portion of the site (Andersen AFB, 2008).

In West AAFB, Northwest Field (NWF), the Munitions Storage Area (MSA), and surrounding areas consist primarily of mixed limestone forest, *Vitex*-dominated forest, mixed herbaceous scrub, mixed shrub, *Casuarina equisetfolia* forest, and developed land (Andersen AFB. 2008).

3.2.1 Vegetation – Proposed Utility Corridors

A qualitative vegetation survey was performed within areas of proposed utility lines on AAFB (Transects 5, 6, and 7). A primary purpose of this survey was to determine if there were any host plants for the two federal-candidate butterfly species *Hypolimnas octocula mariannensis* and *Vagrans egista*. These host plants (*Elatostema calcareum*, *Procris pedunculata*, and *Maytenus thompsonii*) were not observed on any of the transects. Transects were in disturbed limestone forests ranging from highly degraded to somewhat degraded with a primarily indigenous understory.

Two *Tabernaemontana rotensis* trees were observed on Transect 6 in flower and fruit. *Tabernaemontana* is considered an SOGCN by the Government of Guam (GDAWR, 2006).

Several trees of the uncommon *Geniostoma micranthum*, an endemic species, were observed on Transect 7. For more in-depth analysis of the vegetation on Andersen AFB, please refer to Appendix D.

3.2.2 Vegetation – AAFB Finegayan

In 2008, the NAVFAC Pacific biologists performed quantitative surveys along Transect East and Transect West in AAFB Finegayan (Figure 3-4). The results for both transects are as follows:

Transect East – On the transect the number of trees per hectare (ha) was calculated at 3,183 trees/ha. The mean dbh (cm) (with 95 percent confidence interval) was calculated to be 10.86 (9.11-12.61). *Vitex parviflora, Pandanus tectorius, and Spathodea campanulata* were the dominant species in the tree layer. Chart 3-1 identifies the species composition along the transect. *Sida* sp., *Piper guahamense*, *Polypodium punctatum*, *Chromo odorata*, and *Chamaecrista nictitans* were the dominant non-woody species. Ungulate impacts were quite extensive at the site and appear to be causing fragmentation of the habitat.

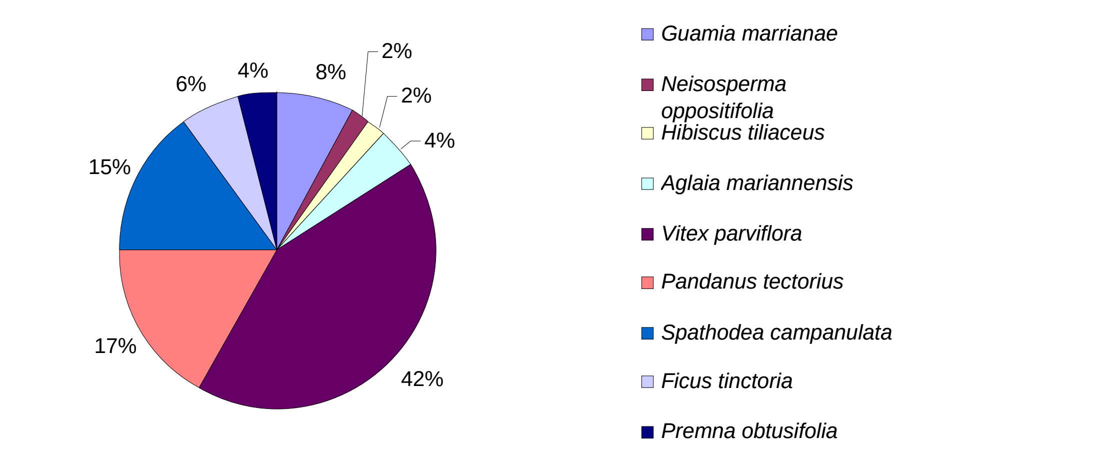


Chart 3-1 Tree Species Composition at AAFB Finegayan, East Transect

Transect West – On the transect the number of trees per hectare (ha) was calculated at 3,695 trees/ha. The mean dbh (cm) (with 95 percent confidence interval) was calculated to be 6.46 (4.85-11.31). *Vitex parviflora and Hibiscus tiliaceus* were the dominant species in the tree layer. Chart 3-2 identifies the species composition along the transect. *Piper guahamense*, *Polypodium punctatum*, *Chromo odorata*, *Stachytarpheta urticifolia*, and *Chamaecrista nictitans* were the dominant non-woody species. It was observed during the survey that deer and pigs are having a pronounced effect on the habitat, preventing regeneration of many native tree species and reducing diversity.

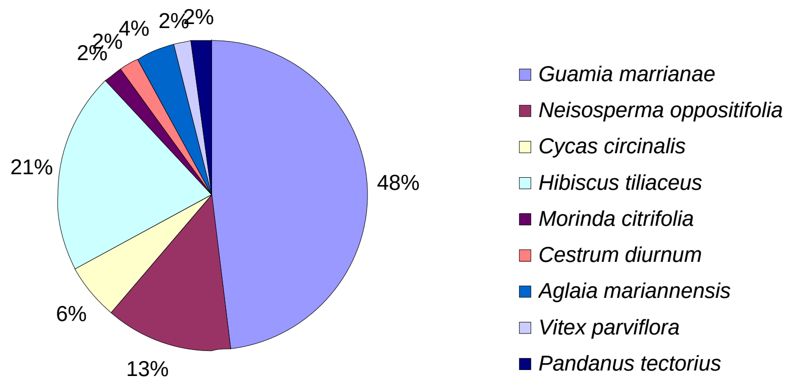


Chart 3-2 Tree Species Composition at AAFB Finegayan, West Transect

3.2.3 Vegetation – Potts Junction Property

In July, 2009, a qualitative study was performed on the Potts Junction parcel (Figure 3-4). The parcel is dominated by a highly disturbed shrub/grassland vegetation community with few native species. Much of the site is low vegetation including *Bidens alba*, *Passiflora suberosa*, and *Fimbristylis cymosa* with patches of grass including *Pennisetum purpureum*, *Pennisetum polystachion*, and *Saccharum spontaneum*. There are patches of trees or shrubs including *Buddleja asiatica*, *Spathodea campanulata*, *Hibiscus tiliaceus*, and *Leucaena leucocephala* and some patches of the fern *Pteris vittata*. There are some *Cocos nucifera* trees near the boundary with the Starts Golf Course.

3.3 Butterfly Survey

A butterfly survey was performed in the wet season (September, 2009) and at the start of the dry season (January, 2010) on Transects 5, 6, and 7 (Figure 3-3). The survey consisted of timed counts and baited traps.

The transects were located in a forested area with a canopy 6-12 m in height with moderate to dense undergrowth. On Transect 5, between the 130 m and 190 m mark, a clearing presents a break in the forest canopy and is vegetated with grasses and a few small isolated trees.

3.3.1 Timed Counts

Five butterfly species were identified during the timed counts:

- Lemon Emigrant (*Catopsilia pomona*)
- Monarch (*Danaus plexippus*)
- Blue-banded King Crow (*Euploea eunice*)
- Blue Moon (*Hypolimnas bolina*)
- Common Mormon (*Paplio polytes*)

None of the five species are considered endangered or threatened, and these species are fairly well distributed throughout Guam and portions of the Mariana Islands (Schreiner and Nafus, 1997). Table 3-3 identifies the numbers of individuals and species observed within the various sampling plots on Andersen AFB in September 2009 and January 2010.

In September 2009, the Common Mormon and Blue-banded King Crow were the two most common butterflies sighted. The Common Mormon and the Blue-banded King Crow comprised 46 and 43.6 percent of the total sightings at AAFB, respectively. Approximately 62 percent (57 of 92 sightings) of the total sightings of the Blue-banded King Crow occurred within two plots along Transect 5 associated with a road cut.

In January 2010, the Blue-banded King Crow and the Common Mormon were the two most common butterflies sighted, comprising 64.5 and 24.8 percent of the total sightings, respectively. Similar to the September findings, a majority of the total sightings on the Blue-banded King Crow (152 of 182 [83.5 percent]) occurred within the first 120 m of Transect A. These sightings also comprised 53.9 percent of the total sightings on AAFB.

The January sightings total of 282 individuals is approximately one-third higher than the September total of 211. Although there were two additional species sighted in September (Blue Moon and Monarch), the total number of individuals of these two species was only three. All of the species sighted are widely distributed throughout the Mariana Islands.

The Mariana Eight-Spot butterfly (*Hypolomnas octocula mariannensis*) and the Mariana wandering butterfly (*Vagrans egistina*), which are both candidate species for listing by the United States Fish and Wildlife Service (USFWS) under the Endangered Species Act of 1973, were not observed on any transect. Moreover, the host plants for this species (refer to Subchapter 3.2.1) were also not observed on AAFB.

3.3.2 Baited Traps

Two baited traps were placed on the transects in the morning and retrieved in the late afternoon. On Transect 5, the traps were placed within a forested area in the beginning of the transect (September 2009 and January 2010) and a second trap was placed within a clearing in the September survey and near the end of the transect in the January survey. On Transects 6 and 7, the traps were placed in forested areas at the beginning and the end of the transects in both the September and January surveys.

No butterflies were captured in the baited traps on AAFB in September 2009. In January 2010, one Blue-banded King Crow was captured on Transect 6.

Table 3-3

Butterfly Sightings on AAFB – Transects 5, 6, and 7

Transect	September 2009						January 2010			
	Distance on Transect	Species					Distance on Transect	Species		
		Common Mormon	Blue-banded King Crow	Lemon Emigrant	Blue Moon	Monarch		Common Mormon	Blue-banded King Crow	Lemon Emigrant
	10		1				0		40	
	40						30	1	9	
	70	1	4				60		28	
	100	2	6				90	1	24	
	130	2	29	2	2		120		51	
	160	3	28	4		1	180	2		
	190						220	1	1	
	230						250	1		
5	260						280	3		
	290	1					310	3	1	
	320	1					340	2	2	
	350						370	2		
	380	2					400	2	4	
	TOTAL	**12**	**68**	**6**	**2**	**1**	**TOTAL**	**18**	**160**	
	Percent of Sightings	**13.5**	**76.4**	**6.7 p**	**2.3**	**1.1**	Percentage of Sightings	**10.1**	**89.9**	**0**
	0						0			
	30						20	1		
	60	2					50	2		1
	90	8	2	3			80	2		
	120	8		1			110	2	1	
	150	3		2			140	1		
	180	5		1			170	3		6
	210		3	1			200	3		3
6	240	1		3			230	2		7
	270	2					260		1	
	300	3		1			290	2		1
	330	2					320	2		4
	360	6					350	2		6
	390	5	17				380	3	1	1
	TOTAL	**45**	**22**	**12**	**0**	**0**	**TOTAL**	**25**	**3**	**29**
	Percent of Sightings	**57.0**	**27.9**	**15.2**	**0.00**	**0.00**	Percent of Sightings	**43.9**	**5.3**	**50.9**
	0	2		1			0	3		
	30						30	2	1	
	60	1					60	2	2	
	90	1					90	5		
	120	3					120	1		
	150	2					150	2	4	
	180	3	2				180	1	6	
	210	4					210	4	1	
7	240	4					240	1	1	
	270						270	4		1
	300	8					300	2		
	330	6					340		1	
	360	4					370			
	390	2					400		3	
	TOTAL	**40**	**2**	**1**	**0**	**0**	**TOTAL**	**27**	**19**	**1**
	Percent Sightings	**93.0**	**4.7**	**2.3**	**0**	**0**	Percent Sightings	**57.4**	**40.4**	**2.1**
Total	Individual s sighted	**97**	**92**	**19**	**2**	**1**	Individuals sighted	**70**	**182**	**30**

3.4 Avian Surveys

Avian surveys were performed within the Northwest Field, North Ramp, and Proposed utility corridors (Subchapter 3.4.1); AAFB Finegayan (Subchapter 3.4.2) and the Potts Junction parcel (Subchapter 3.4.3)

3.4.1 Avian Survey – Northwest Field, North Ramp, and Proposed Utility Corridor.

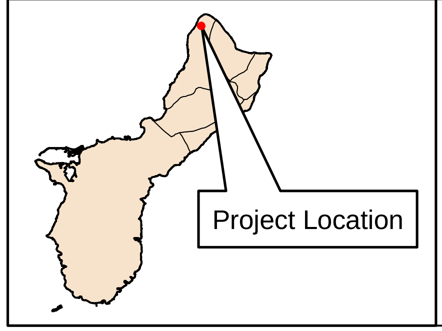
Within AAFB, roadside avian surveys were performed at the Northwest Field (Figure 3-5) and North Ramp (Figure 3-6), and forest bird surveys were performed at Northwest Field, North Ramp, and on the proposed utility corridors along Route 9 (Figure 3-4). Table 3-4 lists the species observed.

With the exception of the Micronesian starling, all other observed species are common to Guam. Table 3-5 specifies the resident status of the observed species. The nomenclature follows Gill et al. (2008). For more information on the avifauna survey and results, refer to Appendix G.

Table 3-4

Species Identified During Roadside and Forest Bird Surveys -- AAFB

Base / Parcel	Survey Type	Number of Stations	Species and Number of Detections	Number of Species	Total Number of Detections
NW Field	Roadside Survey	17	Black Francolin (41) Island Collared Dove(~~15~~) (11) Yellow Bittern (2)	3	54
	Forest Bird Survey	8	Black Francolin (17) Island Collared Dove (6) Black Drongo (1) Eurasian Tree Sparrow (4)	4	28
North Ramp	Roadside Survey	6	Black Francolin (14) Island Collared Dove (4) Black Drongo (11) Eurasian Tree Sparrow (7)	4	36
Proposed Utility Corridors	Forest Bird Survey	12	Island Collared Dove (1) Black Drongo (1) Yellow Bittern (1) Micronesian Starling (1)	4	4



Installation Boundary

Roadside Survey Point

N

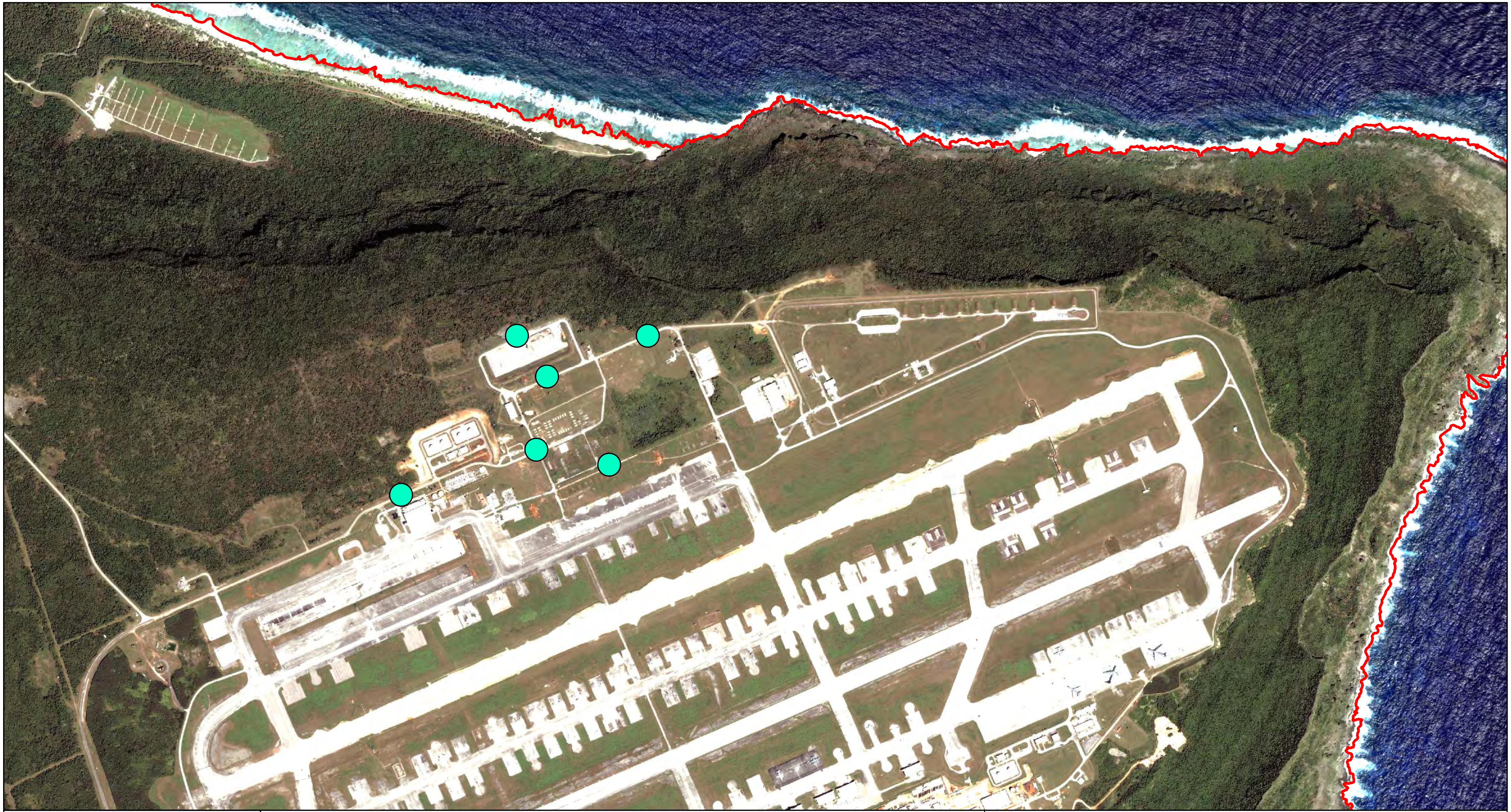
0 200 400 Meters

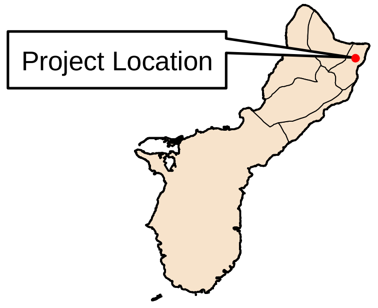
Andersen AFB Northwest Field

Roadside Survey Points

Prepared By: Prepared For:

May 3, 2010	Project No.: 60133557	Figure 3-5





Installation Boundary

Roadside Survey Point

N

0 200 400 Meters

Andersen AFB North Ramp

Roadside Survey Points

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 3-6

Table 3-5

Residence Status of Avifaunal Species Identified during Roadside and Forest Bird Surveys - AAFB

Species	Residence Status[1]
Yellow Bittern *(Ixobrychus sinensis)*	Common native resident - breeding
Island Collared Dove *(Streptopelia bitorquata)*	Common introduced resident - breeding
Black Drongo *(Dicrurus macrocercus)*	Common introduced resident - breeding
Eurasian Tree Sparrow *(Passer montanus)*	Common introduced resident - breeding
Black Francolin *(Francolinus francolinus)*	Common introduced resident - breeding
Micronesian Starling *(Aplonis opaca)*	Guam-listed endangered species Uncommon native resident - breeding
Note: [1] Reichel and Glass 1991.	

3.4.2 Avian Survey - AAFB Finegayan

NAVFAC Pacific biologists performed an avian survey on two transects within AAFB Finegayan. The results of the survey are presented in Table 3-6. All four observed species are common introduced residents the island of Guam.

Table 3-6

Avian Species Detected During AAFB Finegayan

Avian Species	Status on Guam
Black Drongo *(Dicrurus macrocercus)*	Common introduced resident - breeding
Eurasian Tree Sparrow *(Passer montanus)*	Common introduced resident - breeding
Philippine Turtle Dove (*Streptopelia bitorquata*)	Common introduced resident - breeding
Chicken (*Gaullus* sp.)	Common introduced resident - breeding
Note: Status and nomenclature follow Wiles, 2005.	

3.4.3 Avian Survey - Potts Junction Property

On July 16, 2009, a site reconnaissance was performed to identify avian species within the Potts Junction parcel. Only two introduced resident species were identified. Table 3-7 identifies the avifauna that were observed. Both observed species are common introduced residents the island of Guam.

Table 3-7

Avian Species Detected During Potts Junction Survey

Avian Species	Status on Guam
Black francolin (*Francolinus francolinus*)	Introduced resident, breeding
Island collared-dove (*Streptopelia bitorquata*)	Introduced resident, breeding
Note: Status and nomenclature follow Wiles, 2005.	

3.5 Tree Snail Surveys

General and detailed visual surveys were completed on Transects 5, 6, and 7 at AAFB (Figure 3-3). No living partulid tree snails or their shells were observed during any of the surveys conducted along the transects.

Table 3-8

Partulid Tree Snail General and Detailed Visual Survey Results on Department of Defense Lands, Guam - AAFB

General Visual Survey Date	Detailed Visual Survey Date	Transect	Transect Length (m)	Number of Partulid Tree Snails Observed
October 12, 2009	October 23, 2009	5	400	0
October 1, 2009	October 2, 2009	6[1]	400	0
September 25, 2009	September 25, 2009	7	400	0
[1] Manokwar flatworms (*Platydemus manokwari*) recorded along the transect.				

Shells of the introduced Giant African Snail (*Achatina fulica*) and both live individuals and shells of the introduced snail *Satsuma mercatoria* (no common name) were seen at all five transects. Additionally, live introduced Manokwar flatworms (*Platydemus manokwari*) were observed along Transect 6.

No partulid tree snails were observed on the transects on AAFB. However, since there were several known host plant species present throughout the survey area, the possibility that tree snails are present in habitat associated with the surveyed transects cannot be dismissed.

Because no live partulid tree snails were observed during either the general or detailed visual survey, no quadrat surveys were completed. Therefore, temperature, humidity, and air-movement measurements were not taken in areas not inhabited by tree snails.

The presence of flatworms on AAFB is of note, especially since the species was not targeted during the tree-snail surveys and is more likely seen nocturnally when these flatworms are active; flatworms were likely present but undetected at all locations. This flatworm is known to feed on juvenile partulid tree snails in the wild on Guam and Pacific tree snails in captivity, and is believed to be the primary threat to the continued existence of partulid tree snails on Guam, the Northern Mariana Islands, and potentially Oceania (Hopper and Smith, 1992). These authors reported that on Guam, where flatworm abundance was high, partulid tree-snail colonies were rapidly declining.

For more information on the tree snail survey, refer to Appendix H.

3.6 Threatened/Endangered Species and Species of Concern

Several threatened and endangered and Guam-listed SOGN species were identified on AAFB during the natural resource surveys. These species are identified in the following sections.

3.6.1 Herptofauna

During the herptofauna survey, a moth skink was captured on Transect 7, Station 16. Also, a moth skink was observed on AAFB Finegayan. The skink is a Guam-listed endangered species.

3.6.2 Vegetation

During the qualitative vegetation survey, two *Tabernaemontana rotensis* trees were observed on Transect 6. The species is considered an SOGCN species on Guam.

3.6.3 Avifauna

No federally listed endangered or threatened avian species were identified during any of the surveys. One Guam listed endangered species, Micronesian starling, was recorded from the Forest Bird Survey along the Route 9 survey (Transect 6; Station 3) on September 24, 2009. This species was also observed in the same area the day before when the transect was being established.

It is also of note that the federally endangered Mariana crow was not detected during the surveys. Critical habitat has been designated north of AAFB on the Guam National Wildlife Refuge (Figure 3-8). Critical habitat has been designated for the Guam Micronesian Kingfisher north of AAFB on the Guam National Wildlife Refuge (Figure 3-9)

3.6.4 Fruit Bats

On January 28, 2010 on AAFB, a federally listed threatened Mariana fruit bat (*Pteropus mariannus mariannus*) (locally known as fanihi), was sighted. The fruit bat was observed during the day roosting in a *Guamia* tree on Transect 6 at the 50 m station.

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4 Andersen South

Herpetofauna, vegetation, butterfly, avian, tree snail, and fruit bat surveys were conducted on Andersen South. Seven transects were surveyed within Andersen South (Figure 4-1): Transects 1 through 3 were within the central area; Transect 4 was in the southwestern sector; Transects 5 and 6 were in the northwestern sector; and Transect 7 was located in the southeast sector. Transect 7 was established as to provide data for the anticipated relocation of Route 15.

All seven Andersen South transects were surveyed for herpetofauna. Four of the seven transects were located in forest where *Guamia mariannae, Aglaia mariannensis, Neisosperma oppositifolia*, and *Premna obtusifolia* were dominant. Two were in degraded *Leucaena leucocephala*-dominated forest, and one was in non-forested, grassy habitat that traversed pavements.

4.1 Herpetofauna Surveys

A total of nine herpetofauna species were captured or observed on Andersen South. Table 4-1 identifies the species and their status. For more information on the herpetofauna survey and results, please refer to Appendix B.

Table 4-1

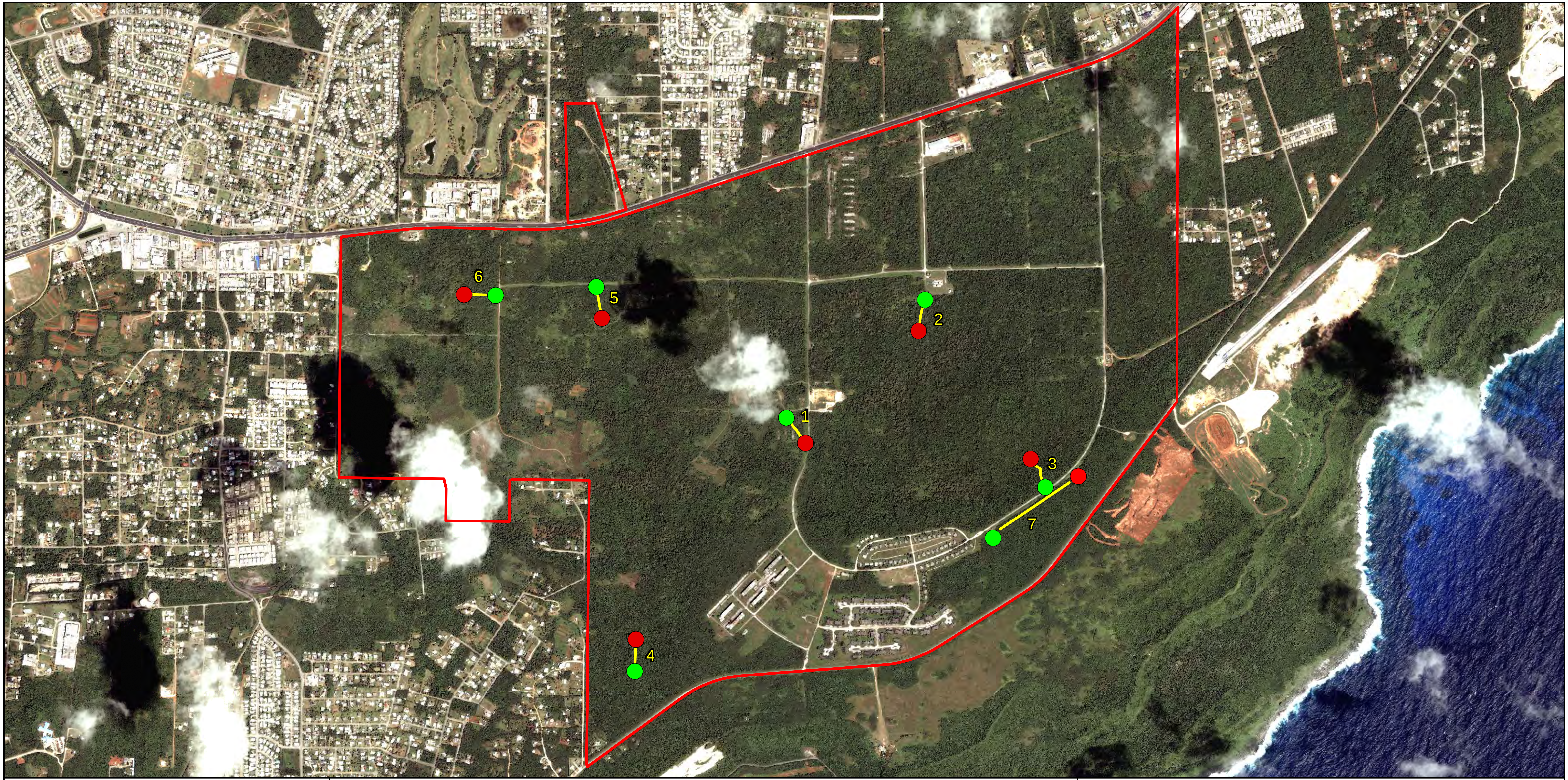
Herpetofauna Captured or Observed on Andersen South

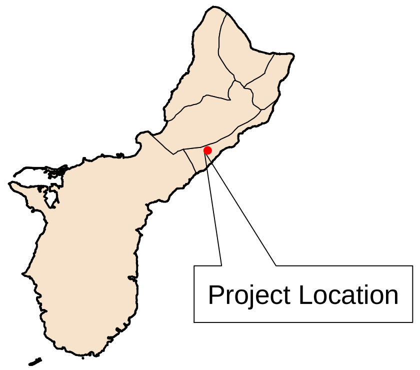
Guild	Species	Status
Skinks	Curious skink (*Carlia ailanpalai*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
Gecko	House gecko (*Hemidactylus frenatus*)	Introduced
	Mutilating gecko (*Gehyra mutilata*)	Native
Snakes	Brown treesnake (*Boiga irregularis*)	Introduced
	Brahminy blind snake (*Ramphotyphlops braminus*)	Introduced
Other	Monitor lizard (*Varanus indicus*)	Introduced
Amphibians	Marine toad (*Rhinella marinus*)	Introduced
	Greenhouse frog (*Eleutherodactylus planirostris*)	Introduced

The continued widespread presence of the brown treesnake and curious skink, as well as other introduced amphibian species, is of concern because of each species' potential deleterious impacts to Guam's native fauna (Rodda et al., 1999, Kraus et al., 1999, Wiles et al., 2003, Christy et al., 2007a). Of particular concern is the potential of the other introduced species to serve as additional food sources for the brown treesnake (Fritts and Rodda, 1998, Christy et al., 2007a).

4.2 Vegetation

Quantitative surveys were performed along seven transects in the forested sectors (Figure 4-1). The results of the survey are provided in the following subchapters.





Beginning Transect Point

End Transect Point

Transect Lines

Installation Boundary

N

0 200 400

Meters

Andersen South

Transect Map

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC Naval Facilities Engineering Command

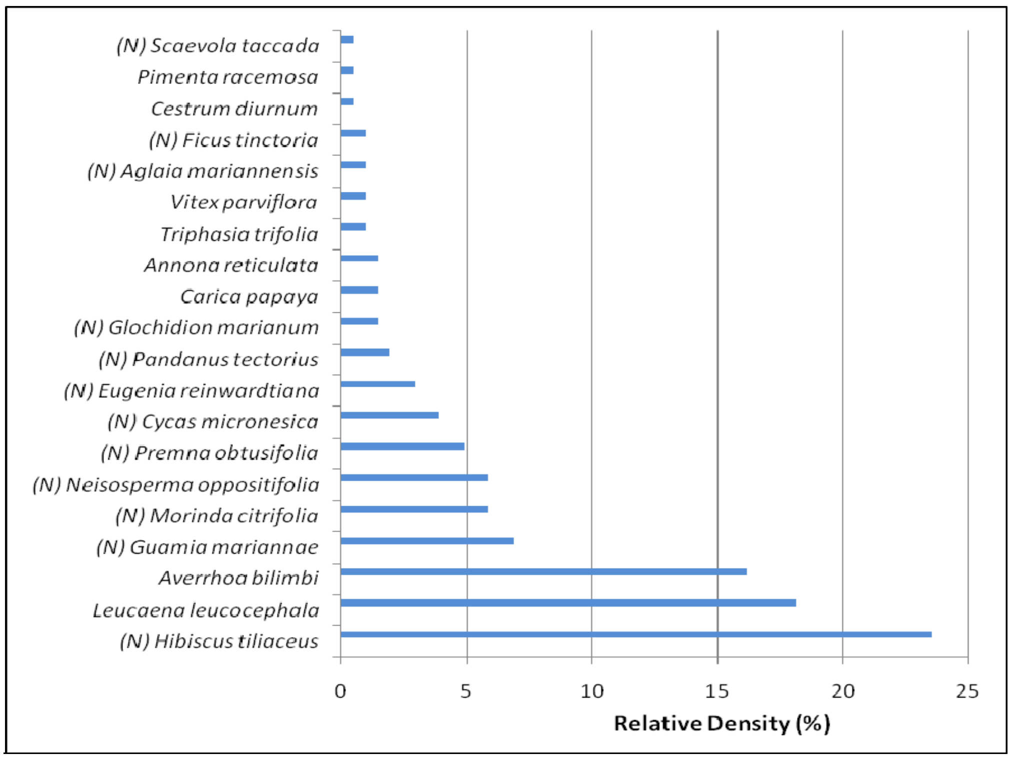
May 3, 2010	Project No.: 60133557	Figure 4-1

4.2.1 Trees

A total of 20 tree species were identified on the transects, of which 12 are native to Guam (Chart 4-1). The overall density for the six transects was calculated at 21.96 trees per 100 m^2. The native pago (*Hibiscus tiliaceus*) is an important species in these forests. Pago had the highest relative density (approximately 24 percent) and highest frequency among species, with specimens quantified on five of the six transects. Pago was also the third most dominant species at Andersen South, following the introduced pickle tree (*Averrhoa bilimbi*) and endemic paipai (*Guamia mariannae*). *Averrhoa bilimbi* and another introduced species, tangantangan (*Leucaena leucocephala*), followed pago with the next highest frequencies. *Averrhoa bilimbi* was common along the transects in the central sector, but it was recorded on every transect at Andersen South. Aside from pickle tree, other non-native species in the survey, such as papaya (*Carica papaya*) and custard apple (*Annona reticulata*), produce edible fruits that are likely dispersed by ungulate activity.

Chart 4-1

Relative Density of Tree Species at Andersen South, Transects 1-6
(N = native)



Native Guam tree species had a collective relative density of 60 percent along the Andersen South transects. Molave tree (*Vitex parviflora*) is a rapidly spreading introduced species that is becoming dominant in many of Guam's forests (Department of Agriculture, 2005), but *Vitex* accounted for less than 2 percent of the relative density at Andersen South, with only two specimens quantified on the transects. The introduced Bay Rum Tree (*Pimenta racemosa*), a relative of allspice (*P. dioica*), was encountered in the northwestern sector. Although this single tree was the only specimen quantified at Andersen South (Transect 5), it was fairly large, with a basal area of over 1,700 square centimeters (cm^2). Bay-rum can be invasive, particularly in southern Guam.

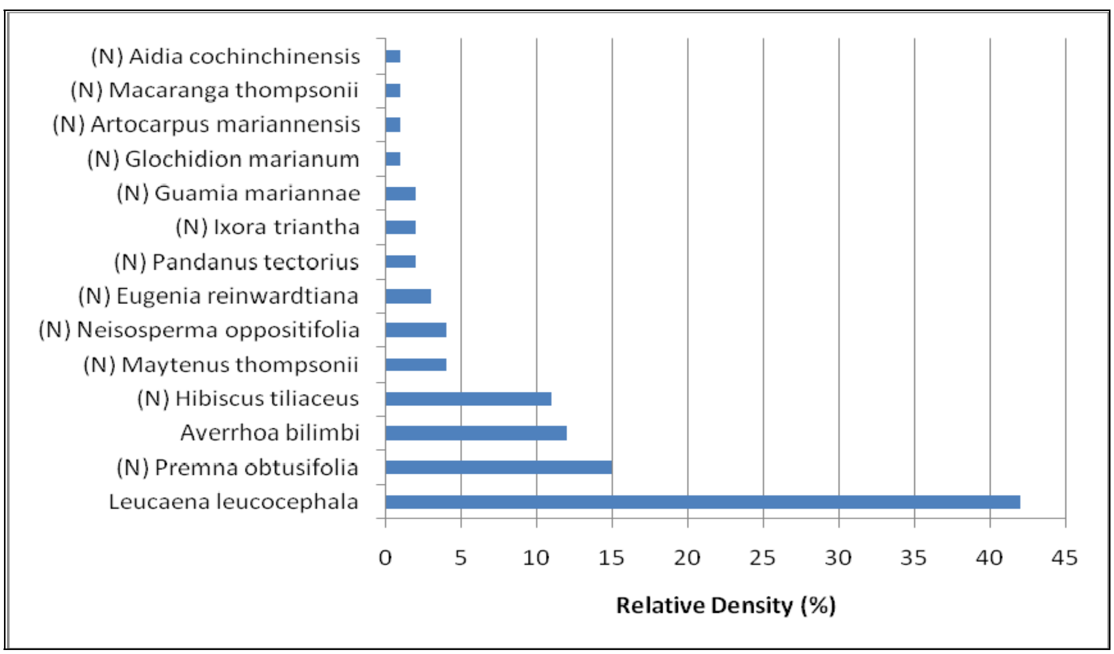
One species that was noticeably absent or present only in low numbers at Andersen South is dugdug or dokdok, the native seeded breadfruit (*Artocarpus mariannensis*). A few trees were seen but not surveyed on Transect 4. Dugdug is a characteristic species of native limestone forests in northern Guam (Fosberg, 1960). Specimens of native breadfruit were observed in other sectors of Andersen South (i.e., east of Transect 1) that were not included in the sampled areas. The recruitment and distribution of seeded breadfruit at Andersen South may be affected by typhoons and ungulate activity, as in other areas of the island.

For Transect 7, the overall density for this transect was calculated at 3,300 trees per hectare. Fourteen species of tree were encountered throughout the survey. The introduced *Leucaena leucocephala* had the highest relative density (approximately 42 percent) of all species (Chart 4-2). Tangantangan and *Averrhoa bilimbi* were the only introduced tree species encountered in this survey, yet accounted for approximately 54 percent of the relative density and 41 percent of the relative dominance of all species combined. *Premna obtusifolia* was the most encountered native tree species and had the highest relative density (approximately 15 percent) of all native species.

In addition, a vegetative survey was performed for the host plants (*Procris pedunculata* and *Elatostema calcareum*) for the Mariana eight-spot butterfly (*Hypolimnas octocula mariannensis*) and the host plant (*Maytenus thompso*nii) for the Mariana Wandering Butterfly (*Vagrans egistina*). Only individuals of *Maytenus thompsonii* were observed on Andersen South.

Chart 4-2

Relative Density of Tree Species at Andersen South, Transect 7
(N = native)



4.2.2 Seedlings

Plots conducted at stations along the six transects quantified more native than introduced seedlings of woody species. Native species had a mean density of approximately 4 seedlings/m^2; in comparison, introduced species had a mean density of less than 2 seedlings/m^2.

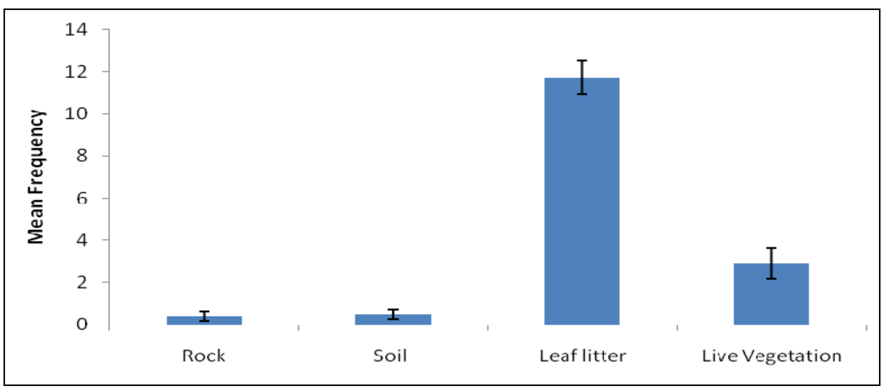
4.2.3 Habitat Quality

The habitat quality at Andersen South may be described through the level of ungulate activity, percentage of native species, and overall species richness. Of the six transects, the calculated species richness was highest for Transect 4. The forest along Transect 4 is the most intact among the six areas sampled in terms of canopy. The native species ratio is also higher than at other Andersen South transects, with 10 of the 14 tree species either native or endemic to Guam or the Northern Mariana Islands.

The ground cover at Andersen South was quantified for all transects. For Transects 1-6, calculations showed that, of the four categories of cover, leaf litter had the highest mean frequency, at 11.7 (Chart 4-3). Transects in the central sector of Andersen South had high levels of leaf litter mostly beneath pickle tree stands. The measure of ungulate activity for all transects revealed that rooting and rubbings were the most common observations, with mean frequencies of 0.59 and 0.50, respectively. For Transect 7, the frequencies for rock, soil, leaf litter, and live vegetation were 4, 37, 40, and 15, respectively.

Chart 4-3

Mean Frequency of Ground Cover along all Transects at Andersen South



Threatened/Endangered Species and Species of Concern

No species listed as threatened or endangered were identified within Andersen South during the current survey.

Species of Concern

The only species of concern identified within Andersen South during the current survey was the native cycad or fadang (*Cycas micronesica*) (Photo 4-1). The GDAWR lists fadang among the island's SOGCNs because of the threat from the introduced Asian cycad scale (GDAWRDA, 2006). Both healthy and injured cycads were noted in the survey. Seven specimens were quantified, with the highest density of cycads observed on Transect 4, at 3.61 trees per 100 m^2.

Incidental species that are not regulated or managed under local or federal law were also noted on the transects. These included water root orchid or saiyaihayon, tall shield orchid (*Nervilia aragoana*), and Z*euxine fritzii*, an inconspicuous ground orchid.

4.3 Butterfly Survey

On Andersen South, the butterfly survey was conducted on Transect 7 (Figure 4-1). The forest canopy is approximately 10 m in height, with moderate to heavy undergrowth.

4.3.1 Timed Counts

Three butterfly species were identified during the timed counts in September 2009 and January 2010. These were:

- Lemon Emigrant, *Catopsilia Pomona.*
- Blue-banded King Crow, *Euploea Eunice.*
- Common Mormon, *Paplio polytes.*

None of the three species observed on Andersen South are considered endangered or threatened and all are widely distributed in the Mariana Islands. Table 4-2 identifies the numbers of individuals and species observed within the various sampling plots on Andersen South in September 2009 and January, 2010.

On Andersen South the Common Mormon was the most numerous sighted butterfly in both September 2009 and January 2010, comprising 88.8 and 56.3 percent of the total sightings, respectively. The numbers of butterflies sighted, on average, also decreased between September and January. This reduction in abundance may be the result of natural cycles in butterfly population, the relatively short observation periods involved, or other factors.

The Mariana Eight-Spot butterfly and the Mariana wandering butterfly, which are both candidate species for listing by the United States Fish and Wildlife Service (USFWS) under the Endangered Species Act of 1973, were not observed on any transect. Moreover, the host plants for these species were not observed along the transects during the vegetation surveys.

4.3.2 Baited Traps

Butterfly traps were set at the 0 and 470 meter mark on the transect. The baited traps were placed on each transect during daylight hours. No butterflies were captured on Andersen South.

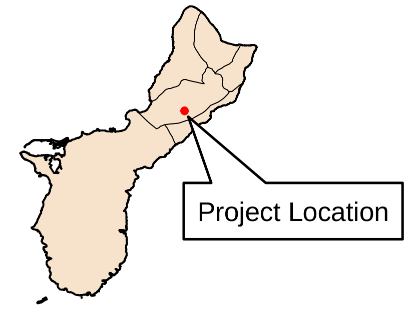
Table 4-2

Butterfly Sightings on Andersen South Transect 7 – September 2009 and January 2010

September 2009				January 2010			
Distance on Transect	Species			Distance on Transect	Species		
	Common Mormon	Blue-banded King Crow	Lemon Emigrant		Common Mormon	Blue-banded King Crow	Lemon Emigrant
0	3			0	3	3	
20	4			30		1	
40	2			60			
60	4			90	3		1
80	4	1	2	120	3	1	
100			1	150	1		
120	6			180			
140	16			210	2		
160	10	1		240	1	1	1
180	2			270		2	
200	4			300			
220	4			330		1	
240	4			360	1		
260	1			390	2		
280	3			420	1	2	
300	3	2		450	1		
320	3		1	480		1	
340	4						
360	3						
380	3	2	1				
400	2						
420	1		1				
440	3						
460	1						
480	3						
500	2						
TOTAL	**95**	**6**	**6**	**TOTAL**	**18**	**12**	**2**
Percent of Sightings	**88.8**	**5.6**	**5.6**	Percent of Sightings	**56.3**	**37.5**	**6.3**

4.4 Avian Surveys

In addition to the forest bird surveys along the seven transects on Andersen South, roadside bird surveys (Figure 4-2) were also conducted in the morning. Table 4-3 lists the species identified during the surveys.



Installation Boundary

Roadside Survey Point

N

0 200 400

Meters

Andersen South

Roadside Survey Points

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 4-2

Table 4-3

Species Identified during Roadside and Forest Bird Surveys – Andersen South

Survey Type	Number of Stations	Species and Number of Detections	Number of Species	Total Number of Detections
Roadside	21	Eurasian Tree Sparrow (5) Black Francolin (4) Pacific Golden Plover (1) Island Collared Dove (2) Yellow Bittern (1)	5	13
Forest Bird	10	Pacific Golden Plover (1) Island Collared Dove (1) Yellow Bittern (1) Black Francolin (3)	4	6

All of the observed species are common to Guam. With the exception of the Pacific golden plover, all the observed species breed on Guam (Table 4-4). For more information on the avifauna survey and results, refer to Appendix G.

Table 4-4

Residence Status of Avifaunal Species Identified during the
Roadside and Forest Bird Surveys – Andersen South

Avifaunal Species	Residence Status[1]
Yellow Bittern (*Ixobrychus sinensis*)	Common resident native - breeding
Common Pigeon (*Columba livia*)	Common introduced resident - breeding
Island Collared Dove (*Streptopelia bitorquata*)	Common introduced resident - breeding
Eurasian Tree Sparrow (*Passer montanus*)	Common introduced resident - breeding
Black Francolin (*Francolinus francolinus*)	Common introduced resident - breeding
Pacific Golden Plover (*Pluvialis fulva*)	Common visitor – not breeding[2]
Notes: * Reichel and Glass 1991; **Johnson et al. 2006.	

4.5 Tree Snail Surveys

A general survey and a detailed visual survey were completed on Transect 7 on October 1, 2009 and October 9, 2009, respectively. No living partulid tree snails or their shells were observed during any of the surveys conducted along the transect. Because no live partulid tree snails were observed during either the general or detailed visual survey, no quadrat surveys were completed. Therefore, temperature, humidity, and air-movement measurements were not taken in areas not inhabited by tree snails.

No partulid tree snails were observed on Andersen South during the survey. However, since there were several known host plant species present throughout the survey area, the possibility that tree snails are present in habitat associated with the surveyed transects cannot be dismissed.

Shells of the introduced Giant African Snail (*Achatina fulica*) and both live individuals and shells of the introduced snail *Satsuma mercatoria* (no common name) were seen along the transect.

4.6 Threatened and Endangered Species

No federally-listed or Guam-listed threatened or endangered species or species of concern were identified on Andersen South. The native cycad (*Cycas micronesica*), a Guam SOGCN, was the only species of concern identified within Andersen South during the current surveys. The plant was observed on several transects with the highest density occurring on Transect 4.

5 Air Force Barrigada

On Air Force Barrigada (sometimes referred to as Air Force Communications Annex Barrigada), natural resource surveys preformed included herpetofauna, vegetation, and avian surveys. Figure 5-1 identifies the locations of the ecological transects. At Air Force Barrigada, one transect was surveyed.

5.1 Herpetofauna Surveys

Reptiles and amphibians were sampled by visual surveys on transects and glue board trapping on the same transects. Four species of reptiles and one amphibian species were documented (Table 5-1).

Table 5-1

Observed Herpetofauna - Air Force Barrigada

Group	Species	Status
Skinks	Curious skink (*Carlia ailanpalai*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
Geckos	House gecko (*Hemidactylus frenatus*)	Introduced
	Mourning gecko (*Lepidodactylus lugubrus*)	Native
Amphibians	Marine toad (*Rhinella marinus*)	Introduced
Notes: It is likely that brown tree snakes, monitor lizards, and mutilating geckos are also present on Air Force Barrigada.		

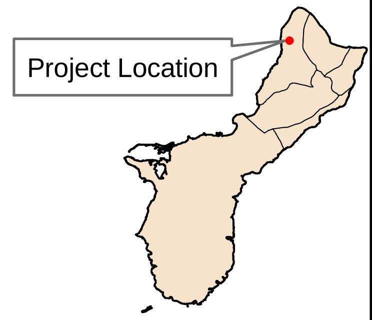
5.2 Vegetation Survey

On Air Force Barrigada the number of trees per hectare (ha) was calculated at 6,309. The mean dbh (with 95 percent confidence interval) was calculated to be 4.50 cm (range 3.85-5.15 cm). *Leuceana leucocephala* comprised the entire tree layer and *Polypodium punctatum*, *Stachytarpheta urticifolia*, and *Chromlaenao odorata* were the dominant non-woody species.

5.3 Avian Survey

An avian survey was performed by NAVFAC Pacific biologists on Air Force Barrigada (Appendix C). Three introduced, resident breeding species were identified. The identified species were the following:

- Black francolin
- Island collared dove
- Chicken



Transect Lines
Installation Boundary
Avian Roadside Observation Stations
Beginning Transect Point
End Transect Point

N

0 100 200 Meters

Air Force Barrigada

Transect Map & Avian Roadside Survey Location Map

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010 | Project No.: 60133557 | Figure 5-1

No threatened or endangered bird species were documented.

5.4 Threatened/Endangered Species and Species of Concern

No threatened/endangered species or species of concern were observed on Air Force Barrigada during the course of the surveys.

6 Navy Barrigada

On Navy Barrigada, natural resource surveys performed included herpetofauna, butterfly, vegetation, avian, and tree-snail surveys. Figure 6-1 shows the locations of the ecological transects.

Three transects were surveyed at Navy Barrigada. The transects were located in forested habitats where *Hibiscus tiliaceus*, *Leucaena leucocephala*, *Guamia mariannae*, and *Aglaia mariannensis* were the most common species.

6.1 Herpetofauna Surveys

Seven herpetofauna species were captured or observed on Navy Barrigada. Table 6-1 identifies the species and their status. For more information on the herpetofauna survey and results, please refer to Appendix B.

Table 6-1

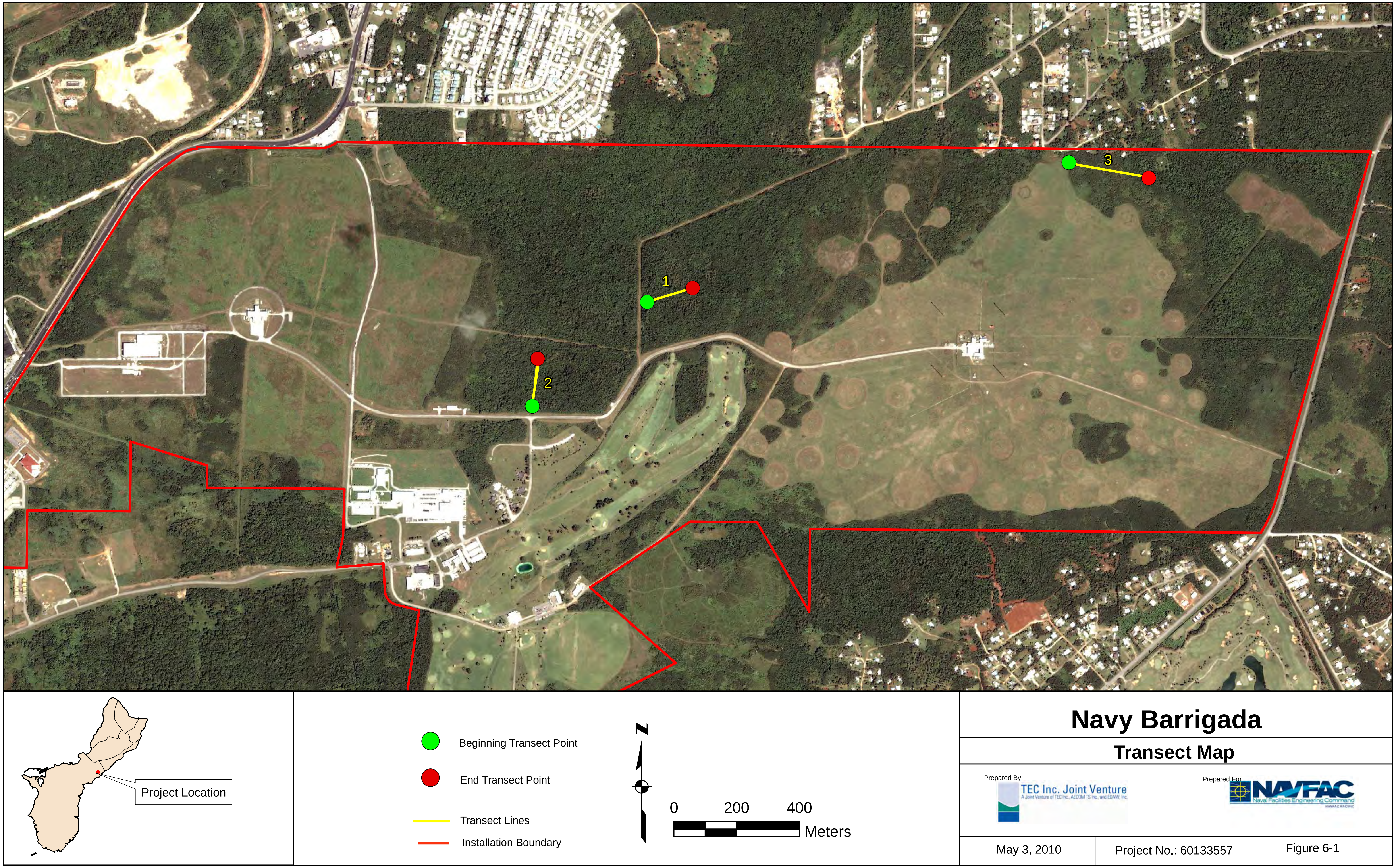
Herpetofauna Captured or Observed on Navy Barrigada

Group	Species	Status
Skinks	Curious skink (*Carlia ailanpalai*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
Gecko	House gecko (*Hemidactylus frenat*us)	Introduced
	Mourning gecko (*Lepidodactylus lugubris*)	Native
	Mutilating gecko (*Gehyra mutil*ata)	Native
Amphibians	Greenhouse frog (*Eleutherodactylus planirostris*)	Introduced
	Hong Kong whipping frog (*Polypedates megacephalus*)	Introduced

The continued widespread presence of curious skink, as well as other introduced amphibian species, is of concern because of each species' potential deleterious impacts to Guam's native fauna (Rodda et al., 1999, Kraus et al., 1999, Wiles et al., 2003, Christy et al., 2007a). Of particular concern is the ability of the introduced species to serve as additional food sources for the brown treesnake (Fritts and Rodda, 1998, Christy et al., 2007a).

6.2 Vegetation

Much of Navy Barrigada is comprised of improved and unimproved roads, open fields, and weedy vegetation, with the remaining forested areas mainly concentrated around Mount Barrigada between two antenna fields. The goal of the vegetation surveys is to locate endangered plant species or species of concern and to characterize the habitat types through a visual walk and conducting a point-quarter survey over the entire length of each transect.



Navy Barrigada

Transect Map

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC Naval Facilities Engineering Command

May 3, 2010	Project No.: 60133557	Figure 6-1

Quantitative surveys were performed along three transects in the forested sectors: Transect 1 along an east-west axis near the toe of Mt. Barrigada; and Transect 2 along a north-south axis to the southwest of Transect 1. Both transects were within a limestone forest community west of the antenna field. A third transect, Transect 3, was located in limestone forest east of the antenna field.

6.2.1 Trees

Tree density, dominance, and frequency were quantified using the point-center quarter method; the results were summarized for both transects. A total of 20 species were quantified along the transects. The highest dominance observed was for the banyan tree (*Ficus prolixa*), an overstory species with numerous aerial roots that contribute to its large footprint. The species with the second- and third-highest dominances were pago (*Hibiscus tiliaceus*) and fagot (*Neisosperma oppositifolia*), which typically occupy the overstory. All three species are native to Guam.

The point-center quarter observations revealed the highest frequencies were for pago, followed by fagot and paipai (*Guamia mariannae*), which is a native forest understory species. Two introduced species – custard apple (*Annona reticulata*) and lemonchina (*Triphasia trifolia*) – had the next-highest frequency values. Although they are not native components, these species have become naturalized in other limestone forests around the island.

Native species had a combined relative density of approximatley 77 percent, far exceeding the relative density of introduced species for both transects at Navy Barrigada. The overall density of trees was calculated at 43.55 trees per 100 m^2 (Chart 6-1). The native species pago, fagot, and paipai had the three highest relative densities (approximately 29 percent, 14 percent, and 9 percent, respectively).

The overall density for Transect 3 was calculated at 4,632 trees per hectare. Seven species of tree were encountered throughout the survey. The introduced *Annona reticulata* and *Leucaena leucocephala* had the two highest relative densities of all species observed (Chart 2), and were the only introduced species encountered throughout the survey. Together, these two species accounted for approximately 58 percent of the relative density and 47 percent of the relative dominance. *Hibiscus tiliaceus* was the most encountered native tree species and had the highest relative density (approximately 17 percent) and relative dominance (approximately 31 percent) of all native species.

6.2.2 Seedlings

A comparison of the woody seedling density revealed a higher density for Transect 2. The density of woody seedlings was greater in Transect 2 than in Transect 1. Both transects, however, showed markedly higher densities of native over introduced species.

Chart 6-1

Relative Density of Tree Species, Navy Barrigada Transects 1 and 2
(N = native)

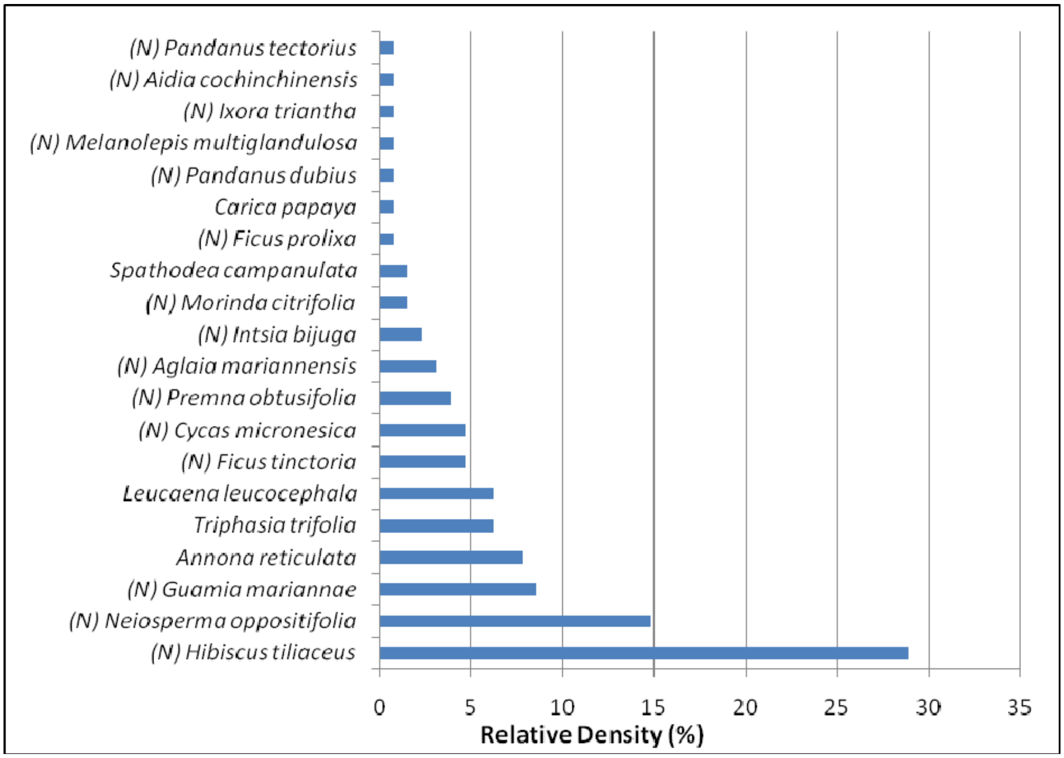
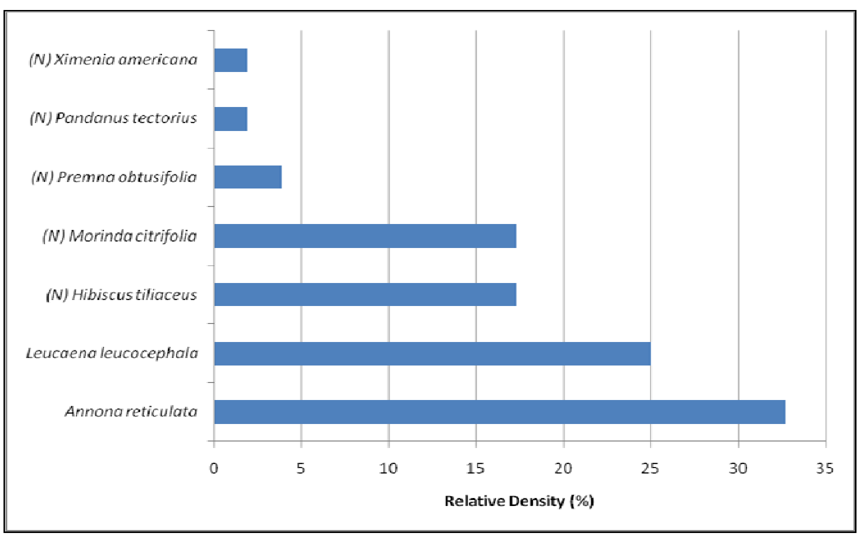


Chart 6-2

Relative Density of Tree Species, Navy Barrigada Transect 3
(N = native)



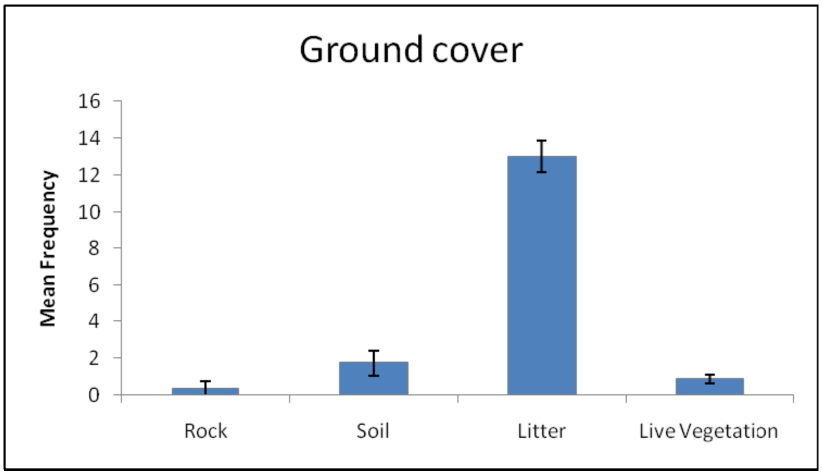
6.2.3 Habitat Quality

The habitat quality at Navy Barrigada may be described through the level of ungulate activity, percentage of native species, and overall species richness.

There was no ungulate activity quantified at the transect stations during the survey. Transects 1 and 2 had a higher level of species abundance than did transect 3. The ground- cover observations revealed a high frequency of leaf litter. Bare soil, rock, and live vegetation had relatively low mean frequencies for Transects 1 and 2 (Chart 6-3). For Transect 3, rock, bare soil, litter, and live vegetation had frequescies of 2,16, 22, and 8, respectively.

Chart 6-3

Ground Cover Frequencies in the Study Plots for Transects 1 and 2



6.2.3.1Threatened and Endangered Species and Species of Concern

Threatened and Endangered Species

In an earlier survey, BioSystems Analysis, Inc. (1989) identified no threatened or endangered species at Navy Barrigada. Likewise, no plant species listed as threatened or endangered were identified within Navy Barrigada during the current survey.

Live specimens of the Pacific tree snail (*Partula radiolata*) were found on fagot (*Neisosperma oppositifolia*) along Transect 2 in the central sector (Photo 6-1). The Pacific tree snail is listed as endangered on the local and federal endangered species lists.

Species of Concern

The current survey found one species of concern – fadang (*Cycas micronesica*) - which is considered a SOGCN by the GDWAR (Photo 6-1). Fadang was found along Transects 1 and 2, with densities of 3.81 and 0.61 trees per 100 m^2, respectively. Specimens were not in good health and were often topped by epiphytes, such as Bird's Nest Fern (*Asplenium nidus*). BioSystems Analysis, Inc. (1989) cited fadang among the dominant species in the limestone forest at Navy Barrigada.

Photo 6-1 *Cycas micronesica* in limestone forest along Transect 2, Navy Barrigada.

6.3 Butterfly Surveys

On Navy Barrigada, one 250-m transect (Transect 3, depicted on Figure 6-1) was surveyed. This transect is located in a forested area, with a canopy of approximately 6-8 m or tall with several small clearings on or near the transect. The forested area is located adjacent to a large, maintained grass field associated with communication towers. The transect began approximately 15 m from the forest's edge.

6.3.1 Species Observed

Four butterfly species were identified during the timed counts. The species were as follows:

- Blue-banded King Crow
- Blue Moon
- Common Mormon
- Common Evening brown

None of the four species are considered endangered or threatened, and all are fairly well-distributed throughout Guam and the Northern Mariana Islands. For a description of each species, refer to Appendix E.

Table 6-2 identifies the numbers of individuals and species observed within the various sampling plots on Navy Barrigada in September, 2009, and January, 2010.

On Navy Barrigada, the Common Mormon was the most frequently observed butterfly in September and January, comprising 73.2 and 52.5 percent of the total sightings, respectively. The numbers of individuals and species showed little variation between September and January.

The Mariana Eight-Spot butterfly (*Hypolomnas octocula mariannensis*) and the Mariana wandering butterfly (*Vagrans egistina*), which are both candidate species for listing by the United States Fish and Wildlife Service (USFWS) under the Endangered Species Act of 1973, were not observed on the transect.

Table 6-2

Butterfly Sightings at Navy Barrigada – September 2009 and January 2010

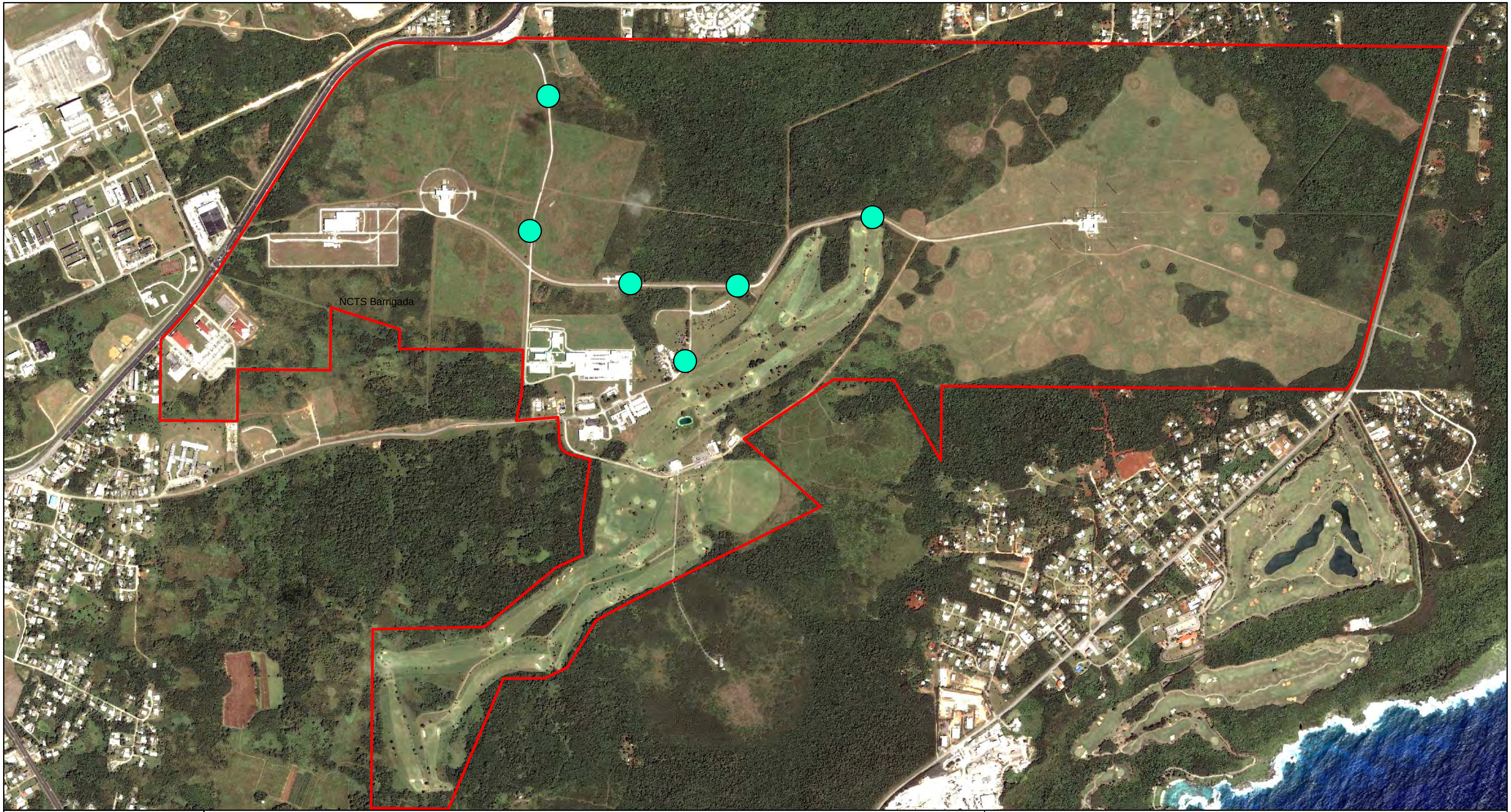
September 2009				January 2010				
Distance on Transect	Species			Distance on Transect	Species			
	Common Mormon	Blue-banded King Crow	Blue Moon		Common Mormon	Blue-banded King Crow	Blue Moon	Evening Brown
0	2	6		0	2	6		1
30	2	2		30	3			
60	7			60	2	1		
90	7	2	1	90	7		1	
120	3			120	1	2		
150	2			150	4	3		
180	2			180		4		
210	1			210	-	-	-	-
240	4			240	2	1		
TOTAL	**30**	**10**	**1**	**TOTAL**	21	17	**1**	**1**
Percent of sightings	**73.2**	**24.4**	**2.4**	Percent of sightings	**52.5**	**42.5**	**2.5**	**2.5**

6.3.2 Baited Traps

Two baited traps were placed on the transect during daylight hours. The trap was placed at the start of the transects, and at approximately the 60 meter mark near a clearing. Two individuals of evening brown butterfly were captured in September 2009. In January 2010, one evening brown was captured.

6.4 Avian Surveys

On Navy Barrigada, roadside surveys (Figure 6-2) were conducted in the evening and forest bird surveys were conducted in the morning. Table 6-3 lists the species identified as part of the surveys.



Navy Barrigada

Roadside Survey Points

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010 | Project No.: 60133557 | Figure 6-2

All of the observed species are common to Guam. Table 6-4 specifies the resident status of the observed species. The nomenclature follows Gill et al., 2008. For more information on the avifauna survey and results, refer to Appendix G.

Table 6-3

Species Identified during Roadside and Forest Bird Surveys – Navy Barrigada

Survey Type	Number of Stations	Species and Number of Detections	Number of Species	Total Number of Detections
Roadside	6	Pacific Golden Plover (18) Black Drongo (9) Western Cattle Egret (8) Island Collared Dove (6) Eurasian Tree Sparrow (6) Black Francolin (3) Yellow Bittern (3)	7	53
Forest Bird	4	*- none -*	*- none -*	*- none -*

Table 6-4

Residence Status of the Avifaunal Species Identified during the Roadside and Forest Bird Surveys – Navy Barrigada

Avifaunal Species	Residence Status[1]
Yellow Bittern (*Ixobrychus sinensis*)	Common resident native - breeding
Island Collared Dove (*Streptopelia bitorquata*)	Common introduced resident - breeding
Black Drongo (*Dicrurus macrocercus*)	Common introduced resident - breeding
Eurasian Tree Sparrow (*Passer montanus*)	Common introduced resident - breeding
Black Francolin (*Francolinus francolinus*)	Common introduced resident - breeding
Pacific Golden Plover (*Pluvialis fulva*)	Common visitor – not breeding [2]
Western Cattle Egret (*Bubulcus ibis*)	Common visitor – not breeding
Notes: * Reichel and Glass 1991; **Johnson et al. 2006.	

6.5 Tree Snail Surveys

General and detailed visual surveys were conducted on Transect 3 at Navy Barrigada (Figure 6-1). No living partulid tree snails or their shells were observed (Table 6-5).

Shells of the introduced Giant African Snail (*Achatina fulica*) and both live individuals and shells of the introduced snail *Satsuma mercatoria* (no common name) were seen on the transects. Additionally, live introduced Manokwar flatworms (*Platydemus manokwari*) were observed along Transect 3 (Table 6-5). Because no live partulid tree snails were observed during general or detailed visual surveys, no quadrat surveys were completed; therefore, temperature, humidity, and air movement measurements were not taken in areas not inhabited by tree snails.

Table 6-5
Partulid Tree Snail General and Detailed Visual Survey Results on Department of Defense Lands, Guam – Navy Barrigada

General Visual Survey Date	Detailed Visual Survey Date	Transect	Transect Length (m)	Number of Partulid Tree Snails Observed
September 29, 2009[1]	October 29, 2009[1]	3[2]	250	0
October 7, 2009[1]	November 6, 2009[1]	3[2]	250	0

1 Survey was completed over the course of two days due to poor weather conditions.
2 Flatworms recorded along the transect.

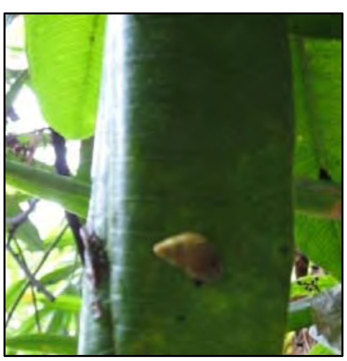
No partulid tree snails were observed. However, since there were several known host plant species present throughout the survey area, the possibility that tree snails are present in habitat associated with the surveyed transects cannot be dismissed.

The presence of flatworms on Navy Barrigada is of note – especially since the species was not targeted during the tree-snail surveys. As flatworms are more likely to be seen nocturnally when they are active, flatworms were likely present but undetected at all locations. This flatworm is known to feed on juvenile partulid tree snails in the wild on Guam and Pacific tree snails in captivity, and is believed to be the primary threat to the continued existence of partulid tree snails on Guam, the Mariana Islands, and potentially Oceania (Hopper and Smith, 1992). The authors reported that on Guam where flatworm abundance was high, partulid tree snail colonies were rapidly declining.

6.6 Fruit Bat Surveys

NAVFAC biologists surveyed two locations on Navy Barrigada in May 2008. No bats were sighted during this survey. For more information on the fruit bat survey and results, refer to Appendix I.

6.7 Threatened and Endangered Species



No threatened or endangered avifauna, butterfly, herpetofauna species or fruit bats were identified on Navy Barrigada. No partulid snails were identified as part of the tree snail survey; however, during the vegetation survey, live specimens of the Pacific tree snail, *Partula radiolata* were found on a fagot, *Neisosperma oppositifolia* plant along Transect 2 in the central sector (Photo 6-2). The Pacific tree snail is listed as endangered on the local and federal endangered species lists. Moreover, several known host plant species present throughout the survey area, the possibility that tree snails are present in habitat associated with the surveyed transects cannot be dismissed.

Photo 6-2 *Partula radiolata* on Neisosperma leaf at Transect 2, Navy Barrigada.

7 North Finegayan

On North Finegayan, natural resource surveys performed included herpetofauna, vegetation, avian, and tree-snail surveys. Figure 7-1 identifies the locations of the nine ecological transects where the surveys were performed. Also, for vegetation surveys, additional transects and survey locations were utilized. The location of these transects and other survey locations are presented when discussed in the respective discipline.

Nine transects were surveyed at North Finegayan. All nine transects were located in secondary forest, dominated by *Pandanus tectorius*, *Guamia mariannae*, *Vitex parviflora*, and *Hibiscus tiliaceus*.

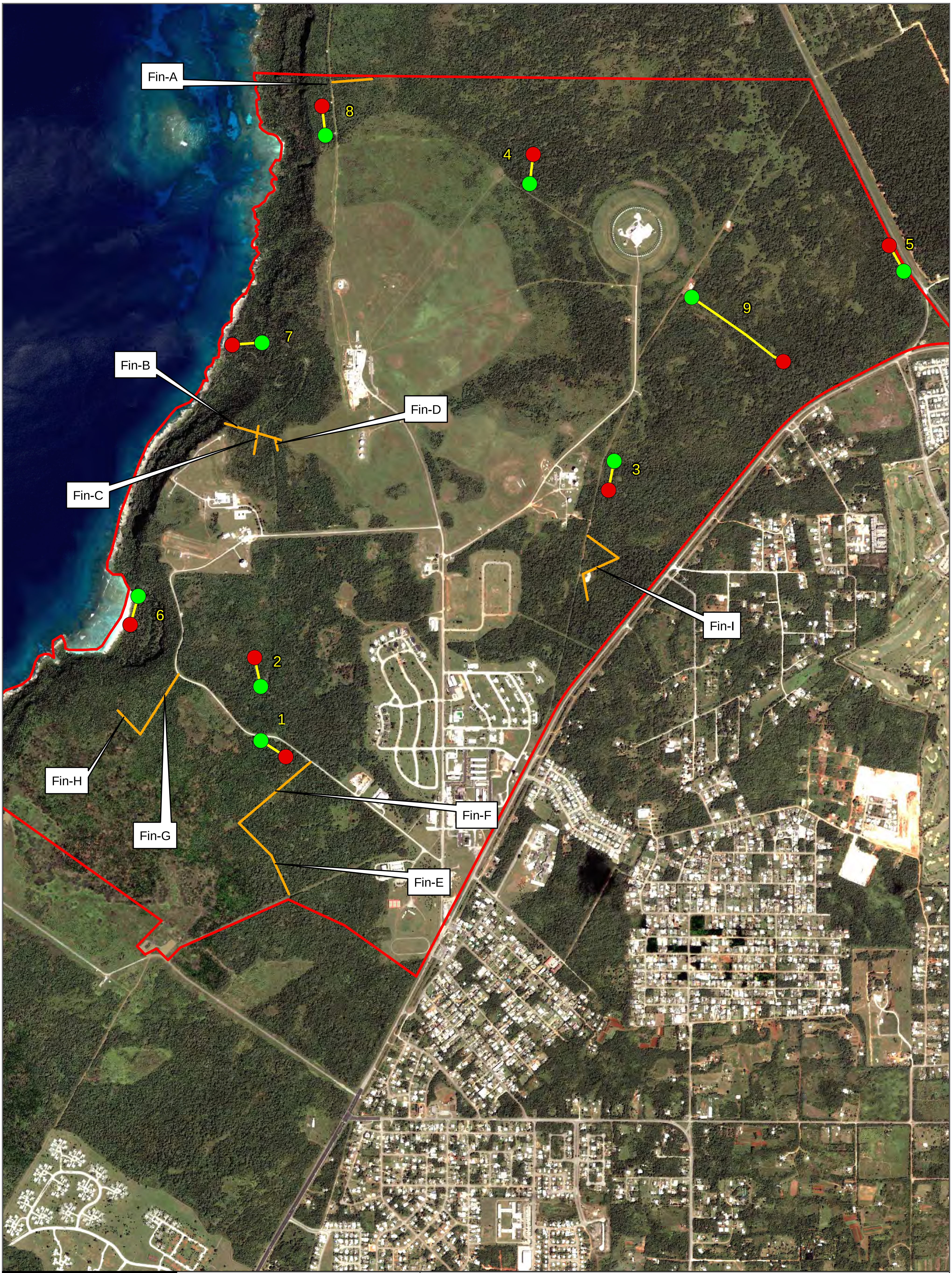
7.1 Herpetofauna Surveys

Ten herpetofauna species were captured or observed on North Finegayan. Table 7-1 identifies the species and their status. For more information on the herpetofauna survey and results, please refer to Appendix B.

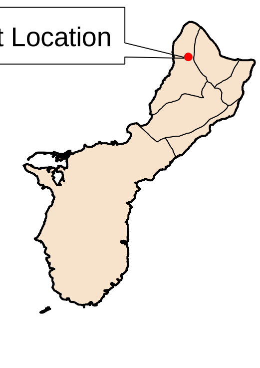
Table 7-1

Herpetofauna Captured or Observed on North Finegayan

Guild	Species	Status
Skinks	Curious skink (*Carlia ailanpalai*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
	Moth skink (*Lipinia noctua*)	Native*
Gecko	House gecko (*Hemidactylus frenatus*)	Introduced
	Mourning gecko (*Lepidodactylus lugubris*)	Native
	Mutilating gecko (*Gehyra mutilata*)	Native
	Pacific slender-toed gecko (*Nactus pelagicus*)	Native*
Snakes	Brown treesnake (*Boiga irregularis*)	Introduced
Other	Monitor lizard (*Varanus indicus*)	Pre-historic
Amphibian	Marine toad (*Rhinella marinus*)	Introduced
Notes: * This species is identified by the Guam Comprehensive Wildlife Conservation Strategies (GCWCS) as SOGCN/Endangered - species of with the highest conservation value.		



Project Location



Beginning Transect Point

End Transect Point

Quantitative Transects

Qualitative Transects

Installation Boundary

N

0 200 400 Meters

North Finegayan

Transect Map

Prepared By: TEC Inc. Joint Venture

A Joint Venture of TEC Inc., AECOM TS Inc., and EDAW, Inc.

Prepared For: NAVFAC Naval Facilities Engineering Command

May 3, 2010	Project No.: 60133557	Figure 7-1

The capture of two Guam- listed endangered species (i.e., moth skink and Pacific slender-toed gecko [Photo 7-1]) is noteworthy. The distribution and abundance of this native skink on Guam is unknown, due to the variability of information presented by authors. The Pacific slender-toed gecko is a rarely seen gecko. The moth skink was captured on Transect 9, Station 17. The pacific slender-toed Gecko was captured on Transect 9 at stations 9, 15, 16, 24, 28, 30, and 34.This study added records of the species at North Finegayan.

Photo 7-1 Photo of the Pacific slender-toed gecko, *Nactus pelagicus*

The continued widespread presence of the brown treesnake and curious skink, as well as other introduced amphibian species, is of concern because of each species' potential deleterious impacts to Guam's native fauna (Rodda et al., 1999, Kraus et al., 1999, Wiles et al., 2003, Christy et al., 2007a). Of particular concern is the potential of the introduced species to serve as additional food sources for the brown treesnake (Fritts and Rodda, 1998, Christy et al., 2007a). For more information on the herpetofauna survey and results, please refer to Appendix B.

7.2 Vegetation

Vegetation surveys on North Finegayan consisted of the following:

- Quantitative Survey - The current quantitative survey areas at North Finegayan comprised three vegetation types: limestone forest, coconut grove, and disturbed/weed community. A disturbed/weed plant community occurred at forest edges and in patches within the forest.

- Qualitative Survey - A qualitative survey was conducted in North Finegayan. The full vegetation survey report is provided in Appendix D.

7.2.1 Quantitative Survey

7.2.1.1 Trees

Native species comprised nearly three-quarters of the relative density of tree species in the six transects in the limestone forest at upper North Finegayan (Chart 7-1). Thirteen of the 19 species (or approximately 68 percent) encountered on the transects were native trees. It is notable that *Vitex parviflora*, an introduced species, is a dominant component of these forests in terms of basal area, absolute dominance, and frequency. *Vitex* had the highest relative density (about 22 percent), followed by native kafu or screwpine (*Pandanus tectorius*) and endemic paipai (*Guamia mariannae*) trees, with densities of about 17 percent each. *Vitex* is a Philippine species that was introduced to Guam prior to 1970 (Stone, 1970) and has since become a common component of its forests (Donnegan et al., 2002).

In the forests of the southern sector (Transects 1 and 2), the three species with the highest relative densities were *Guamia mariannae*, *Pandanus tectorius*, and *Neisosperma oppositifolia*, which collectively accounted for 62 percent of the overall density. Native species had a combined density of 87 percent; two of these species, *Guamia* and *Aglaia*, are endemic to the Mariana Islands, and had a combined density of 27 percent. The non-native element was composed of *Triphasia trifolia* and *Vitex parviflora*, with a combined density of 13 percent.

Non-native species (*Vitex*, *Cestrum*, and *Triphasia*) accounted for 45 percent of the relative density in the limestone forest of the north-central sector of North FinegayanNorth Finegayan (Transects 3 and 4). Native species made up slightly more than half of the overall density, but endemic species (*Guamia* and *Aglaia*) accounted for only 8 percent of the relative density.

The limestone forest in the northeastern sector of North Finegayan (Transect 5) contained similar relative densities of the introduced *Vitex* and the endemic *Guamia* trees. *Vitex parviflora* and African tulip (*Spathodea campanulata*) trees were the non-native species, with a combined relative density of about 32 percent. The three endemic species (*Guamia*, *Eugenia palumbis,* and *Maytenus thompsonii*) accounted for about 30 percent of the relative density.

Transect 6, located along the coast of the Haputo Ecological Reserve Area (ERA) embayment, was located within a coconut (*Cocos nucifera*) grove. A disturbed/weed plant community occurred at forest edges and in patches within the forest. The area is located close to sea level below the limestone plateau of the main annex. Nonag (*Hernandia peltata*), an indigenous tree, had a relative density of about 22 percent; coconut palms comprised the remainder of the trees (Chart 7-2).

The west-central sector of North Finegayan in the vicinity of Pugua Point (Transect 7) contains limestone forest with a native species density of 66 percent and a pronounced *Merrilliodendron megacarpum* component (Chart 7-3). *Merriolliodendron megacarpum* is an indigenous species found in only a few localities on Guam because of its restricted habit. Non-native species accounted for 34 percent of the relative density; *Annona*, *Triphasia*, and *Carica* are successful introductions that have long been naturalized in native forests. Endemic species (*Guamia* and *Aglaia*) accounted for 14 percent of the relative density. The native cycad, *Cycas micronesica*, had a low density of only 3 percent.

Chart 7-1

Relative Density of Tree Species in Transects 1 to 5 and Transect 8, North Finegayan
(N = native)

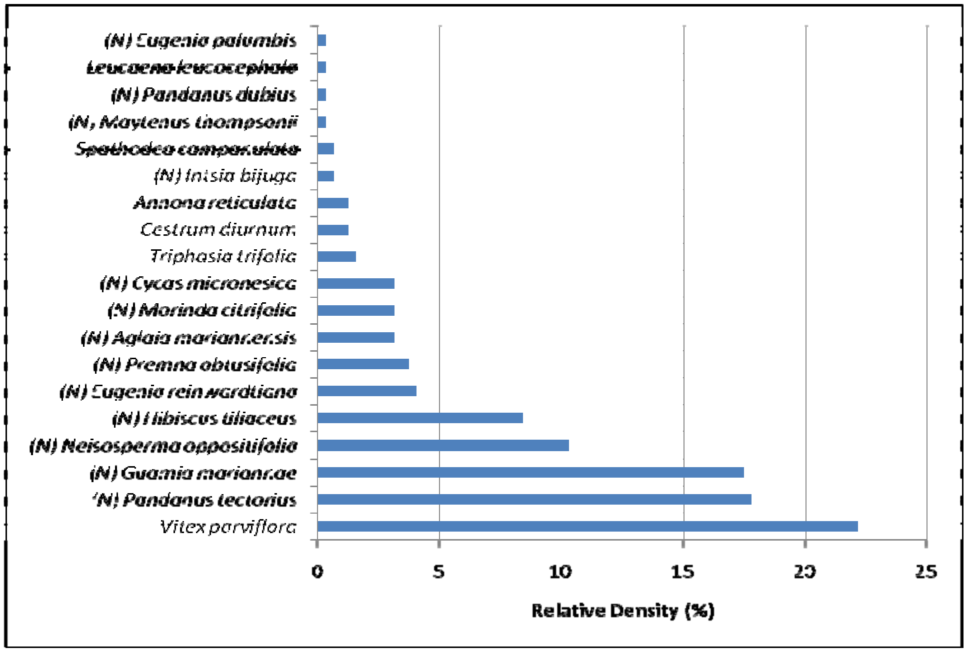


Chart 7-2

Relative Density of Tree Species on Transect 6 – North Finegayan
(N = native)

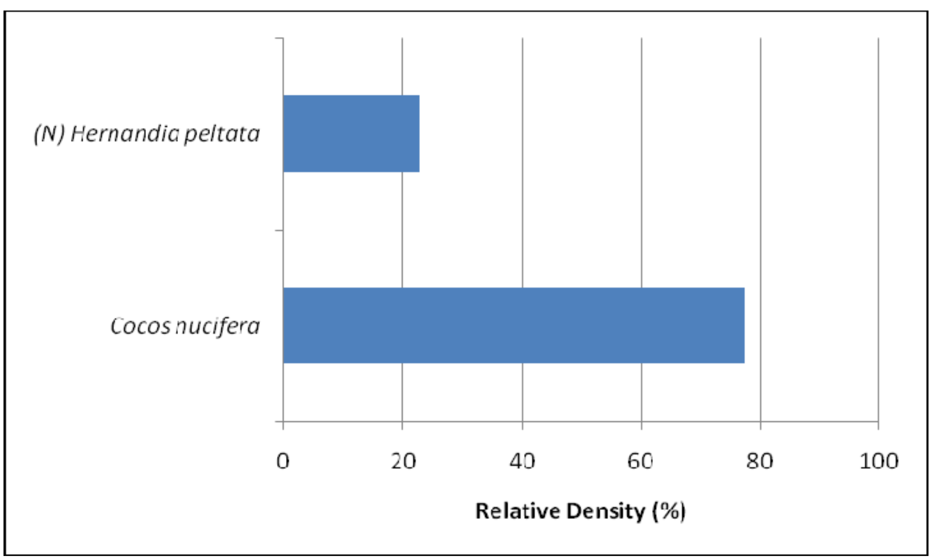
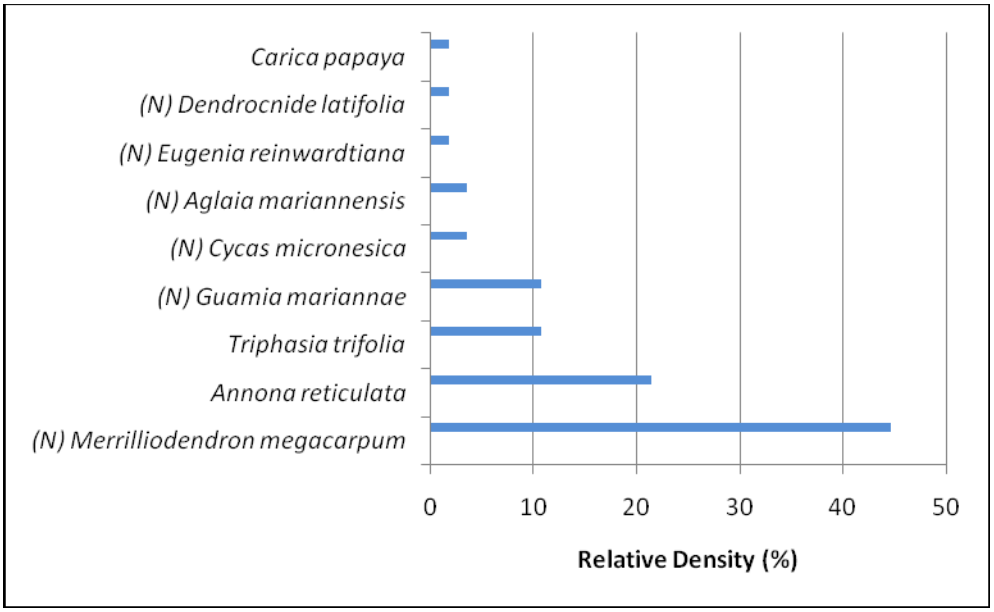


Chart 7-3

Relative Density of Tree Species on Transect 7 – North Finegayan.
(N = native)



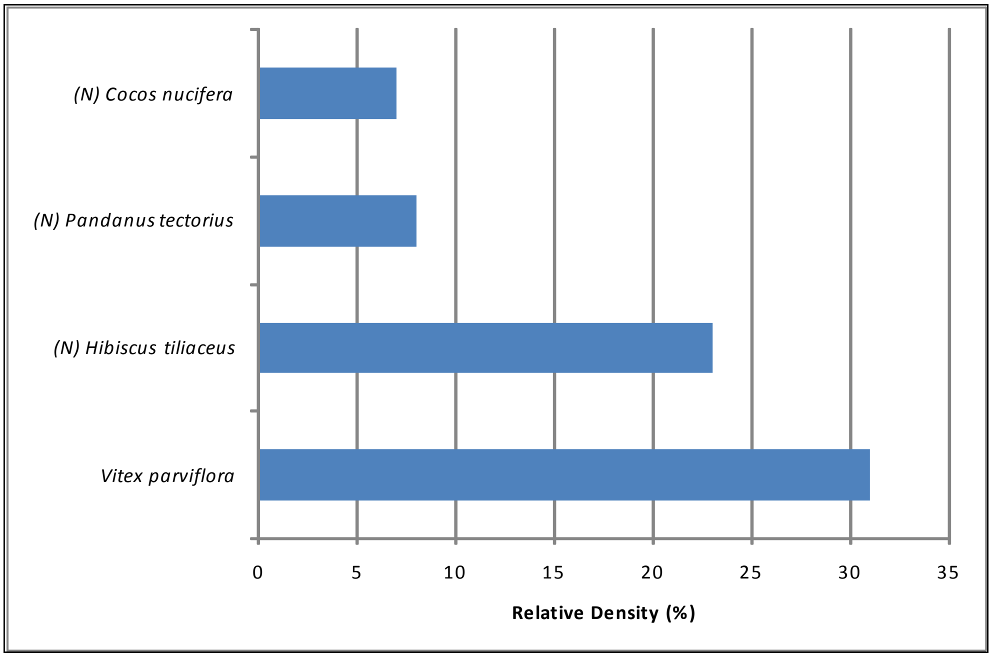
The limestone forest along Transect 7 in lower North Finegayan is a distinctive community composed of a stand of faniok (*Merrilliodendron megacarpum*) trees that provide habitat for the Pacific tree snail (*Partula radiolata*). The forest is situated close to sea level along the base of an escarpment and overlies karstic limestone substrate. From north to south, the site transitions from faniok-dominated forest to a more mixed community.

Transect 8 in the North Finegayan annex was a coconut (*Cocos nucifera*) grove in the Haputo ERA embayment along the western coast. The area is located close to sea level below the limestone plateau of the main annex. Nonag (*Hernandia peltata*), an indigenous tree, had a relative density of about 22 percent; coconut palms comprised the remainder of the trees along this transect.

Transect 9 sampled a forested area on the east side of the parcel. The overall density for this transect was calculated at 1,435 trees per hectare. Only four species of tree were encountered throughout the survey. The introduced *Vitex parviflora* was the most dominant species encountered along this transect, and the only introduced species observed. *Vitex parviflora* had a relative density of 55 percent (Chart 7-4) and a relative dominance of 93 percent. *Hibiscus tiliaceus* and *Pandanus tectorius*, together, had a relative density of 44 percent, yet only accounted for approximately 6 percent of the relative dominance within the transect. One individual of *Cocos nucifera* was encountered.

Chart 7-4

Relative Density of Tree Species on Transect 9 – North Finegayan
(N = native)



7.2.1.2 Seedlings

The percentage of native woody seedlings quantified along the transects exceeded 80 for Transects 4 and 8 in the northern and northwestern sectors on the upper plateau, and for Transect 7 along the west-central coast. Elsewhere, less than 60 percent of the seedlings were native.

The mean woody seedling density for all transects at North Finegayan was slightly higher for native species (1.71 seedlings per m^2) than for introduced species (1.12 seedlings per m^2).

7.2.1.3 Habitat Quality

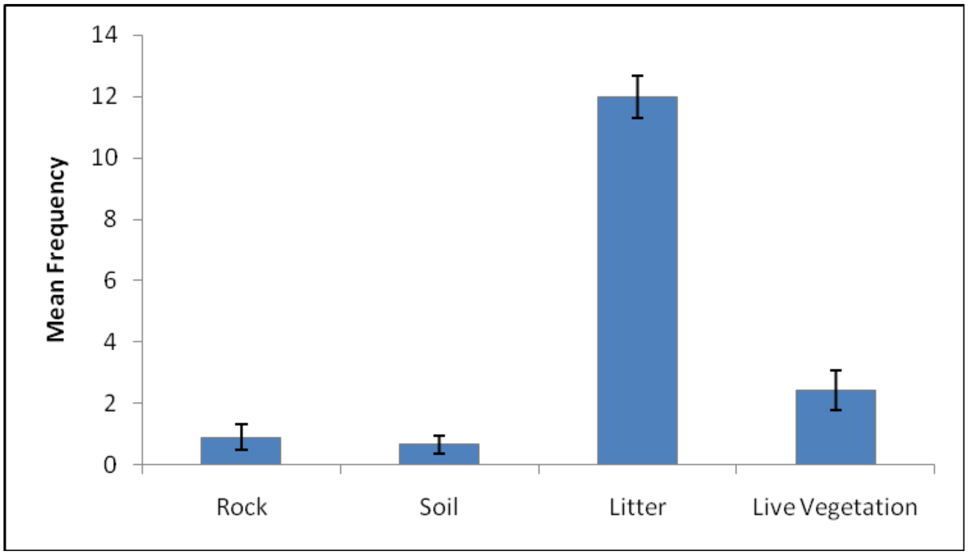
Certain aspects of the plant communities may provide a general indication of the quality of the habitat at North Finegayan. These include ungulate activity, presence of erosion, the percentage of native plant species, and overall species richness.

Analysis of individual transects revealed significantly lower species richness in the coconut grove of Transect 6 compared to all other sites. This transect was in the lower plateau and lacked many of the woody species observed in the remaining seven transects. Similar species richness values were observed for Transect 5 in the northeastern sector and for Transect 8 in the northwestern sector, which are both on the upper plateau.

The ground cover along Transects 1-8 at North Finegayan showed a high mean frequency of litter and relatively low mean frequencies of bare soil and rock (Chart 7-5). Along Transect 9, the rock, soil, litter, and live vegetation frequencies were 0, 1, 71, and 18, respectively. Thus, for all transect on North Finegayan, litter comprised the overwhelming majority of ground cover, with live vegetation being the second most common ground cover. Rock and soil was rarely encountered as ground cover.

Chart 7-5

Mean Frequency of Ground Cover along Transects at North Finegayan



Ungulate activity was observed most frequently in the form of rubbings on tree trunks and browsing. Soil disturbance, such as wallows, was less frequently observed at North Finegayan. An example of the type of ungulate disturbance observed at North Finegayan- is shown in Photo 7-2. Ungulates, most likely feral pigs, have toppled a fadang (*Cycas micronesica*) specimen, possibly to feed on the pith material in the trunk.

Photo 7-2 Ungulate damage to *Cycas micronesica*, Transect 8, North Finegayan

7.2.2 Qualitative Survey

On January 15, 2010 a qualitative survey was performed on eight transects (Figure 7-1) located in a secondary forest in the northeast portion of North Finegayan. No listed or rare species were observed. A small patch of *Procris pedunculata,* the host plant for the Mariana Eight-spot Butterfly, was observed scattered in one area of cockscomb limestone. The cockscomb limestone area also has some large (rising to nearly 6 m in height) *Cycas micronesia*, a SOGCN plant species. For more information on the results of this survey, refer to Appendix D.

7.2.3 Threatened and Endangered Species and Species of Concern - Vegetation

Threatened and Endangered Species

None of the locally-listed or federally-listed endangered plants were detected during the current survey in North Finegayan.

Species of Concern

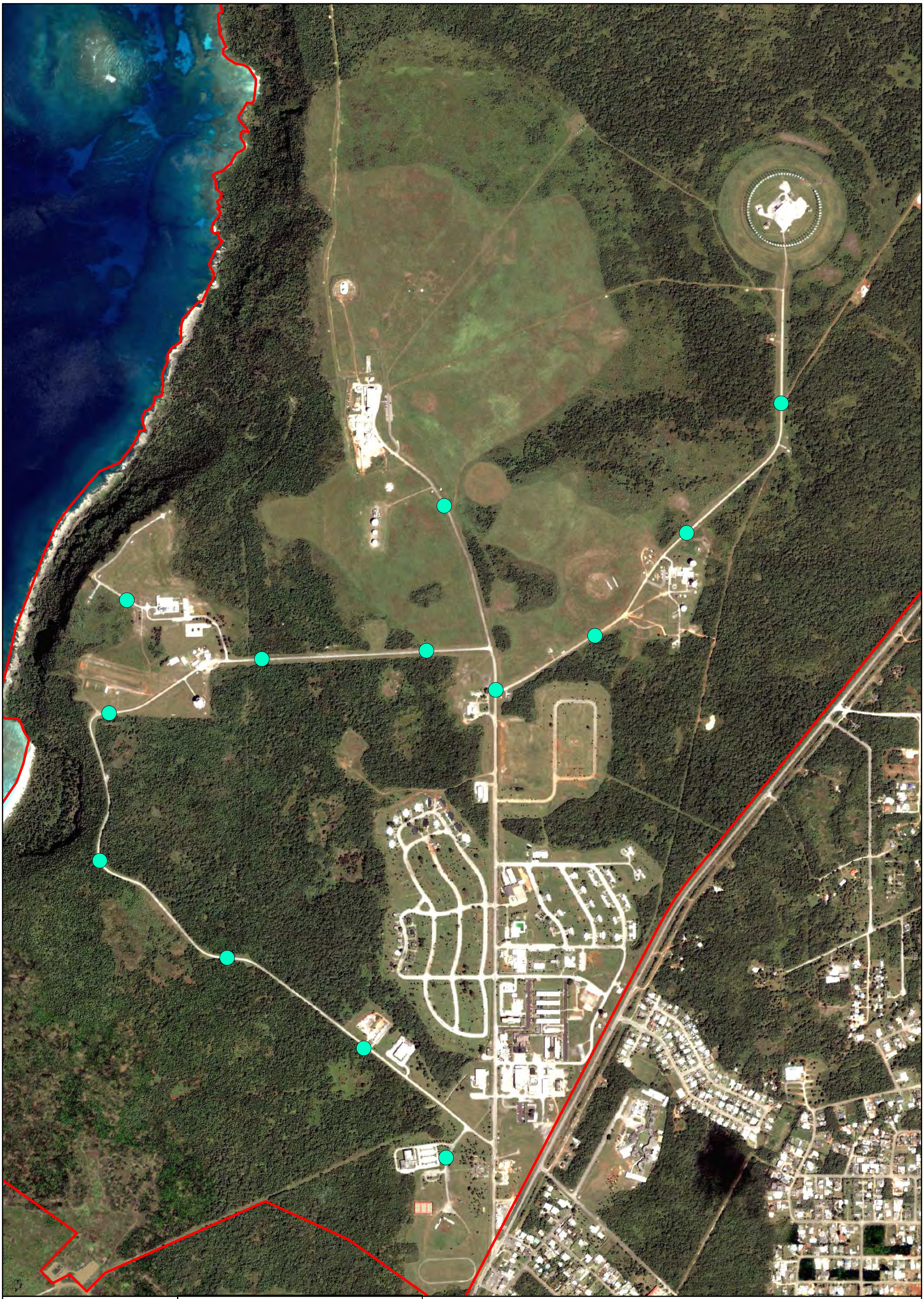
Species of concern are those plants that have biological or cultural significance as determined by recognized authorities or regulatory agencies. The Guam Department of Agriculture/ Division of Aquatic and Wildlife Resources currently lists three plants among the SOGCNs for the island, based on certain criteria.

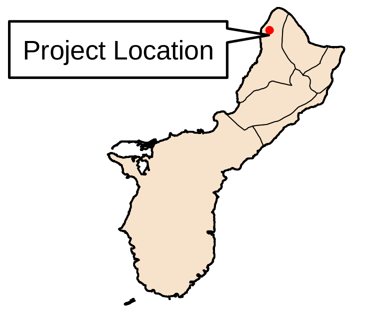
Two SOGCNs are present at North Finegayan: faniok (*Merrilliodendron megacarpum*), fadang (*Cycas micronesica*). According to the *Guam Comprehensive Wildlife Conservation Strategy*, faniok is threatened by herbivory, typhoons, and development (Department of Agriculture, 2005). A faniok stand is present along Transect 7 close to sea level in the west-central sector of the installation. Fadang is typically distributed over limestone and volcanic substrates, but populations island wide are in decline from infestation by the Asian cycad scale (*Aulacaspis yasumatsui*) (Department of Agriculture, 2005). Fadang was quantified only on Transect 7 in the west-central sector and on Transect 8 in the northwestern sector of the upper plateau. These areas also had the most native tree species among those surveyed.

7.3 Avian Surveys

Forest bird surveys (Figure 7-1) and roadside surveys (Figure 7-2) were conducted in the morning. Table 7-2 identifies the species observed as part of the surveys.

All of the observed species are common to Guam. Table 7-3 specifies the resident status of the observed species. The nomenclature follows Gill et al., 2008. For more information on the avifauna survey and results, refer to Appendix G.





Installation Boundary

Roadside Survey Point

0 200 400
Meters

North Finegayan

Roadside Survey Points

Prepared By: Prepared For:

TEC Inc. Joint Venture

NAVFAC

May 3, 2010 | Project No.: 60133557 | Figure 7-2

Table 7-2

Species Identified During Roadside and Forest Bird Surveys – North Finegayan

Survey Type	Number of Stations	Species and Number of Detections	Number of Species	Total Number of Detections
Roadside	13	Pacific Golden Plover (53) Black Francolin (13) Eurasian Tree Sparrow (7) Island Collared Dove (6) Black Drongo (2)	5	81
Forest Bird	17	Island Collared Dove (7) Black Francolin (2) Eurasian Tree Sparrow (1)	3	10

Table 7-3

Residence Status of the Avifaunal Species Identified during the Roadside and Forest Bird Surveys – North Finegayan

Avifaunal Species	Residence Status[1]
Island Collared Dove (*Streptopelia bitorquata*)	Common introduced resident - breeding
Black Drongo (*Dicrurus macrocercus*)	Common introduced resident - breeding
Eurasian Tree Sparrow (*Passer montanus*)	Common introduced resident - breeding
Black Francolin (*Francolinus francolinus*)	Common introduced resident - breeding
Pacific Golden Plover (*Pluvialis fulva*)	Common visitor – not breeding [2]

Notes:

[1] Residence status obtained from Reichel, J. D. and P. O. Glass, 1991, Checklist of the birds of the Mariana Islands. ‘*Elepaio*, 51(1): 3-10.

[2] Residence status obtained from Johnson, O.W., Goodwill, R. & Johnson, P.M. 2006, Wintering ground fidelity and other features of Pacific Golden-Plovers *Pluvialis fulva* on Saipan, Mariana Islands, with comparative observations from Oahu, Hawaiian Islands. *Wader Study Group Bull.* 109: 67–72.

7.4 Tree Snail Surveys

In 2008 a survey was performed on North Finegayan centered on the southern area and at Haputo Beach, and along the cliff line at Pugua Point in the central western area of the base (Appendix H; Smith et. al., 2008). The only colonies found were at Haputo Beach and Pugua Point. At Pugua Point the colony was made up of *Samoan fragilis* and *Partula radiolata* while the colony Comprised both *Partula gibba* and *Partula radiolata* at Haputo Beach.

In addition, a general and detailed visual survey was completed on Transect 9 at North Finegayan (Table 7-4). No living partulid tree snails (or their shells) were observed during any of the surveys conducted along the transect. No partulid tree snails were observed on Transect 9 in North Finegayan, but since there were several known host plant species present throughout the survey area, the possibility that tree snails are present in habitat associated with the surveyed transects cannot be dismissed.

Table 7-4

Partulid Tree Snail General and Detailed Visual Survey Results on Department of Defense Lands, Guam — North Finegayan

General Visual Survey Date	Detailed Visual Survey Date	Transect	Transect Length (m)	Number of Partulid Tree Snails Observed
21 January 2010	21 January 2010	NFIN - 9	500	0
Note: Because no live partulid tree snails were observed during general or detailed visual surveys, no quadrat surveys were completed; therefore, temperature, humidity, and air movement measurements were not taken in areas not inhabited by tree snails.				

Shells of the introduced Giant African Snail (*Achatina fulica*) and both live individuals and shells of the introduced snail *Satsuma mercatoria* (no common name) were seen along the transect.

7.5 Fruit Bat Surveys

NAVFAC biologists surveyed three locations over 10 days on North Finegayan from February to June 2008. Two bats were observed during this survey, one below the cliff line of the Haputo reserve and the other crossing Route 3A. For more information on the fruit bat survey and results, refer to Appendix I.

7.6 Threatened and Endangered Species

No federally-listed threatened or endangered avifauna, butterfly, herpetofauna, or tree snail species were identified at North Finegayan. However as noted above the federally threatened Fruit Bat was sighted at North Finegayan.

The capture of two Guam- listed endangered species (i.e., moth skink and Pacific slender-toed gecko occurred on North Finegayan. The moth skink was captured on Transect 9, Station 17. The pacific slender-toed Gecko was captured on Transect 9 at stations 9, 15, 16, 24, 28, 30, and 34.

Two SOGCN plant species are present at North Finegayan: faniok (*Merrilliodendron megacarpum*) and fadang (*Cycas micronesica*). According to the *Guam Comprehensive Wildlife Conservation Strategy*, faniok is threatened by herbivory, typhoons, and development (Department of Agriculture, 2005). *Procris pedunculata*, the host plant for the Mariana Eight Spot butterfly was observed scattered at North Finegayan.

The Haputo Ecological Reserve Area provides habitat for the Pacific tree snail (*Partula radiolata*) and the last remaining colony of Mariana tree snails (*Samoana fragilis*) on Guam. These species are among the endemic tree snails locally-listed as endangered and federally-listed as candidate species.

8 South Finegayan

On South Finegayan, the natural resource surveys performed included: herpetofauna, vegetation, and avian surveys. Figure 8-1 identifies the locations of the natural resource surveys' transects. On South Finegayan, both transects consisted primarily of *Hibiscus tiliaceus* and *Leucaena leucocephala*; bare ground was also common.

8.1 Herpetofauna Surveys

A total of five herpetofauna species were observed on South Finegayan. Table 8-1 identifies the species and their status. For more information on the herpetofauna survey and results, please refer to Appendix B.

Table 8-1

Herpetofauna Observed on South Finegayan

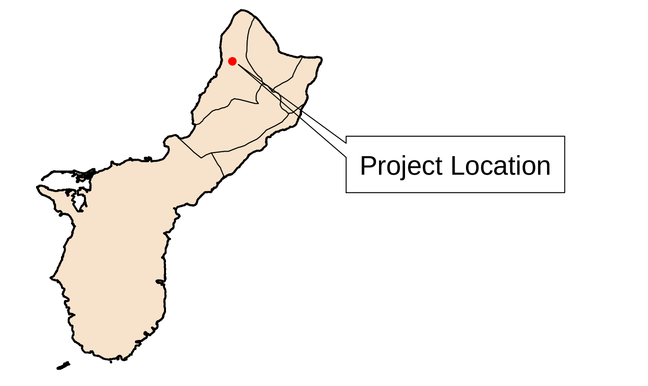
Guild	Species	Status
Skinks	Curious skink (*Carlia ailanpalai*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
Gecko	House gecko (*Hemidactylus frenatus*)	Introduced
	Mutilating gecko (*Gehyra mutilata*)	Native
Amphibian	Marine toad (*Rhinella marinus*)	Introduced

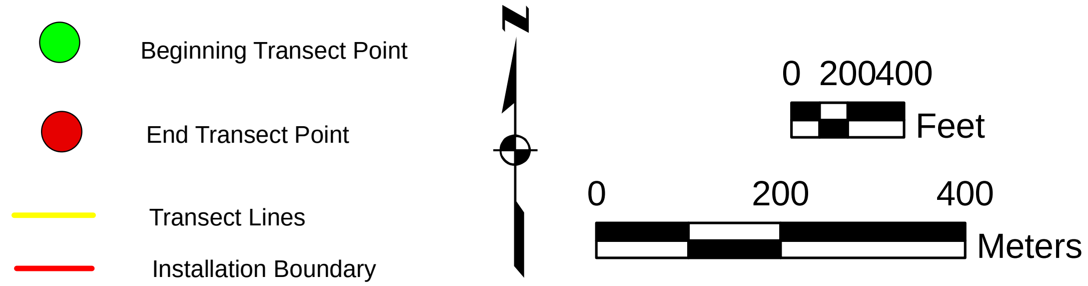
The continued widespread presence of the curious skink as well as of other introduced amphibian species is of concern because of each species' potential deleterious impacts to Guam's native fauna (Rodda et al., 1999, Kraus et al., 1999, Wiles et al., 2003, Christy et al., 2007a). Of particular concern is the potential for the introduced species to serve as additional food sources for the brown treesnake (Fritts and Rodda, 1998, Christy et al., 2007a). For more information on the herpetofauna survey and results, please refer to Appendix B.

8.2 Vegetation

8.2.1 Trees

Calculation of the relative density of tree species on South Finegayan shows that the non-native *Vitex*, tangantangan, and papaya (*Carica papaya*) comprise 67 percent of the trees, with the remaining five species, all of which are native species comprising 33 percent; none are endemic to Guam or the other Northern Mariana Islands. The low native tree component may be attributed to past clearing activities at the site, which is adjacent to a fenced area enclosing what appears to be a hazardous waste remediation site. For more information on the vegetation survey and results, please refer to Appendix D.





South Finegayan

Transect Map

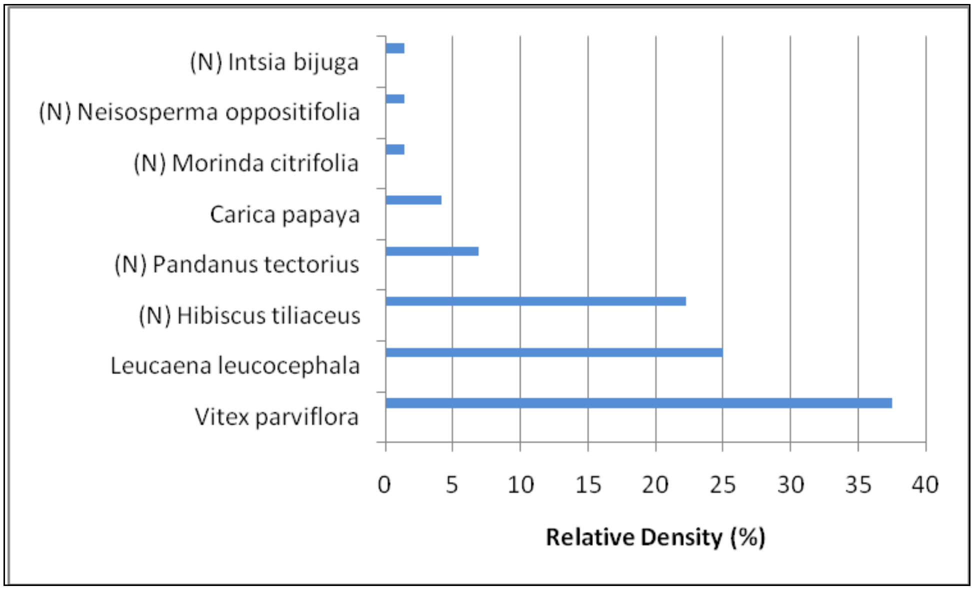
Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 8-1

Chart 8-1

Relative Density of Trees at South Finegayan – Transects 1 and 2
(N = native)

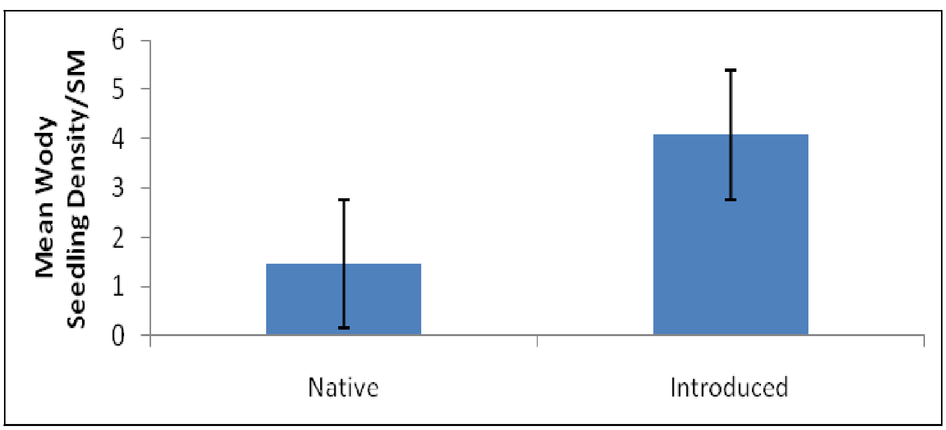


8.2.2 Seedlings

The mean woody seedling density at South Finegayan was lower for native species (1.46 seedlings/m^2) than for introduced species (4.06 seedlings/m^2). Chart 8-2 illustrates this difference between native and introduced seedling density. As can be seen in the figure, there are substantial variation in the number of seedlings per square meter along the transects.

Chart 8-2

Seedling Density of Woody Species at South Finegayan



8.2.3 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat at South Finegayan. These include ungulate activity, presence of erosion, the percent of native plant species, and overall species richness.

Ungulate activity at South Finegayan fell into two categories: rubbings and soil disturbance. The ground cover at South Finegayan was primarily in the form of litter. Little live vegetation was detected.

8.2.4 Threatened and Endangered Species and Species of Concern -

No species listed as threatened or endangered, either by the Federal or local government, were observed along the transects at South Finegayan. Moreover, no species of concern were observed along the transects.

8.3 Avian Surveys

On South Finegayan, forest bird surveys (Figure 8-1) and roadside surveys (Figure 8-2) were conducted in the morning. Table 8-2 identifies the species observed as part of the surveys.

Table 8-2

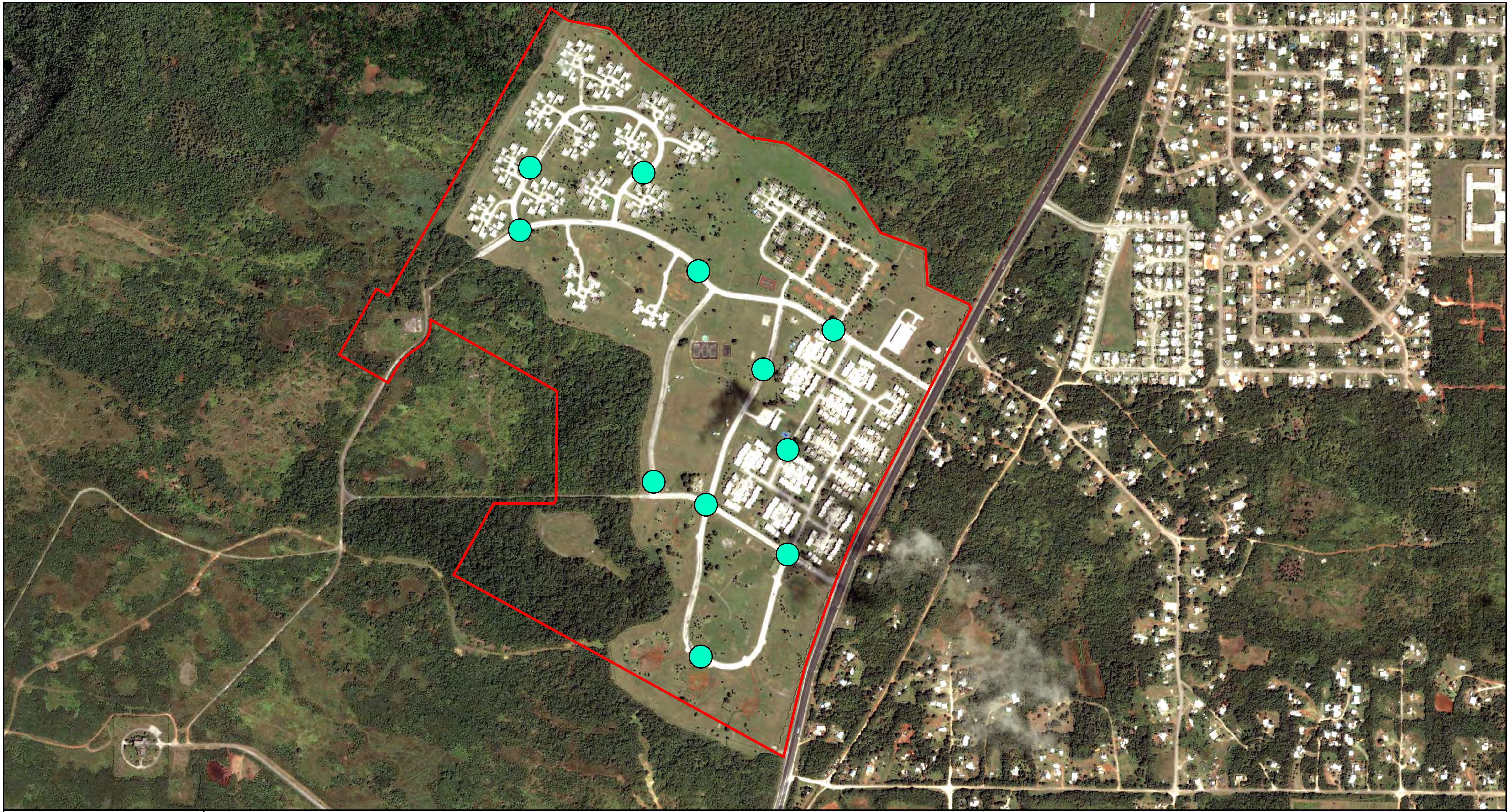
Species Identified During Roadside and Forest Bird Surveys – South Finegayan

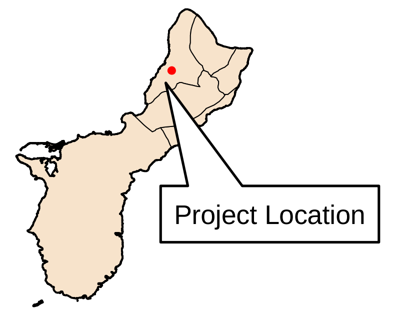
Survey Type	Number of Stations	Species and Number of Detections	Number of Species	Total Number of Detections
Roadside	11	Pacific Golden Plover (53) Island Collared Dove (28) Black Drongo (16) Eurasian Tree Sparrow (14) Common Pigeon (3) Yellow Bittern (1)	5	115
Forest Bird	4	Island Collared Dove (4)	1	4

All of the observed species are common to Guam. Table 8-3 specifies the resident status of the observed species. The nomenclature follows Gill et al., 2008. For more information on the avifauna survey and results, refer to Appendix G.

8.4 Threatened and Endangered Species

No threatened or endangered species were identified on South Finegayan during the natural resource surveys.





Installation Boundary

Roadside Survey Point

N

0 200 400 Meters

South Finegayan

Roadside Survey Points

Prepared By: Prepared For:

May 3, 2010 | Project No.: 60133557 | Figure 8-2

Table 8-3

Residence Status of the Avifaunal Species Identified during the Roadside and Forest Bird Surveys – South Finegayan

Avifaunal Species	Residence Status[1]
Yellow Bittern (*Ixobrychus sinensis*)	Common resident native – breeding
Island Collared Dove (*Streptopelia bitorquata*)	Common introduced resident – breeding
Black Drongo (*Dicrurus macrocercus*)	Common introduced resident – breeding
Eurasian Tree Sparrow (*Passer montanus*)	Common introduced resident – breeding
Pacific Golden Plover (*Pluvialis fulva*)	Common visitor – not breeding [2]

Notes::
[1] Residence status obtained from Reichel, J. D. and P. O. Glass, 1991, Checklist of the birds of the Mariana Islands. '*Elepaio*, 51(1): 3-10.

[2] Residence status obtained from Johnson, O.W., Goodwill, R. & Johnson, P.M. 2006, Wintering ground fidelity and other features of Pacific Golden-Plovers *Pluvialis fulva* on Saipan, Mariana Islands, with comparative observations from Oahu, Hawaiian Islands. *Wader Study Group Bull.* 109: 67–72.

9 Main Base – Orote Point and Inner Apra Harbor and Polaris Point

The natural resource surveys on Main Base were in both terrestrial and aquatic habitats. The terrestrial habitats surveys were Orote Point, Polaris Point, and the Camp Covington Wetlands. The aquatic habitat that was surveyed consisted of portions of Inner Apra Harbor.

Subchapter 9.1 documents the herpetofauna survey conducted within Orote Point and Polaris Point. Subchapters 9.2 and 9.3 discuss the vegetation and avian surveys, respectively, conducted at Orote Point and Polaris Point. The locations of the survey sites are identified on Figure 9-1. In-water marine surveys associated with Inner Apra Harbor are documented in Subchapter 9.4. The locations of the survey sites in Inner Apra Harbor are identified on Figure 9-2.

Five transects were surveyed at Orote Point (Figure 9-1). *Guamia mariannae*, *Aglaia mariannensis*, *Ficus tinctoria*, *Triphasia trifolia*, and *Pandanus tectorius* dominated Transects 1, 2, 3a, and 3b. Transect 4, located below the Spanish Steps toward the beach, was almost entirely *Cocos nucifera*. Two northwest-southeast running transects were surveyed within the vegetated areas of Polaris Point.

9.1 Herpetofauna Surveys

Herptofauna surveys were conducted on Orote Point and Polaris Point. The results of the surveys are provided in Subchapters 9.1.1 and 9.1.2, respectively.

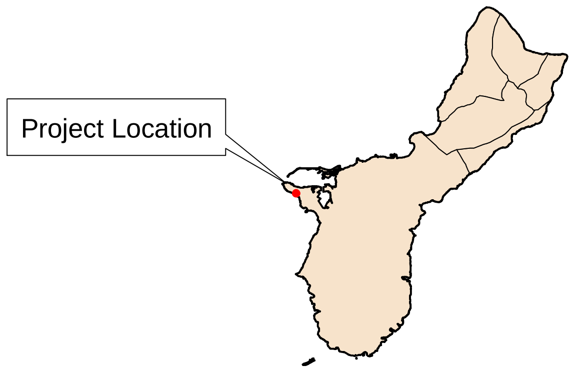
9.1.1 Orote Point

A total of seven herpetofauna species were captured or observed on Orote Point. Table 9-1 lists the species and their status. For more information on the herpetofauna survey and results, please refer to Appendix B.

Table 9-1

Herpetofauna Captured or Observed on Orote Point

Guild	Species	Status
Skinks	Curious skink (*Carlia ailanpalai*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
Gecko	House gecko (*Hemidactylus frenatus*)	Introduced
	Mourning gecko (*Lepidodactylus lugubris*)	Native
	Mutilating gecko (*Gehyra mutilata*)	Native
Snakes	Brown treesnake (*Boiga irregularis*)	Introduced
Other	Monitor lizard (*Varanus indicus*)	Introduced



Beginning Transect Point

End Transect Point

Transect Lines

Installation Boundary

N

0 200 400 Meters

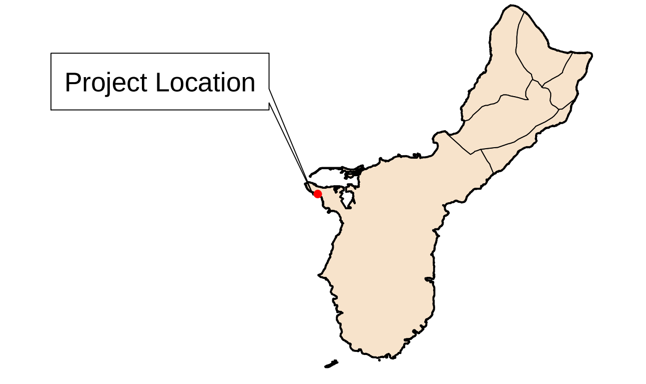
Main Base - Orote Point

Transect Map

Prepared By: TEC Inc. Joint Venture
A Joint Venture of TEC Inc., AECOM TS Inc., and EDAW, Inc.

Prepared For: NAVFAC Naval Facilities Engineering Command NAVFAC PACIFIC

May 3, 2010	Project No.: 60133557	Figure 9-1



Legend

- Inner Apra Harbor Survey Area
- Installation Boundary

N

0 0.5 1 Miles

Main Base - Inner Apra Harbor

Marine Survey Area Map

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 9-2

The continued widespread presence of the brown treesnake and the curious skink, as well as other introduced amphibian species, is of concern because of each species' potential deleterious impacts to Guam's native fauna (Rodda et al., 1999, Kraus et al., 1999, Wiles et al., 2003, Christy et al., 2007a). Of particular concern is the potential for introduced species to serve as additional food sources for the brown treesnake (Fritts and Rodda, 1998, Christy et al., 2007a).

9.1.2 Polaris Point

In 2008, the NAVFAC Pacific biologists performed herpetofauna surveys along two transects in Polaris Point (Figure 9-1). Table 9-2 identifies the herptofauna that were observed. Eight herptofauna species were identified at Polaris Point. The species observed include the endangered moth skink and five introduced species.

Table 9-2

Herpetofauna Captured or Observed on Polaris Point

Group	Species	Status
Skinks	Curious skink (*Carlia ailanpalai*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
	Moth skink (*Lipinia noctua*)	Native*
Geckos	House gecko (*Hemidactylus frenatus*)	Introduced
	Mutilating gecko (*Gehyra mutilata*)	Native
Snakes	Brown treesnake (*Boiga irregularis*)	Introduced
Amphibians	Marine toad (*Rhinella marinus*)	Introduced
Other	Monitor lizard (*Varanus indicus*)	Introduced

Note: *Identified in the Guam Comprehensive Wildlife Conservation Strategy (GCWCS) as Endangered/ Species of Greatest Conservation Need (SOGCN) (GDAWR, 2006).

9.2 Vegetation

Vegetation surveys were performed on Orote Point and Polaris Point. On Orote Point, quantitative surveys were performed along a transect in the upper plateau to the west of the old runway in the southern sector of Orote. The area has a rugged limestone karst topography.

On Polaris Point, a qualitative vegetation survey was performed by Navy biologists in 2008. Subchapter 9.2.2 details the results of the survey at Polaris Point.

9.2.1 Orote Point

9.2.1.1 Trees

Surveys were performed along a transect in the upper plateau to the west of the old runway in the southern sector of Orote. The area has a rugged limestone karst topography.

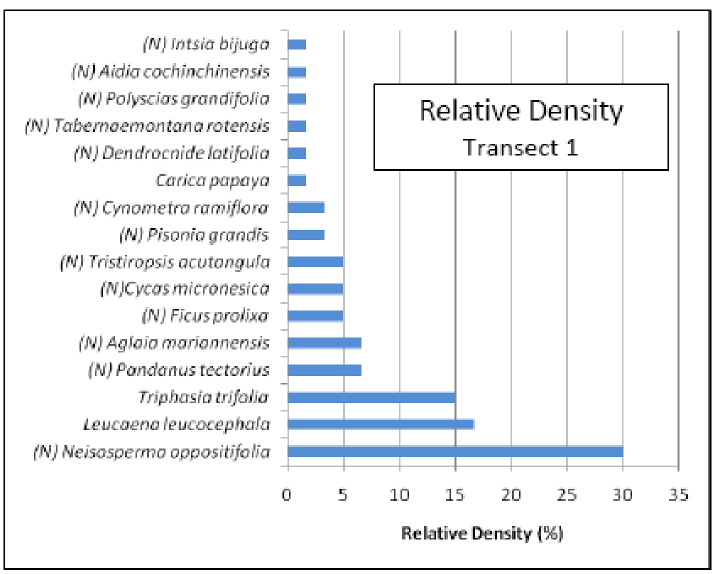
Based on the transect results, the overall density in this sector of Orote is approximately 5,030 trees per ha. The limestone forest was characterized by native fagot (*Neisosperma oppositifolia*) trees, which comprised 28 percent of the relative density, or approximately 1,414 trees per ha. The next highest densities were for the well-established but non-native trees tangantangan (*Leucaena leucocephala*) and Lemon China (*Triphasia trifolia*), with densities of 16 percent and 14 percent, respectively. Collectively, introduced species, including papaya (*Carica papaya*), comprised 33 percent of the relative density (Chart 9-1). The remaining 67 percent of the relative density comprised native species, including the Mariana Islands endemic species *Aglaia marianennsis* and *Tabernaemontana rotensis*.

Absolute cover or dominance was highest for native *Ficus rolix, at* 20.84 m^2/ha, *Pisonia grandis, at* 16.20 m^2/ha, and *Tristiropsis acutangula*, at 15.93 m^2/ha; each had total basal areas exceeding 2,000 cm^2. These species occupy the uppermost canopy of the forest. In comparison, non-native *Leucaena leucocephala*, *Triphasia trifolia*, and *Carica papaya*, which occupy the forest understory, had relatively modest absolute cover values less than 3 m^2/ha.

Absolute frequency was led by native fagot (*Neisosperma oppositifolia*), a mid- to upper-canopy tree, with a value of 56.25. The naturalized species, *Triphasia trifolia* and *Leucaena leucocephala*, had the next highest absolute frequencies, at 37.50 each. *Leucaena* is well-distributed on Orote Point, forming buffers between the periphery of the forest and cleared areas. *Leucaena* had a density of 59.23 trees per 100 m^2 (5,923 trees per ha) and an absolute frequency of 75 in forests sampled near the Kilo Wharf extension project on the northern coast of the Point.

Chart 9-1

Relative Density of Trees along Orote Point Transect 1
(N = native)



9.2.1.2 Seedlings

The woody seedling composition in plots at Orote Point consisted of about 84 percent native seedlings, with a seedling density of 4.04 seedlings/m^2. Introduced seedlings comprised approximately 15 percent, with a density of 0.76 seedlings/m^2.

The native woody seedling density seemed to reflect the higher relative density of native tree species quantified in the point-center quarter transect.

9.2.1.3 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat at Orote Point. These include ungulate activity, the presence of erosion, the percentage of native plant species, and overall species richness. The species richness curve does not show a definite asymptote to indicate that richness has leveled off.

The mean frequency of ground cover in four categories was calculated based on quadrats. The mean frequencies for the categories of rock and vegetative litter were close to one another; live vegetation was very low, and no bare soil was observed in quadrats.

Orote Point is considered free of ungulates because of its topography and relative isolation. Nonetheless, the area was surveyed for soil disturbance or other activity attributed to ungulates, but no ungulate sign was recorded at Orote Point along the vegetation transect.

9.2.1.4 Threatened and Endangered Species and Species of Concern – Orote Point

Threatened and Endangered Species

Guam's only federally-listed plant species, the fire tree or trongkon guafi (*Serianthes nelsonii*), is known to occur only at the northern tip of the island (USFWS, 1994). BioSystems Analysis, Inc. (1989) identified ufa-halomtano (*Heritiera longipetiolata*), an endangered species by the Guam ESA (5 GCA, Chapter 63), as the only listed species within Orote Peninsula. No specimens of *Heritiera longipetiolata* were found in the 2008 survey, which sampled the forest on the southern region of the Peninsula opposite the ammunition wharf.

Notable Species and Species of Concern

The following species of concern were identified within Orote Point during the current survey:

- *Tabernaemontana rotensis* (Apocynaceae) is an endemic tree with distribution limited to the islands of Guam and Rota. The species was proposed for federal listing under the U.S. Endangered Species Act but this candidacy status was removed in 2004. *Tabernaemontana* is considered an SOGCN by the Government of Guam (Department of Agriculture, 2006). One live specimen of *Tabernaemontana* was encountered in the current vegetation survey, which appeared to be a healthy tree with a basal area of 26.96 cm^2. No flowers, fruits, or seedlings were observed.

- *Pisonia grandis* (Nyctaginaceae) is an indigenous tree considered important to the recovery of the Micronesian kingfisher (*Halcyon cinnamomina cinnamomina*) as nesting habitat. A density of 157 trees per ha was calculated for the survey at Orote.

- *Cycas micronesica* (Cycadaceae) is listed by the Guam Department of Agriculture as an SOGCN. This native cycad is under threat by an introduced insect, the Asian scale (*Aulacaspis yasumatsui*).

- *Tristiropsis acutangula* (Balsalminaceae) is an indigenous tree of limited distribution on Guam. Orote had the highest density of *Tristiropsis* (approximately 236 trees *per ha*) *among all DOD* and non-DOD lands investigated in the current survey.

- *Zeuxine fritzii* (Orchidaceae) is an indigenous ground orchid found on forest floors. Feral pigs are known threats because of their rooting activities.

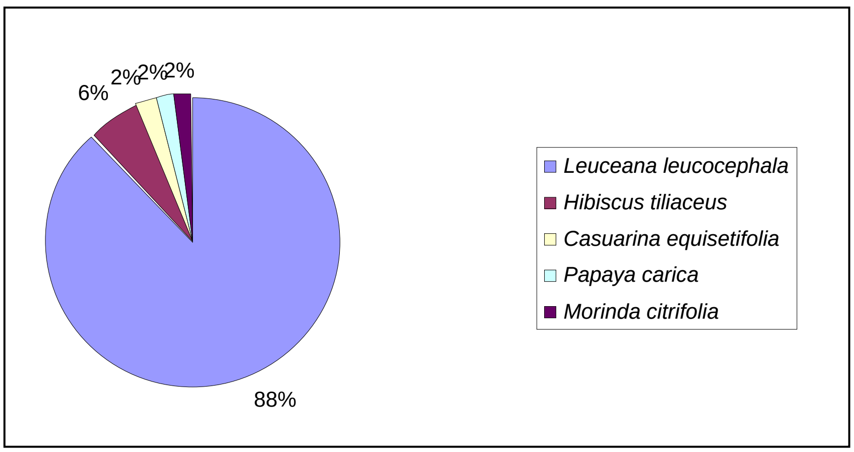
9.2.2 Polaris Point

9.2.2.1 Trees

At Polaris Point the number of trees per hectare (ha) was calculated at 5,004 trees/ha. The mean dbh (cm) (with 95 percent confidence interval) was calculated to be 6.12 (5.03-7.21). *Leuceana leucocephala* comprised 88 percent of the tree layer Chart 9-2 identifies the species composition along the transect.

Chart 9-2

Tree Species Composition at Polaris Point



9.2.2.2 Threatened and Endangered Species – Polaris Point Plant Species

No threatened and endangered species or species of concern were identified at Polaris Point.

9.3 Avian Surveys

On the Main Base, avian surveys occurred on Orote Point, Polaris Point, and the Camp Covington Wetlands.

9.3.1 Orote Point

On Orote Point, both roadside (Figure 9-3) and forest bird surveys (Figure 9-1) were conducted in the morning. Table 9-3 lists the species observed as part of the surveys.

Orote Point

Roadside Survey Points

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010 | Project No.: 60133557 | Figure 9-3

Table 9-3

Species Identified During the Roadside and Forest Bird Surveys – Orote Point

Survey Type	Number of Stations	Species and Number of Detections	Number of Species	Total Number of Detections
Roadside	5	Pacific Golden Plover (50) Black Francolin (12) Whimbrel (11) Island Collared Dove (1) Black Drongo (4)	5	78
Forest Bird	8	Island Collared Dove (1) Yellow Bittern (1) Black Francolin (1)	3	3

All of the observed species are common to Guam. Table 9-4 specifies the resident status of the observed species. The nomenclature follows Gill et al. 2008. For more information on the avifauna survey and results, refer to Appendix G.

Table 9-4

Residence Status of the Avifaunal Species Identified during the Roadside and Forest Bird Surveys – Orote Point

Avifaunal Species	Residence Status[1]
Yellow Bittern (*Ixobrychus sinensis*)	Common resident native – breeding
Island Collared Dove (*Streptopelia bitorquata*)	Common introduced resident – breeding
Black Drongo (*Dicrurus macrocercus*)	Common introduced resident – breeding
Black Francolin (*Francolinus francolinus*)	Common introduced resident – breeding
Whimbrel (*Numenius phaeopus*)	Common visitor – not breeding
Pacific Golden Plover (*Pluvialis fulva*)	Common visitor – not breeding [2]

NOTES:
1 Residence status obtained from Reichel, J. D. and P. O. Glass, 1991, Checklist of the birds of the Mariana Islands. '*Elepaio*, 51(1): 3-10.

2 Residence status obtained from Johnson, O.W., Goodwill, R. & Johnson, P.M., 2006, Wintering ground fidelity and other features of Pacific Golden-Plovers *Pluvialis fulva* on Saipan, Mariana Islands, with comparative observations from Oahu, Hawaiian Islands. *Wader Study Group Bull.* 109: 67–72.

9.3.2 Polaris Point

On Polaris Point, aviafauna surveys were conducted by NAVFAC Pacific biologists along two transects (Figure 9-4). Four species were observed and are provided in Table 9-5.

Transect Lines
Moorhen Survey Transects
Installation Boundary
Avian Roadside Observation Stations

N

0 200 400
Meters

Main Base Camp Covington & Polaris Point

Avian Survey Location Map

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 9-4

Table 9-5

Avian Survey Results – Orote Point

Avifaunal Species	Residence Status[1]
Yellow Bittern *(Ixobrychus sinensis)*	Common resident native – breeding
Black Drongo *(Dicrurus macrocercus)*	Common introduced resident – breeding
Philippine Turtle Dove (*Streptopelia bitorquata*)	Common introduced resident - breeding
Brown noddy (*Anous stolidus*)	Uncommon resident to Guam, nests in numbers on Cocos Island [3]

NOTES:
1 Residence status obtained from Reichel, J. D. and P. O. Glass, 1991, Checklist of the birds of the Mariana Islands. '*Elepaio*, 51(1): 3-10.

2 Residence status obtained from Johnson, O.W., Goodwill, R. & Johnson, P.M., 2006, Wintering ground fidelity and other features of Pacific Golden-Plovers *Pluvialis fulva* on Saipan, Mariana Islands, with comparative observations from Oahu, Hawaiian Islands. *Wader Study Group Bull.* 109: 67–72.

3 USGS, 2010

Three of the species observed in the survey at Polaris Point are common to Guam. However, on species, the brown noddy, nest in numbers on nearby Cocos Island but have not successfully nested on Guam since the brown tree snake populations peaked in the 1970s and 1980s (USGS, 2010).

9.3.3 Avian Endangered Species Survey

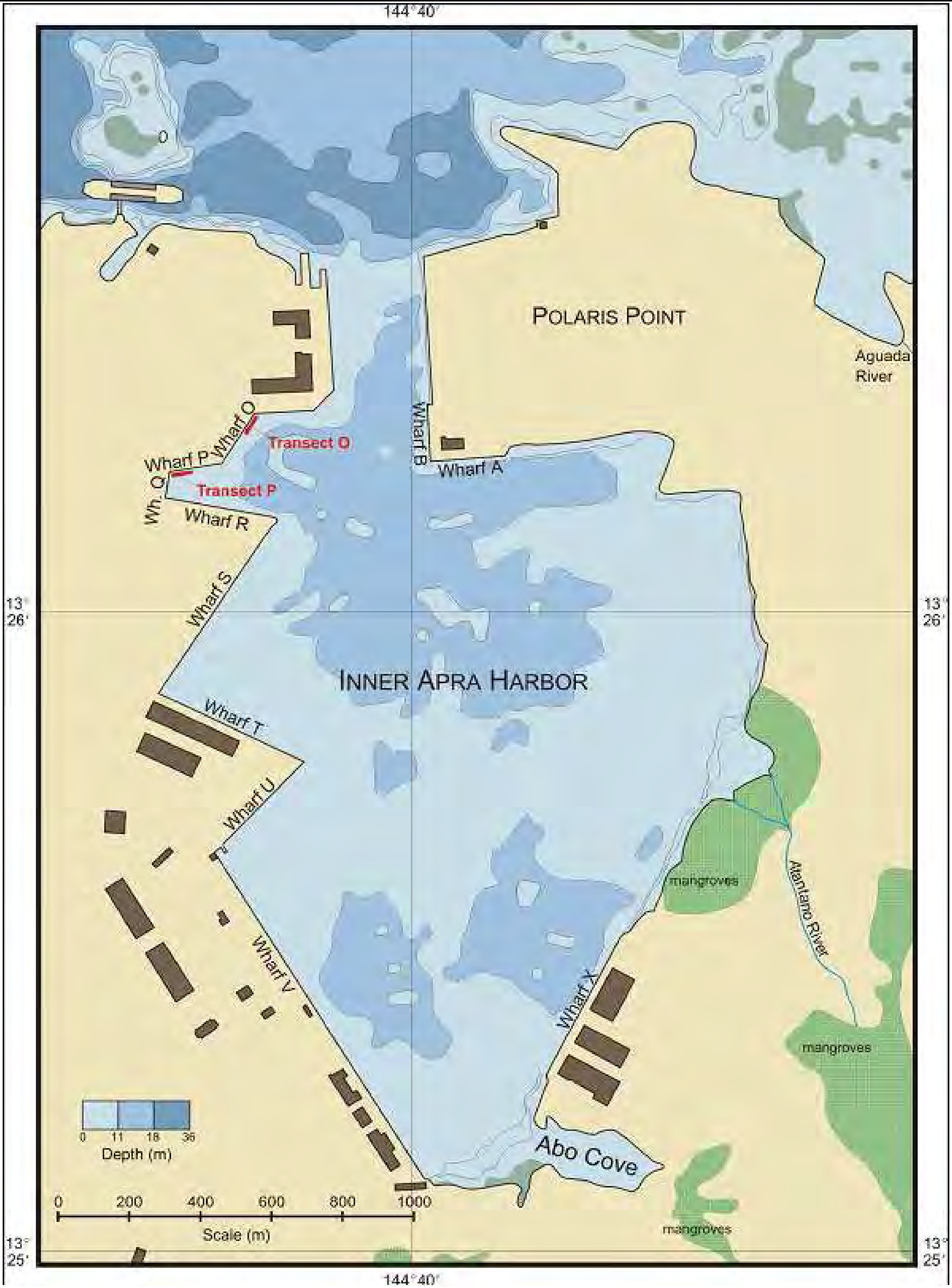
The Camp Covington wetland (Figure 9-4) was identified as a habitat resource requiring special surveys to determine whether the federally endangered Mariana Common Moorhen (*Gallinula chloropus*) was present. Eleven listening stations were strategically positioned around the wetland habitat. Surveys were conducted during the morning hours from sunrise to 1000 hours.

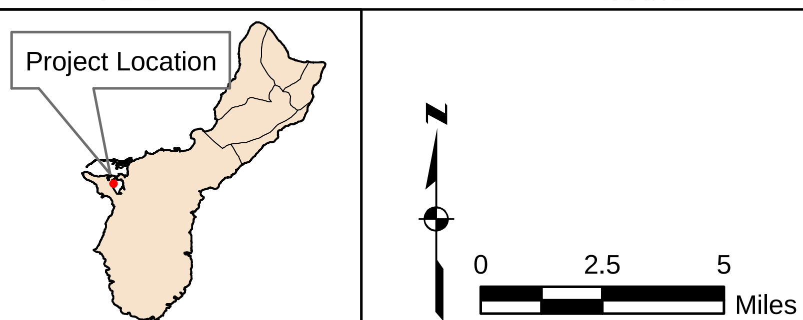
Survey stations were placed a minimum of 150 m apart to minimize double-counting. All moorhen detections were recorded (by visual observation or by song) within one 8-minute survey; no surveys were replicated. Though weather conditions were variable, data quality was not compromised by surveying in inclement weather.

No federally endangered Mariana Common Moorhens were detected during the Endangered Species Survey conducted at the Camp Covington wetland complex.

9.4 Inner Apra Harbor

Within Apra Harbor, marine investigations occurred along the wharves of Polaris Point, Oscar and Papa Wharves (Figure 9-5), and Abo Cove and Wharves S, T, U, V and X (Figure-9-6). Marine surveys were accomplished through visual observation of scientists.





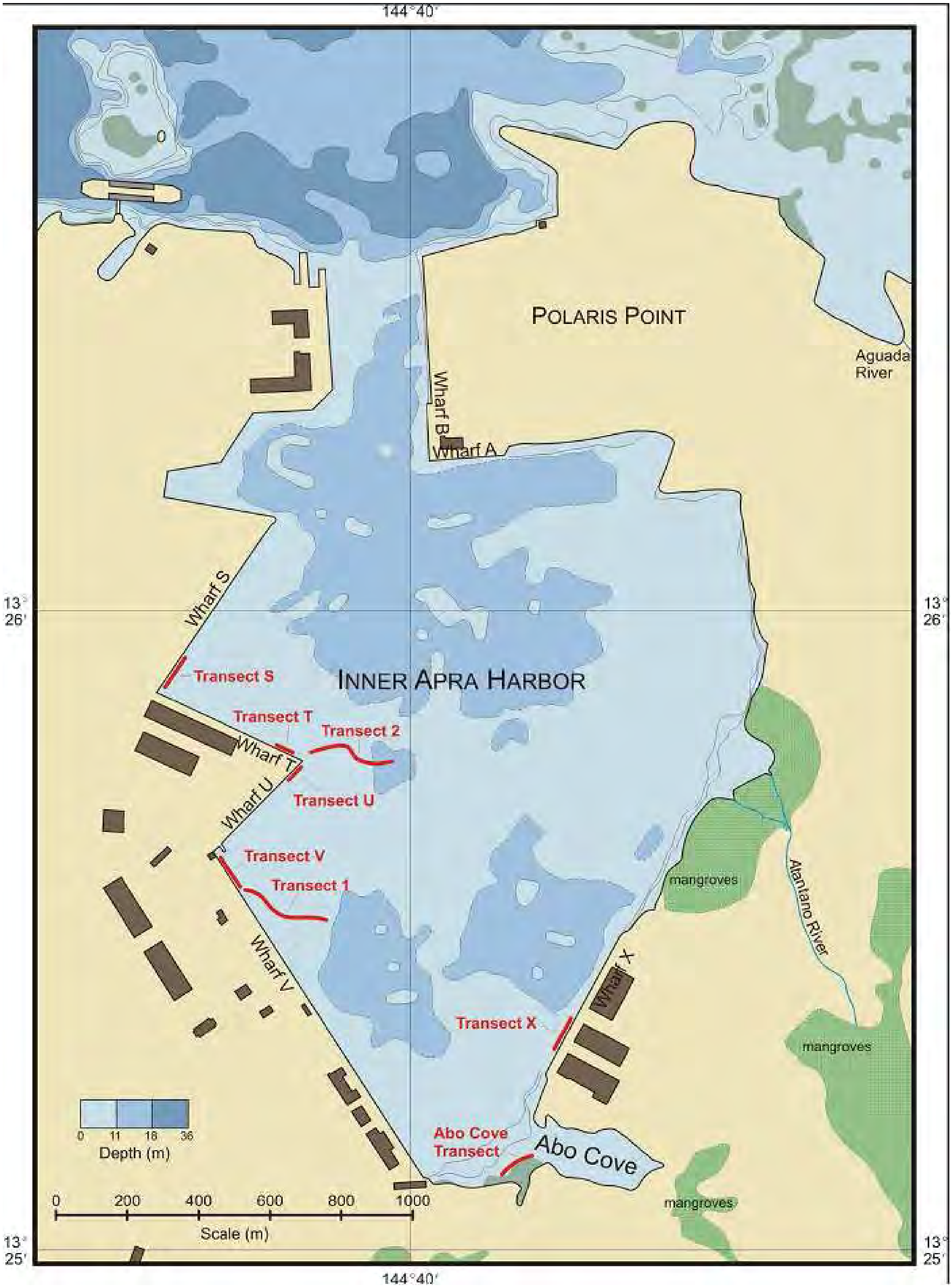
Oscar & Papa Wharves
Marine Survey Transects

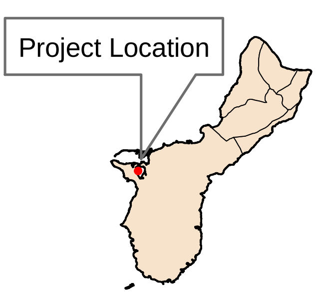
Transect Map

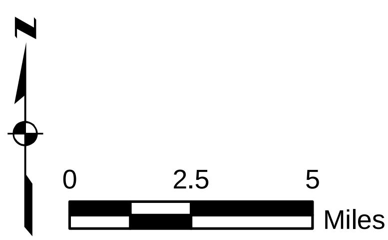
Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010 | Project No.: 60133557 | Figure 9-5







Inner Apra Harbor
Marine Survey Transects

Transect Map

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010 | Project No.: 60133557 | Figure 9-6

9.4.1 Benthic Cover

9.4.1.1 Oscar and Papa Wharves

Mean surface coverage of the vertical substrate along the transects at Oscar and Papa Wharves is presented in Chart 9-3. The harbor floor not sampled. Substrate coverage was divided into seven abiotic and biotic features at the sites. The mean biotic coverage in ten quadrat samples was 20.63 percent at Oscar Wharf and 55.63 percent at Papa Wharf. Sponges were the predominant biotic cover organisms at Oscar Wharf, ranging from 0–18.75 percent cover; macroalgae were predominant at Papa Wharf, ranging from 12.5–62.5 percent cover.

9.4.1.2 Abo Cove and Wharves S, T, U, V and X

A total 70 benthic taxa were recorded and quantified during this study. The total number of taxa recorded is low compared to benthic surveys in other parts of the harbor. Mean surface coverage of the vertical substrate and along the transects is presented in Chart 9-4. The average species richness of the quadrats is also low compared to similar studies in other parts of Guam. There was a large difference in the total number of species and in species richness between quadrats from Abo Cove and the wharf transects. The most authentic "natural" site (Abo Cove) is significantly less taxon-rich than the wharf sites.

Turbidity and sediment deposition are most likely the most important causal factors for this difference. *Caulerpa verticillata* is a green alga that copes well with increased levels of sedimentation and reduced salinities. Exceptionally large specimens of this alga were found in Abo Cove, probably a result of relatively low herbivore pressure. The distribution of the seagrass species *Halophila japonica* also seems to be restricted to Abo Cove in the inner harbor.

Turbidity is high throughout the inner harbor, but the vertical orientation of hard substrates (and probably ship activity) at the wharves results in a lower amount of sediment deposition, favoring the growth of epilithic biota adapted to low-light conditions. Although very different from Abo Cove, the benthic assemblages of the wharves contain interesting taxa as well. Some of the taxa recorded here do not appear in the most recent taxonomic treatises for Guam. For example, the very abundant *Celleporaria sibogae* and the rather uncommon *Lichenopora* sp. are most likely new bryozoan records for Guam, as this group has been virtually unstudied in the region (Paulay, 2003). Diversity measures mimic the differences in species richness between the inner harbor sites. Sponges contribute most to the benthic diversity of the wharves. A number of these probably also constitute new records for Guam, and others are infrequently encountered elsewhere around the island as they are typically confined to deep water, caves, or other cryptic habitats.

As with taxonomic richness and diversity, the benthic assemblages of Abo Cove differ significantly from the wharf sites in having a low overall biotic cover. This is a direct result of the Abo Cove site being a mostly horizontally oriented sedimentation flat. In contrast, the biotic assemblages of the wharves are best developed on the shallow vertical surfaces. It is important to note, however, that corals are the main constituents of the biotic assemblages at Abo Cove, while the wharves are predominantly covered by crustose algae and sponges.

Chart 9-3

Percent Coverage of Algae, Sponges (Porifera), Corals (Cnidaria), and other Covertypes at Oscar and Papa Wharves

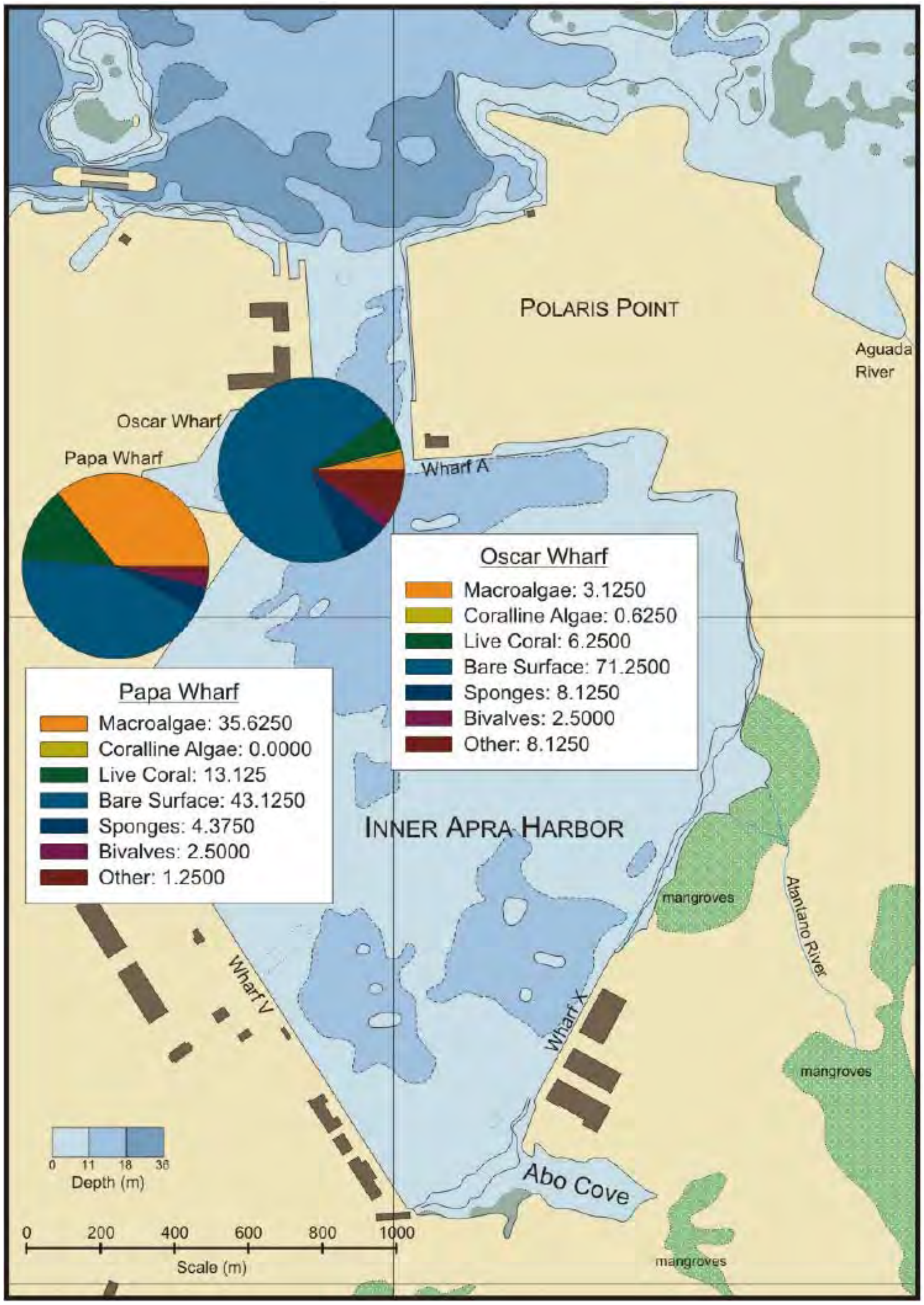
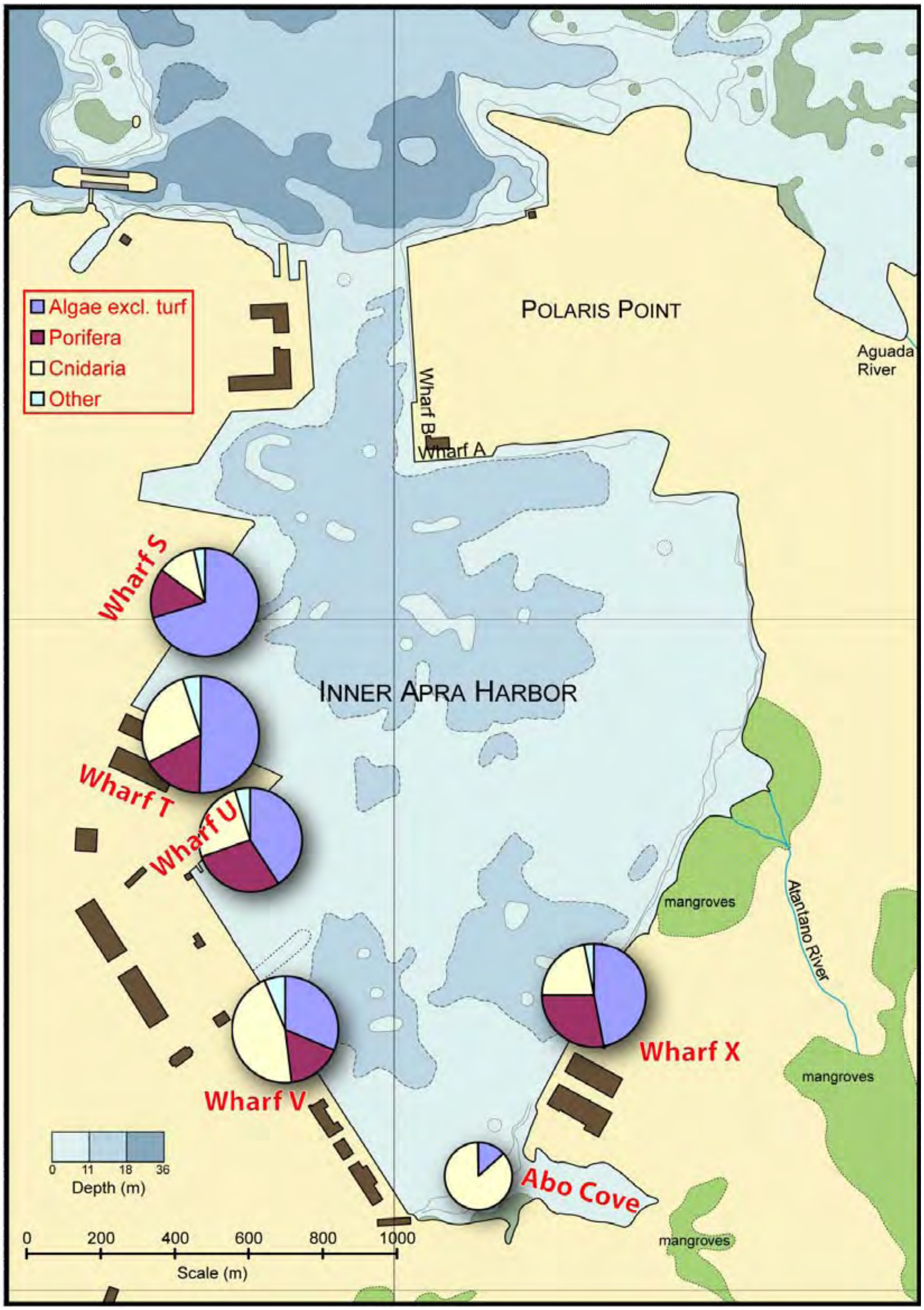


Chart 9-4

Percent Coverage of Algae, Sponges (Porifera), Corals (Cnidaria), and other Covertypes at Abo Coves and Wharves S, T U, V, and X



9.4.1.3 Polaris Point

Sand and mud are the most significant components of benthic cover at Polaris Point, accounting for more than 42-48% of the total cover by depth in all zones. Mean surface coverage of the vertical substrate along the transects at Polaris Point is presented in Chart 9-5. Abiotic cover exceeded biotic cover in all sectors. Macroalgae comprised a very minor proportion of benthic cover in all sections and depths. *Padina boryana, Dictyota bartayersiana* and *Halimeda opuntia* accounted for most of the macroalgae observed at this site.

9.4.2 Corals

9.4.2.1 Oscar and Papa Wharves

Species richness was highest at Oscar Wharf, where six species occurred on the transect; only three species occurred on the transects at Papa Wharf. *Leptastrea purpurea*, *Pocillopora damicornis* and *Porites lobata* were the most frequently observed species. Three species, *Dendrophyllia* sp., *Psammocora haimeana*, and *Porites rus* occurred on the transect only at Oscar Wharf.

9.4.2.2 Abo Cove and Wharves S, T, U, V and X

A total of 13 species of scleractinian corals encountered on six transects in Abo Cove and Wharves S, T, U, V, and X. An additional 13 species of scleractinian corals were observed on substrates adjacent to the transects. Two species of non-scleractinian anthozoans were also recorded. Therefore, a cumulative total of 28 species of corals and related organisms, representing 11 families and 13 genera, was observed at the study site. This count represents a minimum, because several corals could be identified only to genus in the field and, therefore, may consist of more than one species.

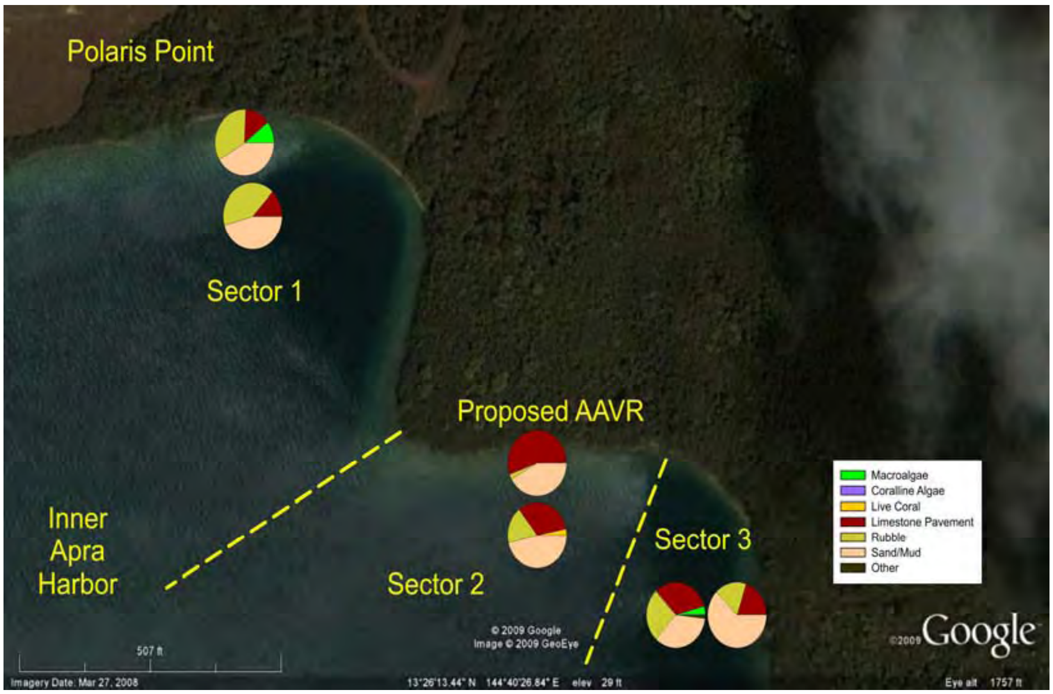
Species richness was highest at X-ray Wharf, where eight species occurred on the transect; only four species occurred on transects at Above Cove and Tango, Uniform, and Victor Wharves. *Porites lutea* and *Pocillopora damicornis* were the most common species, occurring on five of the six transects. Seven species occurred on only one transect, and three of these species were represented by single observations.

Poritid corals were predominant in coverage, averaging some 83 percent relative coverage on transects. Similarly, *Porites* spp. occurred at high frequencies on transects, although smaller species, such as *Pocillopora damicornis* and *Leptastrea purpurea*, exhibited high frequencies as well. The harbor floor consists of fine-grain sediments unsuitable for settlement by coral larvae. Consequently, few corals were encountered on Transects 1 and 2 on the harbor floor. Small colonies of *Porites lutea* were observed on scattered pieces of debris and old pilings that provided the only hard substrate available for settlement of larvae. With the exception of what appeared to be the remains of an old pier extending perpendicularly from Victor Wharf, the amount of debris was greater near the wharves. No corals were observed on the harbor floor at distances of 20 m or more.

The fourth root-transformed relative coral coverage data were analyzed by non-metric multidimensional scaling (NMDS). The two-dimensional NMDS plot shows the biotic affinities between the sites (low stress) and reveals differences not only between Abo Cove and the wharf sites, but between Sierra Wharf and the four remaining wharves. Uniform Wharf and X-ray

Chart 9-5

Percent Coverage of Algae, Corals (Cnidaria), and other Covertypes
at Polaris Point



Wharf cluster together, as do Tango Wharf and Victor Wharf. Coral communities on the four southern wharves are more similar to each other than to either Sierra Wharf or Abo Cove.

9.4.2.3 Polaris Point

Nine species of scleractinian corals, representing 3 families and 3 genera were encountered on the transect lines off Polaris Point. Species richness was generally greater on the deeper transects. *Leptastrea purpurea* was the most common species, occurring on all transects and in the largest numbers. *Porites lutea* (5 transects) and *Porites rus* (4 transects) were also common but the latter species was more abundant. Two species, *Porites compressa* and *P. densa*, were seen on one transect only.

Leptastrea purpurea had the greatest density on the shallow (2m) transect while *Porites lobata* had the greatest on the deep (4m) transect in the western most area. In the center portion of the survey area, *Leptastrea purpurea* had the greatest density on the shallow transect but on the deep transect both *Porites rus* and *P. lobata* had much higher densities. In eastern portion of the site, *Porites lutea* had the greatest density on the shallow transect while *P. rus* had the greatest density on the deep transect.

9.4.3 Macroinvertebrates

9.4.3.1 Oscar and Papa Wharves

Seventeen species of solitary macroinvertebrates were encountered on the transect at Papa Wharf, and 12 species were recorded on the transect at Oscar Wharf. As noted at other sites in Inner Apra Harbor (Smith et al., 2008), 100 percent of the macroinvertebrates encountered on the transects were suspension feeders. Bivalve mollusks (seven species) and solitary ascidians (eight species) dominated the macroinvertebrate fauna at both wharves, and mean densities were generally greater at Papa Wharf. The bivalves *Malleus decurtatus* and *Spondylus squamosus* were remarkably more abundant at Papa Wharf, as was the ascidian *Rhopalaea circula*. Mean densities ranged from less than 1.0 individual/20 m^2 (several species) to 55 individuals/20 m^2 (*Spondylus squamosus* at Papa Wharf). Spondylid bivalves occurred at the greatest density encountered at both sites

9.4.3.2 Abo Cove and Wharves S, T, U, V and X

Twenty species of solitary macroinvertebrates in four phyla were encountered on the transects, and ten additional species were observed in areas adjacent to the transects. Three of the species on transects occurred as single observations, and one species, *Phallusia nigra*, is reported as non-indigenous (Paulay et al., 2001a; Lambert, 2002, 2003). The greatest diversity (i.e., 16 species, or 80 percent of the diversity on transects) was found on the vertical face at Victor Wharf (Transect V), and the least (i.e., eight species) on the coral reef at Abo Cove (Transect A). Bivalve mollusks and ascidians dominated the macroinvertebrate fauna in terms of both diversity and density. Remarkably, 100 percent of the macroinvertebrate species encountered on transects were suspension feeders. Of the total 30 species of solitary macroinvertebrates, all but three are suspension feeders – the three being detritus feeders. The predominance of suspension feeders in lagoonal environments, such as the inner harbor, may be a result of nutrient enrichment by terrestrial runoff and the extended residence time of waters in the lagoon.

Densities of solitary macroinvertebrates ranged from less than one individual of a species to more than 90 individuals/10 m^2, with bivalve mollusks and ascidians being predominant. The hammer oyster *Malleus decurtatus* occurred in the greatest densities (up to 9.3 oysters/ m^2 at Victor Wharf), with thorny oysters, *Spondylus* spp., and jewel box clams, *Chama* spp., also abundant. Among ascidians, *Rhopalaea circula* reached a density of 6.3 individuals/ m^2 at Tango Wharf. The greatest total density was observed at Victor Wharf (Transect V), where there were 143.7 macroinvertebrates/10 m^2; the lowest total density was 4.4 macroinvertebrates/10 m^2 at Abo Cove. As noted above for benthic coverage, this pattern may be explained by the greater availability of hard substrate for post-larval settlement on the vertical faces of the wharves, as compared to the sediment-laden horizontal substrate on the reef at Abo Cove.

The harbor floor is largely depauperate of epibenthic macroinvertebrates. The substrate of the harbor consists predominately of a sticky, fine silt/mud sediment that is easily resuspended. Observed species were associated with debris that provided hard substrate, with the exception of the detritivorous snail *Bittium* sp. Generally, the volume of debris, and therefore the number of macroinvertebrates, diminished with distance from the wharves. Although few epibenthic macroinvertebrates were observed on the harbor floor, large numbers of burrow openings were present, indicating an abundance of infaunal organisms.

Comparison of macroinvertebrate community structure across transects by cluster analysis indicates considerable contrast for horizontal and vertical substrates. The macroinvertebrate community on vertical faces of the wharves form a single large clade that is distinctly different than the community inhabiting the horizontal substrate at Abo Cove. As noted for benthic cover, the similarity between Uniform Wharf and Victor Wharf is high. However, for solitary macroinvertebrates, X-ray Wharf is more similar to these communities than to the community at Tango Wharf. The Abo Cove macroinvertebrate community is distinctly different from the communities on the wharf faces, which clustered together.

Possibly the most abundant solitary invertebrates were neither epibenthic nor conspicuous. The pelagic thecosomate gastropod cf. *Styliola subula* was abundant in surface waters adjacent to all surveyed wharves.

9.4.3.3 Polaris Point

The distribution and abundance of epibenthic macroinvertebrates observed on the surveyed transects provided a total of 41 species from 5 phyla. There were 9 species of sponges (Porifera: Demospongiae), 3 species of polychaete worms (Annelida), 6 species of gastropods (Mollusca), 15 species of bivalves (Mollusca), species of shrimps and crabs (Crustacea), and species of sea squirts (Ascidea). *Haliclona* sp. (blue) was the most common species of sponge observed. The polychaete annelid *Sabellastarte spectabilis* was found all of the transects. Among gastropod molluscs the most commonly observed species was *Cerithium munitum*, the dead shells of which were seen on 4 of the 6 transects. Bivalve molluscs tended to be more common, with *Malleus decurtatus* and *Saccostrea cucullata* both observed on all transects, while *Lithophaga* sp. was seen on transect 6 and *Spondylus squamosus* on transect 5, respectively. *Alpheus djiboutiensis* was the most commonly seen shrimp but was observed only on 2 transectssimilarly, the crab *Calcinus* spp. was observed on 2 transects, as well. As for sea squirts, the most common species was *Rhopalaea circula*, which was observed on all 6 transects.

Densities of macroinvertebrate species tended to be quite low, although some bivalves tended to have the greatest densities across sectors. For example, *Malleus decurtatus* was quite dense along the shallow (2m) in the center portion of the surveyed area. Among ascidians, *Ascidia* sp. had the greatest density on the shallow transect.

9.4.4 Fish

9.4.4.1 Oscar and Papa Wharves

Thirty-five species of fishes were observed on transects surveyed at both wharves. As with other sites within the Inner Apra Harbor surveyed previously (Smith et al., 2008), this low level of species richness represents an impoverished fish fauna (there are about 1,000 species of reef and near-shore fishes reported from the Mariana Islands; Myers and Donaldson, 2003; unpublished data). Components of this fauna, however, are indicative of protected, turbid lagoons or bays of Guam, of which there are relatively few compared to clear water reefs, and thus constitute a relatively unique assemblage of fishes.

Two invasive species were observed at both wharves. One, *Neopomacentrus violescens* (Pomacentridae, damselfishes), has been reported previously (Myers, 1999; Myers and Donaldson, 2003). This species was found more recently on Tango, Uniform and X-ray Wharves (Smith et al., 2008). The second species, *Amblygliphididon ternatensis* (Pomacentridae), was reported from Sierra, Tango, Uniform and Victor Wharves. These damselfishes occur elsewhere in the western Indo-Pacific region in natural habitats somewhat similar to those found in Inner Apra Harbor (Myers, 1999).

Species richness (the number of species observed) ranged from 15 (n = 57 individuals) at Oscar Wharf to 29 (n = 1347 individuals) at Papa Wharf. Generally, species richness was greater on or adjacent to mid-wall and top-wall transects at both wharves, where corals, hanging debris, and oyster shells provided shelter for various species, but especially damselfishes, cardinalfishes and juvenile butterflyfishes. Bottom-transects at both wharves had the lowest number of species and individuals. These included burrowing gobies (mainly *Oplopomus oplopomus*) and transient snappers (*Lutjanus fulvus*).

9.4.4.2 Abo Cove and Wharves S, T, U, V and X

Sixty-two species of fishes were observed on transects surveyed within the Apra Inner Harbor. While this number indicates an impoverished fish fauna (there are approximately 1,000 species of reef and nearshore fishes known from the Mariana Islands; the fauna seems representative of protected, turbid lagoons or bays of Guam. Further, at least three species appear to be invasive or new records for Guam and the Mariana Islands. These species are the following: *N. eviolescens, A. ternatensis* and *Rhamdia cypselurus* (Apogonidae; cardinalfishes). These species has not been reported previously from the Mariana Islands. All three species occur elsewhere in the western Indo-Pacific region in natural habitats somewhat similar to those found in Inner Apra Harbor (Myers, 1999).

Species richness between stations ranged from 2 (harbor floor, Transect 2) to 29 (UniformWharf–bottom, Transect UB). Generally, species richness was greater on the bottom at stations, where debris provided shelter for various species. Some wharf walls (mid-depth transects), however, supported relatively high numbers of species, as well.

Densities of fish species refers to the number of individuals/$m^{2.}$ Small, structure-associated cardinalfishes had the greatest density among stations. *Apogon lateralis* (Apogonidae) densities where high at Sierra Wharf (20/m^2 at mid-depth and 4.4/m^2 at subsurface depth), Victor Wharf, Uniform Wharf, and X-ray Wharf (2.06/m^2 at mid-depth). Another cardinalfish, the apparently invasive *Rhabdamia cypselerus*, had relatively high densities at Sierra Wharf and Tango Wharf. Both species tended to occur in aggregations of several individuals. The invasive damselfish, *Amblyglyphididon ternatensis* (Pomacentridae), was relatively dense at Victor Wharf (2.24/m^2 at mid-depth) and Sierra Wharf (1.16/m^2 at subsurface depth). This species occurred in aggregations as well; many were juveniles. Densities of other species were low to very low and ranged from 0.0033/m^2 to 1.0/m^2.

9.4.4.3 Polaris Point

A total of 47 species were observed at the Polaris Point site. Species richness ranged from 1 on transect to 26. Mean (± SE) species richness was 10.7 (± 2.8) for all transects combined. The number of fishes per transect ranged from 3 to 661. The mean (± SE) number of fishes per transects was 117.7 for all transects combined. Overall, species richness and abundance were highest on shallow transects while diversity was highest on deeper transects. The assemblage of fishes was similar to those reported for other Inner Harbor habitats with coral (Smith et al., 2008) or no coral but debris on sand or silty substrata (Smith et al., 2008; Donaldson et al., 2010).

The density of each reef fish species observed on transects ranged from 0.01. to 2.8 fish per m2. Most species had densities of less than 0.1 per m2, but two species of cardinalfishes associated with structure, *Apogon lateralis* and *Apogon leptacanthus* (Apogonidae), were found at densities of 2.8 and 2.7 per m2 , respectively. The burrowing shrimp goby *Cryptocentrus strigilliceps* (Gobiidae) was found at relatively high densities on shallow transects.

9.4.5 Summary

9.4.5.1 Oscar and Papa Wharves

As shown in a previous study (Smith et al., 2008), the artificial and most anthropogenically-impacted habitats, wharves, might contribute most to the biotic richness and diversity of the inner harbor. The synoptic account of the benthic invertebrates is indicative of unique benthic fauna, especially so for the sponges. Hence, more extensive taxonomic surveys are warranted to assess the biological value of the inner harbor, as well as its potential as an area for potential establishment of invasive species.

The coral fauna of the study area consisted of 19 species of scleractinian corals, and an additional two taxa including a stony hydrozoan and an octocoral. The predominant corals were *Pocillopora damicornis, Porites lobata*, and *Leptastrea purpurea.* The coral assemblage in Inner Apra Harbor is characteristic of environments with high levels of sedimentation and turbidity, with the most common species, in order of tolerance to these conditions, being *Porites lutea*, *Pocillopora damicornis*, and *Leptastrea purpurea* (Amesbury et al., 1977). Coral species (Smith et al., 2008; this report).

Macroinvertebrates communities on the vertical surfaces of Oscar and Papa Wharves were only moderately diverse, with species observed on or near transects. This pattern is consistent with that reported for similar localities within the inner harbor (Smith et al., 2008). For corals, availability of sediment-free hard substrate for sessile and sedentary macroinvertebrates is a limiting factor on horizontal surfaces. Macroinvertebrate assemblages on both wharves were dominated by suspension feeding species, which comprised 100 percent of the species occurring on transects and 90 percent of all species observed.

The species richness and diversity of the fish faunas of Oscar and Papa Wharves, like elsewhere in the inner harbor (Smith et al., 2008), are relatively low compared to habitats elsewhere on Guam. These fauna are highly adapted and representative of protected and turbid habitats usually associated with mangroves, estuaries, and back reefs, with some exceptions. A considerable amount of habitat is provided by artificial shelter in the form of wharves and jetsam and debris (pilings, frames, storage units, etc.), and the microhabitats found on or adjacent to these were utilized by many species of fishes. Larval fishes of these species could have settled and recruited to these habitats and microhabitats, either through natural stochastic processes or by transport (e.g., bilge water), and became established at each of the wharves. Many of the individuals of these species were juveniles or subadults. Alternatively, some species, particularly those that swim actively in the water column, may have colonized these habitats as adults after swimming to them from outside of the inner harbor.

9.4.4.2 Abo Cove and Wharves S, T, U, V and X

This study shows a clear difference between the most authentic inner harbor habitats at Abo Cove and the manmade wharfs (Chart 9-4). Ironically, the artificial and most anthropogenically impacted habitats of the wharfs might contribute most to the biotic richness and diversity of the inner harbor. The synoptic account of the benthic invertebrates is indicative of unique benthic fauna, especially so for the sponges.

The coral fauna of the study area consisted of 30 species, or about 10 percent of the coral fauna of Guam (see Randall, 2003). The predominant corals were massive *Porites* spp., one of which exceeded 1 m in diameter at Abo Cove. The coral assemblage in Inner Apra Harbor is characteristic of environments with high levels of sedimentation and turbidity, with the most common species, in order of tolerance to these conditions, being *Porites lutea*, *Pocillopora damicornis*, and *Leptastrea purpurea* (Amesbury et al., 1977). Coral species richness is highest on relatively sediment-free, hard substrates on vertical faces of wharves.

Macroinvertebrates communities in the inner harbor were only moderately diverse, with 30 species observed on or near transects. As for corals, availability of sediment-free hard substrate for sessile and sedentary macroinvertebrates is a limiting factor on horizontal surface. On the harbor floor, macroinvertebrates were limited to scattered debris that provided the only hard substrate available. Macroinvertebrate assemblages in the inner harbor were dominated by suspension feeding species, which comprised 100 percent of the species occurring on transects and 90 percent of all species observed. Except for a single species of marine snail, no macroinvertebrates were observed on the soft sediments of the harbor floor.

The species richness and diversity of the fish fauna within the Inner Harbor are relatively low compared to habitats elsewhere on Guam. However, the fauna are highly adapted and representative of protected and turbid habitats usually associated with mangroves, estuaries, and back reefs, with some exceptions. A considerable amount of habitat is provided by artificial shelter in the form of wharves, and the microhabitats found on or adjacent to those wharves was utilized by many species of fishes. Larval fishes of these species could have settled and recruited to these habitats and microhabitats, either through natural stochastic processes or by transport (i.e., bilge water), and became established at each of the stations. Many of the individuals of these species were juveniles or subadults. Alternatively, some species, particularly those that swim actively in the water column, may have colonized these habitats as adults after swimming to them from outside of the inner harbor.

Perhaps the only unusual species present at most or all stations are the bottom dwelling, burrowing goby species that may be specific only to sand bottoms in back bay or estuarine areas. The extent of the distribution of these species is not well known, however, because of the generally poor visibility encountered in such areas (i.e., Inner Apra Harbor and Sasa Bay in western Guam, and the estuaries of the Pago, Ylig, and Talofofo Rivers in eastern Guam).

9.4.5.3 Polaris Point

While this site is seemingly unremarkable in terms of diversity, it should be noted that the coral colonies observed on the slope here are of relatively recent origin, ca. 60+ years (R.H. Randall, personal communication), and are the product of settlement and colonization of previously-disturbed habitat. Nine species of corals were observed during the survey and of these, certain species (e.g., *Porites lobata*, *P. lutea*, and *P. rus*) are important for reef building and for providing habitat for other species. Sand and mud accounted for most benthic cover, with macroalgae (6 species) playing such a minor part. Among significant macroinvertebrates, 41 species were observed. More prominent groups included sponges, bivalve molluscs, and the gastropod *Cerithium munitum*. The burrowing shrimp *Alpheus djiboutiensis*, commensal with the shrimp goby *Cryptocentrus strigilliceps*, was seen on shallow transects. Fish species richness was relatively low at this site.

9.5 Fruit Bat Surveys

NAVFAC biologists surveyed one location on Orote Point during this survey in April 2008. No Fruit bats were observed. For more information on the fruit bat survey and results, refer to Appendix I.

9.6 Threatened and Endangered Species

No federally-listed threatened or endangered avifauna were identified on the Navy Main Base. However, a Guam-listed endangered species: moth skink (herptofauna) was observed on Polaris Point.

During the marine survey, a green turtle was observed from the boat in waters between Abo Cove and the southern end of Victor Wharf. *Chelonia mydas* is listed as a threatened species under the federal ESA. The observed individual was small (0.5–1.0 m carapace length).

Because of the fine-grained, muddy composition of the shoreline of Inner Apra Harbor, the beaches in the vicinity are not considered as potential nesting sites for endangered and threatened marine turtles known to occur in the seas around Guam. The nearest documented nesting beaches are near Gabgab Beach, in the outer harbor. Therefore, it is assumed that the individual sighted was foraging.

10 Naval Munitions Site

On Naval Munitions Site (NMS, formerly known as Naval Magazine) and along the Proposed Access Road Option A, natural resource surveys performed included herpetofauna, vegetation, and avian surveys. Figure 10-1, NMS – Northern Transects Map, and Figure 10-2, NMS – Southern Transects Map, show the locations of the ecological transects. Figure 10-3 identifies the location of Proposed Access Road Option A.

At the NMS, eleven transects were surveyed. Ten of the eleven transects were situated almost entirely in native forest consisting of *Premna obtusifolia, Aglaia mariannensis,* and *Guamia mariannae.* Some transects passed over streams and swampy ground where *Cocos nucifera, Pandanus tectorius,* and *Hibiscus tiliaceus* were dominant. One transect was dominated by *Miscanthus floridulus.*

10.1 Herpetofauna Surveys

At NMS, herpetofauna surveys were conducted within the NMS and within a corridor for the potential Proposed Access Road Option A. The results of the surveys within the NMS are presented in Subchapter 10.1.1. The results of the surveys conducted within the proposed access road corridor are presented in Subchapter 10.1.2.

10.1.1 NMS - Results

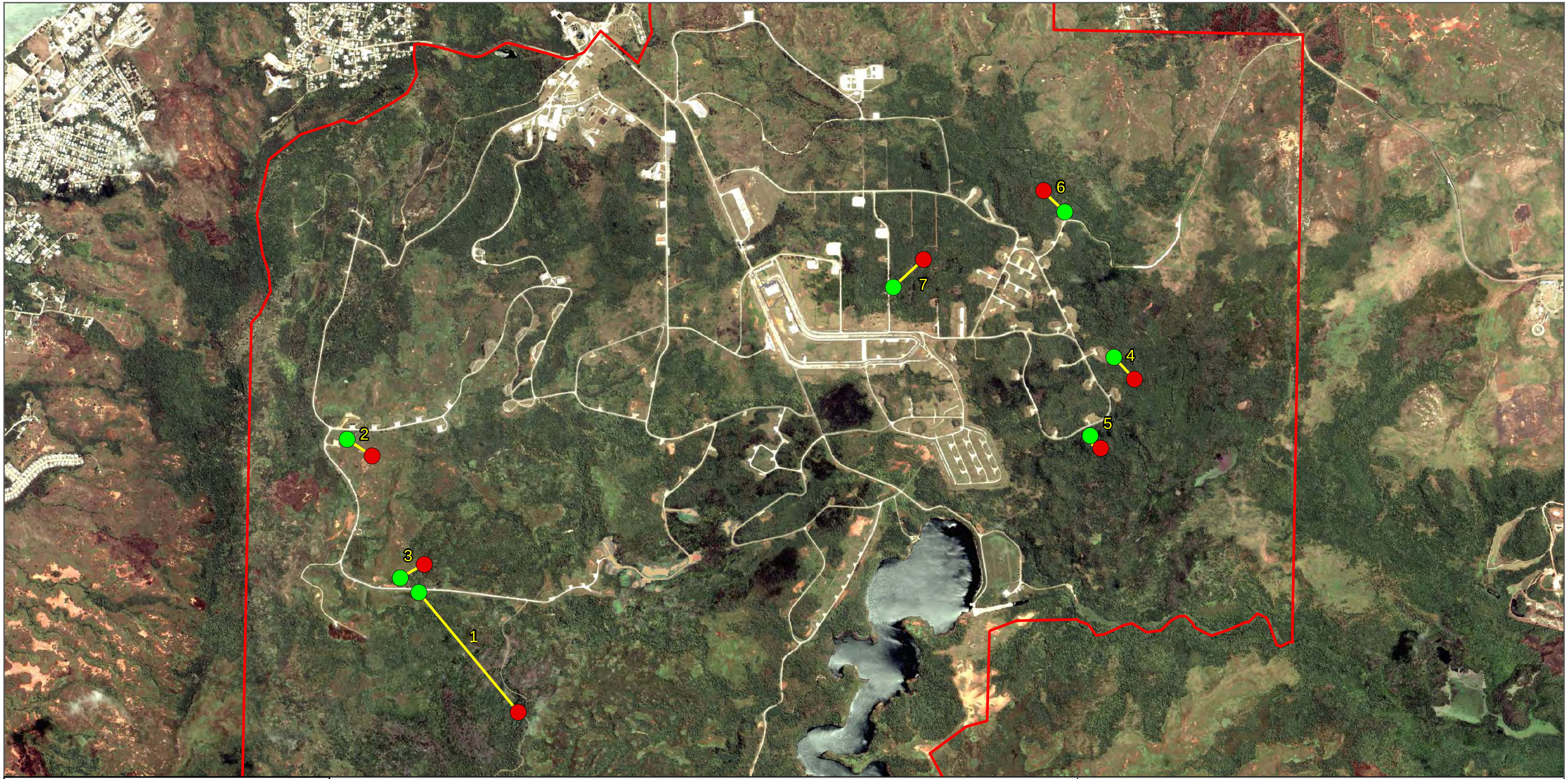
Six herpetofauna species were captured or observed on NMS. Table 10-1 identifies the species and their status. For more information on the herpetofauna survey and results, please refer to Appendix B.

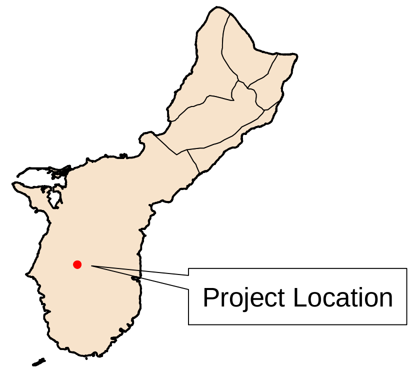
The capture of moth skink and Pacific slender-toed gecko at NMS is noteworthy. The distribution and abundance of this native skink on Guam is unknown, due to the variability of information presented by authors. Since the transect on which the species was caught was the only transect not to be visually searched at night, the number of moth skink detected during this survey might have been higher if a night search had been conducted.

The continued widespread presence of the brown treesnake and the curious skink, as well as other introduced amphibian species, is of concern because of each species' potential deleterious impacts to Guam's native fauna (Kraus et al., 1999, Wiles et al., 2003, Christy et al., 2007a).

10.1.2 Proposed Access Road Option A

This site consisted of three transects in forested areas, situated alongside the trail leading into the top NMS (Figure 10-3). The first two were in degraded forest of *Leucaena leucocephala, Hibiscus tiliaceus,* and *Flagellaria indica.* The third, at the highest elevation, was primarily native forest; *Pandanus tectorius* and *Aglaia mariannensis* were common at this location.





- Beginning Transect Point
- End Transect Point
- Quantitative Transects
- Qualitative Transects
- Installation Boundary

N

0 400 800 Meters

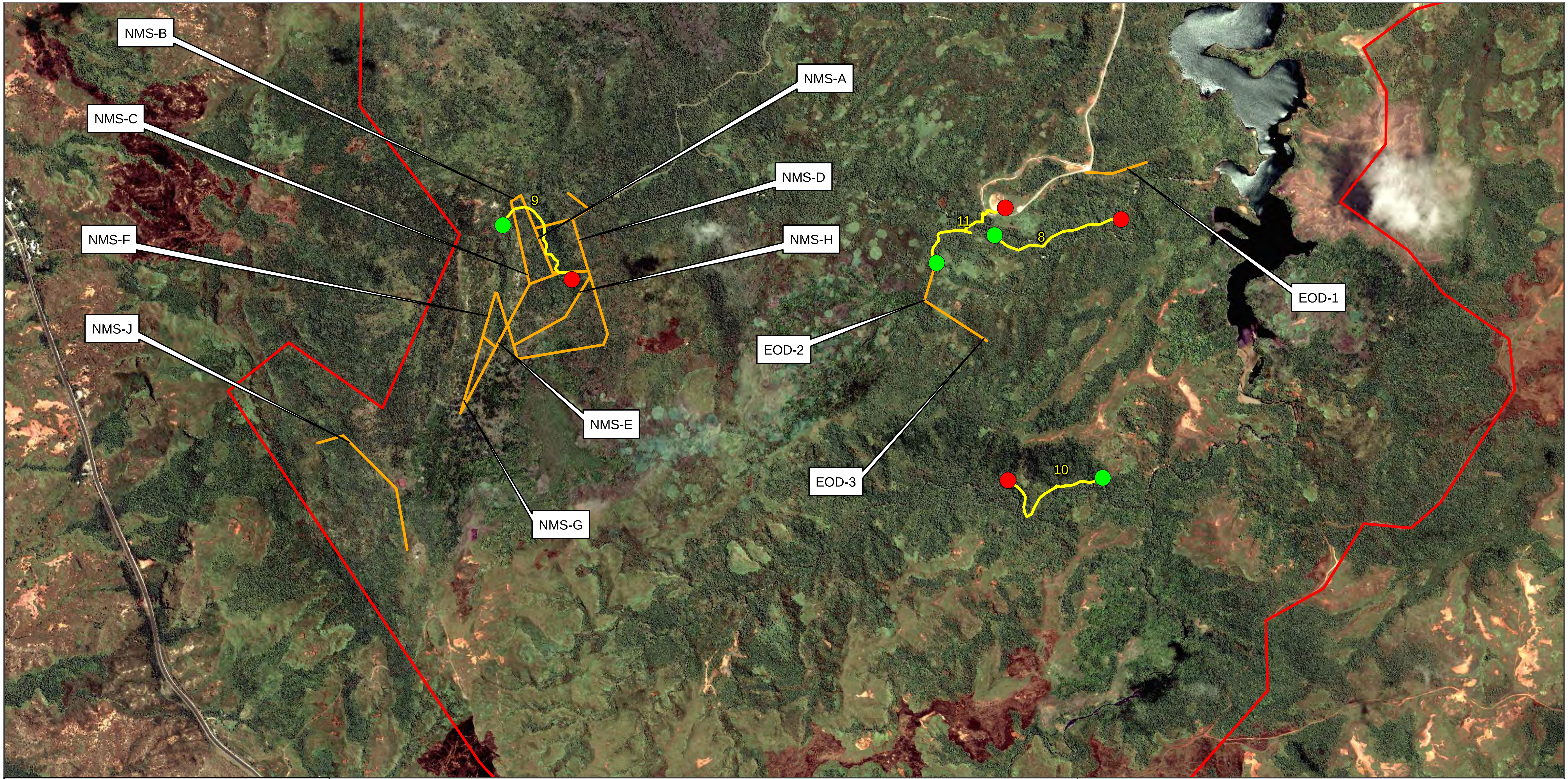
Naval Munitions Site

Northern Transect Map

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 10-1



Beginning Transect Point

End Transect Point

Quantitative Transects

Qualitative Transects

Installation Boundary

N

0 400 800 Meters

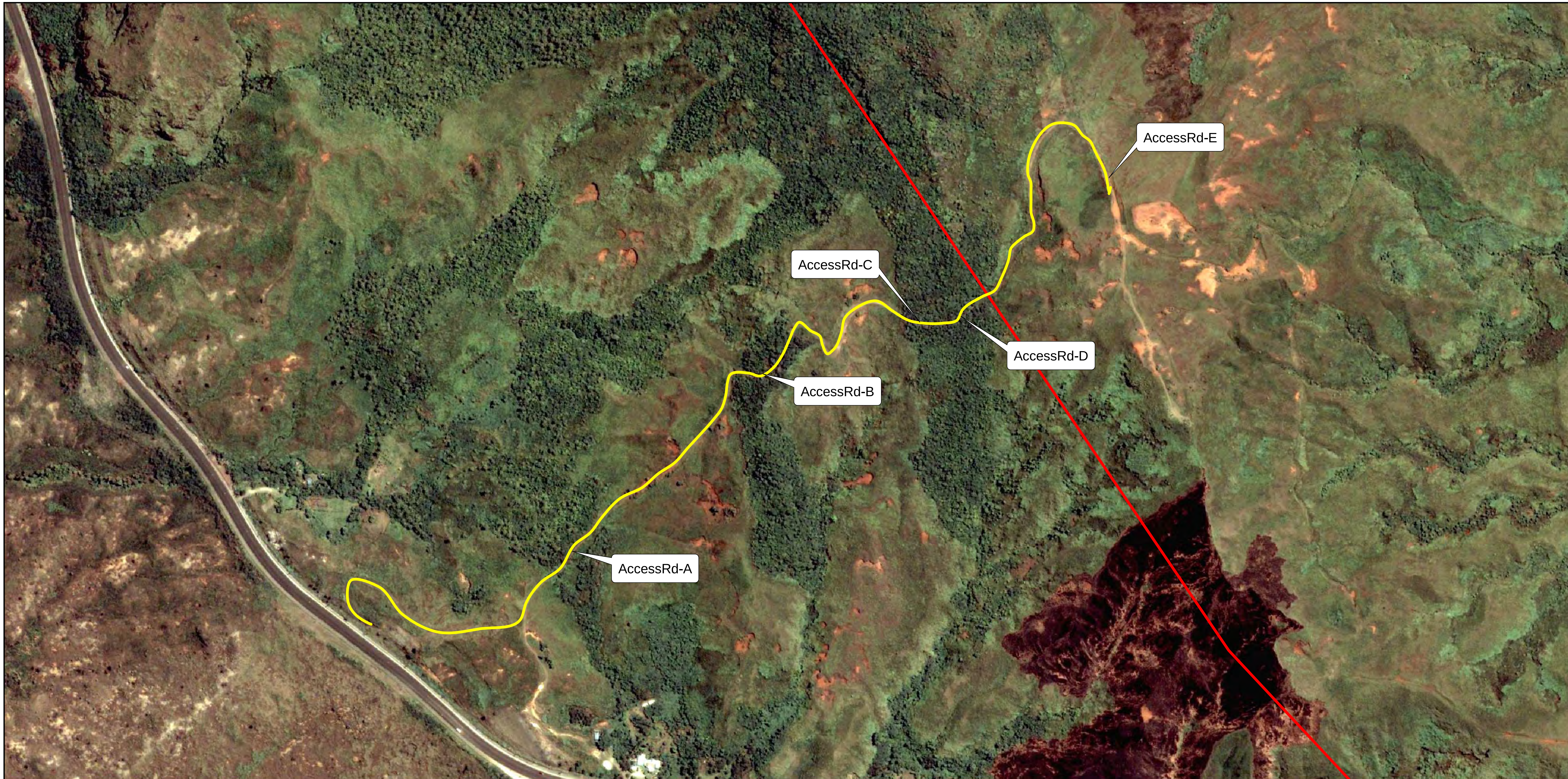
Naval Munitions Site

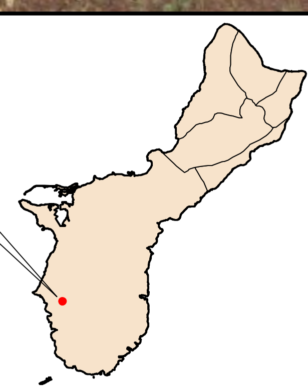
Southern Transect Map

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 10-2





Potential Access Road
Installation Boundary

0 200 400 Feet

Potential Access Road Option A

Survey Areas

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 10-3

Table 10-1

Herpetofauna Captured or Observed on NMS

Guild	Species	Status
Skinks	Curious skink (*Carlia ailanpalai*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
	Moth skink (*Lipinia noctua*)	Native*
Gecko	House gecko (*Hemidactylus frenatus*)	Introduced
	Mourning gecko (*Lepidodactylus lugubris*)	Native
	Mutilating gecko (*Gehyra mutilata*)	Native
	Pacific slender-toed gecko (*Nactus pelagicus*)	Native*
Snake	Brown treesnake (*Boiga irregularis*)	Introduced
Amphibians	Marine toad (*Rhinella marinus*)	Introduced
	Eastern dwarf tree frog (*Litoria fallax*)	Introduced
	Crab-eating frog (*Fejervarya cancrivora*)	Introduced
	Gunther's Amoy frog (*Sylvirana guentheri*)	Introduced
Notes: * This species is identified by the Guam Comprehensive Wildlife Conservation Strategies (GCWCS) as SOGCN/Endangered - species of with the highest conservation value.		

Four herpetofauna species were captured or observed within the Proposed Access Road Option A area. Table 10-2 identifies the species and their status. For more information on the herpetofauna survey and results, please refer to Appendix B.

The continued widespread presence of *Carlia fusca* as well as other introduced amphibian species is of concern because of each species' potential deleterious impacts to Guam's native fauna (Rodda et al., 1999, Kraus et al., 1999, Wiles et al., 2003, Christy et al., 2007a).

Table 10-2

Herpetofauna Captured or Observed on Proposed Access Road Option A

Guild	Species	Status
Skinks	Curious skink (*Carlia fusca*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
Gecko	House Gecko (*Hemidactylus frenatus*)	Introduced
Amphibians	Marine Toad *(Rhinella marinus*)	Introduced

10.2 Vegetation

10.2.1 Quantitative Surveys

Quantitative surveys were performed along transects in ravine forest, limestone forest, and a savanna grassland community. Due to the size of the NMS surveys, transects are divided into the northern and southern sectors, as described below.

- **Northern Sector** (Transects 1 through 7).
  - In the northwestern portion of NMS, ravine forest was sampled along Transects 1 and 3, which both cross stream channels. Transect 1 was the longest, and traversed the most variable terrain, of the seven transects conducted in northern NMS.
  - Transect 2 sampled a grassland; thus, no data are presented with respect to trees (e.g., species, density, etc.).
  - Transects 4, 5, and 6, were in the vicinity of stream channels.
  - In the north-central sector, which is near active and former operations areas, Transect 7 sampled a ravine forest.

- **Southern Sector** (Transects 8 through 11).
  - In the southern sector of NMS, Transects 8 and 11 sampled the ravine forest and coconut grove surrounding the Explosive Ordnance Disposal (EOD) Range.
  - Transect 9 sampled the faniok (*Merrilliodendron megacarpum*) forest around Mount. Almagosa.
  - Transect 10 sampled ravine forest along the Sadog Gagu River, which drains into Fena Reservoir.

10.2.1.1 Northern Sector

Native species accounted for approximately 70 percent of the relative density among the 11 tree species quantified along Transect 1 (Chart 10-1). The overall density for this transect was calculated at approximately 1,203 trees per ha. The native kafu or screwpine (*Pandanus tectorius*) had the highest relative density (over 50 percent) and was the most dominant species among the 11 tree species encountered on the transects.

The ravine forest sampled in Transect 3 had a density of approximately 1,700 trees per ha. Betelnut palms (*Areca catechu*), which are thought to be an aboriginal introduction, had the highest relative density (29 percent) among the seven species on the transect (Chart 10-2). Aside from betelnut and *Vitex parviflora*, the transect was made up of native species that accounted for approximately 67 percent of the relative density.

The transects in the northeastern sector (Transects 4 through 6) revealed a calculated density of approximately 5,261 trees per ha. The native kafu (*Pandanus tectorius*) had the highest cover and third-highest relative density (about 17 percent) among the 11 tree species in the transects (Chart 10-3). The introduced and often invasive BayRum Tree(*Pimenta racemosa*) had the highest relative density (about 20 percent), followed closely by native pago (*Hibiscus tiliaceus*) with about 19 percent. Both native gulos (*Cynometra ramiflora*) and introduced Lemon China (*Triphasia trifolia*) had densities of about 16 percent. These five species each had relative densities exceeding 15 percent; in contrast, on Transect 1 the relative density of kafu was slightly more than 50 percent and the densities of each of the remaining species were less than 14 percent.

Chart 10-1

Relative Density of Trees Along Transect 1 – NMS
(N = native)

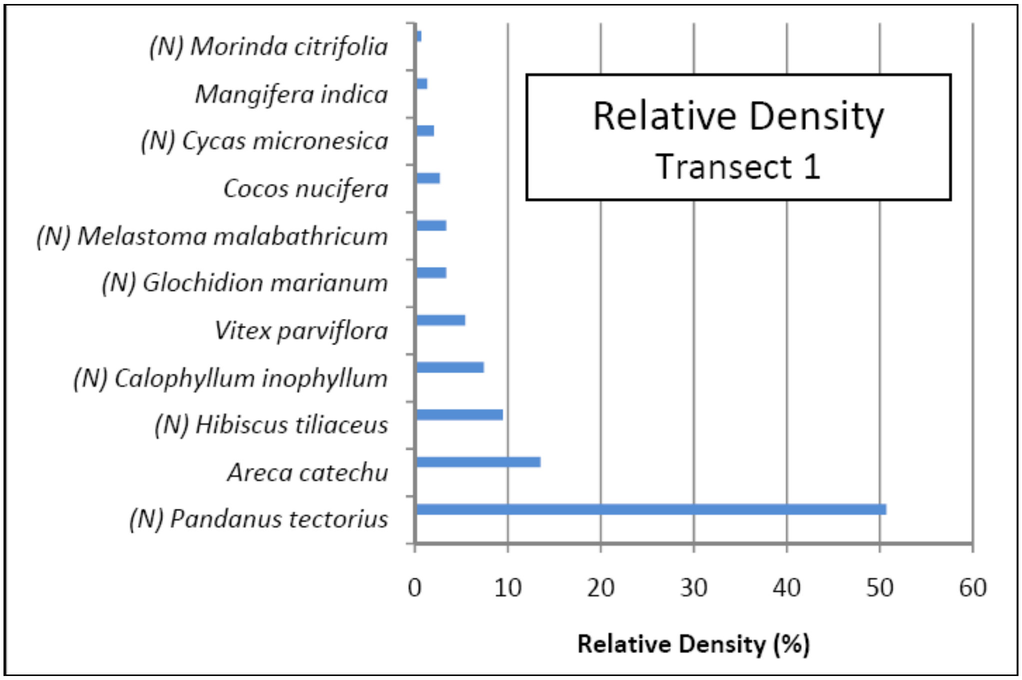


Chart 10-2

Relative Density of Trees Along Transect 3 – NMS
(N = native)

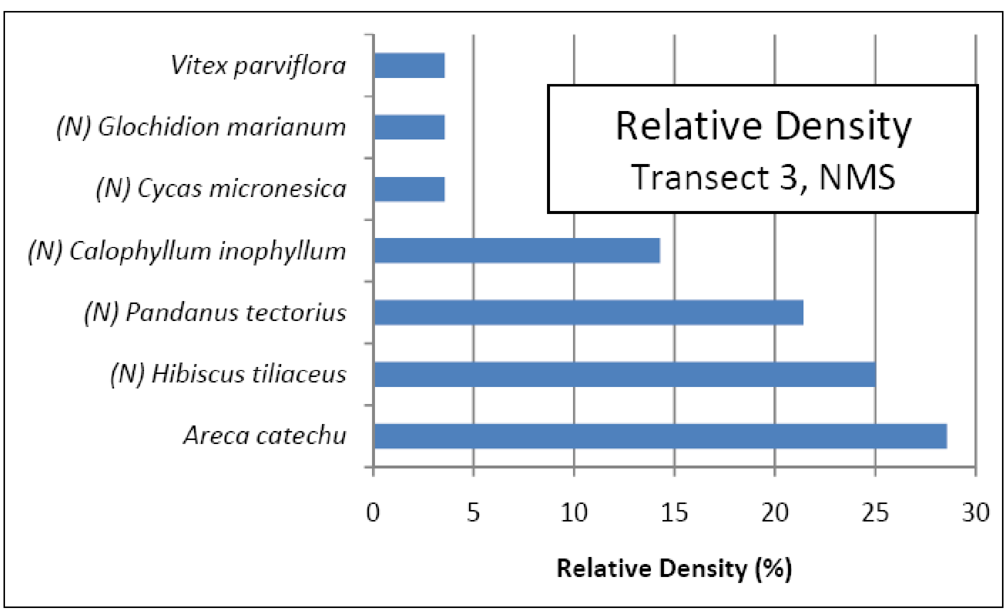
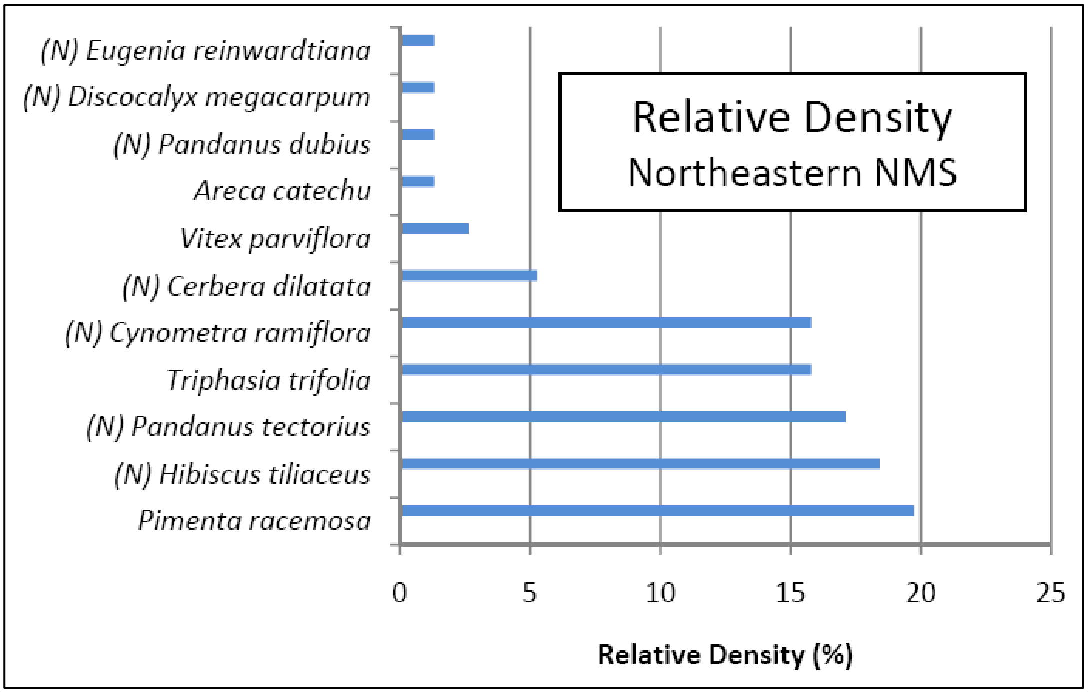


Chart 10-3

Relative Density of Trees Along Transects 4, 5, and 6 – NMS
(N = native)



The ravine forest sampled along Transect 7 had a calculated density of approximately 1,791 trees per ha. The four highest relative densities were for species native to Guam, and ranged from about 33 percent to 10 percent. Introduced species accounted for less than 13 percent of the relative density among the nine species on the transect (Chart 10-4).

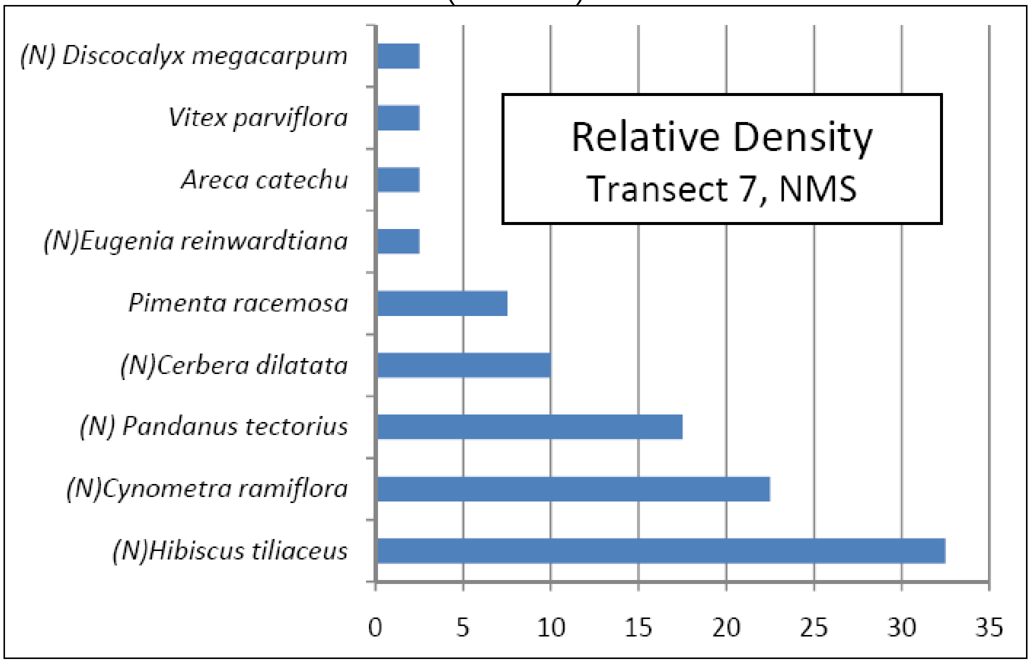
10.2.1.2 Southern Sector

Transect 9 sampled the ravine forest in the valley slopes surrounding Mt. Almagosa. The overall density was calculated at approximately 2,637 trees per hectare. The forest is characterized by the dominant faniok (*Merrilliodendron megacarpum*) trees that comprised over 63 percent of the relative density (Chart 10-5). Faniok had an absolute cover of 21.31 m^2/ha, well above any other species on the transect.

Transect 10 sampled the ravine forest along the Sadog Gagu River in the southern sector of the annex. Point-center quarter results revealed an overall tree density of approximately 1,474 trees per ha. Two introduced and naturalized species, coconut (*Cocos nucifera*) and Milla (*Vitex parviflora*), outranked all other species, with cover values of 13.46 m^2/ha and 8.02 m^2/ha, respectively. *Vitex* also had the highest relative density (28 percent), followed by the betelnut palm or pugua (*Areca catechu*) (22 percent) (Chart 10-5). The overall relative density of native species was approximately 33 percent, which is lower than the densities observed in ravine forest transects in the northern sectors of the annex.

Chart 10-4

Relative Density of Trees Along Transect 7 – NMS
(N = native)



The ravine forest in the southwestern sector of the annex was sampled along Transects 8 and 11, located south and west of the explosive ordnance disposal (EOD) range, respectively. The survey revealed an overall density of about 1,500 trees per ha. Coconut (*Cocos nucifera*) and betelnut palms were dominant with native kafu (*Pandanus tectorius*) in terms of density, dominance and frequency (Chart 10-6).

The remaining species had low relative densities. The native cycad or fading (*Cycas micronesica*) was represented by two specimens with a mean basal area of 630 cm^2; both trees were sampled on Transect 8.

10.2.2 Seedlings

The study plots analyzed in the northern NMS revealed a lower native woody seedling density of approximately 1.83 seedlings/m^2 compared with introduced seedlings, which had a density of about 2.44 seedlings/m^2. Transect 4 in the northeastern sector had a particularly high density of bay-rum (*Pimenta racemosa*) seedlings, which contributed to the higher overall density of introduced seedling species. Bay-rum appears to be thriving in the northeastern sector, possibly in part because of its prolific seed production.

The southern sector of NMS had a native woody seedling density of about 17.19 seedlings/m^2. This was higher than the density of introduced seedlings, which was approximately 1.06 seedlings/m^2. Native mapunao (*Aglaia mariannensis*) trees were prolific seedling producers on Transect 9, which contributed to the higher native seedling density in southern NMS.

Chart 10-5

Relative Density of Trees Along Transect 9 – NMS
(N = native)

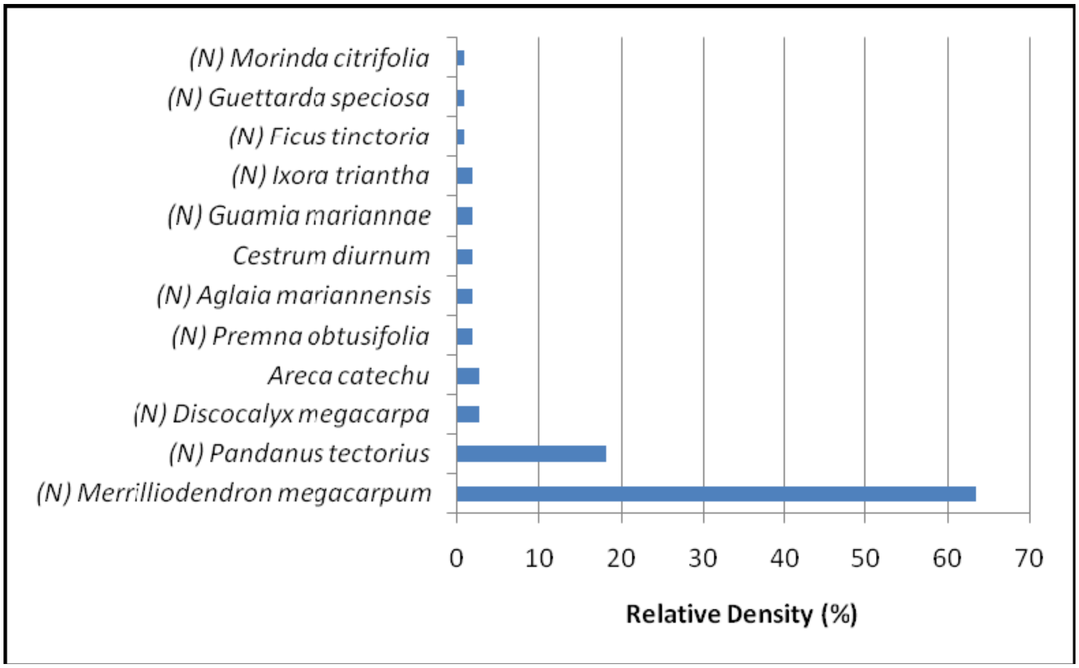


Chart 10-6

Relative Density of Trees Along Transect 10 – NMS
(N = native)

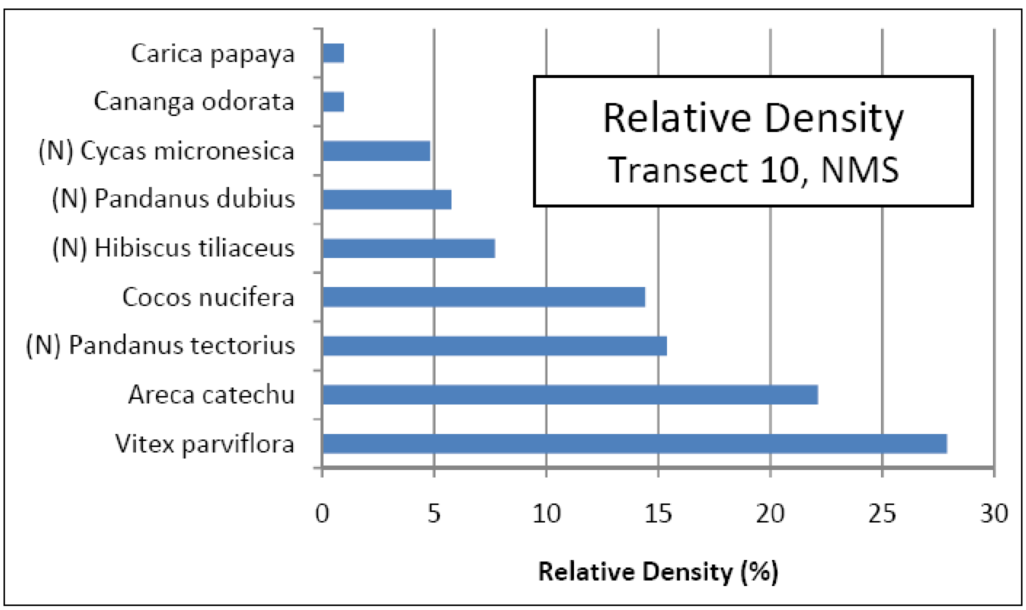
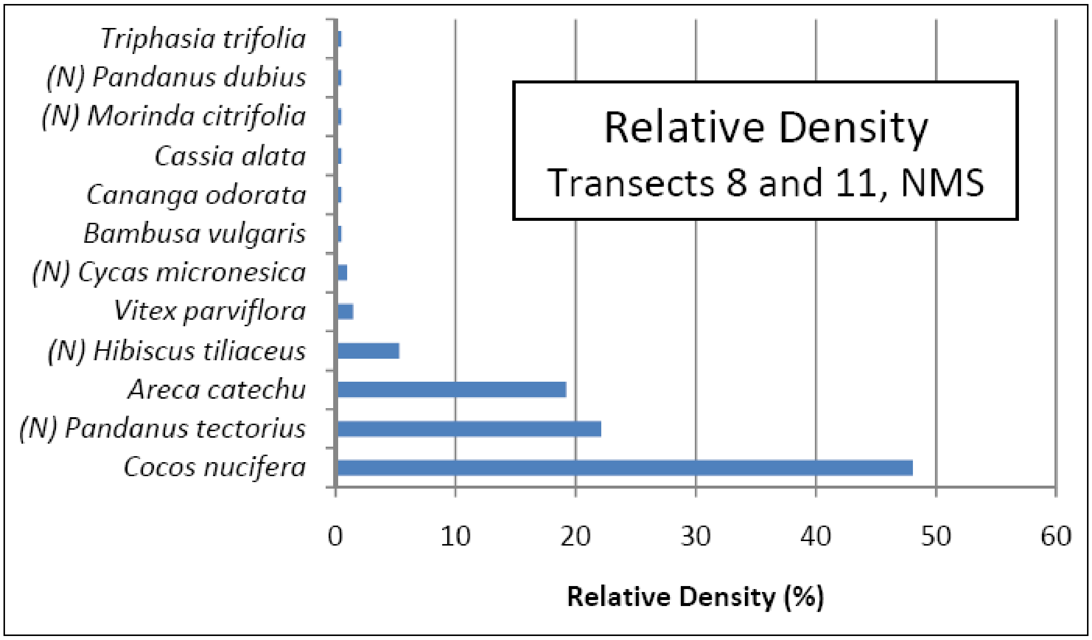


Chart 10-7

Relative Density of Trees Along Transects 8 and 11 – NMS
(N = native)



10.2.3 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat at NMS. These include ungulate activity, the presence of erosion, the percentage of native plant species, and overall species richness. Among the transects sampled in the northern sector of NMS, species richness was highest for Transect 5, followed by Transects 7, 1, 6, 3, and 4, respectively. Transect 1 and Transect 7 appear to have similar points of inflection; rarefaction would indicate that richness is similar among these transects, although fewer samples were obtained for Transect 7.

Species richness curves indicate a higher species richness for Transect 9 in the *Merrilliodendron megacarpum* forest than for other transects in the southern sector of NMS (Transects 8, 10, and 11). Transect 9 also had the highest relative density of native versus introduced species among all transects at NMS.

Overall, the lowest species richness in the southern sector of NMS was along Transect 11 in the ravine forest west of the EOD Range, which contained only seven tree species. This forest contains a high proportion of coconut (*Cocos nucifera*) (approximately 55 percent of the relative density) among mostly kafu (*Pandanus tectorius*), betelnut (*Areca catechu*), and pago (*Hibiscus tiliaceus*) trees. In the northern sector of NMS, the lowest species richness was observed along Transect 4; only five species were sampled on this transect, which contained similar relative densities of native and introduced species.

Ungulate activity was quantified at stations along Transects 1 through 11. Soil disturbance, such as rooting, had the highest mean frequency, followed by browsing. Erosion, vegetation damage and other disturbance from wild pigs (*Sus scrofa*), deer (*Cervus unicolor*), and carabao (*Bubalis*

bubalis) are considered major problems at NMS. The ungulate activity was especially conspicuous along Transect 11 in the southern sector of NMS, where active wallows, rooting, and live feral pigs were observed.

10.2.4 Threatened and Endangered Species and Species of Concern

10.2.4.1 Threatened and Endangered Species

The only federally- or locally-listed species identified at NMS by BioSystems Analysis, Inc. (1989) was the tree fern tsatsa (*Cyathea lunulata*), which is locally protected as an endangered species. However, no tree ferns or other listed species were observed at NMS during the current survey.

10.2.4.2 Species of Concern

The Guam Department of Agriculture lists fadang (*Cycas micronesica*) among the six plant SOGCNs (Department of Agriculture, 2005). This was the only SOGCN observed during the current survey. In the northern sector of NMS, fadang had a relative density of less than 4 percent on Transects 1 and 3; it was not sampled on other transects in the northern sector of NMS. In the southern sector of NMS, fadang appeared only on Transects 8 and 10, where it had relative densities of approximately 2 percent and 4 percent, respectively.

BioSystems Analysis, Inc. (1989) cited the presence of several rare but unprotected species at NMS. These species were the following:

- *Thelypteris warburgii*, a fern indigenous to Guam and Papua New Guinea that occurs only at NMS along the Bonya, Tolaeyuus and Maemong Rivers. *T. warburgii* is also considered a species of concern by the USFWS (USFWS, 2005).
- *Eria rostiflora*, an epiphytic orchid found only at NMS.
- *Coelogyne guamensis*, an epiphytic orchid found locally only at NMS.
- *Nervilia platychila*, a ground orchid found locally only at NMS.
- *Maesa* sp., a tree found locally only at NMS.
- *Fagraea berteriana*, a native tree found locally only at NMS.
- *Merrilliodendron megacarpum*, a native tree with limited distribution on Guam.

With respect to these species of concern, the findings of the current surveys were as follows:

- *Thelypteris warburgii* was identified near Transects 5 and 6, with only one plant at each site.
- *Fagraea berteriana* - a few specimens of were observed along Transects 1 and 9, some of which were flowering and fruiting.
- *Merrilliodendron megacarpum* was quantified in the forest stands along Transect 9 around Mount Almagosa.

The following uncommon species were also noted along transects at NMS, although they are not regulated or managed by the federal or local authorities: *Hedyotis laciniata*, an endemic herb of the savannas; *Tuberolabium* (*Trachoma*) *guamensis*, an endemic epiphytic orchid found on Guam and Rota; and *Luisia teretifolia*, an indigenous epiphytic orchid found on Guam and Rota.

10.2.5 Qualitative Survey

10.2.5.1 NMS

A qualitative survey was performed on twelve transects within the NMS (Figure 10-1). Three separate *Merrilliodendron megacarpum* stands were mapped totaling 10 acres (4 hectares). In addition, numerous other smaller scattered patches of *Merrilliodenron megacarpum* were noted in the area. Several uncommon species were observed including *Dishidia puberula* and *Coelogyne guamense*, the latter an orchid species found primarily in the branches of large trees on high limestone ridges and found on Guam, Rota, and Palau (Raulerson and Rinehart, 1992).

10.2.5.2 Proposed Access Road

A qualitative vegetative survey was performed along the Proposed Access Road Option A. The proposed access road would follow an existing foot trail that traverses savanna vegetation with a few stands of forest in minor valleys. The area surveyed was within approximately 25 m of either side of the trail. *Merrilliodendron megacarpum* forest, an uncommon forest type on Guam, was present and dominated a portion of the small forest on either side of the trail at the highest forest stand encountered along the trail. On both sides of the trail, the *Merrilliodendron megacarpum* forest did not appear to extend much, if at all, beyond the survey corridor. No threatened or endangered or rare species were observed.

10.3 Avian Surveys

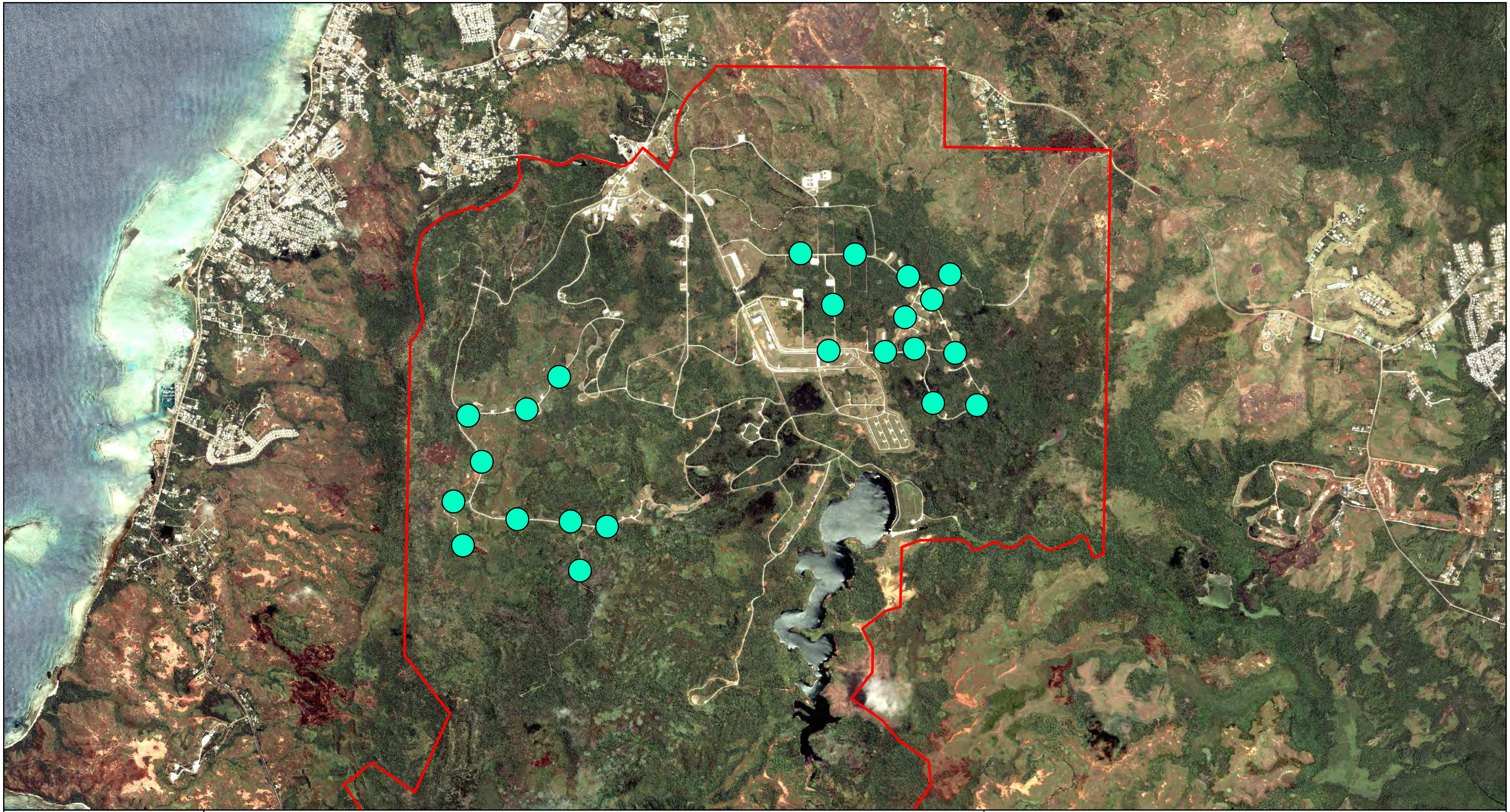
On the NMS, roadside bird surveys (Figure 10-4) and forest bird surveys were conducted in the morning. Table 10-3 lists the species observed as part of the surveys.

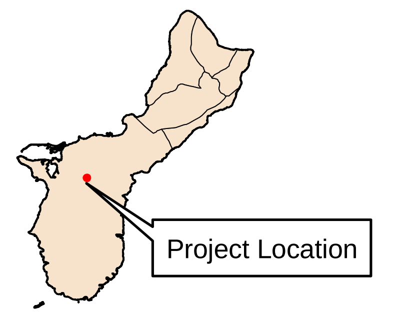
Table 10-3

Species Identified during Roadside and Forest Bird Surveys – NMS

Survey Type	Number of Stations	Species and Number of Detections	Number of Species	Total Number of Detections
Roadside	23	Island Collared Dove (13) Black Francolin (11) Pacific Golden Plover (6) Black Drongo (3) White Tern (2)	5	35
Forest Bird	29	Black Francolin (8) White Tern (3) Island Collared Dove (2) Yellow Bittern (1) Grey-tailed Tattler (1)	5	15

With the exception of the white tern, all of the observed avian species are common to Guam. Although the white tern is uncommon, it does breed on Guam. Table 10-4 specifies the resident status of the observed species. The nomenclature follows Gill et al., 2008. For more information on the avifauna species below, refer to Appendix A.





Installation Boundary

Roadside Survey Point

N

0 200 400
Meters

Naval Munitions Site

Roadside Survey Points

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 10-4

Table 10-4

Residence Status of Avifaunal Species Identified during the Roadside and Forest Bird Surveys – NMS

Avifaunal Species	Residence Status[1]
White Tern *(Gygis alba*)	Uncommon, native resident - breeding
Yellow Bittern *(Ixobrychus sinensis*)	Common resident native - breeding
Island Collared Dove *(Streptopelia bitorquata*)	Common introduced resident - breeding
Black Drongo *(Dicrurus macrocercus*)	Common introduced resident - breeding
Eurasian Tree Sparrow *(Passer montanus*)	Common introduced resident - breeding
Black Francolin *(Francolinus francolinus*)	Common introduced resident - breeding
Pacific Golden Plover *(Pluvialis fulva*)	Common visitor – not breeding [2]
Grey-tailed Tattler (*Tringa brevipes*)	Common visitor – not breeding

Notes:
1 Residence status obtained from Reichel, J. D. and P. O. Glass, 1991, Checklist of the birds of the Mariana Islands. '*Elepaio*, 51(1): 3-10.

2 Residence status obtained from Johnson, O.W., Goodwill, R. & Johnson, P.M., 2006, Wintering ground fidelity and other features of Pacific Golden-Plovers *Pluvialis fulva* on Saipan, Mariana Islands, with comparative observations from Oahu, Hawaiian Islands. *Wader Study Group Bull.* 109: 67–72.

10.4 Tree Snail Surveys

In 2008 a survey was performed at select locations in the Naval Munitions (Appendix H; Smith et. al., 2008). Two colonies of partulid snails were found near Kitts Road. Only *Partula radiolata* were found at the two locations.

Additional surveys were conducted along transects in the southern Naval Munitions site and along the southern access road. In their report Barry Smith and Richard Randall (2010) state that no endangered tree snails were observed at any transect surveyed. However, one dead ground shell of *Partula gibba* was found near Almagosa Spring. The tree snail survey report is provided in Appendix H.

10.5 Threatened and Endangered Species

No federally-listed threatened or endangered avifauna, herpetofauna, tree snail, or vegetation species were identified on the NMS.

Two Guam-listed SOGCN amphibians (moth skink and Pacific slender-toed gecko) were identified on NMS. The moth skink was identified on Transect 1, Stations 18, 47, and 50; Transect 10, Station 14; and Transect 11, Station 18. The Pacific slender-toed gecko was observed on Transect 8, Station 18; Transect 10, Stations 17 and 22; and Transect 11, Station 19. Fadang (*Cycas micronesica*), a SOGCN plant species was observed on Transects 1and 3 within the northern section of NMS and Transects 8 and 10 in the southern section of NMS.

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11 Route 1 River Crossings

Five bridges along Route 1require structural upgrades as some are not structurally sound to carry current loads and to support the ABM Transports. At these five locations, both avian and in-stream surveys were conducted. The five bridges cross the following rivers from south to north: the Atantano, Aquada, Sasa, Asan, and Agana. Figure 11-1 depicts the locations of the river crossing study areas.

At each river crossing, scientists measured the width of the stream bed at the upstream and downstream location of the river's crossing under Route 1. The depth was also measured immediately upstream and downstream of Route 1. Finally, within 50 m upstream and downstream of the bridge, the benthic substrate, flow, the height and composition of river banks, fish species utilizing the area, and the general ecological setting were also recorded. Avian surveys were performed at the five river crossings; however, no avifauna were observed at any location.

The investigations were conducted twice, first during the rainy season of 2009, when some areas were obscured due to turbid water conditions, and second during the dry season (in January 2010), when water conditions were less turbid.

11.1 Atantano River

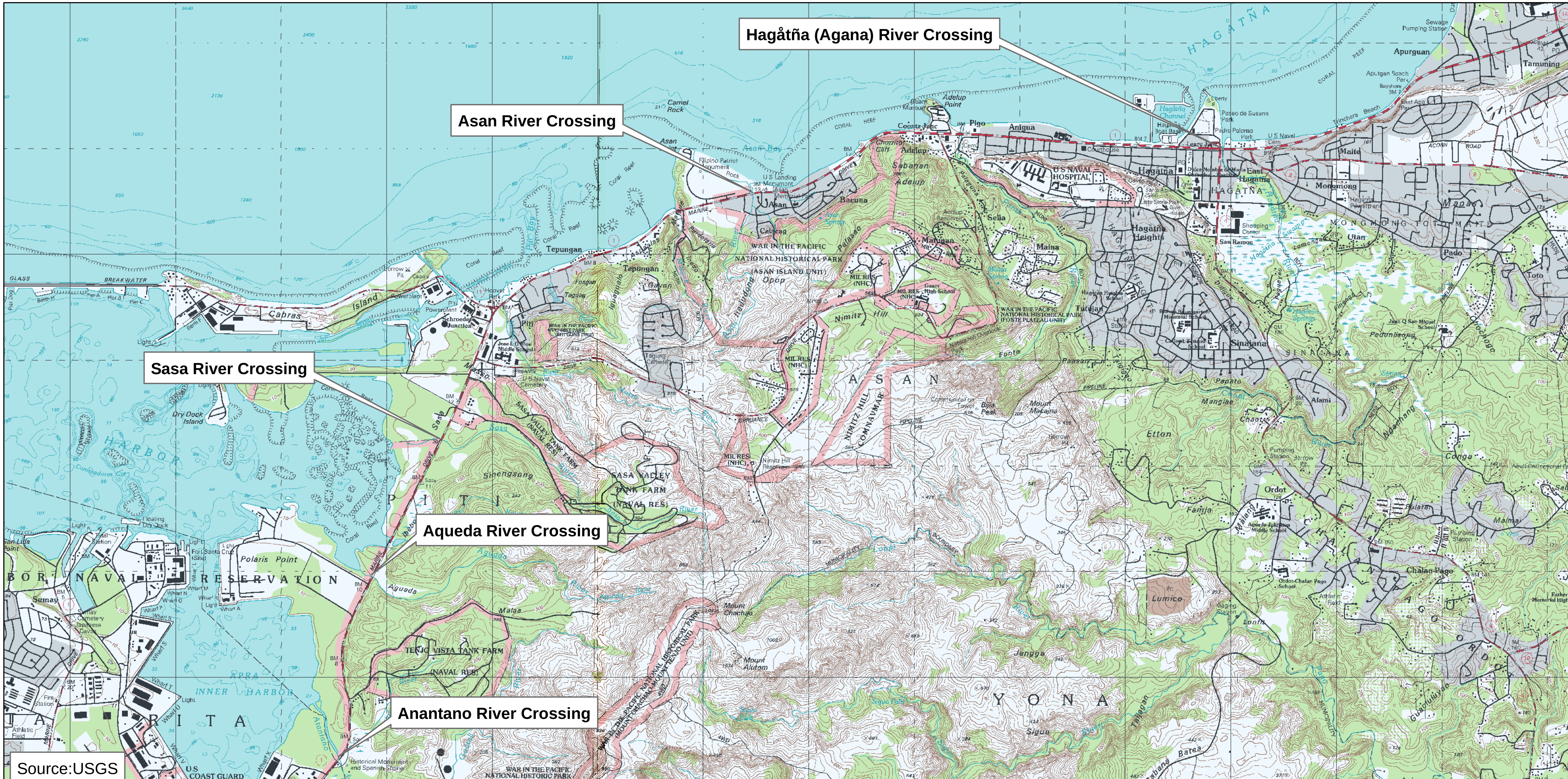
The Atantano River crossing of Route 1 is located approximately 0.7 kilometers (km) north of the main gate of the Apra Harbor Naval Reservation. The areas immediately adjacent to the banks are largely undeveloped. The crossing is approximately 0.5 km upstream of the river's confluence with Inner Apra Harbor.

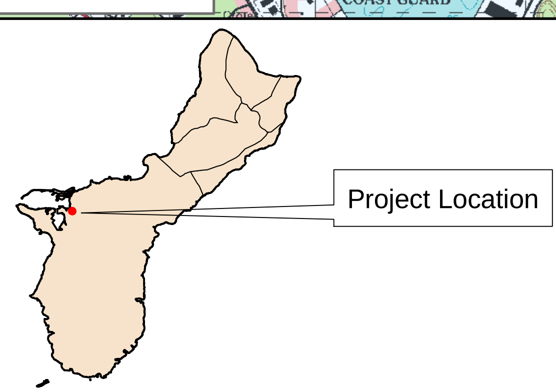
At the Route 1 crossing, the Atantano River is 13.2 m wide and 2 m deep at the downstream location and 13.4 m wide and 2.8 m deep at the upstream location. Immediately downstream of Route 1, the river's banks consist of vertical sheet piling encrusted with marine life. Further downstream, woody vegetation is present to the edge of the bank.

Upstream of the bridge, the river banks consist of vertical eroded earthen banks approximately 1.3 m in height. Immediately adjacent to the bridge, the tops of the banks are cleared, but further upstream woody vegetation occurs to the edge of the banks. Photos 11-1 and 11-2 illustrate the views downstream and upstream from the bridge, respectively.

Due to turbid conditions in September 2009, no in-water observations of marine life or benthic substrate were conducted. In January 2010, snorkel surveys were performed within the river. The benthic substrate consisted of silty sand with some isolated rocks. No submerged aquatic vegetation was observed within the study area. Marbled eel (*Anguilla marmorata*) and rock flagtail (*Kuhlia rupestris*) were the only fish observed within the river. Both species are native to Guam.

In 2008, a Biological and Habitat Assessment of the Atantano River conducted by GDAWR indicated that the river has the largest and best developed mangrove swamp on Guam (GDAWR, 2008). The report also acknowledged that the river experiences perturbations from adjacent





Route 1 River Crossings

River Crossings Map

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 11-1

shipping, docking, and oil refinery facilities. The assessment also indicated that a variety of fish and invertebrate species utilize the river as habitat. A list of these species are the following:

Photo 11-1 Looking downstream from Route 1 at the Atantano River.

Photo 11-2 Looking upstream form Route 1 at the Atantano River.

- Fish – Native species include: Common Glass Fish (*Ambassis buruensis*), Dusky Sleeper (*Eleotris fusca*), Rock Flagtail *(Kuhlia rupestris*), snappers *(*Family Lutjanidae), Silver Moony (*Monodactylus argenteus*), Bluespot mullet (*Moolgarda seheli*), Bandfin mullet goby (*Mugilogobius cavifrons*), mudskipper (*Periophthalmus argentilineatus*), Bigmouth Goby (*Redigobius bikolanus*), gobies (*Stenogobius sp.*), Feathered River-garfish (*Zenarchopterus dispar*). Introduced species include: Mosquitofish (*Gambusia affinis*) and Guppy (*Poecilia reticulata.*

- Invertebrates. Native species include: Ninja Shrimp (*Caridina serratirostris*), Shrimp (*Caridina sp.*), Tahitian Prawn (*Macrobrachium lar*), Snail (*Neritina squamipicta*), and *Thiara granifera.* Invasive species included leeches, Class Clitellata.

During the course of the natural resource survey, no avifauna were observed. Also, no chance observations of herptofauna or mammals were observed either during the survey.

11.2 Aquada River

The Aquada River crossing of Route 1 is located approximately 3.1 km north of the Atantano River. The areas adjacent to the banks are largely undeveloped. The crossing is approximately 0.2 km upstream of the river's confluence with Apra Harbor.

At the Route 1 crossing, the Aquada River is 9.2 m wide and 3.4 m deep at the upstream location and 9.1 m wide and 3.2 m deep at the downstream location. Approximately 15 m upstream of the bridge, the river narrows to less than 1 m wide and less than 0.3 m deep. During the time of the investigation the stream had an imperceptible flow and was choked with vegetation due to a downstream logjam that had backed up the flow. Photos 11-3 and 11-4 illustrate the views downstream and upstream from the bridge, respectively.

Upstream of the bridge a forested area dominates the landscape (Photo 11-5). Within the forest, numerous drainage channels were observed. The channels were mostly dry during the investigation but evidence of hydrology (e.g., sediment staining of vegetation, drift lines, and water-stained leaves) indicated that these channels do convey surface water to the Aquada River during wetter periods of the year.

Downstream of the bridge, the river pools and is approximately 9 m wide and 15 m long; the pool then empties into a swiftly-flowing stream that is less than 1 m wide. On the southern bank of the pool, a strip of hydrophytic vegetation is present. Downstream of the pool, the river is swift-flowing, clear, with a rocky bottom. This portion of the river flows through a forested area dominated by palms and bamboo (Photo 11-6). The forested area has a hummocky surface.

Due to turbid conditions in September 2009, no in-water observations of marine life or benthic substrate were conducted. In January 2010, it was determined that damming of the water by logs had caused stagnant conditions. Due to safety concerns, no snorkel surveys were performed. From the bank, flagtail fish were observed swimming in the river. Upstream and downstream of the bridge, in the portions of the river that are narrower and with increased flows, native species such as gobies (*Awaous* sp., *Stenogobius* sp., and *Sicyopus* sp.) likely utilize the river as habitat.

In 2008, a Biological and Habitat Assessment of the Aquada River was conducted by GDAWR (GDAWR, 2008). The assessment indicated that a variety of fish and invertebrate species utilize the river as habitat. A list of these species are the following:

- Fish –species include: Giant Marbled Eel (A*nguilla marmorata*) and Goby (S*icyopus spp*.);

- Invertebrates. Native species include: Green Lace Shrimp (*Atyoida pilipes*), shrimp *(Caridina sp.*), Malaysian Trumpet Snail (*Melanoides tuberculata*), snail (*Neritina pettiti*), Mayfly larvae, Dragonfly Larvae, and Pyralid caterpillars.

During the course of the natural resource survey, no avifauna were observed. Also, no chance observations of herptofauna or mammals were observed either during the survey.

Photo 11-3 Looking downstream from Route 1 at the Aquada River.

Photo 11-4 Looking upstream from Route 1 at the Aquada River. Note the high water and waterbody choked with vegetation.

Photo 11-5 Looking further upstream from Route 1. During the time of the investigation (January 2010), the river flowed through a 5-m wide, vegetation-choked stream bed. The river was approximately 0.3 m foot wide and 0.2 m deep.

Photo 11-6 Looking further down stream at the wetland area south of the bridge. The wetland is dominated by palms and bamboo. The river (see photo) is narrow and swift flowing.

11.3 Sasa River

The Sasa River crossing of Route 1 is located approximately 1.6 km north of the Lagaus River. The land areas adjacent to the banks are largely undeveloped. The crossing is approximately 0.7 km upstream of the river's confluence with Apra Harbor.

At the Route 1 crossing, the Sasa River is 7.4 m wide and 0.1 m deep at the upstream location and 5.6 m wide and 0.45 m deep at the downstream location. Approximately 5 m upstream of the bridge a logjam measuring some 20 m long was observed. Further upstream from the logjam, the river continues to be broad and shallow, with a flat, sandy-gravel bottom with numerous gravel bars. During the time of the investigations, the river's flow was estimated at 0.22 meters per second (mps).

Downstream of the bridge, the river is shallow, with a flat sandy bottom with gravel and cobbles. Approximately 25 m downstream, a logjam occurred. The river's banks are earthen, 1.2 m high, and vertical. Photos 11-7 and 11-8 illustrate the views upstream and downstream from the bridge, respectively.

Upstream and downstream of the bridge forested areas occur. Downstream of the bridge within the study area, the vegetation is low and denser, whereas upstream of the bridge large bamboo stands line the river banks (Photo 11-9). No submerged aquatic vegetation was observed in the study area, although some filamentous green algae were observed on rocks immediately downstream of the bridge.

No fish were observed during the surveys. However, the riverine habitat is similar to other rivers on the islands that support fish species such as Guam goby (*Awaous guamensis*), rock flagtail (*Kuhlia rupestris*), other gobies (*Sicyopterus* and *Stiphodon sp.*), and marbled eel (*Anguilla marmorata*).

In 2008, a Biological and Habitat Assessment of the Sasa River conducted by GDAWR indicated that the river does incur impacts from adjacent shipping, docking, and oil refinery facilities (GDAWR, 2008). The assessment also indicated that a variety of fish species utilize the river as habitat. A list of these species are the following:

- Fish – Native species include: Engel's mullet (*Moolgarda engeli*), Bandfin Mullet Goby (*Mugilogobius cavifrons*), Mudskipper (*Periophthalmus argentilineatus*), Feathered River-garfish (*Zenarchopterus dispar*). Invasive species included the Mozambique tilapia (*Oreochromis mossambicus*).

During the course of the natural resource survey, no avifauna were observed. Also, no chance observations of herptofauna or mammals were observed either during the survey.

Photo 11-7 Looking upstream from Route 1 at the Sasa River.

Photo 11-8 Looking downstream from Route 1 at the Sasa River.

Photo 11-9 Looking upstream at the Sasa River. Here the stream is shallow and swift flowing with coarse-grained sediments comprising the river bed. Note the near vertical banks and large bamboo stands that line the river.

11.4 Asan River

The Asan River is located 0.6 km east of Asan Point. Upstream, residential and commercial developments occur along the river banks. Downstream, the banks are managed as the river flows through a national park. The crossing is approximately 100 m upstream of the river's confluence with Asan Bay.

The Asan River is 13.8 m wide and up to 1 m deep at the upstream location and 14.1 m wide and up to 1 m deep at the downstream location. Upstream of the bridge, wing walls occur along the banks. The land areas adjacent to the banks are developed with residential and commercial properties. The river is tidally influenced, with a flat, sandy bottom.

Downstream of the bridge, the river is tidally influenced and shallow, with a flat, sandy bottom. During periods of higher tides, wave action occurs within the river south of the bridge. Species that inhabit this area include flagtails, eels, snapper, puffer, and goat fish. Photos 11-10 and 11-11 illustrate the views downstream and upstream from the bridge, respectively. Land areas adjacent to the banks downstream of the bridge are mowed lawns comprising the National Park.

In 2008, a Biological and Habitat Assessment of the Asan River conducted by GDAWR indicated that the river is channelized and heavily developed (GDAWR, 2008). The assessment also indicated that a variety of fish and invertebrate species utilize the river as habitat. A list of these species are the following:

- Fish – Native species include: Giant Marbled Eel (*Anguilla marmorata*), Dusky Sleeper (*Eleotris fusca*), Rock Flagtail *(Kuhlia leucisus*), River Gobies *(Stiphodon spp.*). Introduced species included the Mozambique Tilapia (*Oreochromis mossambicus*).

- Invertebrates. Native species include: Ninja Shrimp (*Caridina serratirostris*), Shrimp (*Caridina sp.*), Tahitian Prawn (*Macrobrachium lar*), Snail (*Neritina pulligera*), Snail (*Neritina variegata*), (*Septaria porcellana*), *and* (*Thiara granifera*).

Upstream of the bridge, no fish species were observed. Downstream of the bridge, observed species included species common to shallow, coastal flats, such as wrasses (Family Labridae), Guam goby, eels, pufferfish (Family Tetraodontidae), acute-jawed mullet (*Neomyxus leucisus*), and damselfish (Family Pomacentridae). In addition, in January 2010, small crabs (Decapods) were observed in shallow-water areas along the banks.

During the course of the natural resource survey, no avifauna were observed. Also, no chance observations of herptofauna or mammals were observed either during the survey.

Photo 11-10 Looking downstream from Route 1 at the Asan River. Note the river's confluence with Asan Bay and the Philippine Sea in the distance.

Photo 11-11 Looking upstream from the Route 1 at the Asan River. Note the outfalls and engineered banks.

11.5 Agana River

The Agana River is located approximately 2.2 km east of the Fonte River. The Agana River's banks are occupied by commercial and recreational properties associated with the City of Hagatna. The crossing is approximately 100 m upstream of the river's confluence with Agana Bay.

At the Route 1 crossing, the Agana River is 10.6 m wide and up to 0.7 m deep at the upstream location and 10.7 m wide and up to 0.4 m deep at the downstream location. Upstream of the bridge, the river has a swift flow and a flat, sandy bottom with boulders. The banks are vertical concrete walls with outfall pipes. Photos 11-12 and 11-13 depict the upstream and downstream habitats, respectively.

Downstream of the bridge, the river has a swift flow with a flat, sandy bottom with boulders. The banks are vertical concrete walls with outfall pipes. Species identified included the Guam goby, damselfish, snapper, flagtail, angelfish, yellow lip emperor (*Lethrinus xanthochilus*), diamond-scale mullet (*Liza vaigiensis*), acute-jawed mullet (*Neomyxus leucisus*), and keeltail needlefish (*Platybelone argalus*).

In 2009, a Biological and Habitat Assessment of the Agana River conducted by GDAWR indicated that the river is heavily channelized and developed (GDAWR, 2008). The assessment also indicated that a variety of fish and invertebrate species utilize the river as habitat. A list of these species are the following:

- Fish – Native species include: Indonesian Shortfin Eel (*Anguilla bicolor* (Giant Marbled Eel (*Anguilla marmorata*) Guam Goby (*Awaous guamensis*) Dusky Sleeper (*Eleotris fusca*) Yellow Tail Mullet (*Ellechelon*, Rock Flagtail (*Kuhlia leucisus*) *False mullet Neomyxus leucisus*) river gobies (*Stiphodon spp.*) Feathered River-garfish (*Zenarchopterus dispar*. Introduced species include: Walking Catfish (*Clarias batrachus*) Common Carp (*Cyprinus carpio*) Mosquitofish (*Gambusia affinis*) Mozambique Tilapia (*Oreochromis mossambicus*) Guppy (*Poecilia reticulata*) and Tilapia (*Tilapia zillii*).

- Invertebrates. Native species include: Tahitian Prawn (*Macrobrachium lar*).

During the course of the natural resource survey, no avifauna were observed. Also, no chance observations of herptofauna or mammals were observed either during the survey.

Photo 11-12 Looking downstream for Route 1 at the Agana River. Here too, note the close proximity to the ocean.

Photo 11-13 Looking upstream from Route 1 at the Agana River.

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12 Route 15 Lands

The Route 15 Lands are immediately east of Andersen South. The Route 15 Lands comprise the plateau area and the Sasajyan Valley. Figure 12-1 identifies the locations of the ecological transects. Ecological surveys on the Route 15 Lands included vegetation, avian, and fruit bat surveys. Also, for the vegetation survey, additional transects and survey locations were utilized. The location of these transects and other survey locations are presented when discussed in the respective discipline. Surveys on the Sasajyan Valley transect were not possible because of access issues.

Two transects were located on top of the cliff line in limestone karst forest. The first started with native forest which included *Guamia mariannae, Aglaia mariannensis, Ficus tinctoria,* and *Triphasia trifolia* before opening up to a degraded forest with some *Leucaena leucocephala, Chromolaena ordata,* and *Stachytarpheta cayennensis.* The second transect traversed through similar native forest. The third was situated below the cliff line and consisted mostly of *Cocos nucifera.*

12.1 Herpetofauna

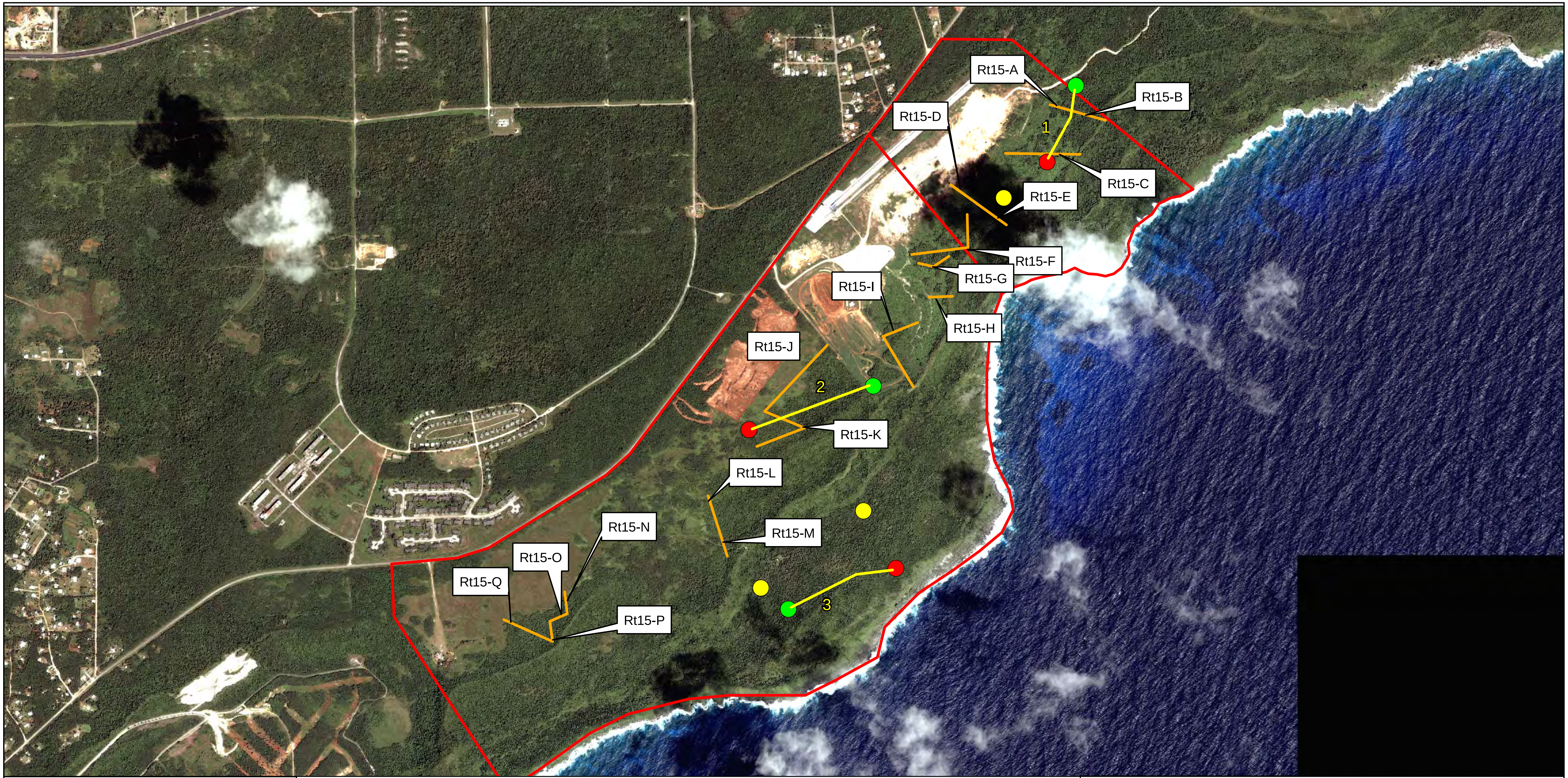
A total of six herpetofauna species were captured or observed on the Route 15 Lands. Table 12-1 identifies the species and their status. For more information on the herpetofauna survey and results, please refer to Appendix B.

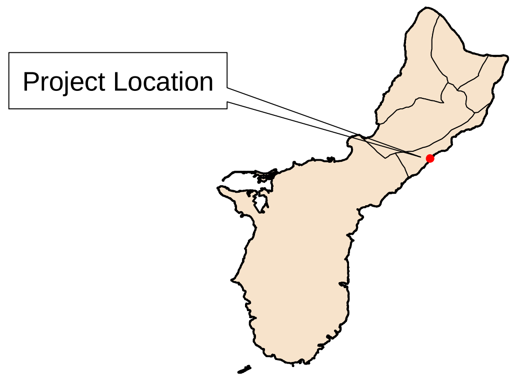
Table 12-1

Herpetofauna Captured or Observed on Route 15 Lands

Guild	Species	Status
Skinks	Curious skink (*Carlia ailanpalai*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
Gecko	House gecko (*Hemidactylus frenatus*)	Introduced
Snakes	Brown treesnake (*Boiga irregularis*)	Introduced
Other	Monitor lizard (*Varanus indicus*)	Introduced
Amphibians	Marine toad (*Rhinella marinus*)	Introduced
	Greenhouse frog (Eleutherodactylus planirostris)	Introduced
	Eastern dwarf tree frog (*Litoria fallax*)	Introduced

The continued widespread presence of the brown treesnake and the curious skink, as well as other introduced amphibian species, is of concern because of each species' potential deleterious impacts to Guam's native fauna (Rodda et al., 1999, Kraus et al., 1999, Wiles et al., 2003, Christy et al., 2007a). Of particular concern is the potential of these introduced species to serve as additional food sources for the brown treesnake (Fritts and Rodda, 1998; Christy et al., 2007a).





Beginning Transect Point

End Transect Point

Fruit Bat Survey

Quantitative Transects

Qualitative Transects

Installation Boundary

N

0 200 400

Meters

Route 15 Lands

Transect Map

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 12-1

12.2 Vegetation

Both quantitative and qualitative vegetation surveys were performed in the Route 15 Lands. The results of these surveys are provided in Subchapter 12.2.1 and 12.2.2, respectively.

12.2.1 Quantitative Survey

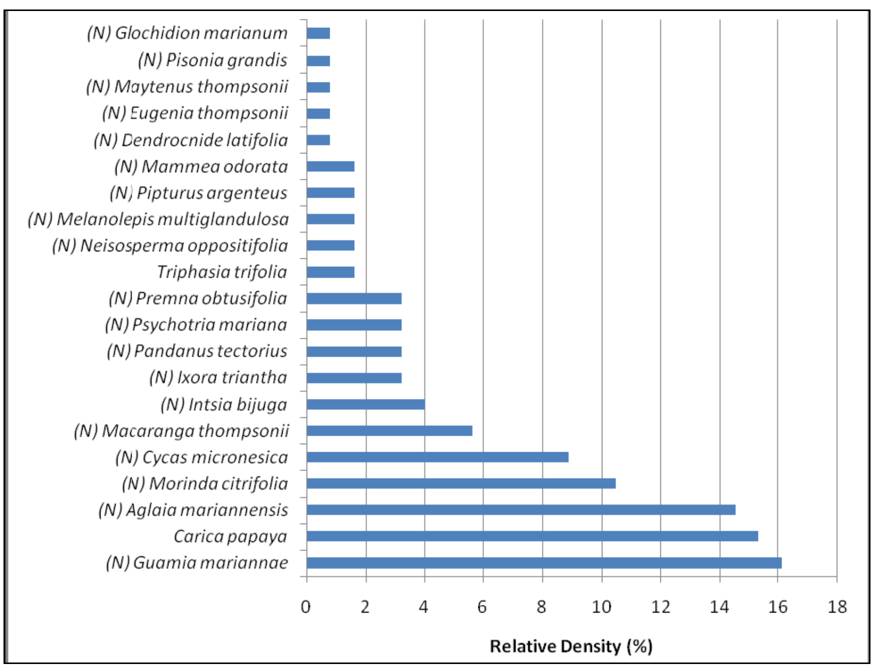
12.2.1.1 Trees

Surveys were performed along three transects in the limestone forest communities of the Route 15 Lands. Transect 1 was located in the northeastern sector of the Route 15 parcel along a north-south axis; Transect 2 was located to the south along a north-south axis; and Transect 3 was located along a north-south axis on a plateau below Transect 2.

The quantitative observations from the point-center quarter survey along Transect 1 revealed an absolute density of approximately 3,148 trees/ha. Native ading (*Cycas micronesica*) and ifil (*Intsia bijuga*), and introduced papaya (*Carica papaya*) were the most dominant species, with absolute cover values from 3.73 to 5.33 $m^{2/}$ha. Pengua (*Macaranga thompsonii*), a species endemic to the Mariana Islands, was the next most dominant species, with an absolute cover of 3.08 m^2/ha. The relative density was highest for paipai (*Guamia mariannae*), papaya, and mapunao (*Aglaia mariannensis*), with relative densities of approximately 16 percent, 15 percent, and 14.5 percent, respectively (Chart 12-1). These species also had the highest absolute frequencies, indicating that they are well-distributed along the transect.

Chart 12-1

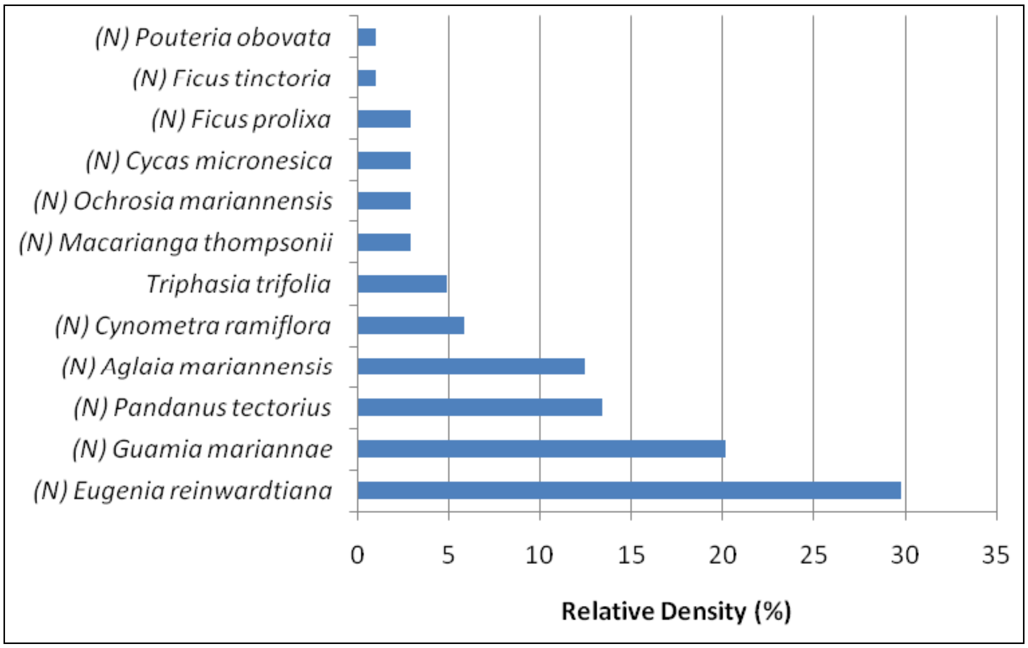
Relative Density of Trees Along Transect 1 – Route 15 Lands
(N = native)



Transect 2 had an absolute density of 4,566 trees per ha. This was the highest overall density among the three transects in the Route 15 project area. On this transect, the native a'abang (*Eugenia reinwardtiana*) was dominant, with an absolute cover of 8.19 m^2/ha and an absolute density of 1,321 trees/ha. A'abang was also well-dispersed, and had the highest frequency (57.69) among the 12 species on the transect (Chart 12-2). Pengua had an even higher absolute cover (5.13 m^2 per ha) than in Transect 1, although absolute density was lower, at 131.73 trees/ha. The relative density of trees was highest for a'abang, at nearly 30 percent, followed by paipai (*Guamia mariannae*) and kafu (*Pandanus tectorius*), at 20 percent and 13 percent, respectively. Fadang (*Cycas micronesica*) had a lower absolute density (131.73 trees/ha), absolute cover (218.61 cm^2), and absolute frequency (7.69) than in Transect 1.

Chart 12-2

Relative Density of Trees Along Transect 2 – Route 15 Lands
(N = native)



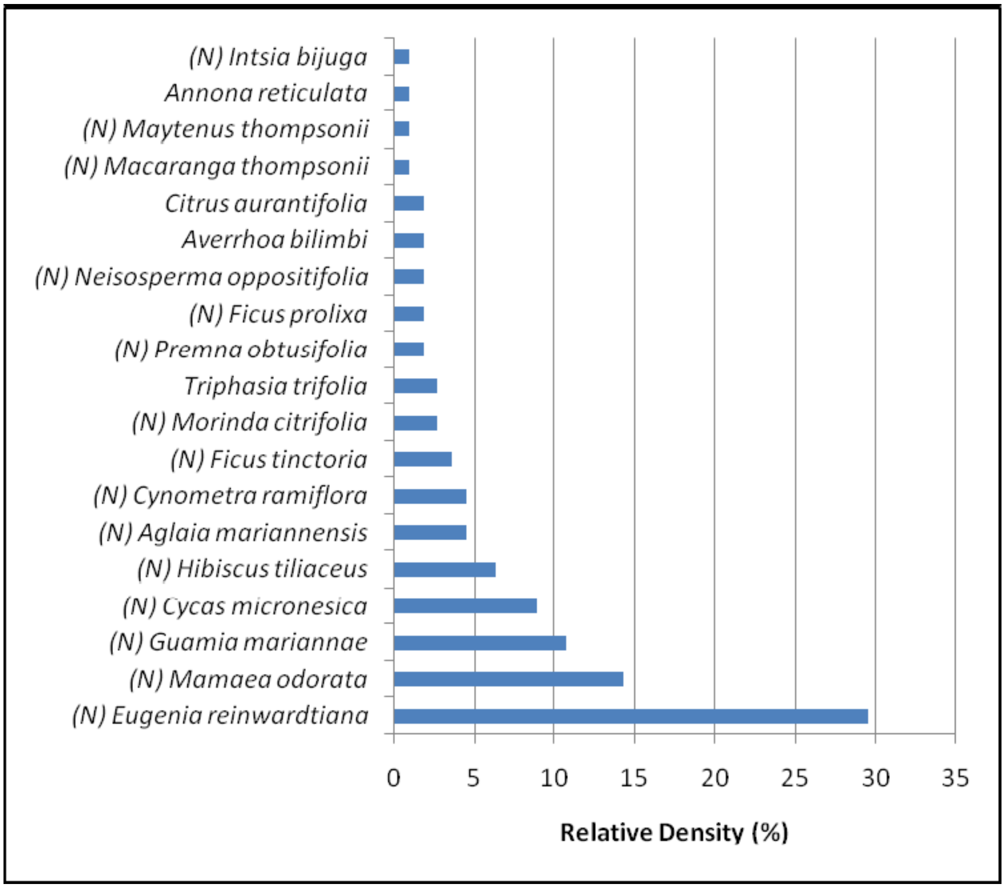
Transect 3, on the lower plateau, was closest to sea level of the three transects in the Route 15 Lands, but was further inland from the halophytic/xerophytic plant community along the coast. The absolute density was approximately 3,183 trees/ha (Chart 12-3). As in Transect 2, a'abang was a dominant component, with the highest absolute density (938 trees/ha).

12.2.1.2 Seedlings

The mean woody seedling density was calculated for the three transects at Route 15. Native seedlings exceeded mean density of 6 seedlings per m^2, compared with a mean density of approximately 1 seedling per m^2 for non-native species. Native seedlings outranked introduced seedlings in every transect, especially in Transect 1. The numbers of non-native seedlings were nearly equivalent to those of native seedlings along Transect 3, which can be attributed to the presence of naturalized introductions such as *Triphasia trifolia*, pickle tree (*Averrhoa bilimbi*), and custard apple (*Annona reticulata*), and some cultivated species, such as sweetsop (*Annona squamosa*) and citrus trees.

Chart 12-3

Relative Density of Trees Along Transect 3 – Route 15 Lands
(N = native)



12.2.1.3 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat at the Route 15 study area. These include ungulate activity, the presence of erosion, the percentage of native plant species, and overall species richness. Species richness curves for Transects 1 and 3 indicate higher richness for these areas than for Transect 2 in the GEDCA parcel south of Lot 7161-R1.

Leaf and vegetative litter had the highest frequency (8.7) among the four categories of ground cover quantified on the three transects. Live vegetation (3.9), rock (2.3), and soil (1.0) had significantly lower frequencies. Limestone rock outcrops were prevalent along all three transects as a natural feature of the terrain.

Ungulate activity along all three transects was highest in the form of soil disturbance (0.4), such as rooting or wallows. Rubbing and signs of browsing had similar frequencies, each approaching 0.2, while other signs, such as scat, were least observed, with a frequency of around 0.1.

12.2.2 Qualitative Survey

A general pedestrian survey was conducted by two biologists on the Route 15 Lands. The survey involved walking along informal transects to document the plant community and record any notable species. The central portion of the parcel is a flat open expanse with a network of jeep trails through a weed/grassland community. The grassland is dominated by foxtail (*Pennisetum polystachion*) about 1 m high interspersed with assorted herbs such as horseweed (*Conyza canadensis*), buttonmint (*Hyptis capitata*) and ferns (*Nephrolepis hirsutula*). Scattered shrubs, such as lada (*Morinda citrifolia*) and aplokating (*Psychotria mariana*), also dot the landscape. Prior to clearing, the vegetation in the area most likely resembled the remnant limestone forest communities in this eastern sector of the island.

The grassland abruptly transitions into a thick stand of native pago (*Hibiscus tiliaceus*) trees towards the eastern sector. Naturalized species, such as lantana (*Lantana camara*), lemon China (*Triphasia trifolia*), and tangantangan (*Leucaena leucocephala*), are common within the stand. The composition is indicative of a mixed-shrub community, a sub-type of Fosberg's (1960) weed community. Species typical of a limestone forest occur sporadically in the stand. These include fagot (*Neisosperma oppositifolia*) and fadang (*Cycas circinalis*). The invasive scarlet gourd vine (*Coccinia grandis*) drapes the pago branches, forming a tangled mass that obstructs passage. The understory, however, shows heavy disturbance by feral ungulates. Extensive rooting, rubbing, ripped and shredded tree trunks, and pig trails were observed. Further towards the eastern cliff line, the terrain becomes treacherous, as karst topography dominates the area. Limestone forest species also gradually dominate the composition of the plant community, which resembles the mixed moist forest described by Fosberg (1960). Succulent herbs, such as *Lapportea ruderalis*, and ground orchids, such as *Nervilia aragoana* and *Zeuxine fritzii*, are found on the limestone outcrops. The forest floor and outcrops are covered in a mossy layer. For more information regarding the qualitative survey, refer to Appendix D.

12.2.3 Threatened and Endangered Species and Species of Concern

12.2.3.1 Threatened and Endangered Species

A previous survey identified 22 ufa-halomtano (*Heritiera longipetiolata*) trees, with 184 associated seedlings (Duenas and Associates, Inc., 2000). This species is endemic to the Mariana Islands and is listed as endangered by the Government of Guam, which considers ungulate damage, typhoons, and infrequent flowering as major threats to the viability of the population (Department of Agriculture, 2006). Other threats appear to be present, since several of the trees in Lot 7161-R1 were infested with termites or ants, or were parasitized by other plants, such as strangling fig (*Ficus* spp.) (Duenas and Associates, Inc., 2000). Several trees were left intact within a designated conservation area at the Guam Raceway Park as a required condition of the Department of Agriculture. No Ufa-halomtano trees were observed on the transects; a single specimen was found near Transect 2 in the adjacent parcel. The tree was mostly dead, except for a 7-cm-diameter branch near the base. The main trunk had a dbh of 37 cm.

12.2.3.2 Species of Concern and Notable Species

The following species of concern were identified within the Route 15 Lands:

- *Cycas micronesica*, which is considered an SOGCN by the Government of Guam (Department of Agriculture, 2006). The island-wide populations are threatened by an introduced scale insect, *Aulocapsis yasumatsui*.

- *Elatostema calcareum* (Urticaceae) and *Procris pedunculata* (Urticaceae), which are indigenous succulent herbs that grow in limited habitats over limestone rock outcrops in moist limestone forest. These plants serve as host species for the Mariana Eight Spot butterfly (*Hypolimnas octocula*), which is listed as a species of concern by the USFWS. One butterfly was found along Transect 2 in the GEDCA parcel. Other species were noted, although they are not managed or protected by either the local or federal governments.

- *Zehneria* (*Melothria*) *guamensis* (Cucurbitaceae), which is a rare endemic vine. The species was found in one small area of Lot No. 7161-R1.

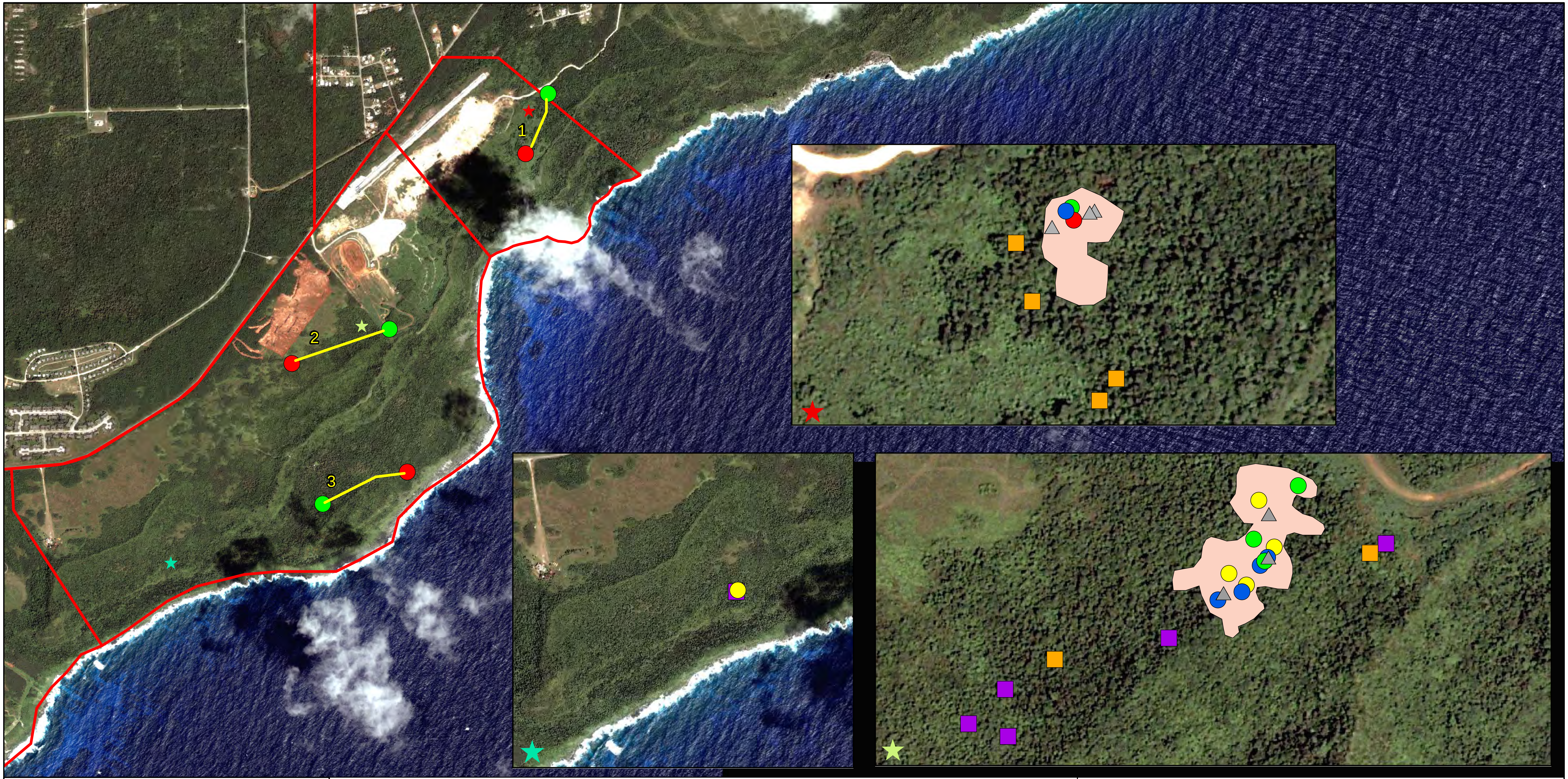
12.3 Butterfly Surveys

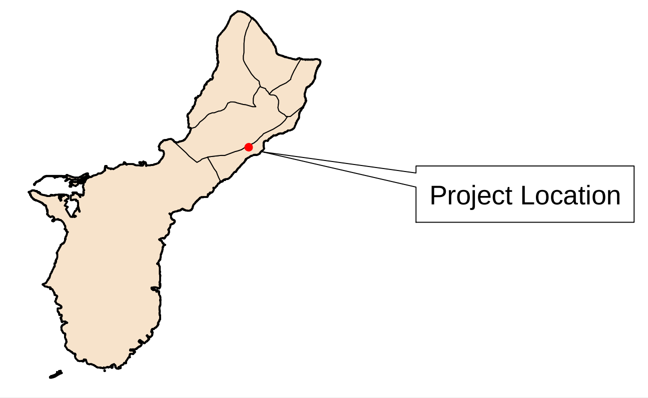
After the sighting of the Mariana Eight Spot butterfly on the Route 15 Lands during the vegetation surveys an in-depth survey was performed by two NAVFAC biologists. The survey report is provided in Appendix E.

The survey identified two areas that contained both host plants and Mariana Eight Spot butterflies on the Route 15 Lands and one location along the Pagat Trail (Figure 12-2). No butterflies of any species were observed in the bait pans. The survey results indicate that there is at least one population of the Mariana Eight Spot butterfly in the area. In addition, there are two areas that contain many of both host plant species, and which appear to be sustaining the butterfly population.

12.4 Avian Surveys

Forest bird surveys were conducted during the mornings. No avifauna were observed on the Route 15 Lands as part of the forest bird surveys. However, as part of the fruit bat survey, a survey was performed for endangered avian species, specifically the Mariana swiftlet. During the surveys, no endangered Mariana swiftlets were recorded. However, avian species that were identified in flight or vocalizing within habitat associated with the station count locations are shown in Table 12-2. No of the observed species are listed as threatened or endangered.





Beginning Transect Point
End Transect Point
Transect Lines
Installation Boundary

Egg
Butterfly
Chrysalis
Caterpillar
Bait_pans
Procris pedunculata
Elatostema calcareum
Mixed Host Plants

N

0 200 400
Meters

Route 15 Lands

Butterfly Survey Locations

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 12-2

Table 12-2

Avian Species Detected during Mariana Fruit Bat Station Count Surveys in the Lumuna/Asdonlucas/Pagat Region, 6 - 22 October 2009.

Avian Species	Status on Guam
Black francolin (*Francolinus francolinus*)	Introduced resident, breeding
Yellow bittern (*Ixobrychus sinensis*)	Native resident, breeding
Pacific reef heron (*Egretta sacra*)	Native resident, breeding
Pacific golden-plover (*Pluvialis fulva*)	Migratory or wintering species, non-breeding
White tern (*Gygis alba*)	Native resident, breeding
Island collared-dove (*Streptopelia bitorquata*)	Introduced resident, breeding
Note: Status and nomenclature follow Wiles, 2005.	

12.5 Fruit Bat Surveys

Surveys for the Mariana fruit bat, locally known as fanihi, (*Pteropus mariannus mariannus*) were carried out in October 2009 in the Lumuna/Asdonlucas/Pagat region (adjacent to Route 15). The fruit bat survey report is provided in Appendix I.

Throughout the 20th century, the fruit bat population on Guam steadily declined. Illegal hunting appears to be the key reason for the fruit bat's dramatic decline on Guam, while habitat destruction and predation by introduced brown treesnakes (*Boiga irregularis*) may also be contributing factors (Wiles et al., 1989, Wiles et al., 1995, Morton and Wiles, 2002, Brooke, 2008).

The Mariana fruit bat was reclassified as a federally threatened species by the USFWS in 2005. The Government of Guam included the fanihi in the GCWCS as an SOGCN (GDAWR, 2006).

12.5.1 Survey Locations

Three survey locations (count stations) were situated on the east side of Route 15 in the northeast region of Guam, stretching from the Lumuna region through the Asdonlucas area south to Pagat Point (Figure 12-1).

The three locations were as follows:

- **Location 1 -** This count station was situated along the cliff line overlooking a forested basin below and mixed forest above.

- **Location 2 -** Count Station 2 was located along the cliff line and provided an unobstructed view of a forested basin below, as well as mixed forest above.

- **Location 3** - Count Station 3 was situated along the cliff line and afforded a clear view of a forested basin below, and mixed forest and a cleared region above.

12.5.2 Results

Fruit Bat Observations

Between October 6 and October 22, 2009, 12 station count surveys were completed at three locations (Table 12-3). No Mariana fruit bats were observed during any of the surveys.

The survey method utilized during this project relies on observing fruit bats in low light and daytime conditions. Any fruit bats that were using the area prior to or after the survey period would not have been detected. No fruit bats were observed during the 12 station count surveys. However, the survey area is suitable for the Mariana fruit bat to roost and forage because it is situated away from dense human habitation and includes several known Mariana fruit bat roosting and food tree species. The survey area is also close (within about 12.1 km) to the last remaining colonial roost location of fruit bats known on Guam. Therefore, it is possibile that fruit bats use the area for roosting and/or foraging as well as flight paths.

Table 12-3

Mariana Fruit Bat Station Count Results in the Lumuna/Asdonlucas/Pagat Region

Survey Date	Survey Location	Start Time	Stop Time	Number of Bats Observed
October 6, 2009	1	0545 h	0745 h	0
October 6, 2009	2	0545 h	0745 h	0
October 13, 2009	2	0525 h	0740 h	0
October 13, 2009	3	0530 h	0740 h	0
October 14, 2009	3	0515 h	0745 h	0
October 14, 2009	1	0530 h	0740 h	0
October 20, 2009	2	0510 h	0740 h	0
October 20, 2009	1	0520 h	0740 h	0
October 21,2009	3	0510 h	0740 h	0
October 21, 2009	2	0520 h	0740 h	0
October 22, 2009	1	0520 h	0740 h	0
October 22, 2009	3	0520 h	0740 h	0

At the time of the survey, there was loud noise associated with construction and rock-blasting activities on the property adjacent to survey location 3. The associated noise and possibility of hunting may prevent Mariana fruit bats from establishing permanent roosts in the area.

It is worth recognizing that three native, breeding resident avian species and one migratory avian species were detected flying above habitat associated with the survey area.

12.6 Tree Snail Surveys

Tree Snail surveys were conducted on transects located on the Route 15 parcels. In their report Barry Smith and Richard Randall (2010) state that no endangered tree snails were observed at any transect surveyed. However, one dead ground shell of *Partula gibba* was found on Transect 2 and one on Transect 3. The tree snail survey report is provided in Appendix H.

12.7 Threatened and Endangered Species

No threatened or endangered avifauna, herpetofauna, or tree snail species were identified on the Route 15 parcels. Several Ufa-halomtano (*Heritiera longipetiolata*) trees were left intact within a designated conservation area at the Guam Raceway Park as a required condition of the Department of Agriculture. No Ufa-halomtano trees were observed on the transects; a single specimen was found near Transect 2 in the adjacent GEDCA parcel.

The Mariana Eight Spot butterfly (Photo 12-1) was sighted on the Route 15 parcel (Figure 12-2). As indicated in section 12.3, host plants for the butterfly do occur on the parcel.

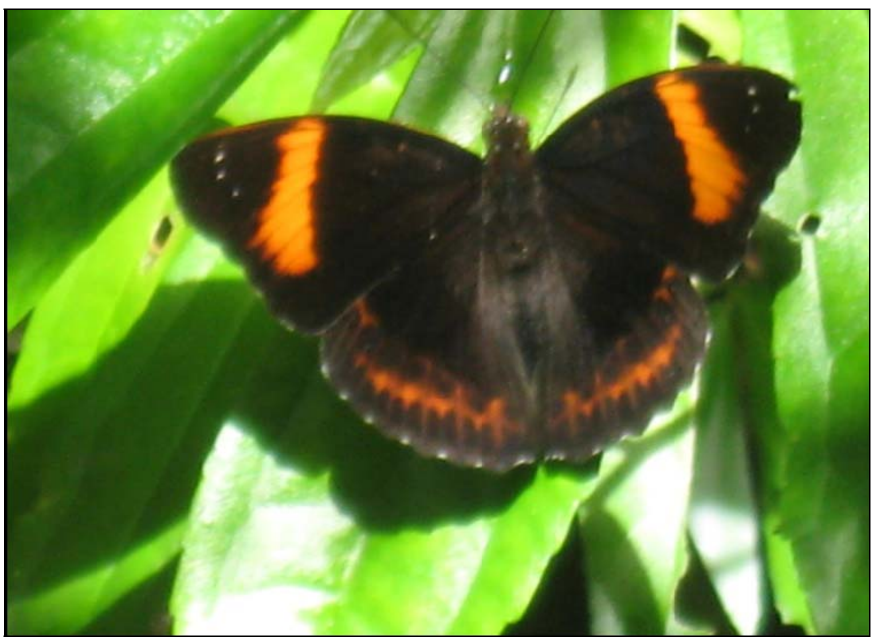


Photo 12-1 Mariana Eight-Spot Butterfly

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13 Former FAA Parcel

On the former FAA parcel, natural resource surveys performed included herpetofauna, vegetation, and avian surveys. Figure 13-1 shows the locations of the three natural resource survey transects.

FAA parcel transects were situated in a degraded forest of white lead tree (*Leucaena leucocephala*), *Coconut palm* (*Cocos nucifera*), and Sea hibiscus (*Hibiscus tiliaceus*).

13.1 Herpetofauna

Four herpetofauna species were captured or observed on the former FAA parcel. Table 13-1 identifies the species and their status. For more information on the herpetofauna survey and results, please refer to Appendix B.

Table 13-1

Herpetofauna Captured or Observed on the Former FAA Parcel

Guild	Species	Status
Skinks	Curious skink (*Carlia ailanpalai*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
Amphibians	Greenhouse frog (*Eleutherodactylus planirostris*)	Introduced
	Marine toad (*Rhinella marinus*)	Introduced

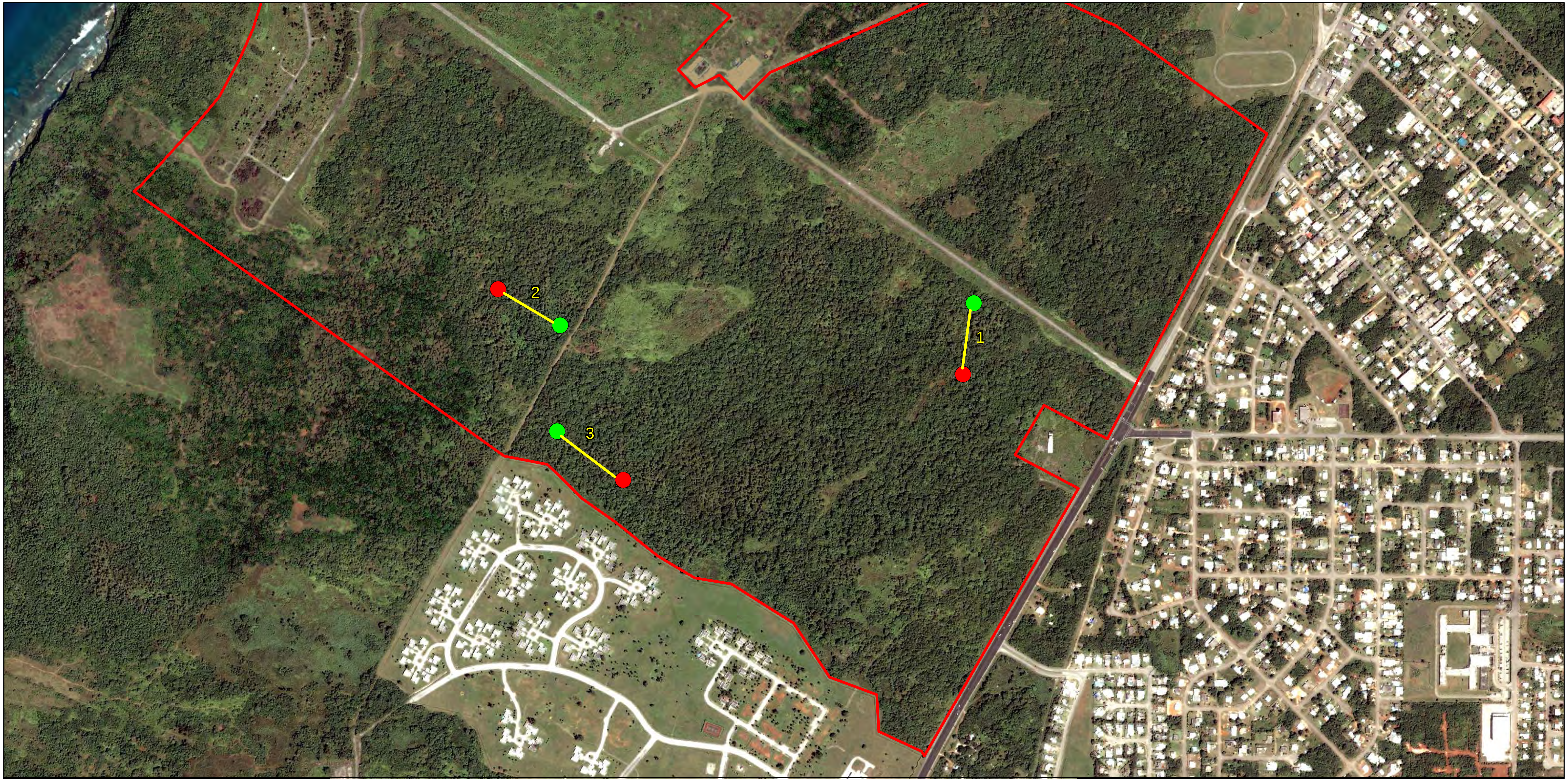
The continued widespread presence of the curious skink, as well as other introduced amphibian species, is of concern because of each species' potential deleterious impacts to Guam's native fauna (Rodda et al., 1999, Kraus et al., 1999, Wiles et al., 2003, Christy et al., 2007a). Of particular concern is the potential for these introduced species to serve as additional food sources for the brown treesnake (Fritts and Rodda, 1998, Christy et al., 2007a).

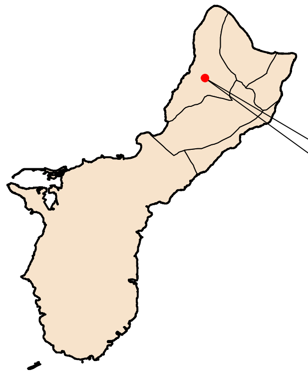
13.2 Vegetation

Quantitative surveys were performed using the point-center quarter method along three transects in the former FAA parcel. Transect 1 was located along a north-south axis in the eastern sector and Transects 2 and 3 were located along a northwest-southeast axis in the central-southern sector. The full vegetation survey report is provided in Appendix D.

13.2.1 Trees

Overall tree density among the three transects was lowest in the eastern sector (Transect 1), with 1,798 trees/ha and a total absolute cover of 25.85 m^2/ha. Pago (*Hibiscus tiliaceus*) was dominant, with the highest density (687.44 trees/ha) and absolute frequency (58.82), but this native species had a modest absolute cover of 2.03 m^2/ha. Pago occurred as a mid-canopy species and





Beginning Transect Point

End Transect Point

Transect Lines

Installation Boundary

0 200400 Feet

0 200 400 Meters

Former FAA Parcel

Transect Map

AECOM

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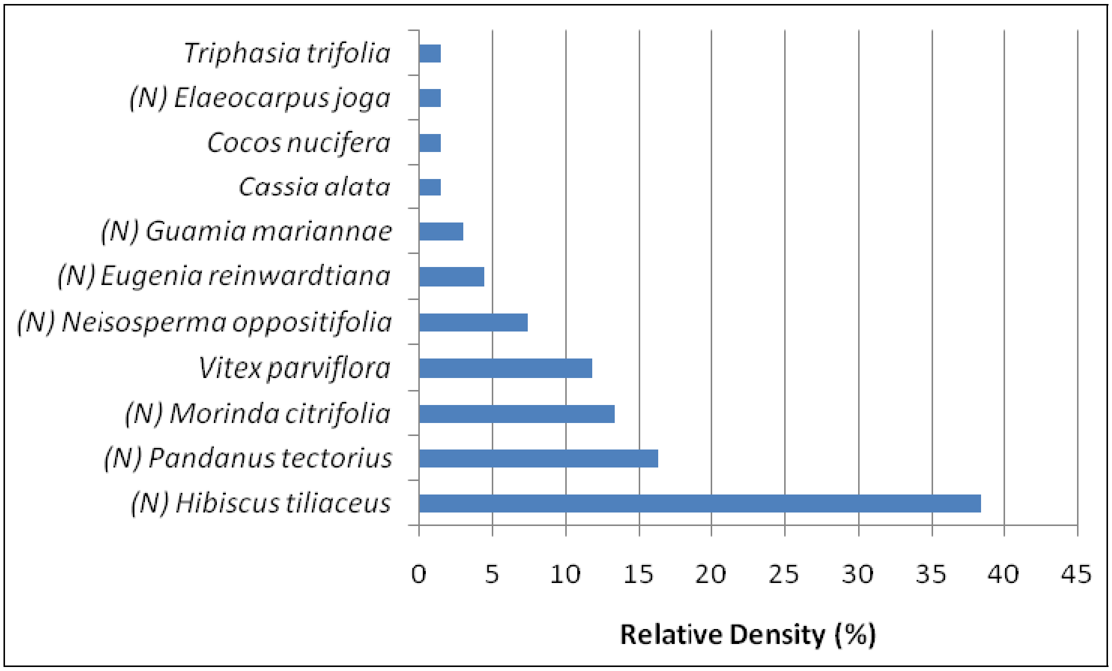
Bloomfield, NJ 07003
www.aecom.com

May 3, 2010 | Project No.: 60133557 | Figure 13-1

comprised approximately 38 percent of the relative density among the 11 tree species encountered on Transect 1 (Chart 13-1). Native species had a much higher relative density (approximately 84 percent) than introduced species (approximately 16 percent). Aside from pago, kafu (*Pandanus tectorius*), lada (*Morinda citrifolia*) and *Vitex parviflora* had relative densities greater than 10 percent. Kafu and lada are native mid-canopy species; non-native *Vitex* occupied the upper canopy. Yoga (*Eleocarpus joga*), a native emergent canopy species, had the highest total basal area (4,126 sq cm) and absolute cover (10.91 m^2/ha), although only one specimen was encountered. *Eleocarpus* was not encountered along the other transects.

Chart 13-1

Relative Density of Trees Along Transect 1 – FAA Parcel
(N = native)

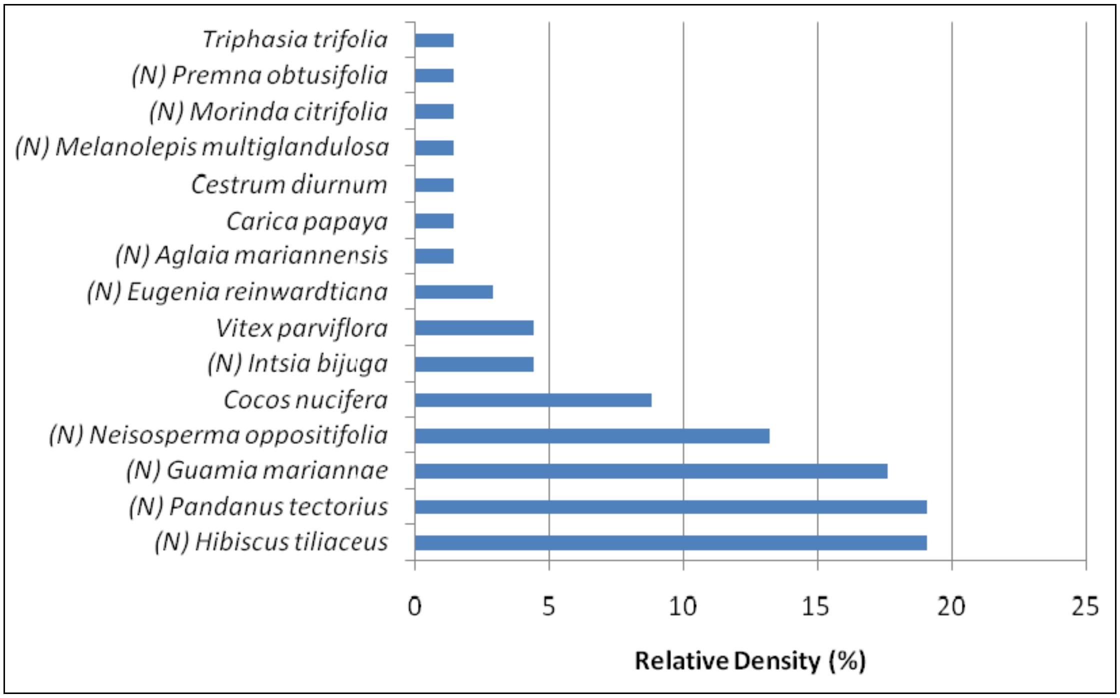


Transect 2 in the central-southern sector had the highest density among the transects, with 2,856.98 trees/ha and a total absolute cover of 24.86 m^2/ha. Both pago and kafu prevailed over other species with densities of 546.19 trees/ha and absolute frequencies of 47.06. These species, and paipai (*Guamia mariannae*) and fagot (*Neisosperma oppositifolia*), had relative densities exceeding 10 percent (Chart 13-2). Overall, native species had a higher relative density (about 82 percent) than introduced species (about 18 percent), which was similar to the proportion observed in the eastern sector along Transect 1. Two species, paipai and mapunao (*Aglaia mariannensis*), are endemic to the Mariana Islands.

Coconut (*Cocos nucifera*) was dominant overall in absolute cover (12.75 m^2/ha), followed by kafu, fagot and ifil (*Intsia bijuga*). *Vitex parviflora* was less dominant than in Transect 1 in density (126 trees/ha) and absolute cover (0.93 m^2/ha). The mean basal area of *Vitex parviflora* (73.91cm^2) was also the lowest observed among the transects.

Chart 13-2

Relative Density of Trees Along Transect 2 – FAA Parcel
(N = native)



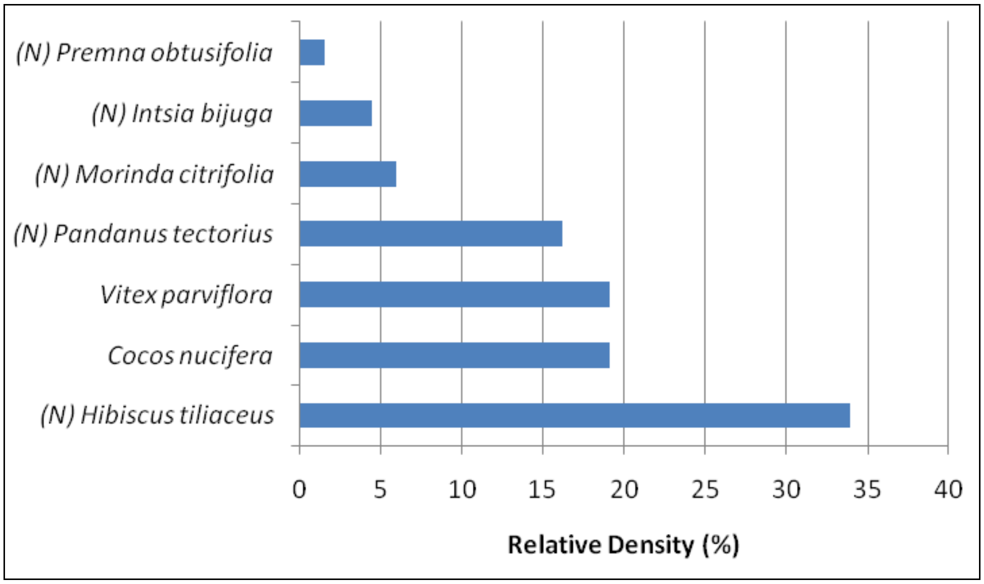
Transect 3 had an overall tree density of 1,868.79 trees/ha and a total absolute cover of 41.24 m^2/ha. The overall absolute cover was the highest among the three transects. Pago was consistently dominant among the transects, with the highest individual density (632.09 trees/ha) on Transect 3, and a relative density of about 33 percent (Chart 13-3). Pago also had the highest frequency among the seven species on Transect 3. Collectively, native species had a relative density of about 62 percent, which was the lowest proportion of native species among the three transects. Coconut comprised the bulk of absolute cover (20.52 m^2/ha) on Transect 3; both density (357 trees/ha) and absolute cover were higher than in Transect 2. *Vitex parviflora* had the next- highest absolute cover, and was as equally well-distributed along the transect as coconut, with an absolute frequency of 41.18.

13.2.2 Seedlings

The mean woody seedling density was significantly higher for native species (2.7 seedlings/m^2) than for non-native species (0.3 seedlings/m^2). The proportion of native to introduced seedlings was similar for Transects 1 and 2, and slightly lower for Transect 3. The seedling density reflects the higher native component observed in the relative tree densities along the transects.

Chart 13-3

Relative Density of Trees Along Transect 3– FAA Parcel
(N = native)



13.2.3 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat in the former FAA parcel. These include ungulate activity, the presence of erosion, the percentage of native plant species, and overall species richness. Species richness curves indicate that the highest tree species richness among the transects was along Transect 2, while Transect 3 had the lowest richness.

Leaf and vegetative litter comprised the highest mean frequency (5.6) among the four ground cover categories in the survey. Live vegetation had a similar frequency (5.0), while the limestone substrate and rocky terrain were reflected in the moderate frequency for rock (3.8). The lowest mean frequency was for bare soil (1.6).

Ungulate activity was encountered most frequently as soil disturbance, such as pig wallows and rooting. The mean frequency for soil disturbance appeared to be significantly higher than for rubbing and browsing on vegetation. Other signs of ungulate activity, such as scat, were not observed on the transects.

13.3 Avian Surveys

On the former FAA parcel, the forest bird survey was conducted in the mornings Table 13-2 identifies the species observed as part of the surveys. The nomenclature follows Gill et al. 2008. For more information on the avifauna survey and results, refer to Appendix G.

Table 13-2

Species Identified during the Forest Bird Survey – Former FAA Parcel

Survey Type	Number of Stations	Species and Number of Detections	Number of Species	Total Number of Detections
Forest Bird	6	Island Collared Dove*	1	7
Notes: * the Island Collard Dove's resident status is identified as "Common introduced resident – breeding" Residence status obtained from Reichel, J. D. and P. O. Glass, 1991, Checklist of the birds of the Mariana Islands. '*Elepaio*, 51(1): 3-10.				

13.4 Tree Snail Surveys

Tree snail surveys were conducted along transects on the former FAA site. In their report Barry Smith and Richard Randall (2010) state that no endangered tree snails were observed at any transect. The tree snail survey report is provided in Appendix H.

13.5 Threatened and Endangered Species

No threatened or endangered avifauna, fruit bat, herpetofauna, tree snail, or vegetation species were identified on the former FAA Parcel.

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APPENDIX A

A SPECIES DESCRIPTIONS

During the course of the natural resources surveys on Guam, numerous species were observed. The text below provides descriptions of avifauna, butterfly, and herpetofauna species.

A1 Herpetofauna

A variety of herpetofauna were captured or observed during the herpetofauna surveys. Descriptions of each species are provided below. The species are listed in alphabetical order by scientific names; when available, the local Chamorro name is also provided.

A.1.1 Skinks

Curious skink, *Carlia fusca,* (Chamorro name: guali'ek halom tano') – The curious skink was initially introduced to Saipan in the 1960s, and then to Guam around 1968 (Rodda and Dean-Bradley, 2006). It is a brown terrestrial lizard, common and ubiquitous in all habitats on Guam (Vogt and Williams, 2004). Curious skinks grow to 70 mm in body length and lack a fifth toe on the front feet (USGS, 2005a; Zug 2004). This species feeds on insects and small lizards (Vogt and Williams, 2004) and is prey for the *Boiga irregularis* on Guam (Fritts and Rodda, 1998).

Pacific blue-tailed skink, *Emoia caeruleocauda* (Chamorro Name: guali'ek halom tano') – The Pacific blue-tailed skink is indigenous to the Mariana Islands, and on Guam can be found in all habitats (Vogt and Williams, 2004). It is mostly observed on the ground, but will climb shrubs and trees (Wiles et al., 1990). Juveniles have three stripes on their back and a bright blue tail, but as they grow the tail fades to brown (Wiles et al., 1990). Adult males tend to lose their stripes, but females will often retain theirs (Wiles et al., 1990). Pacific blue-tailed skinks are insectivorous and grow to 55 mm snout to vent (Vogt and Williams, 2004).

Moth skink, *Lipinia noctua* (Chamorro name: guali'ek halom tano') – Moth skinks are widespread across the western Pacific, although Guam is the only Mariana Island on which the species occurs. Two individuals were observed on Rota, but species status on the island is unknown (Rodda et al., 1991). Moth skinks are not common but can still be found in native forests in central Guam. As of the early 1990s, the species was known from Hilaan Point, Haputo Beach, and Acae Point along Guam's northwest coast (GDAWR, 2006). Moth skinks are one of the only diurnal, primarily arboreal species in the region (Rodda et al., 1991). The moth skink is a Guam-listed endangered species.

A1.2 Geckos

Mutilating gecko, *Gehyra mutilata* (Chamorro name: guali'ek) – The mutilating gecko is an insectivorous, tan/gray gecko with dark spots and thin skin that is easily sloughed or damaged (Vogt and Williams, 2004;, USGS, 2005a). The 64-mm-long mutilating gecko can be found in most natural habitats on Guam, in addition to the sides of houses and other structures (USGS, 2005a). It is also found on most islands in the Mariana archipelago (Vogt and Williams, 2004). There is uncertainty whether the mutilating gecko is native to Guam (e.g., USGS, 2005a and Vogt and Williams, 2004); for the purpose of this report, *Gehyra mutilata* is assumed to be native.

House gecko, *Hemidactylus frenatus* (Chamorro name: guali'ek) – The house gecko is very common on Guam in urban (Wiles et al., 1990) and natural habitats (Rodda and Dean-Bradley, 2006). This brown stripy gecko has a characteristic spiked tail and can grow to 60 mm body length (Vogt and Williams, 2004). House geckos feed primarily on insects, and are found on most islands in the Mariana archipelago (Vogt and Williams, 2004).

Mourning gecko, *Lepidodactylus lugubrus*, (Chamorro name: guali'ek) – The mourning gecko is a small insectivorous gecko found throughout Guam and most of the Mariana Islands (Vogt and Williams, 2004). It is observed in all habitats and quite often on houses (Wiles et al., 1990). The mourning gecko is light gray or tan with dorsal chevron banding (Vogt and Williams, 2004). The species is relatively small, attaining an average body length of 50 mm (Vogt and Williams, 2004). At night, these geckos can regularly be heard chirping to one another. Apart from *Nactus pelagicus*, *L. lugubrus* is the only other native reptile in the Mariana that is parthenogenic (USGS, 2005a).

Pacific Slender-toed Gecko, *Nactus pelagicus* (Chamorro name: guali'ek) - Unlike other geckos on Guam, Pacific slender-toed geckos are primarily ground-dwelling, and are mainly observed in rocky areas (Wiles et al., 1990). Captures of the Pacific slender-toed gecko have been rare since 1945. The decline of this species is possibly a result of the introduction of the brown treesnake (*Boiga irregularis*) and the musk shrew (*Suncus murinus*) (USGS, 2005a). The species is listed as endangered on Guam. Recent sightings have occurred in restricted areas in the northern limestone forests of Guam (Rodda, unpublished data). Rota and Tinian are known to support Pacific slender-toed geckos (USGS, 2005a).

A1.3 Snakes

Brown Tree Snake, *Boiga irregularis* (Chamorro name: kolepbla) – The brown treesnake can reach 3 m long, but on Guam averages around 1 m (Rodda et al., 1999). This snake inhabits all ecosystems; smaller snakes are usually observed in trees, larger ones on the ground (Rodda et al., 1999). The brown treesnake was introduced to Guam in the late 1940s, possibly on military cargo (Savidge, 1987). These snakes are directly responsible for the extirpation of numerous species of birds, and for the diminishing numbers of native lizards on the island (Savidge, 1987; Wiles et al., 2003). They feed on birds, small mammals, and lizards (Savidge, 1987). Brown treesnakes are native to northern Australia, Indonesia, the Solomon Islands, and New Guinea (Rodda et al., 1999).

Blind snake, *Ramphotyphlops braminus* – The blind snake reaches only 15 mm in length, is black in color, and often is confused with earthworms (Vogt and Williams, 2004). Blind snakes are parthenogenic (Vogt and Williams, 2004) and burrow in the dirt (fossorial), feeding on termites and ants (USGS, 2005b).

A1.4 Monitor Lizard

Monitor Lizard, *Varanus indicus* (Chamorro name: hilitai) – The presence of the monitor lizard in forested habitat on Guam is common, although it is possible that its abundance has declined in the last two decades. This decline may be a combined result of the introduction of the brown treesnake, which is capable of eating eggs and small juveniles, and of the poisonous marine toad, *Bufo marianus* (*Rhinella marianus*) (USGS, 2005). The monitor lizard is also found in numerous other locations, including Palau, New Guinea, the Caroline Islands, the Marshall Islands, the Solomon Islands, northern Australia, and throughout the Mariana Islands (Vogt and Williams, 2004).

A1.5 Frogs and Toads

Greenhouse frog, *Eleutherodactylus planirostris* – This species is nocturnal, but will readily move during rainy weather (Krauss et al., 1999).

Crab-eating frog, *Fejervarya cancrivora* – This species was accidentally introduced to Guam via an aquaculture shipment from the Philippines in 2002 (Christy et al., 2007b).

Eastern dwarf tree frog, *Litoria fallax* – A species native to Australia, it was introduced to Guam in 1968 (Christy et al., 2007a).

Hong Kong whipping frog, *Polypedates megacephalus* – This is an introduced species.

Marine toad, *Bufo marianus* (*Rhinella marinus*) – This species of toad has inhabited the island for the longest period of time, and is the only amphibian on Guam to be poisonous to animals that try to consume it (Vogt and Williams, 2004).

Gunther's Amoy frog, *Sylvirana guentheri* –This species was also introduced via the aquaculture trade from China, possibly as early as 2001 (Christy et al., 2007b).

A2 Tree Snails

A variety of tree snails were captured or observed during the surveys. Descriptions of each species are provided below. The species are listed in alphabetical order by scientific names.

Fat Guam Partula tree snail/Mariana Islands tree snail, *Partula gibba* - This species has a dark-colored body. The shell is light to dark brown. The shell's whorls darken between the apex and suture. The Mariana Islands tree snail is endemic species to Guam and the northern Mariana Islands. Currently, the status of this tree snail population is unknown. The Mariana tree snail prefers cool, shaded forest habitats with high humidity. This species occupies tree branches.

Guam or Pacific tree snail, *Partula radiolata.* - The Pacific tree snail has a tan to cream colored body and a shell with light and dark stripes. The snail is endemic to Guam. Currently, the population's status is unknown though it was found in the Mount Santa Rosa and Fadian Point. The Pacific tree snail prefers cool shaded forested areas with high humidity.

Mt. Alifan tree snail, *Partula salifana* – This species was first found on Guam in the 1920s in the west-central highlands region of the island.

Fragile tree snail, *Samoana fragilis* - This species was first discovered in 1820 and was considered uncommon. Currently, the fragile tree snail population remains uncommon. The species prefers cool shaded forest habitats with high humidity.

A3 Avifauna

A variety of avifauna were observed during the surveys. Descriptions of each species are provided below. The species are listed in alphabetical order by scientific names; when available, the local Chamorro name is also provided.

Micronesian starling, *Aplonis opaca* – (Chamorro name: sali), live in groups and nest in cavities. These black birds eat fruits, seeds and insects. Sali used to be found throughout Guam but predation by the kulepbla (brown treesnake) has restricted them primarily to Cocos Island, Andersen Air Force Base, parts of Agana, and certain coastal areas in the south (GDAWR, 2010).

Common Pigeon, *Columba livia* – sometimes referred to as Rock Dove, are common species to Guam and other continents.

Black Drongo, *Dicrurus macrocercus* – a native to Taiwan, this species was first introduced to Rota (CNMI) by the Japanese South Seas Development Company in 1935 in order to control destructive insects (Baker 1951). Since Rota lies approximately 50 km north of Guam, it is believed that the drongo either flew on its own accord or possibly was purposely introduced to Guam as the species first appeared in Northern Guam in the early 1960s (Engbring and Ramsey, 1984).

Black francolin, *Francolinus francolinus* - This species is a common introduced resident that has an established breeding population. A native to Southern Asia, this species was introduced as a game bird to Guam in 1961 (USFWS, 1984).

Grey-tailed tattler, *Heteroscelus brevipes* – The Grey-tailed Tattler is a medium-sized wader, with long wings and tail. Grey-tailed Tattlers breed in Siberia and on passage are seen along the East Asian-Australasian Flyway (the migration route to Australia). When non-breeding they are found in China, Philippines, Taiwan, Vietnam, Malay Peninsula, Indonesia, New Guinea, Micronesia, Fiji, New Zealand and Australia.

Whimbrel, *Numenius phaeopus* – Whimbrels are large shorebirds with long, curved bills. They are smaller in size than the similar-looking Long-billed Curlew, and their bills are shorter. Whimbrels nest in the tundra, not far from the tree line, in a variety of open habitats from wet lowlands to dry uplands. During migration, they use wetlands, dry, short grasslands, farmland (especially plowed fields), and rocky shores.

Eurasian tree sparrow, *Passer montanus* – an Old World native, was introduced to Guam from 1945-1960 and is commonly found in the urban areas (Engbring and Ramsey, 1984).

Pacific Golden Plover, *Pluvalis fulva* – This species is a common non-breeding visitor to Guam. The Pacific Golden Plover breeds on the Arctic tundra in western Alaska. It winters in South America and islands of the Pacific Ocean to India, Indonesia and Australia. In Australia it is widespread along the coastline. The species is found on muddy, rocky and sandy wetlands, shores, paddocks, saltmarsh, coastal golf courses, estuaries and lagoons (Birds in Backyards, 2010).

Island Collared Dove, *Streptopelia bitorquata* – a common introduced resident that has an established breeding population. A native to the Philippines, Borneo and surrounding islands, this species was believed to have been introduced by the Spanish perhaps as long as 200 years ago. (Engbring and Ramsey, 1984).

A4 Butterflies

A list of the species and a brief description of each species is provided below. The descriptions of the species are based on Schreiner and Nafus (1997). The species are listed in alphabetical order by scientific names.

Lemon migrant, *Catopsilia Pomona* – The species is found in the Mariana and Palau islands. The larvae feed on various species of the Shower tree, *Cassia* sp. The species is often found in moist open areas and engages in migratory flights.

Monarch, *Danaus plexippus* – This species' range includes the Americas, Australia and numerous Pacific Islands, including the Mariana Islands. In Micronesia, the species feeds on Milkweed, *Asclepias curassavica* and Crown flower (*Caltropis gigantean*). The species is a known migrant, capable of flying thousands of miles.

Blue-banded King Crow, *Euploea Eunice* – This species' range extends from India to Micronesia. The larvae feed on Ficus, *Ficus* sp., edible figs, and oleander. They are often sighted hanging on aerial roots of fig trees, other vegetation, or structures.

Blue Moon, *Hypolimnas bolina* – This species ranges from Madagascar to New Zealand, and is considered the most widely distributed butterfly in the world. The species is recorded as taking migratory flights from Australia to New Zealand.

Common Evening brown, *Melanitis leda* – In the Pacific, the evening brown butterfly occurs within the Mariana Islands and Caroline Island Chains. On Guam, the species has been found on corn, Guinea grass, and Napier grasses. The larvae also feed on grasses.

Common Mormon, *Paplio polytes* – This species is found throughout southeast Asia, the Philippines, Palau, Yap, and the Mariana Islands, although it is thought to be a recent arrival in the Mariana. Common Mormons are attracted to salt and frequently observed near puddles. They are also attracted to citrus trees found within the flowering plant tree family, Rutaceae.

APPENDIX B
Herpetological Surveys

Herpetological Surveys on Department of Defense Lands, Guam, In Support Of A Marine Corps Relocation Initiative To Various Locations On Guam. SWCA Environmental Consultants. June 21, 2010**.**

2010

HERPETOLOGICAL SURVEYS ON DEPARTMENT OF DEFENSE LANDS, GUAM, IN SUPPORT OF A MARINE CORPS RELOCATION INITIATIVE TO VARIOUS LOCATIONS ON GUAM

Photo credit: I. Chellman

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1.0 INTRODUCTION

Herpetological surveys were carried out as part of an extensive effort to locate, identify, and assess the distribution and abundance of Guam's herpetofauna on Department of Defense (DoD) and private lands. Survey methods were designed to target important or rare reptiles, excluding sea or turtles. Although survey methods did not target non-native reptiles or amphibians, their presence was recorded when observed. This report provides data on the presence of herpetofauna in various habitats throughout the survey locations.

1.1 Species Description, Distribution, and Status

The 23 known terrestrial herpetofauna (excluding turtles) on Guam can be divided into three main groups: lizards (including skinks, geckos, and monitor lizards), snakes, and amphibians (Table 1).

Skinks are small, smooth-skinned lizards with scales. Most are diurnal (active during the day), but can be observed at night when disturbed. Although these quick-moving species are often observed on the ground, they can climb trees if necessary. Some species lay eggs (ovipary) while others give birth to live young (vivipary).

Geckos are lizards with specialized toe pads, which enable them to climb almost any surface type. They are normally nocturnal (active at night), and can be heard eliciting chirping noises to one another.

Monitor lizards are larger-bodied than most skinks and geckos with powerful and well-developed limbs.

Amphibians are smooth-skinned vertebrates that include frogs, toads, salamanders, and caecilians. They typically undergo an aquatic and terrestrial stage during their life cycle. All amphibian species on Guam are non-native.

Native terrestrial herpetofauna on Guam were historically composed of skinks and geckos. Due to the island's isolated location, its native vertebrate fauna were limited to those that can either fly, such as birds and bats, or those capable of surviving long ocean journeys on floating vegetation. On Guam, native and endemic species are those that established prior to human settlement or without human assistance. Of the 11 native reptile species, only six are known to be currently present on Guam. The Pacific blue-tailed skink (*Emoia caeruleocauda*) and the mourning gecko (*Lepidodactylus lugubris*) are common. Mutilating gecko *(Gehyra mutilata)* is uncommon in many areas but locally common in others. The moth skink (*Lipinia noctua*), tide-pool skink (*Emoia atrocostata*), and Pacific slender-toed gecko (*Nactus pelagicus*) are rare and currently known only from restricted localities.

Table 1: Terrestrial reptile and amphibian species (excluding turtles) known to occur on Guam. "Status" denotes general distribution and abundance of each species. "Listing" refers to whether or not the species is locally listed, the level of listing, or whether it is non-native. The Guam Comprehensive Wildlife Conservation Strategy (GCWCS) identifies Species of Greatest Conservation Need (SOGCN) and Endangered as species of highest conservation value (GDAWR 2006). Species considered extinct are not included as SOGCN. Except for sea turtles, there are currently no reptile or amphibian species listed as federally endangered or threatened on Guam.

Common Name	Scientific Name	Chamorro Name	Status	Listing
Guam Listed Species				
Snake-eyed skink	*Cryptoblepharis poecilopleurus*	Guali'ek Halom Tano'	Unknown	SOGCN, Endangered
Azure-tailed skink	*Emoia cyanura*	Guali'ek Halom Tano'	Unknown	SOGCN, Endangered
Slevin's skink	*Emoia slevini*	Guali'ek Halom Tano'	Unknown	SOGCN, Endangered
Moth skink	*Lipinia noctua*	Guali'ek Halom Tano'	Locally restricted	SOGCN, Endangered
Micronesian gecko	*Perochirus ateles*	Guali'ek	Unknown	SOGCN, Endangered
Tide-pool skink	*Emoia atrocostata*	Guali'ek Kantun Tasi	Rare	Endangered
Oceanic gecko	*Gehyra oceanica*	Achiak	Unknown	Endangered
Pacific slender-toed gecko	*Nactus pelagicus*	Guali'ek	Locally restricted	Endangered
Native				
Pacific blue-tailed skink	*Emoia caeruleocauda*	Guali'ek Halom Tano'	Common	Not listed
Mutilating gecko	*Gehyra mutilata*	Guali'ek	Locally Common	Not listed
Mourning gecko	*Lepidodactylus lugubris*	Guali'ek	Common	Not listed
Non-native				
Brown treesnake	*Boiga irregularis*	Kolepbla	Common	Recent Introduction
Brahminy blind snake	*Ramphotyphlops braminus*	Ulo' Attilong	Common	Prehistoric Introduction
Monitor lizard	*Varanus indicus*	Hilitai	Locally abundant	Prehistoric Introduction
Curious skink	*Carlia ailanpalai*	Guali'ek Halom Tano'	Common	Recent Introduction
House gecko	*Hemidactylus frenatus*	Guali'ek	Common	Recent Introduction
Green anole	*Anolis carolinensis*	Guali'ek	Locally common	Recent Introduction
Marine toad	*Rhinella*(formally *Bufo*) *marinus*		Common	Recent Introduction
Greenhouse frog	*Eleutherodactylus planirostris*		Locally common	Recent Introduction
Crab-eating frog	*Fejervarya cancrivora*		Locally common	Recent Introduction
Eastern dwarf tree frog	*Litoria fallax*		Locally common	Recent Introduction
Gunther's Amoy frog	*Sylvirana guentheri*		Locally common	Recent Introduction
Hong Kong whipping frog	*Polypedates megacephalus*		Locally common	Recent Introduction

1.1.1 Federally Listed Species

Except for sea turtles, there are currently no reptile or amphibian species listed as federally endangered or threatened on Guam.

1.1.2 Guam Listed Species

Eight species of lizard are listed as Guam endangered species, either because they are rare with reduced populations, or have been potentially extirpated (USGS 2005). Of these, five are identified in the Guam Comprehensive Wildlife Conservation Strategy (GCWCS) as Species of Greatest Conservation Need (SOGCN). Species considered extinct are not included as SOGCN.

1.1.2.1 Snake-eyed Skink

Scientific name: *Cryptoblepharis poecilopleurus*
Chamorro name: Guali'ek Halom Tano'
Status: Unknown
Guam listing: SOGCN, Endangered

The snake-eyed skink (also known as oceanic snake-eyed skink) has a body length of approximately 1.7 in (45 mm) and is usually found in coastal areas on rocks and shrubs (Vogt and Williams 2004). The eyelids are clear and fused, giving the appearance of being constantly open (USGS 2005). Overall coloration is tan to dark brown with light-colored spots on the sides (Vogt and Williams 2004). Three golden stripes on the back fuse to form two stripes on the tail, the middle stripe is of a more intense copper color than the bronze dorsolateral stripes (USGS 2005).

The last recorded snake-eyed skink on Guam was in 1969 (USGS 2005). However, four specimens were found on the small off-shore islet of Fofos (near Merizo) in the mid 1990s (Perry et al. 1998). This find may suggest a continued presence on Guam. The status of the snake-eyed skink on Guam is unknown but the species is still known to occur on Cocos, Saipan, Tinian, Rota, and most of the smaller northern Mariana Islands (USGS 2005).

1.1.2.2 Azure-tailed Skink

Scientific name: *Emoia cyanura*
Chamorro name: Guali'ek Halom Tano'
Status: Unknown
Guam listing: SOGCN, Endangered

The azure-tailed skink is endemic to Guam. The identification of this species can easily be confused with the Pacific blue-tailed skink (*Emoia caeruleocauda*). However, where they exist together, azure-tailed skinks are found on the forest edge and Pacific blue-tailed skinks are found in the forest interior (USGS 2005). The species reportedly specializes in hot, dry, open areas, particularly near the coast (McCoy 1980).

Historically, azure-tailed skinks occurred in southern Guam around the Geus River. Currently, the skink is thought to still occur on Cocos, but its status remains unknown (GDAWR 2006).

1.1.2.3 Slevin's Skink
Scientific name: *Emoia slevini*
Chamorro name: Guali'ek Halom Tano'
Status: Unknown
Guam listing: SOGCN, Endangered

The Slevin's (or Mariana) skink can reach up to 3 in (75 mm) in body length. It is usually brown or tan in color with white dorsal markings. The posterior two-thirds of the body can be bright orange (USGS 2005). Slevin's skinks are generally found on forest floors, tree trunks, and in old fields.

Slevin's skink was historically found throughout the island. However, it has not been observed on Guam since 1945. The species was known to occur on Cocos until the early 1990s; no recent sightings have been recorded in recent years. Populations of this species can still be found on the island of Sarigan, Guguan, Alamagan, Pagan, and Asuncion (GDAWR 2006).

1.1.2.4 Moth Skink
Scientific name: *Lipinia noctua*
Chamorro name: Guali'ek Halom Tano'
Status: Locally restricted
Guam listing: SOGCN, Endangered

Moth skinks reach around 2.1 in (55 mm) in body length and are usually brown to tan with a characteristic yellow spot on the head. This spot may be contiguous with a light-colored stripe on the dorsal surface and light spots on the flanks. The lips are marked with black and white bands and the belly is orange to yellow. Moth skinks are often found in low limbs and tree trunks. To escape predators, the skink is capable of breaking off its toes and tail (USGS 2005). The species is viviparous, which is not known in any other lizard species found in the Marianas (Vogt and Williams 2004). Moth skinks are one of the only diurnal, primarily arboreal species in the region (Rodda et al. 1991).

Although moth skinks are widespread across the western Pacific, Guam is the only island in the Marianas on which the species occurs. Two individuals were observed on Rota but species status on the island is unknown (Rodda et al. 1991). Moth skinks are not common but can still be found in native forests in central Guam. As of the early 1990s, the species was known from Hilaan Point, Haputo Beach, and Acae Point along Guam's northwest coast (GDAWR 2006).

1.1.2.5 Micronesian Gecko
Scientific name: *Perochirus ateles*
Chamorro name: Guali'ek
Status: Unknown
Guam listing: SOGCN, Endangered

The Micronesian gecko is large, reaching an average body length of 3.5 in (90 mm). Body coloration is usually brown to green with small black spots on the ventral surface. Defining physical attributes include a flattened, spiny tail and a reduced fifth toe (Vogt and Williams 2004). Similar to the oceanic gecko, the Micronesian gecko is closely associated with undisturbed habitat, primarily native limestone forest. However, a number of geckos have been found in untended coconut groves (Sabath 1981).

In 1969, the Micronesian gecko was considered common on Guam. However, the last specimen was collected in 1978. The current status is unknown. Other than Guam, the Micronesian gecko has been reported from Cocos, Tinian, Rota, and Saipan, where its status is also unknown (Rodda 2003).

1.1.2.6 Tide-pool Skink
Scientific name: *Emoia atrocostata*
Chamorro name: Guali'ek Kantun Tasi
Status: Rare
Guam listing: Endangered

Indigenous to the Mariana Islands, the tide-pool skink (also known as littoral skink) is found in coastal areas on rocks and shrubs, but is rarely seen. It has a mix of black and tan coloring, and grows to 3.3 in (85 mm) in body length. The species is tolerant of salt water and will use the ocean to move around and escape predators (Vogt and Williams 2004).

There have been reported sightings of tide-pool skinks on Guam in the vicinity of Inarajan Pools as recently as 2007 (Reed et al. 2007). A survey of the islets surrounding Guam conducted in the mid 1990s detected nine specimens on Agrigan Islet near Merizo, and Anae Islet near Agat (Perry et al. 1998).

1.1.2.7 Oceanic Gecko
Scientific name: *Gehyra oceanica*
Chamorro name: Achiak
Status: Unknown
Guam listing: Endangered

The oceanic gecko has light coloring, usually gray, tan, or dark brown, often with a white-spotted dorsal surface. It is the largest terrestrial lizard in the Marianas, reaching up to 4 in (100 mm) in body length. This species prefers poorly lit surfaces and is often most abundant in trees, vegetation, and stony outcrops. As a result, oceanic geckos are associated with undisturbed habitat and may be less tolerant of urbanization than other gecko species occurring in the Marianas (Sabath 1981). For the purpose of this report, the oceanic gecko is considered native although some authors argue the species is a recent arrival (Vogt and Williams 2004, Rodda unpublished data). Oceanic geckos still occur on the islands of Cocos, Rota, Tinian, Saipan, Guguan, Alamagan, and Asuncion where they appear common. The species has not been sighted on Guam in over a decade. The last verified observation was made on the University of Guam Campus in Mangilao (Rodda unpublished data).

1.1.2.8 Pacific Slender-toed Gecko
Scientific name: *Nactus pelagicus*
Chamorro name: Guali'ek
Status: Locally restricted
Guam listing: Endangered

The Pacific slender-toed gecko is gray, with dark bands and small bumps on its back and tail. A distinguishing feature of the species is its straight non-adhesive toes, which are thin compared to the large toe pads of other geckos (USGS 2005). Unlike other geckos on Guam, Pacific slender-toed geckos are primarily ground dwelling, mainly observed in rocky areas (Wiles et al. 1990). At night, the gecko can be found foraging on the ground and rocky substrates. This species is comprised only of females, and utilizes an asexual form of reproduction known as parthenogenesis (USGS 2005) whereby development of embryos occurs without fertilization by a male.

Captures of the Pacific slender-toed gecko have been rare since 1945. The decline of this species is possibly a result of the introduction of the brown treesnake (*Boiga irregularis*) and the musk shrew (*Suncus murinus*) (USGS 2005). Recent sightings have occurred in restricted areas in the northern limestone forests of Guam (Rodda unpublished data). Additionally, four specimens were found on the small southern off-shore islet Anae (near Agat) between 1994 and 1997 (Perry et al. 1998). Rota and Tinian are known to support Pacific slender-toed geckos (USGS 2005).

1.1.3 Species Native to Guam But Not Listed

1.1.3.1 Pacific Blue-tailed Skink
Scientific name: *Emoia caeruleocauda*
Chamorro name: Guali'ek Halom Tano'
Status: Common
Guam listing: Not listed

Juvenile Pacific blue-tailed skinks have three dorsal stripes and a bright blue tail. As they mature, the tail fades to brown. Adult males tend to lose their stripes, but females often retain them. Pacific blue-tailed skinks can grow to 2.1 in (55 mm) in body length (Vogt and Williams 2004).

On Guam, the Pacific blue-tailed skink can be found in all habitats throughout the island (Vogt and Williams 2004). They have been observed primarily on the ground, but will readily climb shrubs and trees (Wiles et al. 1990).

1.1.3.2 Mutilating Gecko

Scientific name: *Gehyra mutilata*
Chamorro name: Guali'ek
Status: Locally common
Guam listing: Not listed

The mutilating gecko is tan or gray with dark spots and a slightly flattened tail. The species has thin skin that is easily sloughed or damaged (Vogt and Williams 2004, USGS 2005). Body length averages about 1.6 in (42 mm).

The mutilating gecko is found in a variety of habitats, both forested and man-made. Its distribution on Guam is not fully known although it is considered patchy. The gecko is uncommon in some areas and locally abundant in others. Specimens have been collected from several offshore islets (Perry et al. 1998). The mutilating gecko is also known to occur on the islands of Cocos, Rota, Tinian, Saipan, Sarigan, Guguan, Alamagan, Pagan, and Agrihan (USGS 2005).

1.1.3.3 Mourning Gecko

Scientific name: *Lepidodactylus lugubris*
Chamorro name: Guali'ek
Status: Common
Guam listing: Not listed

The mourning gecko is light gray or tan with black bars on its back forming a chevron pattern. While primarily nocturnal, activity can also occur during the day in shaded locations (USGS 2005). At night, these geckos will vocalize and can regularly be heard chirping to one another. Mourning geckos are relatively small, attaining an average body length of 2 in (50 mm) (Vogt and Williams 2004). Reproduction in this species can occur via parthenogenesis (USGS 2005).

This species of gecko occurs throughout Guam in virtually all habitats. Other islands in the Marianas where the mourning gecko is present are Cocos, Rota, Tinian, Saipan, Alamagan, Agrihan, and Ascuncion (Vogt and Williams 2004).

1.1.4 Non-native Species

Although non-native species were not specifically targeted during this survey, captures or sightings of key species were documented whenever they occurred.

1.1.4.1 Brown Treesnake
Scientific name: *Boiga irregularis*
Chamorro name: Kolepbla
Status: Common
The brown treesnake on Guam averages around 3 ft (1 m), but can reach 9 ft (3 m) in length (Rodda et al. 1999). The snake was introduced to Guam in the late 1940s possibly on military cargo from the Admiralty Islands (Rodda et al. 1992). This snake is implicated in the extirpation of numerous species of birds and for diminishing numbers of native lizards on the island (Savidge 1987, Wiles et al. 2003). The brown treesnake is a generalist predator that will feed on birds, small mammals, and lizards (Savidge 1987).

The brown treesnake can be found in all habitats throughout Guam (Rodda et al. 1999).

1.1.4.2 Brahminy Blind Snake
Scientific name: *Ramphotyphlops braminus*
Chamorro name: Ulo' Attilong
Status: Common

The brahminy blind snake is inconspicuous and often confused with earthworms. Body size for this species reaches only 0.6 in (15 mm) in length, with a coloration that is solid black (Vogt and Williams 2004). The snake is an all female species that reproduces by means of parthenogenesis. Blind snakes are fossorial and feed on termites and ants (USGS 2005). This species is regarded as a prehistoric introduction but its mode of arrival to Guam is unknown. However, the species is known to be accidentally transported in flower pots (Vogt and Williams 2004).

The brahminy blind snake can be found in all habitats throughout Guam. Records of this species also exist from Rota, Tinian, Saipan, Anatahan, Sarigan, Alamagan, Pagan, and Agrihan, though it has potentially been established on all the Mariana Islands (Vogt and Williams 2004).

1.1.4.3 Monitor Lizard
Scientific name: *Varanus indicus*
Chamorro name: Hilitai
Status: Locally abundant

The monitor lizard on Guam is dark brown to black with yellow flecks. Body size can reach up to 4.9 ft (1.5 m). Monitor lizards are diurnal scavengers that feed on almost anything including insects, other species of lizards, small mammals, birds, eggs, crabs, and carrion (Dryden 1965). The establishment of the monitor lizard on Guam is thought to be prehistoric, coinciding with the arrival of ancient human inhabitants.

Presence of the monitor in forested habitat on Guam is common, although it is possible that its abundance has declined in the last two decades. This decline may be a combined result of the introduction of the brown treesnake, which is capable of eating eggs and small juveniles, and the introduction of the poisonous marine toad (USGS 2005). The monitor lizard is also found in numerous other locations, including Palau, New Guinea, Caroline Islands, Marshall Islands, Solomon Islands, northern Australia, and throughout the Mariana Islands (Vogt and Williams 2004).

1.1.4.4 Curious Skink
Scientific name: *Carlia ailanpalai*
Chamorro name: Guali'ek Halom Tano'
Status: Common

The curious skink was accidentally introduced to Guam and nearby Micronesian islands through the post-WWII transport of military supplies (Zug 2004). The first recorded specimen of the curious skink on Guam occurred in 1968. Native to the New Guinea region and Palau (Vogt and Williams 2004), the skink is a brown, terrestrial lizard that can be distinguished from other skinks by the lack of a fifth toe on the front feet (Zug 2004). Curious skinks grow to 2.8 in (70 mm) in body length. This species is primarily insectivorous but is known to feed on other small lizards (USGS 2005).

By the early 1990s, the curious skink was the most abundant skink on Guam and found in all habitats (McCoid 1993). It has been reported to be common in open and disturbed areas (Vogt and Williams 2004). The curious skink is also known to occur on the islands of Cocos, Saipan, and Tinian (USGS 2005).

1.1.4.5 House Gecko
Scientific name: *Hemidactylus frenatus*
Chamorro name: Guali'ek
Status: Common

The house gecko is very common in all habitats on Guam, particularly urban areas on buildings and fences and in natural habitats on branches and tree trunks (Rodda and Dean-Bradley 2006). Body color can vary from a light tan to dark brown with occasional dorsally-located stripes. Body length can reach 2.4 in (60 mm). A defining physical characteristic of this species is the spiked tail (Vogt and Williams 2004). The behavior of the house gecko is thought to possibly affect that of the mourning gecko (Vogt and Williams 2004).

No introduction date is known for this species, though implications of its presence exist prior to 1906 (Van Denburgh 1917 as referenced in McCoid 1993). McCoid (1993) described the house gecko as the most abundant gekkonid on Guam.

1.1.4.6 Green Anole
Scientific name: *Anolis carolinensis*
Chamorro name: Guali'ek
Status: Locally common

The green anole is usually bright green, but can change to brown depending on the surrounding environment (USGS 2005). Growing to 2.8 in (75 mm), males are generally larger than females. The males of this species also have a throat pouch (dewlap) that is used to display during courting behavior or when disputes over territory arise (Vogt and Williams 2004). Green anoles are diurnal and primarily feed on insects and spiders (Vogt and Williams 2004).

The introduction of the green anole to Guam was intentional, occurring in the mid-1950s as a means for insect control (Eldredge 1988). Its distribution on Guam has become locally common in urban areas, while populations have declined in forest habitat (Rodda et al. 1991). This habitat bias may be a result of predation by the brown treesnake (Rodda et al. 1999). Introductions of the green anole have also occurred on Rota, Saipan, and Tinian (Vogt and Williams 2004).

1.1.5 Amphibians

Guam has no native amphibian species. However, via accidental and intentional introductions, 13 species have found their way to Guam. Of these, eight are recorded as present, five of which are known to have established populations on the island (Government of Guam 1940, Christy et al. 2007b, Christy et al. 2007a). Species most likely to be encountered during surveys include the following:

Marine toad *(Rhinella marinus [formally Bufo]*) – Intentional introduction in 1937
Greenhouse frog (*Eleutherodactylus planirostris*) – Accidental introduction in 2003
Crab-eating frog (*Fejervarya cancrivora*) - Accidental introduction in 2002
Eastern dwarf tree frog (*Litoria fallax*) – Unknown introduction pathway in 1968
Gunther's Amoy frog (*Sylvirana guentheri*) - Accidental introduction around 2001
Hong Kong whipping frog (*Polypedates megacephalus*)

2.0 METHODS

2.1 Survey Locations

Herpetofauna surveys were undertaken at 11 locations on DoD and privately-owned lands on Guam (Table 2). Transects were set up within various habitat types to increase the possibility of detecting target species. General habitat descriptions of each survey location and corresponding transects are discussed below.

2.1.1 Andersen Air Force Base (7 transects)

Habitat type varied among transects from degraded forest (dominant species *Wikstroemia elliptica*, *Morinda citrifolia* and *Hibiscus tiliaceus*) to native limestone forest (predominately *Guamia mariannae*, *Aglaia mariannensis*, *Premna obtusifolia*, *Neisosperma oppositifolia*, and *Pandanus tectorius*).

2.1.2 North Finegayan (9 transects)

All nine transects were located in secondary forest, dominated by *Pandanus tectorius*, *Guamia mariannae*, *Vitex* sp., and *Hibiscus tiliaceus*.

Table 2: Herpetofauna surveys were carried out at 11 locations on DoD and private lands on Guam. Each site was designated a site-specific code. The number of transects and total length of transects varied between sites. Sites are ordered from north to south on the island.

Site	Site Code	Number of Transects	Total Transect Length (m)
Andersen Air Force Base	AAFB	7	2115
North Finegayan	NFIN	9	1720
South Finegayan	SFIN	2	150
Federal Aviation Administration	FAA	3	460
Andersen South	ANDS	7	1165
Route 15	RT15	3	1300
NCTS Barrigada	NBAR	3	555
Cabras	CABR	1	500
Orote Point	OROT	4	460
Naval Munitions Site	NMS	11	3830
Access Road – Option A	ACRD	3	400

2.1.3 South Finegayan (2 transects)

Both transects at this location consisted primarily of *Hibiscus tiliaceus* and *Leucaena leucocephala.* Bare ground was also common on each transect.

2.1.4 Federal Aviation Administration Parcel (3 transects)

FAA parcel transects were situated in degraded forest of *Leucaena leucocephala, Cocos nucifera*, and *Hibiscus tiliaceus*.

2.1.5 Andersen South (7 transects)

Four of the seven transects were located in forest where *Guamia mariannae, Aglaia mariannensis, Neisosperma oppositifolia*, and *Premna obtusifolia* were dominant. Two were in degraded *Leucaena leucocephala*-dominated forest and one in non-forest, grassy habitat that traversed pavements.

2.1.6 Route 15 (3 transects)

Two transects were located on top of the cliff line in limestone karst forest. The first started with native forest including *Guamia mariannae, Aglaia mariannensis, Ficus tinctoria, Triphasia trifolia* before opening up to a degraded forest with some *Leucaena leucocephala, Chromolaena odorata,* and *Stachytarpheta* sp. The second transect also traversed through similar native forest. The third was situated below the cliff line and consisted mostly of *Cocos nucifera.* Surveying of herpetofauna on the "Route 15 valley transect" was not possible because of access issues.

2.1.7 NCTS Barrigada (3 transects)

Transects were set in forested habitats where *Hibiscus tiliaceus*, *Leucaena leucocephala*, *Guamia mariannae*, and *Aglaia mariannensis* were common.

2.1.8 Cabras (1 transect)

The single transect was located in wetland. *Hibiscus tiliaceus*, *Spathodea campanulata*, and *Flagellaria indica* were common throughout.

2.1.9 Orote Point (4 transects)

Guamia mariannae, Aglaia mariannensis, Ficus tinctoria, Triphasia trifolia, and *Pandanus tectorius* dominated three of the four transects. The fourth, below Spanish Steps towards the beach, was almost entirely *Cocos nucifera*.

2.1.10 Naval Munitions Site (11 transects)

Ten of the eleven transects were situated almost entirely in native forest consisting of *Premna obtusifolia, Aglaia mariannensis,* and *Guamia mariannae.* Some transects passed over streams and swampy ground where *Cocos nucifera*, *Pandanus tectorius,* and *Hibiscus tiliaceus* were dominant. One transect was dominated by *Miscanthus floridulus.*

2.1.11 Access Road Option A at Mt. Jumullong (3 transect)

This site consisted of three transects in forest, situated along-side the trail leading to the top of Mt. Jumullong. Two transects were in degraded forest of *Leucaena leucocephala, Hibiscus tiliaceus, and Flagellaria indica.* The third, at highest elevation, was primarily native forest. *Pandanus tectorious and Aglaia mariannensis* were common at this location.

2.2 Herpetological Surveys

Herpetological surveys were performed by up to three herpetologists at each transect. Surveys were conducted nocturnally (targeting geckos) and diurnally (targeting skinks) on each transect to increase the possibility of encountering as many species as possible within each habitat. Reptiles and amphibians were documented by capture using glue board traps (traps) and/or visual surveys. Capturing individuals was valuable for identification of fast moving, cryptic or morphologically similar species. Visual surveys were intended to detect species that might not be trapped.

2.2.1 Trap Surveys

Day surveys commenced between 0730 and 0830, and night surveys between 1730 and 1830. If rain was present or imminent, trapping was delayed until the threat of rain ceased. On each transect, two non-scented Catchmaster™ mouse and insect glue board traps (henceforth referred to as traps) were set at 50 ft (15 m) intervals, one on the ground and one in a nearby tree. If no tree was available within 15 ft (5 m), only ground traps were used at that location. All traps were set in a shaded area approximately 3 ft (1 m) adjacent to the transect.

Tree traps were nailed to plants with a minimum diameter of 1.5 in (50 mm) at breast height (dbh), between 3 and 6 ft (1 - 2 m) high. Locations of traps were numbered and marked with flagging tape. Trap set and removal times were recorded along with time of each trap check. During the day, traps were generally checked within two hours (but never more than four hours) from opening. Traps were set for up to 12 hours overnight. A mortality level below 10 percent was considered acceptable. If mortality exceeded 10 percent, traps were repositioned or removed.

In order to decrease human disturbance along transects, traps were checked in the order in which they were set. Along with check time, the species type and number of individuals found on a trap were recorded. Non-target fauna and a change in weather conditions were also noted. Each animal was removed and placed into a correspondingly-numbered plastic bag until the trap was closed to prevent recapture. Once a trap was checked, it was closed or removed.

Individuals were removed from the traps slowly and carefully to minimize stress and physical damage. If removal was difficult, a small amount of vegetable oil was applied to decrease stickiness of the glue. Lizards that escaped but left their tail attached to the trap were recorded as a capture. When effectiveness of traps decreased due to dampness or an accumulation of debris or non target species, its location was noted and the trap replaced. Trapping was aborted in heavy or persistent rain and reopened when inclement weather passed. After completion of trap checks, individuals were released at their capture point.

Species caught by hand were recorded anecdotally.

2.2.2 Visual Surveys

Visual surveys were conducted both during the day and at night. Day searches commenced between 0800 and 1000 and night surveys between 1830 and 2130. A typical search speed of 0.2 to 0.4 mi/h was maintained. Any search speed variation was attributed to the density of the vegetation and abundance of species observed.

When a species was encountered, the information was chronicled on the data sheet. Species, perch taxon or substrate, and location were recorded. Any unidentified individual was captured where possible and photographed to aid in identification. Stop time and weather conditions were recorded at the completion of the visual surveys. Incidental observations and comments were also recorded.

3.0 RESULTS

Herpetofauna were surveyed along 53 transects at 11 locations between the 17th of February 2008 and the 21st of October 2009. Daytime and nighttime trap and visual surveys were carried out on all transects at all locations except NMS 1, where no nighttime visual survey was conducted due to safety concerns. Appendix 1 provides a full list of survey sites with transects and the associated date for each survey type.

Since transect length varied, results are presented as number of individuals or species recorded per meter (individuals/m or species/m). Amphibians were not considered a priority species; therefore abundance data are not included except where specifically noted.

3.1 Overall Results

Data presented in this section represent the combined results of trap and visual surveys; separate results for these surveys can be found in sections 3.2 and 3.3.

3.1.1 Individual and Species Abundance

A total of 2,900 individuals representing 15 herpetofauna species were recorded during trap and visual surveys along almost 13,000 meters of transect. The greatest number of individuals detected per meter was 0.50 (*n* = 275 individuals) at NBAR and 0.43 (*n* = 195 individuals) at OROT (Figure 1).

The highest number of species recorded per meter was 0.03 (*n* = 5 species) at SFIN (Figure 2). The location with the greatest number of species recorded was NMS (*n* = 11 species); however, since the total length of transects surveyed at NMS was high relative to other locations, the number of species per meter was the lowest recorded (0.003 species).

The highest number of native herpetofauna individuals recorded per meter was 0.21 (*n* = 118 individuals) at NBAR. Non-native individuals were most abundant at NBAR (0.28 individuals/m; *n* = 156) and OROT (0.28 individuals/m; *n* = 129) (Figure 3).

SFIN had the highest number of both native (0.013 species/m; *n* = 2) and non-native (0.02 species/m; *n* = 3) species recorded per meter (Figure 4). However, the locations with the most native herpetofauna species were NFIN (*n* = 5) and NMS (*n* = 5). The ANDS survey location contained the most non-native species (*n* = 7).

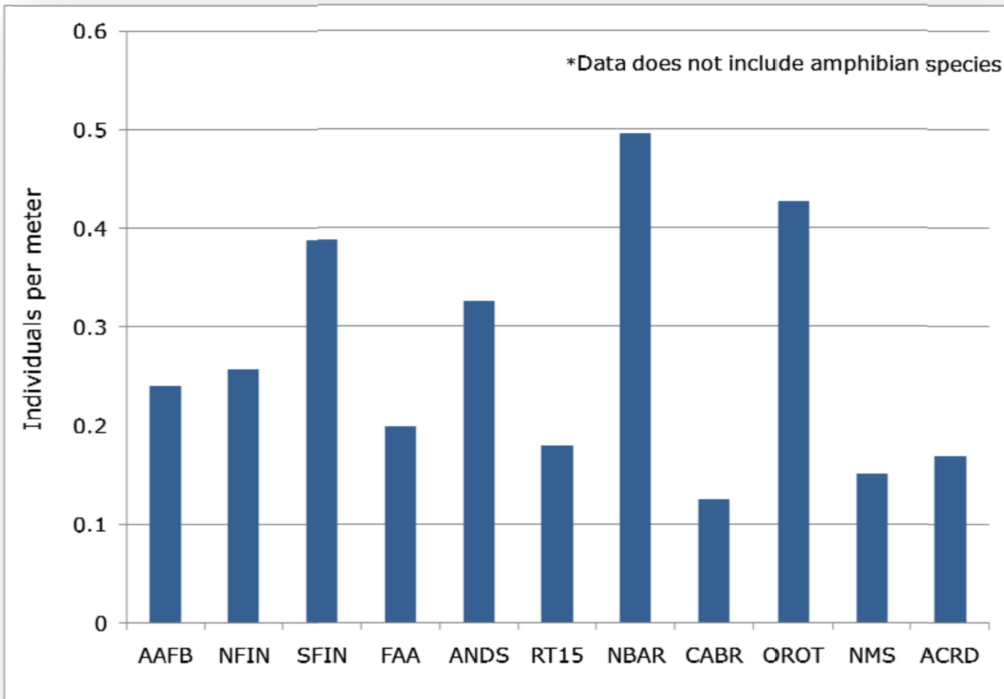

Figure 1. Number of herpetofauna individuals detected per meter at each survey location. See Table 2 for site code definitions.

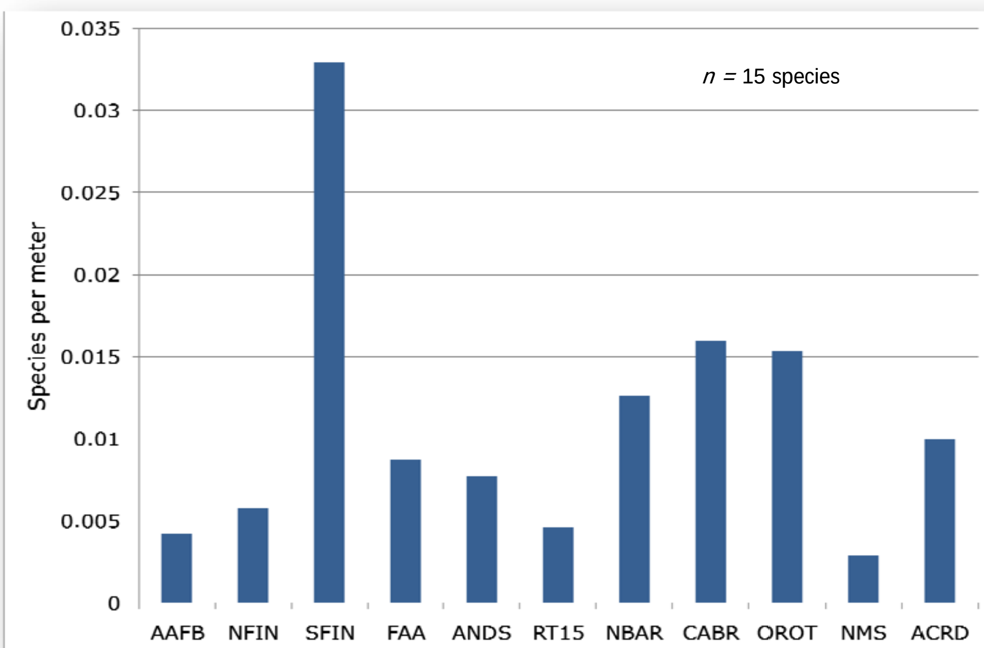

Figure 2. Number of species recorded per meter at each survey location. See Table 2 for site code definitions.

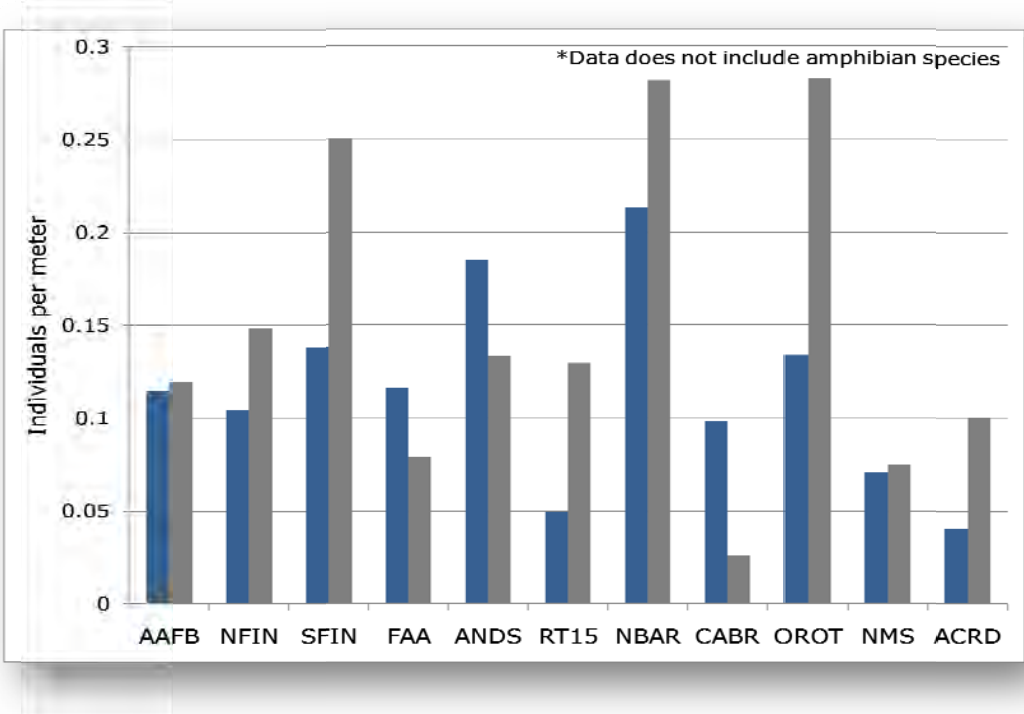

Figure 3. Number of native (blue) and non-native (grey) herpetofauna individuals recorded per meter at each survey location. See Table 2 for site code definitions.

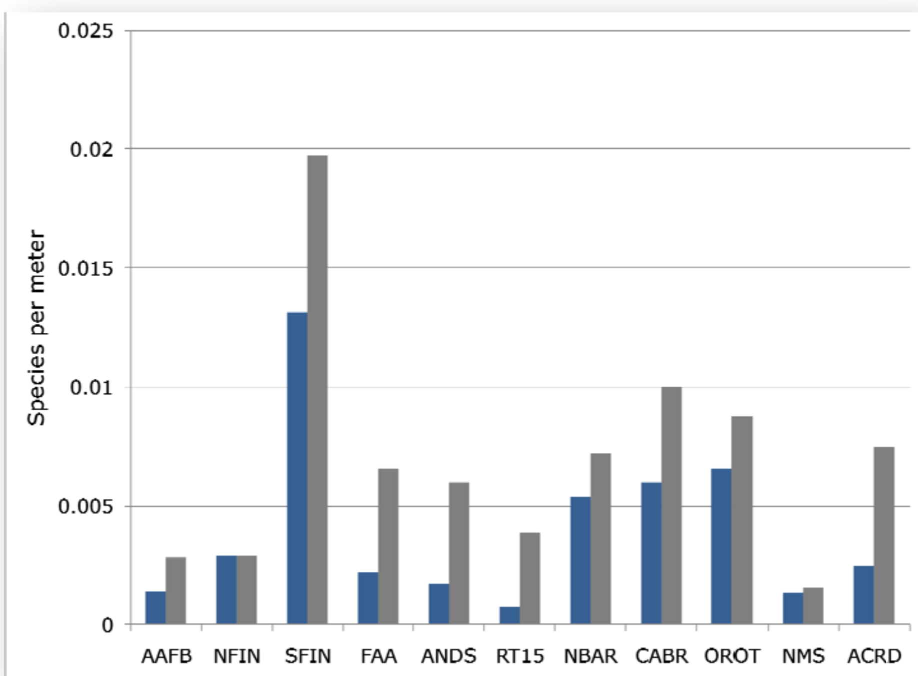

Figure 4. Number of native (blue) and non-native (grey) herpetofauna species recorded per meter at each survey location. See Table 2 for site code definitions.

3.1.2 Notable Species

Of the 15 herpetofauna species recorded during the surveys, five were native and ten non-native (Table 3). Two native skinks (moth skink and Pacific blue-tailed skink) and three native geckos (Pacific slender-toed gecko, mourning gecko, and mutilating gecko) were either captured or observed. The non-native curious skink and native Pacific blue-tailed skink were the only species observed and captured at all 11 survey locations. The house gecko and mutilating gecko were the most widespread of the geckos in the surveys, recorded at 10 and 8 of the 11 survey locations, respectively. The invasive brown treesnake was detected at seven survey locations and the marine toad at nine. An additional four amphibian species were recorded during the surveys. Gunther's Amoy frog, was observed at NMS after completion of a visual survey and while exiting the site.

Two Guam listed species were detected during the surveys: the moth skink (n = 8 individuals; Figure 5) at AAFB, NFIN, CABR, and NMS (Figure 7), and the Pacific slender-toed gecko (n = 14 individuals; Figure 6) at NFIN and NMS (Figure 7). Appendix 2 provides details associated with all moth skink and Pacific slender-toed gecko captures and observations.

Table 3. Herpetofauna detected at 11 locations during trap and visual surveys on DoD and privately-owned lands, Guam: 17 February 2008 - 21 October 2009. C = Captured; O = Observed. AAFB = Andersen Air Force Base; ANDS = Andersen South; NBAR = Barrigada; FAA = Federal Aviation Administration; NMS = Naval Munitions Site; NFIN = North Finegayan; OROT = Orote; RT15 = Route 15; SFIN = South Finegayan; CABR = Cabras; ACRD = Access Road Option A. The moth skink and Pacific slender-toed gecko (highlighted in blue) are both Guam listed species.

	Status	AAFB	NFIN	SFIN	FAA	ANDS	RT15	NBAR	CABR	OROT	NMS	ACRD
Skinks												
Snake-eyed skink	Native											
Pacific blue-tailed skink	Native	C,O	C,O	C,O	C, O	C,O	C,O	C,O	C,O	C,O	C,O	C,O
Tide-pool Skink	Native											
Slevin's skink	Native											
Azure-tailed Skink	Native											
Moth Skink	Native	C	C						C		C	
Curious skink	Non-native	C,O	C,O	C,O	C, O	C,O	C,O	C,O	C,O	C,O	C,O	C,O
Geckos												
Mourning gecko	Native		O					O		C	O	
Mutilating gecko	Native	C,O	C,O	C,O		C,O		C	C,O	C,O	C,O	
Pacific slender-toed gecko	Native		C,O								C,O	
Oceanic gecko	Native											
Micronesian gecko	Native											
House gecko	Non-native	C,O	C,O	O		C,O	C,O	O	O	O	C,O	O
Snakes												
Brown treesnake	Non-native	O	O			O	O		O	O	O	
Brahminy blind snake	Non-native	O				C						
Other												
Green anole	Non-native											
Monitor lizard	Non-native		O			C,O				O		

	Status	AAFB	NFIN	SFIN	FAA	ANDS	RT15	NBAR	CABR	OROT	NMS	ACRD
Amphibians												
Marine toad	Non-native	O	C,O	O	O	C,O	C,O		C,O		C,O	C,O
Greenhouse frog	Non-native	O			O	O	O	O				
Eastern dwarf tree	Non-native								O		O	
Crab-eating frog	Non-native										O	
Gunther's Amoy frog	Non-native										*	
Hong Kong whipping frog	Non-native							O				

* Gunther's Amoy frog observed off the transect following survey completion. Data not included in analysis.

Figure 5. Moth skink (*Lipinia noctua*) was recorded at four locations during the surveys. Photo: SWCA.

Figure 6. Pacific slender-toed gecko (*Nactus pelagicus*) was recorded at two locations during the surveys. Photo: SWCA.

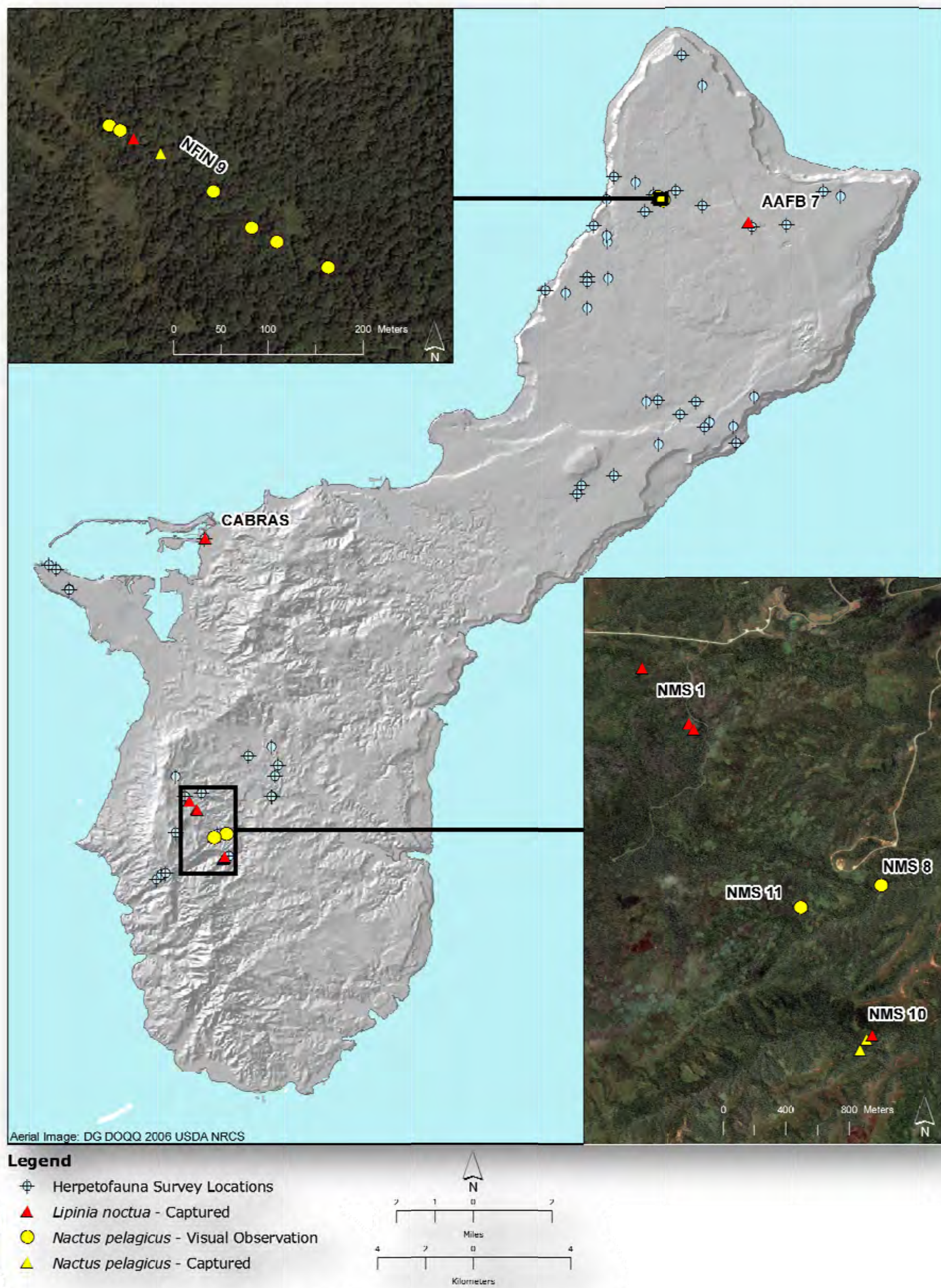

Figure 7. Herpetofauna survey locations where moth skinks (*Lipinia noctua*) and Pacific slender-toed geckos (*Nactus pelagicus*) were recorded during the surveys. See Table 2 for site code definitions.

3.2. Trap Surveys

3.2.1 Individual and Species Abundance

Ten species (*n* = 1,104 individuals) were captured during trap surveys at 11 locations. The highest number of individuals trapped was at AAFB (*n* = 227), whereas the most individuals trapped per meter was at SFIN (0.2; *n* = 31 individuals). Not only did SFIN have the highest number of individuals trapped per meter, the location also had the greatest number of species trapped per meter (0.02; *n* = 3 species). NFIN, ANDS, and NMS yielded the greatest number of species trapped (*n* = 7 at each location).

The locations with the most native herpetofauna species trapped were NFIN (*n* = 4) and NMS (*n* = 4). However, the highest number of native species trapped per meter was 0.013 (*n* = 2 individuals) at SFIN. The most non-native herpetofauna species trapped was at ANDS (*n* = 5), whereas the most non-native species captured per meter was at SFIN (0.007; *n* = 1 species).

The non-native curious skink and the native Pacific blue-tailed skink were the most frequently captured species during the surveys. These two skinks were captured at all 11 locations in high numbers (*n* = 539 curious skinks, *n* = 493 Pacific blue-tailed skinks). The most commonly trapped geckos were the native mutilating gecko (*n* = 20, captured at 8 locations) and the non-native house gecko (*n* = 21, captured at 5 locations).

Although only expected to be detected visually a monitor lizard was also caught by a glue board trap at ANDS (Figure 8). The individual had escaped between trap checks, but evidence of capture of foot scales left on the trap was recorded. It appears the monitor lizard became entangled in the trap attempting to depredate a curious skink.

A list of captured species by site can be found in Table 3.

3.2.2 Notable Species

By far the most important trap captures were those of the moth skink and Pacific slender-toed gecko. All eight moth skinks were captured on glue board traps at four sites: AAFB (*n* = 1), NFIN (*n* = 1), CABR (*n* = 1), and NMS (*n* = 5) (Table 3, Figure 7). In addition, four of the 14 Pacific slender-toed geckos detected during the surveys were trapped at two sites; NFIN (*n* = 2) and NMS (*n* = 2; Figure 7).

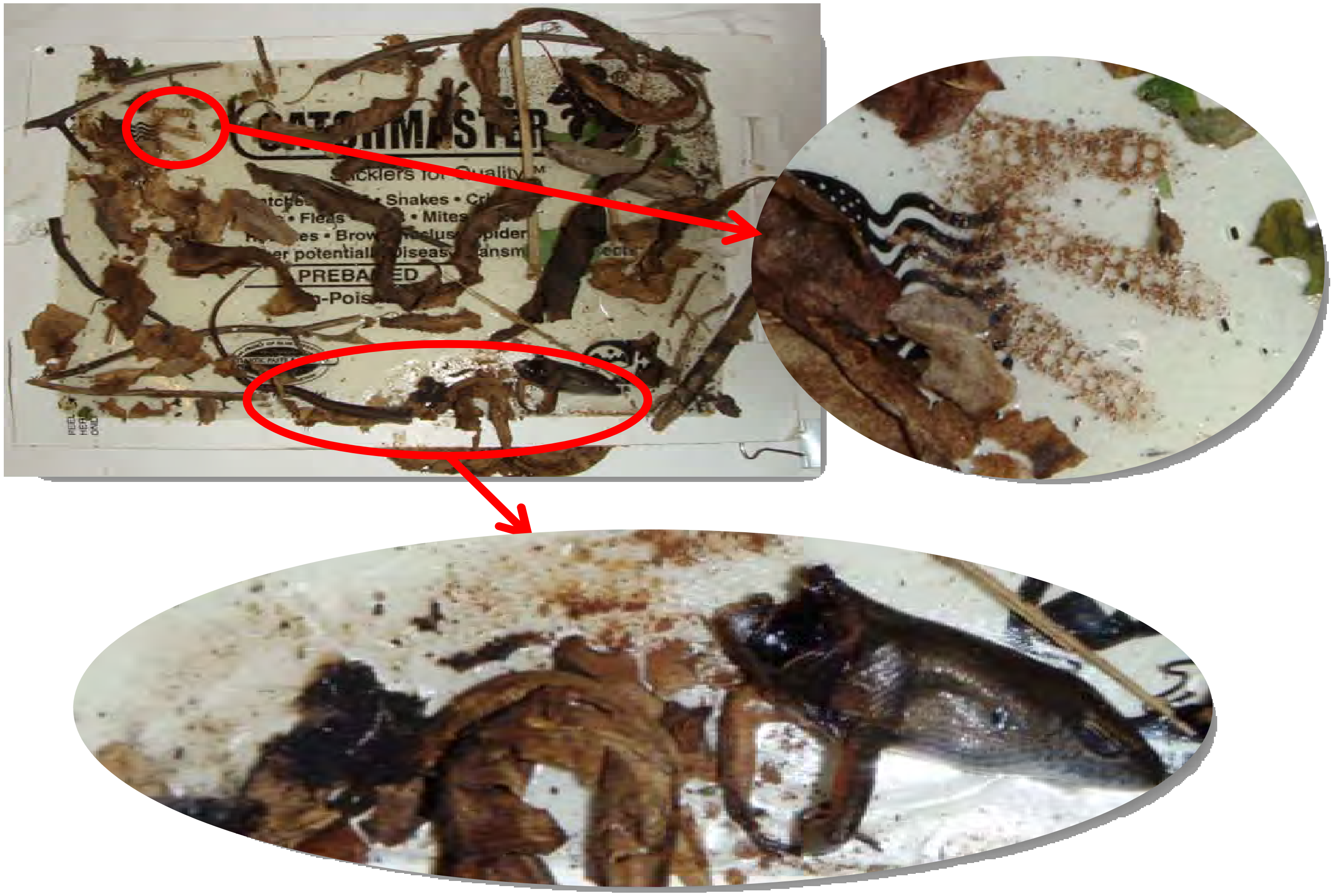

Figure 8**.** Evidence of a monitor lizard capture on a glue board on ANDS. Top circle shows monitor lizard foot scales. Lower circle shows the remains of a curious skink that appears to have been depredated by the lizard.

3.3 Visual Surveys

3.3.1 Individual and Species Abundance

A total of 1,796 herpetofauna individuals, comprising 14 species were observed during visual surveys at 11 locations (Table 3).

More individuals were observed per meter at NBAR than in any other location (0.39; *n* = 217 individuals). The most number of observed species was recorded at NMS (*n* = 10); however, the greatest number of observed species per meter was 0.03 (*n* = 5) at SFIN.

Four native species were observed during visual surveys at NFIN and NMS. However, the most native species observed per meter was at SFIN (0.013; *n* = 2 species). Six non-native species were observed at three locations: AAFB, ANDS, and NMS. Considering the area surveyed, the most non-native species observed per meter was at SFIN (0.02; *n* = 3 species).

3.3.2 Notable Species

The Pacific slender-toed gecko was observed at NFIN (*n* = 7) and NMS (*n* = 3).

The non-native curious skink and native Pacific blue-tailed skink were the most frequently observed species and sighted at all 11 survey locations. The non-native house gecko was the most commonly observed gecko; 95 individuals were visually detected at 10 sites. The native mutilating gecko was also frequently observed; 23 individuals were visually detected at seven locations.

Non-native marine toads (*n* = 9 locations) and greenhouse frogs (*n* = 5 locations) were relatively frequently observed. Both species were often observed in large numbers, particularly following rainfall. At several locations including AAFB and ANDS, greenhouse frogs were so abundant that numbers of individuals could not be determined. Other amphibians (eastern dwarf tree frog, crab-eating frog, and Hong Kong whipping frog) were also observed. A Gunther's Amoy frog was observed on NMS after completion of a visual survey.

4.0 DISCUSSION

This survey of herpetofauna on Guam's DoD lands resulted in 16 species (including Gunther's Amoy frog, which was not recorded during the surveys); eleven non-native species and five native species. The continued widespread presence of the curious skink, marine toad, and brown treesnake, as well as five frog species recorded during this survey is distressing. This presence of non-native herpetofauna on Guam is a concern because of their deleterious impacts to Guam's native fauna by competition, as well as possibly serving as food sources for the brown treesnake (Christy et al. 2007a, b).

Native skinks and geckos not recorded during this survey include the snake-eyed skink, Slevin's skink, azure-tailed skink, tide-pool skink, oceanic gecko, and the Micronesian gecko. Nevertheless, this does not indicate these species are not present at any of the 11 localities surveyed. Seasonality (wet or dry season) and habitat type may have influenced the presence and/or absence of common, rare, and uncommon species during the surveys.

Capture of five Guam listed moth skinks at NMS, and one capture at AAFB, NFIN, and CABR are noteworthy. The official status of this native skink on Guam is unknown due to the variability of information presented by past authors. The number of moth skinks observed during this survey may have been higher if a nighttime visual survey was performed along the NMS 1 transect. However, due to safety concerns, this particular transect was only surveyed during daylight hours.

The Pacific slender-toed gecko is a rarely observed gecko that is listed on as endangered by the Government of Guam. This study provided additional records of the species at NFIN and NMS. Their presence at these sites is noteworthy and should be considered during future planning and development. When potential development projects arise at any of this study's 11 survey locations, consideration should be given to the suitability of the existing native and secondary forest not only for Guam's herpetofauna but other Guam species of concern.

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APPENDIX 1 SURVEY DATES AND LOCATIONS BY TRANSECT

Department of Defense and private lands were surveyed for herpetofauna species at 11 sites between the dates of the 17th of February 2008 and the 21st of October 2009.

Site	Transect	Search Type	Date
Andersen Air Force Base (AAFB)	1	Day Visual	11-Jun-2008
		Night Visual	10-Jun-2008
		Day Trap	11-Jun-2008
		Night Trap	11-Jun-2008
	2	Day Visual	18-Jun-2008
		Night Visual	18-Jun-2008
		Day Trap	18-Jun-2008
		Night Trap	19-Jun-2008
	3	Day Visual	18-Jun-2008
		Night Visual	18-Jun-2008
		Day Trap	18-Jun-2008
		Night Trap	19-Jun-2009
	4	Day Visual	11-Jun-2008
		Night Visual	10-Jun-2008
		Day Trap	11-Jun-2008
		Night Trap	11-Jun-2008
	5	Day Visual	12-Oct-2009
		Night Visual	14-Oct-2009
		Day Trap	14-Oct-2009
		Night Trap	15-Oct-2009
	6	Day Visual	1-Oct-2009
		Night Visual	14-Oct-2009
		Day Trap	14-Oct-2009
		Night Trap	15-Oct-2009
	7	Day Visual	12-Oct-2009
		Night Visual	14-Oct-2009
		Day Trap	14-Oct-2009
		Night Trap	15-Oct-2009
North Finegayan (NFIN)	1	Day Visual	5-Mar-08
		Night Visual	4-Mar-08
		Day Trap	8-Mar-08
		Night Trap	5-Mar-08
	2	Day Visual	5-Mar-08
		Night Visual	4-Mar-08

Site	Transect	Search Type	Date
North Finegayan (NFIN) cont.		Day Trap	8-Mar-08
		Night Trap	5-Mar-08
	3	Day Visual	9-Mar-08
		Night Visual	6-Mar-08
		Day Trap	7-Mar-08
		Night Trap	7-Mar-08
	4	Day Visual	9-Mar-08
		Night Visual	6-Mar-08
		Day Trap	7-Mar-08
		Night Trap	7-Mar-08
	5	Day Visual	5-Mar-08
		Night Visual	4-Mar-08
		Day Trap	8-Mar-08
		Night Trap	5-Mar-08
	6	Day Visual	13-Mar-08
		Night Visual	12-Mar-08
		Day Trap	13-Mar-08
		Night Trap	13-Mar-08
	7	Day Visual	13-Mar-08
		Night Visual	12-Mar-08
		Day Trap	13-Mar-08
		Night Trap	13-Mar-08
	8	Day Visual	9-Mar-08
		Night Visual	6-Mar-08
		Day Trap	7-Mar-08
		Night Trap	7-Mar-08
	9	Day Visual	21-Jul-09
		Night Visual	20-Jul-09
		Day Trap	20-Jul-09
		Night Trap	21-Jul-09
South Finegayan (SFIN)	1	Day Visual	13-Mar-08
		Night Visual	12-Mar-08
		Day Trap	13-Mar-08
		Night Trap	13-Mar-08
	2	Day Visual	13-Mar-08
		Night Visual	12-Mar-08
		Day Trap	13-Mar-08
		Night Trap	13-Mar-08

Site	Transect	Search Type	Date
Federal Aviation Administration (FAA)	1	Day Visual	21-Nov-08
		Night Visual	24-Nov-08
		Day Trap	21-Nov-08
		Night Trap	24-Nov-08
	2	Day Visual	21-Nov-08
		Night Visual	24-Nov-08
		Day Trap	21-Nov-08
		Night Trap	24-Nov-08
	3	Day Visual	18-Dec-08
		Night Visual	17-Dec-08
		Day Trap	18-Dec-08
		Night Trap	18-Dec-08
Andersen South (ANDS)	1	Day Visual	15-Apr-2008
		Night Visual	9-Jun-2008
		Day Trap	15-Apr-2008
		Night Trap	18-Apr-2008
	2	Day Visual	16-Apr-2008
		Night Visual	9-Jun-2008
		Day Trap	16-Apr-2008
		Night Trap	18-Apr-2008
	3	Day Visual	16-Apr-2008
		Night Visual	10-Jun-2008
		Day Trap	16-Apr-2008
		Night Trap	18-Apr-2008
	4	Day Visual	18-Apr-2008
		Night Visual	10-Jun-2008
		Day Trap	18-Apr-2008
		Night Trap	18-Apr-2008
	5	Day Visual	15-Apr-2008
		Night Visual	9-Jun-2008
		Day Trap	15-Apr-2008
		Night Trap	18-Apr-2008
	6	Day Visual	15-Apr-2008
		Night Visual	9-Jun-2008
		Day Trap	15-Apr-08
		Night Trap	18-Apr-08

Site	Transect	Search Type	Date
	7	Day Visual	9-Oct-09
Andersen South (ANDS) cont.		Night Visual	14-Oct-09
		Day Trap	14-Oct-09
		Night Trap	15-Oct-09
Route 15 (RT15)	1	Day Visual	19-Nov-08
		Night Visual	25-Nov-08
		Day Trap	19-Nov-08
		Night Trap	25-Nov-08
	2	Day Visual	19-Nov-08
		Night Visual	25-Nov-08
		Day Trap	19-Nov-08
		Night Trap	26-Nov-08
	3	Day Visual	2-Dec-08
		Night Visual	1-Dec-08
		Day Trap	2-Dec-08
		Night Trap	2-Dec-08
NCTS Barrigada (NBAR)	1	Day Visual	17-Feb-08
		Night Visual	18-Feb-08
		Day Trap	17-Feb-08
		Night Trap	18-Feb-08
	2	Day Visual	17-Feb-08
		Night Visual	18-Feb-08
		Day Trap	17-Feb-08
		Night Trap	18-Feb-08
	3	Day Visual	7-Oct-09
		Night Visual	20-Oct-09
		Day Trap	20-Oct-09
		Night Trap	21-Oct-09
Cabras (CABR)	1	Day Visual	24-Jun-09
		Night Visual	24-Jun-09
		Day Trap	24-Jun-09
		Night Trap	25-Jun-09
Orote (OROT)	1	Day Visual	25-Apr-08
		Night Visual	30-Apr-08
		Day Trap	25-Apr-08
		Night Trap	1-May-08
	2	Day Visual	25-Apr-08
		Night Visual	30-Apr-08
		Day Trap	25-Apr-08
		Night Trap	1-May-08

Site	Transect	Search Type	Date
Orote (OROT) cont.	3	Day Visual	25-Apr-08
		Night Visual	30-Apr-08
		Day Trap	25-Apr-08
		Night Trap	1-May-08
	4	Day Visual	25-Apr-08
		Night Visual	30-Apr-08
		Day Trap	25-Apr-08
		Night Trap	1-May-08
Naval Munitions Site (NMS)	1	Day Visual	1-Mar-08
		Night Visual	None
		Day Trap	22-Feb-08
		Night Trap	22-Feb-08
	2	Day Visual	23-Feb-08
		Night Visual	26-Feb-08
		Day Trap	23-Feb-08
		Night Trap	26-Feb-08
	3	Day Visual	23-Feb-08
		Night Visual	26-Feb-08
		Day Trap	23-Feb-08
		Night Trap	26-Feb-08
	4	Day Visual	21-Feb-08
		Night Visual	26-Feb-08
		Day Trap	21-Feb-08
		Night Trap	26-Feb-08
	5	Day Visual	21-Feb-08
		Night Visual	26-Feb-08
		Day Trap	21-Feb-08
		Night Trap	26-Feb-08
	6	Day Visual	21-Feb-08
		Night Visual	26-Feb-08
		Day Trap	20-Feb-08
		Night Trap	26-Feb-08
	7	Day Visual	21-Feb-08
		Night Visual	26-Feb-08
		Day Trap	20-Feb-08
		Night Trap	26-Feb-08
	8	Day Visual	9-Dec-08

Site	Transect	Search Type	Date
		Night Visual	8-Dec-08
Naval Munitions Site (NMS) cont.		Day Trap	9-Dec-08
		Night Trap	9-Dec-08
	9	Day Visual	11-Dec-08
		Night Visual	10-Dec-08
		Day Trap	11-Dec-08
		Night Trap	11-Dec-08
	10	Day Visual	8-Jan-09
		Night Visual	7-Jan-09
		Day Trap	7-Jan-09
		Night Trap	8-Jan-09
	11	Day Visual	9-Dec-08
		Night Visual	8-Dec-08
		Day Trap	9-Dec-08
		Night Trap	9-Dec-08
Access Road (ACRD)	ARCD-1	Day Visual	15-Jul-08
		Night Visual	14-Jul-08
		Day Trap	14-Jul-09
		Night Trap	15-Jul-09
	ARCD-2	Day Visual	15-Jul-08
		Night Visual	14-Jul-08
		Day Trap	14-Jul-09
		Night Trap	15-Jul-09
	ARCD-3	Day Visual	15-Jul-08
		Night Visual	14-Jul-08
		Day Trap	14-Jul-09
		Night Trap	15-Jul-09

APPENDIX 2 NOTABLE SPECIES DETECTION INFORMATION

Nactus pelagicus

Date	Transect	Location Easting	Location Northing	Number of individuals	Visual/Capture
12/8/2008	NMS 8	250139	1476478	2	Visual
3/30/2009	NMS 11	249630	1476337	1	Visual
7/20/2009	NFIN 9	268054	1503381	2	Visual
7/20/2009	NFIN 9	268232	1503256	1	Visual
7/20/2009	NFIN 9	268066	1503375	1	Visual
7/20/2009	NFIN 9	268165	1503310	1	Visual
7/20/2009	NFIN 9	268205	1503271	1	Visual
7/20/2009	NFIN 9	268286	1503228	1	Visual
1/8/2009	NMS 10	250051	1475481	1	Capture
1/8/2009	NMS 10	250010	1475411	1	Capture
7/21/2009	NFIN 9	268109	1503350	1	Capture
7/21/2009	NFIN 9	268054	1503381	1	Capture
			TOTAL	14	

Lipinia noctua

Date	Transect	Location Easting	Location Northing	Number of individuals	Visual/Capture
2/22/2008	NMS 1	248620	1477879	1	Capture
2/22/2008	NMS 1	248920	1477516	1	Capture
2/22/2008	NMS 1	248952	1477483	1	Capture
3/31/2009	NMS 11	249640	1476347	1	Capture
6/25/2009	Cabras	249272	1488964	1	Capture
7/20/2009	NFIN 9	268080	1503366	1	Capture
10/15/2009	AAFB 7	271845	1502281	1	Capture
1/8/2009	NMS 10	250087	1475509	1	Capture
			TOTAL	8	

APPENDIX C
Terrestrial Natural Resource Surveys

Terrestrial Natural Resources Surveys on Guam, In Support Of The Joint Guam Project Office Environmental Impact Statement. NAVFAC Pacific, Pearl Harbor, Hi. October 2009

TERRESTRIAL NATURAL RESOURCES SURVEYS ON GUAM, IN SUPPORT OF THE JOINT GUAM PROJECT OFFICE ENVIRONMENTAL IMPACT STATEMENT

Prepared by
S. Vogt, NAVFAC Pacific, Pearl Harbor, HI
October 2009

INTRODUCTION

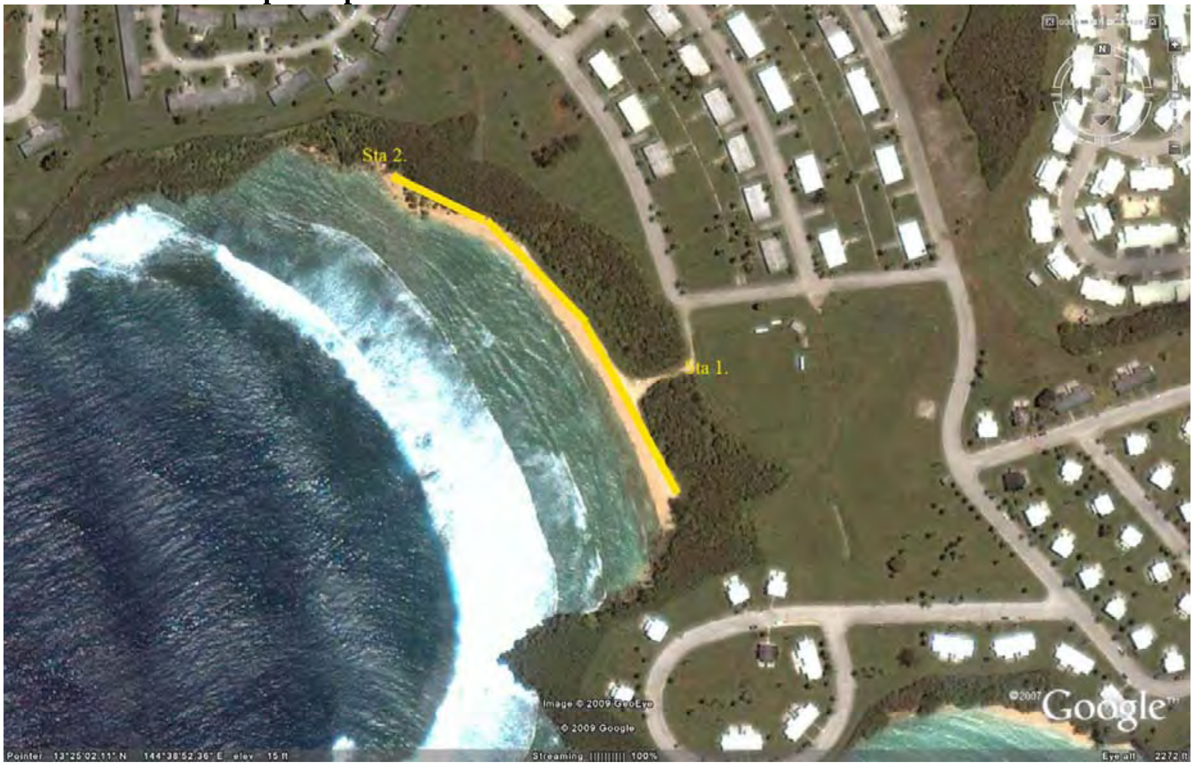
As part of the proposed transfer of U.S. Marines from Okinawa to Guam, natural resource surveys were performed in areas to be impacted as a result of this transfer. Avian, reptile, amphibian, and botanical surveys were performed in August, September, October and November, 2008.

STUDY SITES

Sites that were sampled include Dadi (Map 1) and Tipalao (Map 2) beach areas at the Naval Installation (Naval Base Guam), Air Force Barrigada (Map 3), Anderson Air Force Base (AAFB) Finegayan (Map 4), and Polaris Point (Map 5).

Map 1. Dadi beach area transects and bird count stations

Map 2. Tipalao beach area transects and bird count stations



Map 3. Air Force Barrigada transect and bird count stations

Map 4. AAFB Finegayan transects: bird count stations are on the transects

Map 5. Polaris point transect and bird count stations

METHODS

Bird Surveys

Because the sites varied in size, the avian surveys consisted of a point count survey along each transect (count stations every 100 meters [m] on the transect) and/or, depending on the site, a roadside breeding bird type survey. Surveys started between 0600 am and 0700 am and were completed by 1100 am. Due to the small size of the areas surveyed the number of stations at each site was less than 10.

For the breeding bird surveys avian identification was performed along roadside survey routes. Each survey route utilized available Base roadways in areas planned for development. Sampling locations (i.e., stops) were at ~500-m intervals. At each stop, an 8-minute point count was conducted. During the count, every bird seen within a 0.25-mile radius or heard was recorded.

Forest birds were surveyed using the variable circular plot (VCP) method (Scott et al. 1986). All birds seen or heard during an 8-minute count period at each station were recorded with the detection type (audio, visual or combined detection) and the distance to the bird when first detected, estimated to the nearest meter. Observations between stations were not recorded.

Reptile and Amphibian Surveys

Reptiles and amphibians were sampled by visual surveys on transects and adhesive, “sticky”, trapping on the same transects.

Visual surveys were performed during the morning and evening hours. Adhesive traps were placed every 15 meters on the transect up to 15 traps. One trap was placed on the ground and 1 was stapled to the nearest tree at ~breast height. Ground traps were placed between 0800 am and 0900 am and left out for 4 hours. Tree traps were placed at the same time but left over night. Tree traps were checked in the late afternoon so that lizards could be removed before nightfall.

Botanical Surveys

The goal of the vegetation surveys was to locate endangered plant species or species of concern through a visual walk over the entire transect length and a point-quarter survey. The point-quarter survey was performed, with stations every 50 m to identify to species and measure the nearest tree in each quarter greater than 2-cm diameter at breast height (dbh). At the point quarter station, the presence or absence of signs of ungulate (deer and pigs) activity within a 5-m radius around the station point was noted. Within this same 5-m radius, vegetation was counted and identified to species for tree seedlings that are smaller than 2-cm dbh. At each station ground cover was assessed with a 50 cm x 50 cm PVC square grid or quadrant frame, divided into a grid of 25 squares (use wire or string on the PVC frame), each 10 x 10 cm, providing 16 interior points where the grid lines intersected. At each station the frame was dropped in one of the cardinal directions approximately 1 meter from the station center. The types of ground cover that each intersecting gridline touched was recorded as follows: Litter (dead vegetation), rock, bare soil, and live vegetation.

RESULTS

Bird surveys

Nine bird species were documented although not all species were observed at any one site (Table 1). No threatened or endangered bird species were documented. There were not enough birds detected of any species to provide an estimate of population density or abundance.

Table 1. Bird species documented at survey sites

Species	*Dadi*	*Tipalao*	*Polaris Point*	*AAFB Finegayan*	*Air Force Barrigada*
Drongo	X	X	X	X	
Yellow Bittern			X		
White Tern		X			
Black Francolin					X
Tattler sp.		X			
Brown Noddy			X		
Eurasian Tree Sparrow	X	X		X	
Philippine Turtle Dove	X	X	X	X	X
Chicken				X	X

Reptile and Amphibian Surveys

Seven species of reptiles and one amphibian species were documented (Table 2). No federally threatened or endangered species were documented. Even though not all species were documented at all sites, it is assumed that all occur each site.

Table 2. Reptiles and amphibians documented at survey sites

Species	*Dadi*	*Tipalao*	*Polaris Point*	*AAFB Finegayan*	*Air Force Barrigada*
Carlia fusca	X	X	X	X	X
Emoia caeruleocauda	X	X	X	X	X
Hemidactylus frenatus	X	X	X	X	X
Lepidodactylus lugubrus	X	X	X	X	X
Gehyra mutilata	X		X	X	
Varanus indicus	X		X		
Boiga irregularis	X		X	X	
Bufo murinus	X		X	X	X

Botanical Surveys

See Table 3 for the tree density and mean size (diameter at breast height [DBH]) at each site. Because the floral communities between the eastern and western areas of the AAFB Finegayan parcel were markedly different they are presented separately.

Table 3. Tree density and mean size at survey sites

Site	*Number of trees per hectare (ha) and mean DBH (cm) (with 95% confidence interval)*
Dadi	5,632 trees/ha; DBH = 6.36 (4.96-7.76)
Tipalao	5,569 trees/ha; DBH = 7.16 (4.23-10>09)
Polaris Point	5,004 trees/ha; DBH = 6.12 (5.03-7.21)
Air Force Barrigada	6,309 trees/ha; DBH = 4.50 (3.85-5.15)
AAFB Finegayan West	3,695 trees/ha; DBH = 6.46 (4.85-11.31)
AAFB Finegayan East	3,183 trees/ha; DBH = 10.86 (9.11-12.61)

See Charts 1-6 for the tree species composition at each site.

Chart 1. Tree Species Composition at Tipalao Beach

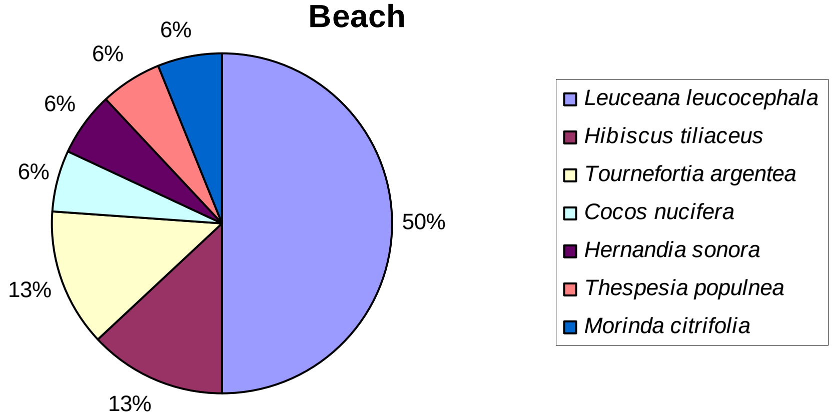


Chart 2. Tree Species Composition at Dadi Beach

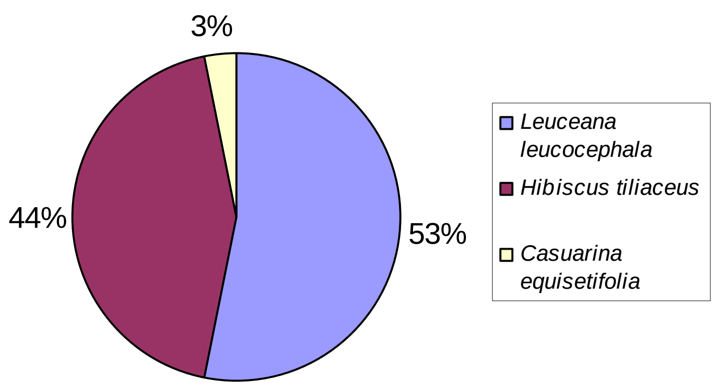


Chart 3. Tree Species Composition at Polaris Point

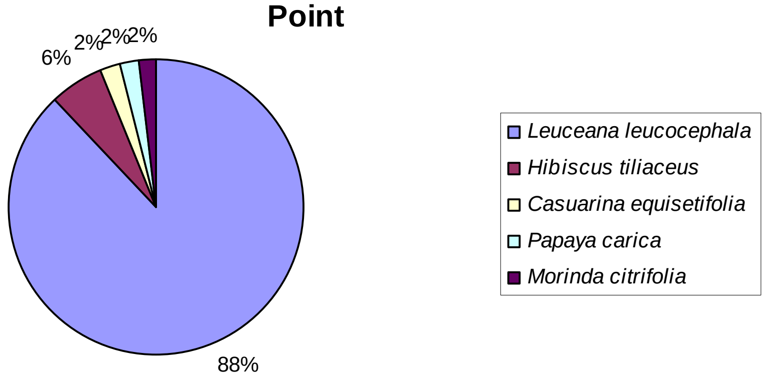


Chart 4. Tree Species Composition at Air Force Barrigada

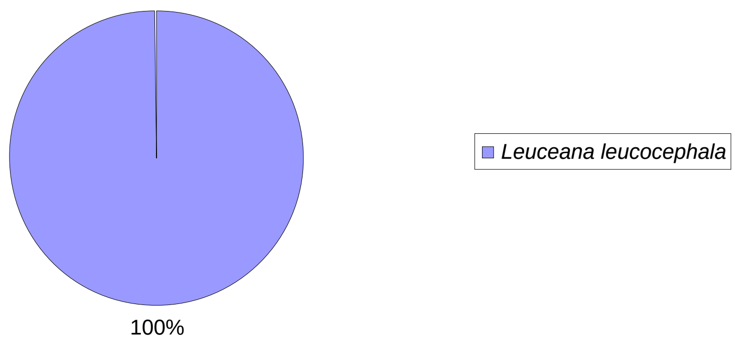


Chart 5. Tree Species Composition at AAFB Finegayan, East transect

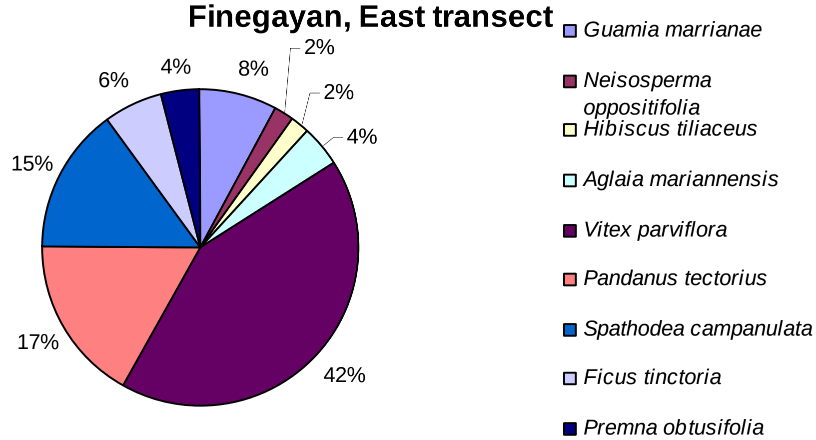
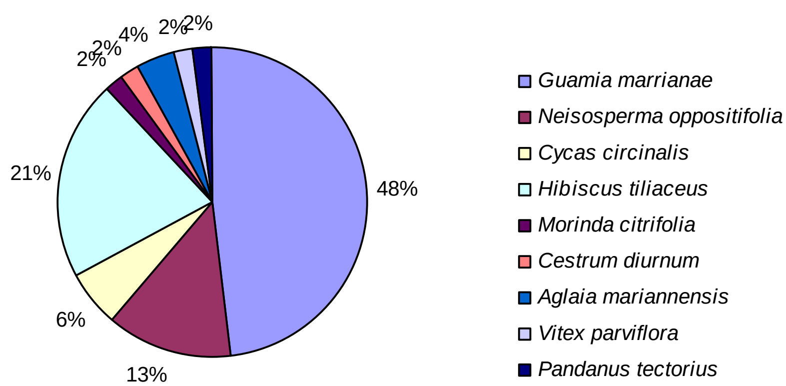


Chart 6. Tree Species Composition at AAFB Finegayan, West Transect



See Table 4 for non-woody plants documented at each site.

Table 4. Non-woody plants documented at survey sites

Site	*Non-woody species documented*
Dadi	Lilies
Tipalao	*Polypodium scolopendria*, Lilies
Polaris Point	*Sida sp., Polypodium scolopendria, Chromo odorata, Nephrolepis* sp., *Euphorbia leterophella, Stachytarpheta urticifolia*
Air Force Barrigada	*Polypodium punctatum, Stachytarpheta urticifolia, Chromo odorata*
AAFB Finegayan West	*Piper guahamense, Polypodium punctatum , Chromo odorata, Stachytarpheta urticifolia, Chamaecrista nictitans*
AAFB Finegayan East	*Sida* sp., *Piper guahamense, Polypodium punctatum , Chromo odorata, Chamaecrista nictitans*

Ungulate (deer or pig) sign was documented at Air Force Barrigada (deer and pig), Polaris point (pig), and both east and west AAFB Finegayan (deer and pig). AAFB Finegayan had very prominent and numerous ungulate signs.

DISCUSSION

Bird surveys

Due to the impacts of the introduced brown treesnake (*Boiga irregularis*) most of Guam's native forest birds are either extinct or extirpated. The few birds that are able to co-exist with the snake tend to be introduced or seabird/shorebirds with large size and nesting habits that preclude snake predation. The results of these surveys support this generalization.

Reptile and Amphibian Surveys

With the exception of sea turtles, the Marianas islands do not have any federally listed reptile or amphibian species. There are several locally listed species of concern and none of these were documented at the survey sites.

Botanical Surveys

No endangered plant species or species of concern were documented. Ungulate impacts were quite extensive at the AAFB site and appear to be causing fragmentation of the habitat. The western side of this parcel lacked canopy species trees and is becoming scrubby and open. The dominant tree species are native (*Guamia mariannae*, *Hibiscus tileaceus* and *Neisosperma oppisitifolia*) but are not canopy species. The eastern side of the parcel has an enclosed canopy and large trees but these are dominated by the introduced species *Vitex parviflora* and *Spathodea campanulata*. It is obvious that deer and pigs are having a pronounced effect on the habitat, preventing regeneration of many native tree species and reducing diversity.

LITERATURE CITED

Scott, J.M., S. Mountainspring, F.L. Ransey, and C.B. Kepler. 1986. Forest bird communities of the Hawaiian Islands: their dynamics, ecology, and conservation. Studies in Avian Biology 9.

APPENDIX D
Vegetation Surveys

Vegetation Survey of Various DoD and Non-DoD lands on Guam and M.I. Duenas, Camacho & Associates, Inc. March, 2010; and

Guam Vegetation Surveys in Support of the Military Buildup EIS at Various Locations on Guam. TEC Inc. April, 2010

VEGETATION SURVEY
OF VARIOUS DOD AND NON-DOD LANDS
GUAM, M.I.

Prepared for
AECOM and TEC Joint Venture

Prepared by
Duenas, Camacho& Associates, Inc.

June 2010

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1.0 INTRODUCTION

This vegetation survey is prepared for the U.S. Navy through a NAVFAC contract (Task Order 0016 and TO 0007 Mod 04 for Natural Resource (NR) Surveys on Guam) for AE Services for Environmental Planning to Support Strategic Forward Basing Initiatives. The survey is intended to provide information on the terrestrial plant communities within certain Department of Defense (DOD) and non-DOD lands that are being considered in the Environmental Impact Statement (EIS) for the Marine Corps Relocation Initiative to Various Locations on Guam. The information collected will supplement the Final Natural Resources Survey and Assessment Report of Guam and Certain Islands of the Northern Mariana Islands (NAVFAC, 2007).

1.1 Study Area

Eight survey areas comprising DOD and non-DOD lands were included in the vegetation survey study area. Table 1.1-1 summarizes the acreage, total transect length, and number of transects at each site.

Table 1.1-1. Summary of Transect Lengths and Locations

Survey Area	Approximate Area (Acres)	Total Transect Length (Feet)	Number of Transects
North Finegayan	240	3,500	8
South Finegayan	418	500	2
Orote Peninsula	240	500	1
Navy Barrigada	400	1,000	2
Andersen South	2,024	4,000	6
Ordnance Annex	3,347	6,000	11
FAA Parcel	592	1,500	3
Route 15	395	4,265	3

The DOD parcels included six northern sites: North Finegayan, Navy Barrigada, South Finegayan housing area, and Andersen South housing area (Figure 1-1). Two DOD parcels were surveyed in southern Guam: Orote Peninsula and Ordnance Annex. The former Federal Aviation Administration (FAA) parcel and Route 15 parcels are non-DOD lands located in northern Guam.

2.0 MATERIALS AND METHODS

This section describes the procedures used in conducting a vegetation survey of selected terrestrial plant communities on DOD lands on Guam using Point-Center Quarter and Point Quadrat methodology (Mueller-Dombois, 1979). These procedures give descriptions of equipment and field procedures necessary to obtain qualitative and quantitative data on vegetation throughout the study area. All surveys were performed by Duenas, Camacho & Associates, Inc. and TEC, Inc. biologists.

2.1.1 Equipment and Supplies

The following equipment and resources were used in the field during the vegetation surveys:

1. Digital Camera
2. Field Notebook
3. Aerial Photographs and Maps covering the Survey Areas
4. Handheld Global Positioning System (GPS)
5. Vegetation Field Guides
6. Binoculars
7. Personal protective equipment (PPE)

2.1.2 Guidelines

Transect lines were previously identified and flagged at the initial and terminal points by others prior to the start of the field survey. Biologists walked the entire length of the transect lines and performed general and quantitative observations of the vegetation based on the methodology below. Plants were identified to species whenever possible. Vouchers of questionable specimens (e.g., non-flowering plants or seedlings) were collected when necessary.

2.1.2.1 General observations

Biologists walked each transect line observing the vegetation with the goal of locating any sensitive species, i.e., threatened or endangered plant species, or species of concern (Table 2.1-1). Upon identifying a sensitive species, the biologist would photograph the specimen and note its location relative to the nearest sampling station. The general health of the plant was noted, e.g., healthy, damaged, or infested.

2.1.2.2 Quantitative Observations

Concurrent with the general observations for sensitive species, a point-center quarter survey was performed at regular intervals along the same transect line (Mueller-Dombois and Ellenberg, 1979). The nearest tree in each quarter greater than 2 cm dbh was measured. The sampling interval was adjusted based on the size of the sampled area and transect length.

At the point-center quarter station, the presence or absence of ungulate sign (deer and pigs) was noted within a 5-meter radius around the station point. Within this same 5-meter radius, the tree seedlings smaller than 2 cm dbh were identified and tallied.

EcoSim (Acquired Intelligence, Inc.) was used to analyze the matrix of species presence × distance for each of the point-centered quarter sampling units along the different transects to generate rarefaction curves of species richness. Rarefaction curves are a useful method to compare the species richness between transects as well as to characterize overall species diversity at a site (Ludwig and Reynolds, 1988). This technique involves resampling the observed distribution of species presences from transect data and generating probabilistic species richness curves for a range of iterations. The number of iterations is equivalent to the abundance of individuals in a transect while species richness, an index of diversity, is equal to species number.

The point-center quarter station also served as a station for the point-quadrat survey. Ground cover was assessed with a 50 cm by 50 cm square quadrat frame, divided into a grid of 25 squares using string. Each 10 by 10 cm square provided 16 interior points where the grid lines intersect. At each station the frame was dropped in one of the cardinal directions approximately 1 meter from the station center. The types of ground cover that each intersecting gridline touched was recorded as follows: litter (dead vegetation), rock, bare soil, and live vegetation. The data for each station totaled 16 observations.

2.1.3 Documentation

Observations and data were recorded on data forms with the following information:

- Responsible person’s name
- Dates and times of activities
- Location description and GPS location
- General and quantitative observation data collected in the surveys
- Information (e.g., date, location) regarding each photograph
- Meteorological conditions

2.2 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat, such as ungulate activity, the presence of erosion, percent of native plant species, and overall species richness. The conspicuous presence of ungulates is a factor in the health and status of the native vegetation. Feral pigs tread on native seedlings and tear up the understory growth, interrupting recruitment of new plants. Heavy browsing and rubbing by deer also affect the health of native plant communities. A high level of ungulate sign, is therefore, related to a more degraded and disturbed environment.

2.3 Threatened, Endangered and Sensitive Species

2.3.1.1 Sensitive Species

The *Guam Comprehensive Wildlife Conservation Strategy* was prepared by the Guam Department of Agriculture with the goal of promoting the recovery and sustainable use of Guam's native aquatic and terrestrial species, especially those of greatest conservation need. The Strategy listed 65 species recommended as Species of Greatest Conservation Need (SOGCN) for Guam. Five terrestrial plant species, all trees, were listed. These include *Heritiera longipetiolata*, *Merrilliodendron megacarpum*, *Serianthes nelsonii*, *Tabernaemontana rotensis*, and *Cycas micronesica*. The SOGCN were listed based on the following criteria:

- The status of the population of the species is not known, but the species is not extinct;
- The population of the species does not contain a self-sustained breeding population, there is no known breeding population, or is extirpated;
- The population size is considered threatened or endangered;
- A monitoring program is not in place;
- The range of the population is limited; or,
- A funded program is not in place for that species.

Guam Department of Agriculture also considers the native cycad tree, Fadang (*Cycas micronesica*) as a species of concern. Cycads are a component of native limestone and ravine forest.

2.3.1.2 Endangered Species

The U.S. Endangered Species Act (16 U.S.C. 1531-1544) of 1973, as amended, prohibits the taking of any listed species without prior approval of the Secretary of the Interior. The U.S. Fish and Wildlife Service (USFWS) lists 13 local species under the Act, including one plant, *Serianthes nelsonii*, which is listed as endangered for Guam (USFWS, 2005).

The Guam Department of Agriculture lists 31 species as endangered under the Endangered Species Act of Guam (5 GCA, Section 63205(c)). The list includes three plants: *Serianthes nelsonii* (fire tree or hayun lagu), *Cyathea lunulata* (tree fern or tsatsa), and *Heritiera longipetiolata* (looking-glass tree or ufa' halom-tano).

Table 2.1-1. Plant Species Listed as Threatened, Endangered or Species of Concern

Species	Chamorro/Common Name	Guam	Federal
Serianthes nelsonii	Hayun-lago, Fire tree	Endangered, SOGCN	Endangered
Cyathea lunulata	Tsatsa, Tree fern	Endangered	Not listed
Heritiera longipetiolata	Ufa-halomtano, Looking-glass tree	Endangered, SOGCN	Not listed
Coelogyne guamensis	Orchid	Not listed	SOC
Lycopodium phlegmaria	Disciplina	Not listed	SOC
Nervilia jacksoniae	Orchid	Not listed	SOC
Thelypteris warburgii	Fern	Not listed	SOC
Tinosperma homosepela		Not listed	SOC
Tabernaemontana rotensis		SOGCN	Not listed
Cycas micronesica	Fadang	SOGCN	Not listed
Merrilliodendron megacarpum	Faniok	SOGCN	Not listed

Key: SOC = Species of Concern; SOGCN = Species of Greatest Conservation Need

Only one plant, the fire tree (*S. nelsonii*), is protected under the U.S. Endangered Species Act. Other species listed include the five Species of Concern identified by the U.S. Fish and Wildlife Service. These and the other listed species above were noted if they were encountered during the field investigations (Table 2.1-1).

3.0 RESULTS AND DISCUSSION

This section presents the general and quantitative data collected during this survey. The following plant communities were documented in the project areas: primary limestone forest, scrub forest, ravine forest, savanna grassland, coconut grove, halophytic/xerophytic scrub, strand, and open field/weed community. Species names and distribution follow Raulerson (2006). Common and local names are taken from Stone (1970).

Primary limestone forest is considered the original forest type on the limestone plateau prior to man's habitation and disturbance. Little remains of this climax plant community on Guam because of the island's human and feral ungulate population growth and intensive urban development that has cleared much of the forest, especially in the last century. The best examples are typically in areas where extreme terrain or military controls prevent ready or easy access. The characteristic species include native breadfruit or dokdok (*Artocarpus mariannensis*), paipai (*Guamia mariannae*), mapunao (*Aglaia mariannensis*), yoga (*Eleocarpus joga*), *Pisonia* spp., *Pandanus* spp., and *Ficus* spp. Several plant associations that have been described as types or variations of limestone forest. These include the five types described by Fosberg (1960) based on the dominant species: *Artocarpus-Ficus* forest; *Mammea* forest; *Cordia* forest; *Merrioliodendon-Ficus* forest; and *Pandanus* forest.

Scrub forest is a derivative of and degraded form of primary limestone forest. It contains native and naturalized species in varying proportions and has been subjected to disturbance by feral ungulates, typhoons, and human activities. The forest is a scrubby, low-canopy community often with a tangled understory of vines (especially bejuco halomtano or *Flagellaria indica*) among the shrubs or small trees. The forest composition is variable, but *Vitex parviflora* is a particularly common, if not dominant, overstory and understory tree species.

Ravine forest is a distinct forest on volcanic soils with a shorter, shrubbier stature than limestone forest but with some overlapping species. Typical tree species include betelnut or pugua (*Areca catechu*) palms, screwpines (*Pandanus* spp.), and ilang-ilang (*Cananga odorata*).

Savanna grasslands are found over volcanic soils where forest has been cleared and replaced by homogeneous stands of swordgrass or neti (*Miscanthus floridulus*) and fields of foxtail (*Pennisetum polystachion*), *Dimeria chloridiformis*, and other low herbs and grasses. Trees such as ironwood or gagu (*Casuarina equisetifolia*) and shrubs such as nanaso (*Scaevola taccada*) are sparingly distributed in this community.

Coconut grove communities comprise nearly homogeneous monocultures of coconut (*Cocos nucifera*) palms and are found not far from sandy beaches. Other native tree species may be present, such as *Hernandia*, *Cordia subcordata*, and *Pandanus*.

The open field/weed community comprises low-stature herbaceous and shrubby vegetation of mostly introduced but naturalized species. The community arises from clearings by human or ungulates.

Halophytic/xerophytic scrub is located on limestone cliffs exposed to salt spray, and includes some components of limestone forest and strand communities. The vegetation is often stunted and gnarled from constant ocean spray and windy conditions.

Strand communities comprise the coastal vegetation on sandy beaches. The area closest to the shoreline, or forestrand, typically contains vines, such as *Ipomoea pes-caprae*, and grasses (e.g., *Thuarea involuta*) that bind the sand and may sprawl for long stretches. Other salt-tolerant plants often found in this zone are hunig (*Tournefortia argentea*), nigas (*Pemphis acidula*), and nanaso (*Scaevola taccada*). Further inland is the backstrand community, which often contains binalo (*Thespesia populnea*), kafu (*Pandanus tectorius*), gasoso (*Colubrina asiatica*), fadang (*Cycas micronesica*), coconut (*Cocos nucifera*) and nonag (*Hernandia nymphaeaefolia*).

3.1 North Finegayan

3.1.1 Location

North Finegayan comprises approximately 2,952 acres in northwestern Guam in the Municipality of Dededo. This U.S. Navy installation extends west from Route 3 to the Philippine Sea, and lies between Andersen Air Force Base and the former Federal Aviation Administration (FAA) parcel. Partial perimeter fencing encloses the base along the southern, eastern and western boundaries.

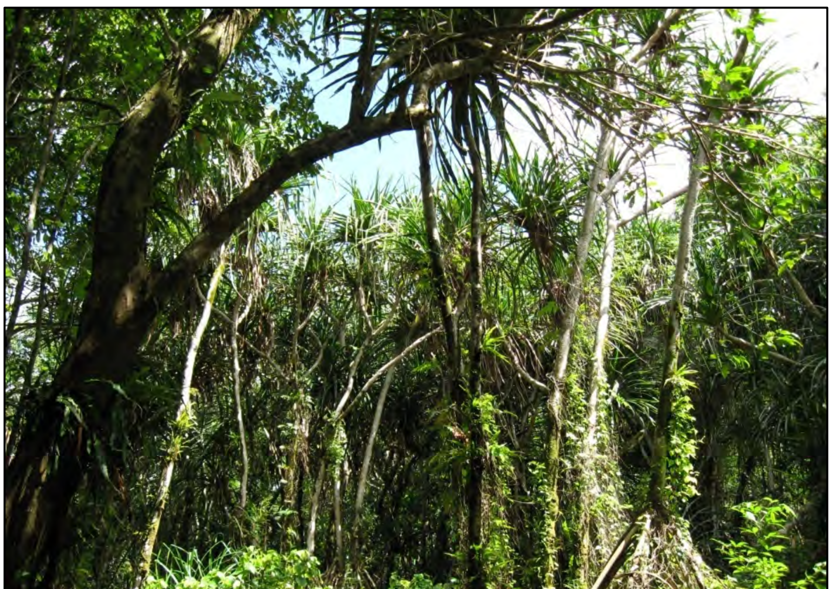


Figure 3.1-1. Limestone forest along Transect 4, upper NCTS North Finegayan.

3.1.2 Previous Studies

North Finegayan was formerly named Naval Communication Station (NCS) Finegayan, and also Naval Communications and Area Master Station (NAVCAMS) Finegayan. Previous studies of vegetation at the installation include a 1978 survey and letter report by Philip Moore (BioSystems Analysis, Inc. 1989); a plant survey conducted in conjunction with a reconnaissance of the Haputo Ecological Reserve Area (ERA) by U.S. Fish and Wildlife Service (1986); and a natural resources survey by BioSystems Analysis, Inc. (1989). The most comprehensive of these studies was performed by BioSystems Analysis, Inc. (1989), which examined 40% of the limestone forest and strand areas at Navy Finegayan and Navy Barrigada. The BioSystems survey identified four vegetation types at Navy Finegayan: limestone forest (171 acres); degraded limestone forest (1,175 acres); coastal strand (16 acres); and halophytic/xerophytic scrub (160 acres).

3.1.3 Quantitative Observations

The current quantitative survey areas at North Finegayan comprised three vegetation types: limestone forest, coconut grove, and disturbed/weed community. Limestone forest was present along six transects on the upper plateau (Transects 1 through 5, and Transect 8) (Figure 3.1-1) as well as below the cliffline along Transect 7 south of Double Reef (Figure 3.1-2). The coconut grove was sampled in Transect 6 in the Haputo ERA embayment. A disturbed/weed plant community occurred at forest edges and in patches within the forest.

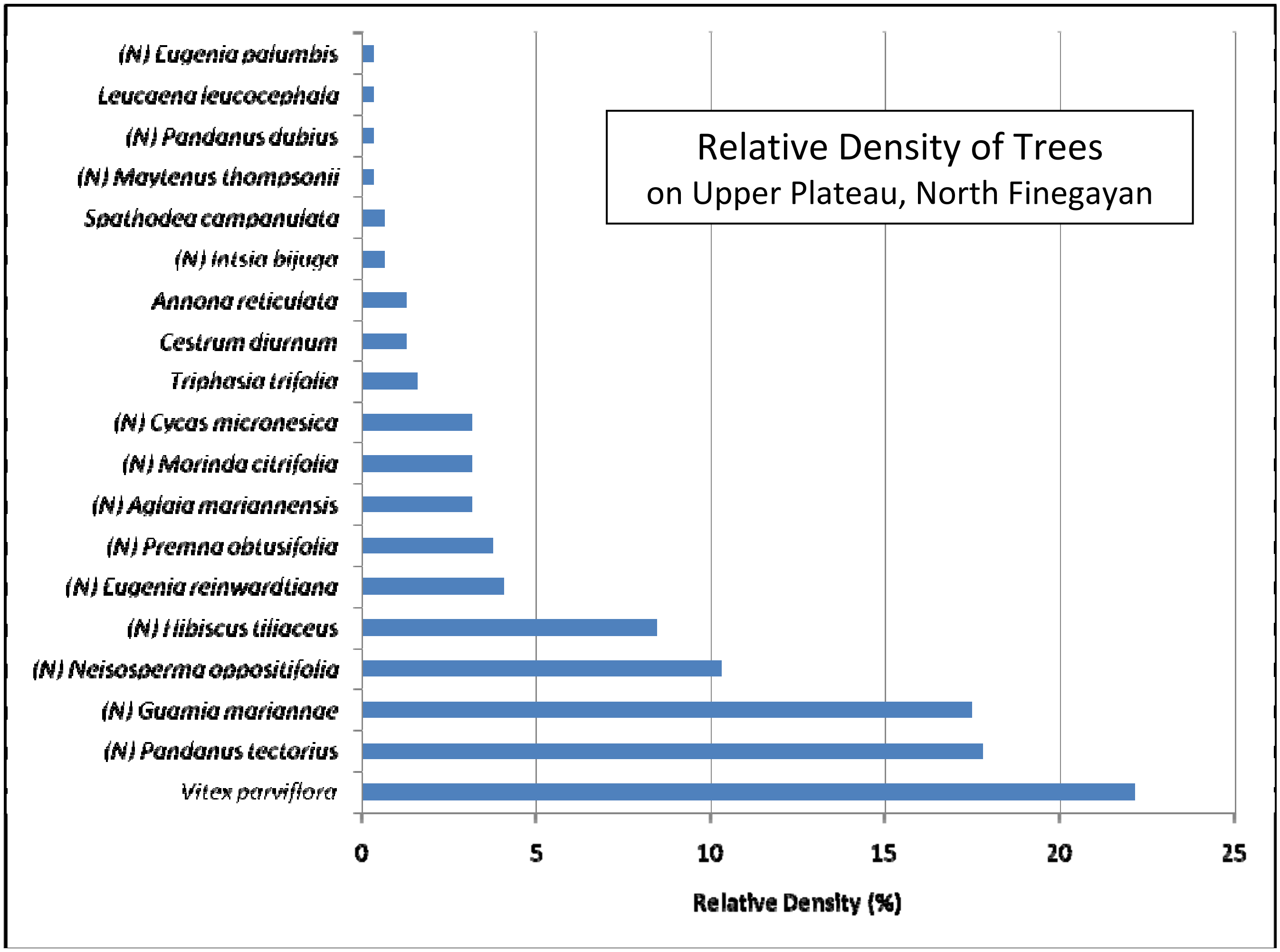
Point-center quarter surveys were performed along eight transects in the southern, northern and western sectors of North Finegayan (Figure 1 in Attachment A). Transects 1 through 5 and Transect 8 were in limestone forest. The results of these six surveys in the upper plateau of North Finegayan are summarized in Table 3.1-1. Thirteen or approximately 68% of the 19 species encountered on these transects were native trees. It is notable that *Vitex parviflora*, an introduced species, is a dominant component of these forests in terms of basal area, absolute dominance and frequency. The relative density of species among these six transects is presented in Figure 3.1-3. *Vitex* had the highest relative density (about 22%), followed by native kafu or screwpine (*Pandanus tectorius*) and endemic paipai (*Guamia mariannae*) trees with densities of about 17% each. *Vitex* is a Philippine species that was introduced to Guam prior to 1970 (Stone, 1970), and has since become a common component of its forests (Donnegan et al., 2004). *Guamia* is typically an understory tree.

Figure 3.1-2. Limestone forest with *Merrilliodendron megacarpum* and *Piper guahamense* along Transect 7, lower NCTS North Finegayan.

Table 3.1-1

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST
NF-1, NF-2, NF-3, NF-4, NF-5, NF-8 NORTH FINEGAYAN, FEB. 2008

SPECIES	STATUS	NO. TREES IN QTRS.	NO. SPECIES IN 100 SM	TOTAL BASAL AREA (sq. cm)	MEAN BASAL AREA (sq. cm)	ABSOLUTE DOMINANCE	ABSOLUTE FREQUENCY
Neisosperma oppositifolia	N	33	1.92	41750.80	1265.18	2428.42	30
Pandanus tectorius	N	57	3.32	14921.03	261.77	867.88	46.25
Eugenia reinwardtiana	N	13	0.76	2798.18	215.24	162.76	12.5
Guamia mariannae	N	56	3.26	8120.10	145.00	472.30	40
Vitex parviflora	I	71	4.13	103353.93	1455.69	6011.53	47.5
Hibiscus tiliaceus	N	27	1.57	3947.59	146.21	229.61	20
Aglaia mariannensis	N	10	0.58	3428.86	342.89	199.44	11.25
Premna obtusifolia	N	12	0.70	9604.84	800.40	558.66	13.75
Triphasia trifolia	I	5	0.29	190.66	38.13	11.09	5
Morinda citrifolia	N	10	0.58	282.82	28.28	16.45	8.75
Cestrum diurnum	I	4	0.23	651.76	162.94	37.91	5
Leucaena leucocephala	I	1	0.06	41.83	41.83	2.43	1.25
Eugenia palumbis	N	1	0.06	5.72	5.72	0.33	1.25
Intsia bijuga	N	2	0.12	473.53	236.76	27.54	2.5
Maytenus thompsonii	N	1	0.06	29.21	29.21	1.70	1.25
Spathodea campanulata	I	2	0.12	326.76	163.38	19.01	2.5
Annona reticulata	I	4	0.23	153.43	38.36	8.92	2.5
Cycas micronesica	N	10	0.58	5590.11	559.01	325.15	6.25
Pandanus dubius	N	1	0.06	122.66	122.66	7.13	1.25



Note: (N) indicates native species; others are introduced.

Figure 3.1-3. Relative density of tree species in Transects 1 to 5 and Transect 8, North Finegayan.

The limestone forest along Transect 7 in lower North Finegayan is a distinctive community comprising a stand of faniok (*Merrilliodendron megacarpum*) trees that provide habitat for the Pacific tree snail (*Partula radiolata*). The forest is situated close to sea level along the base of an escarpment and overlies karst limestone substrate. From north to south, the site transitions from faniok-dominated forest to a more mixed community.

Native species comprised nearly three-quarters of the relative density of tree species among the six transects in the limestone forest at upper North Finegayan (Figure 3.1-4).

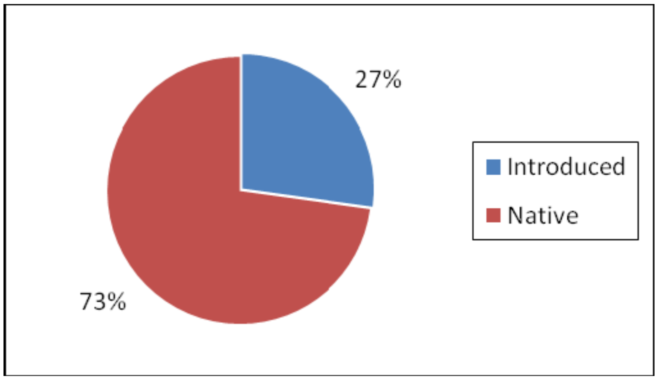
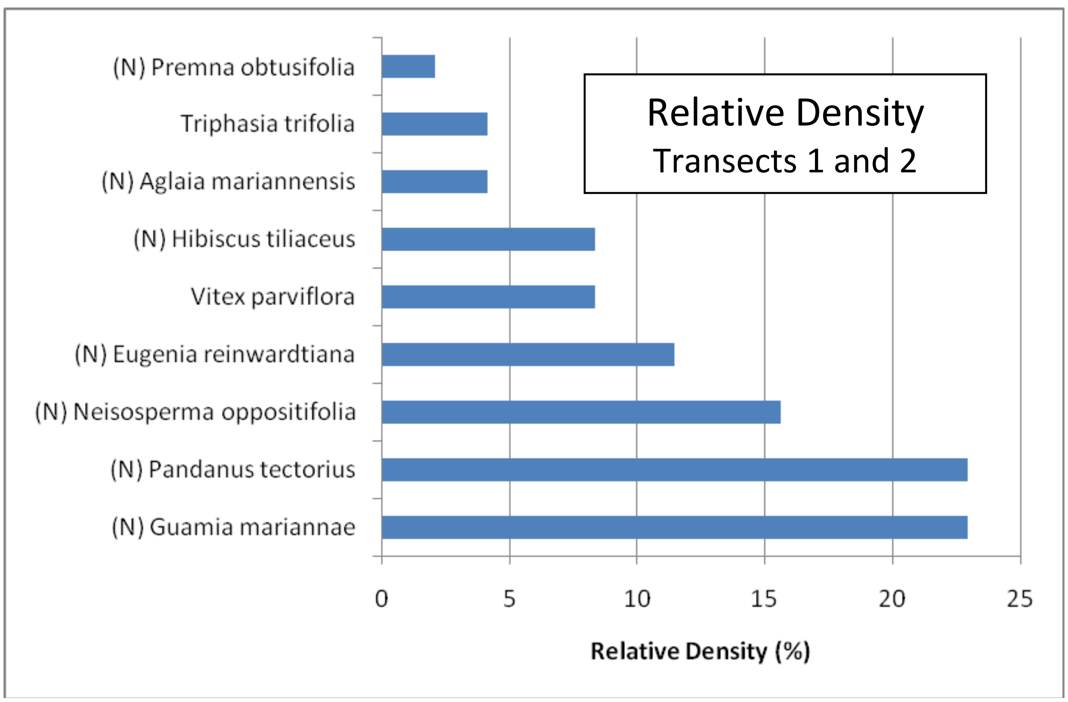


Figure 3.1-4. Relative density of native tree species in Transects 1 to 5 and Transect 8, North Finegayan.

In the forests of the southern sector (Transects 1 and 2), the three species with the highest relative densities were *Guamia mariannae*, *Pandanus tectorius*, and *Neisosperma oppositifolia*, which collectively accounted for 62% of the overall density (Figure 3.1-5). Native species had a combined density of 87%; two of these species, *Guamia* and *Aglaia*, are endemic to the Mariana Islands, and had a combined density of 27%. The non-native element comprised *Triphasia trifolia* and *Vitex parviflora* with a combined density of 13%.

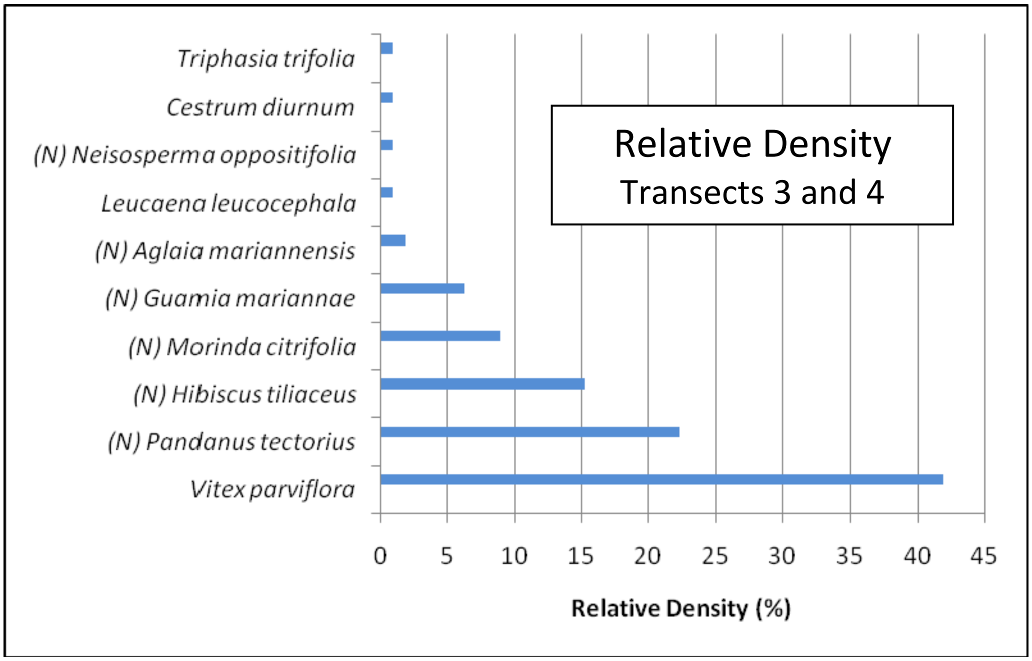


Note: (N) indicates native species; others are introduced.

Figure 3.1-5. Relative density (%) of trees in southern sector at North Finegayan.

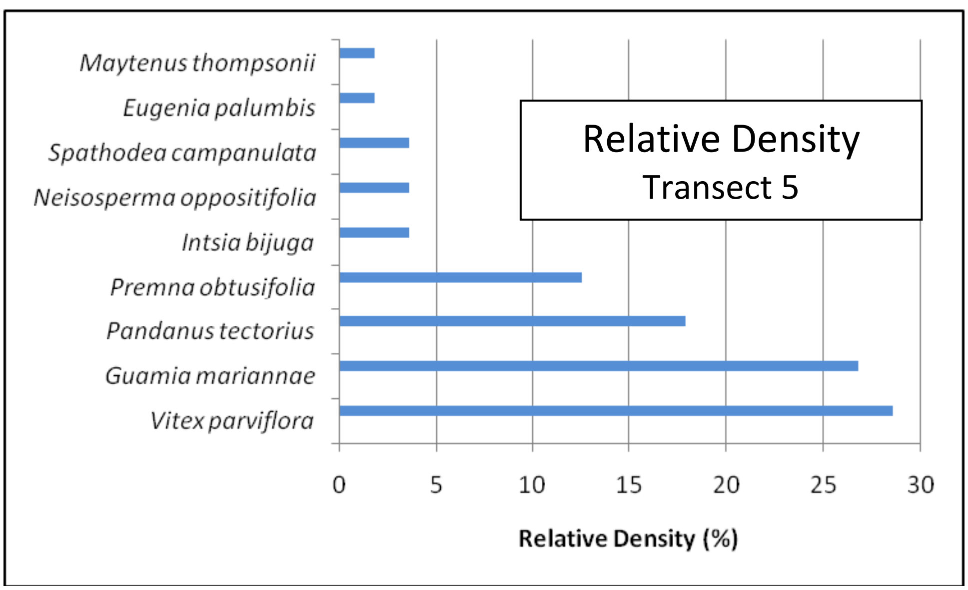
Non-native species (*Vitex*, *Cestrum*, and *Triphasia*) accounted for 45% of the relative density (Figure 3.1-6) in the limestone forest of the north-central sector of North Finegayan (Transects 3 and 4). Native species comprised slightly more than half of the overall density; however, endemic species (*Guamia* and *Aglaia*) accounted for only 8% of the relative density.

The limestone forest in the northeastern sector of North Finegayan (Transect 5) contained similar relative densities of the introduced *Vitex* and the endemic *Guamia* trees. *Vitex parviflora* and African tulip (*Spathodea campanulata*) trees comprised the non-native species, with a combined relative density of about 32% (Figure 3.1-7). The three endemic species (*Guamia*, *Eugenia palumbis*, and *Maytenus thompsonii*) comprise about 30% of the relative density.



Note: (N) indicates native species; others are introduced.

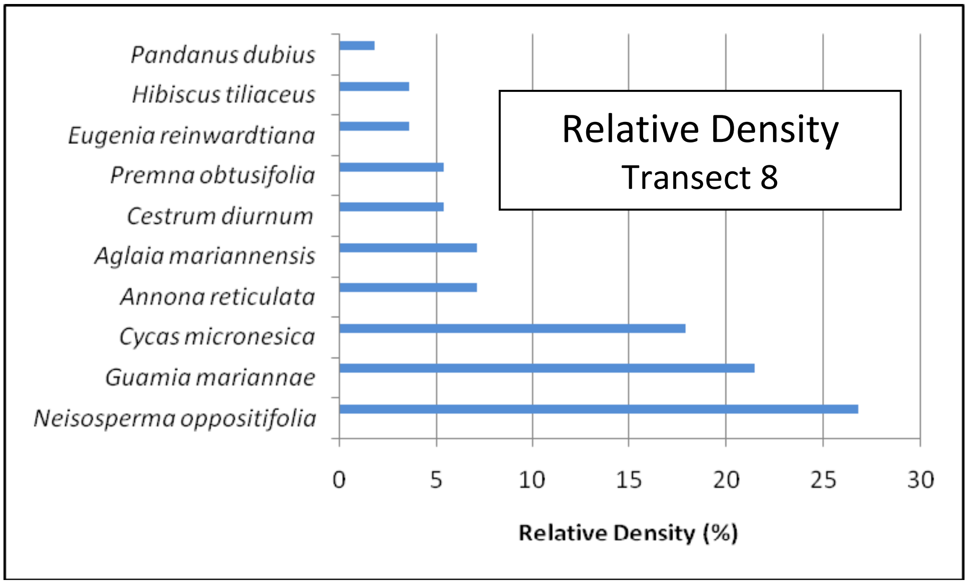
Figure 3.1-6. Relative density (%) of trees in north-central sector at North Finegayan.



Note: (N) indicates native species; others are introduced.

Figure 3.1-7. Relative density (%) of trees in northeastern sector at North Finegayan.

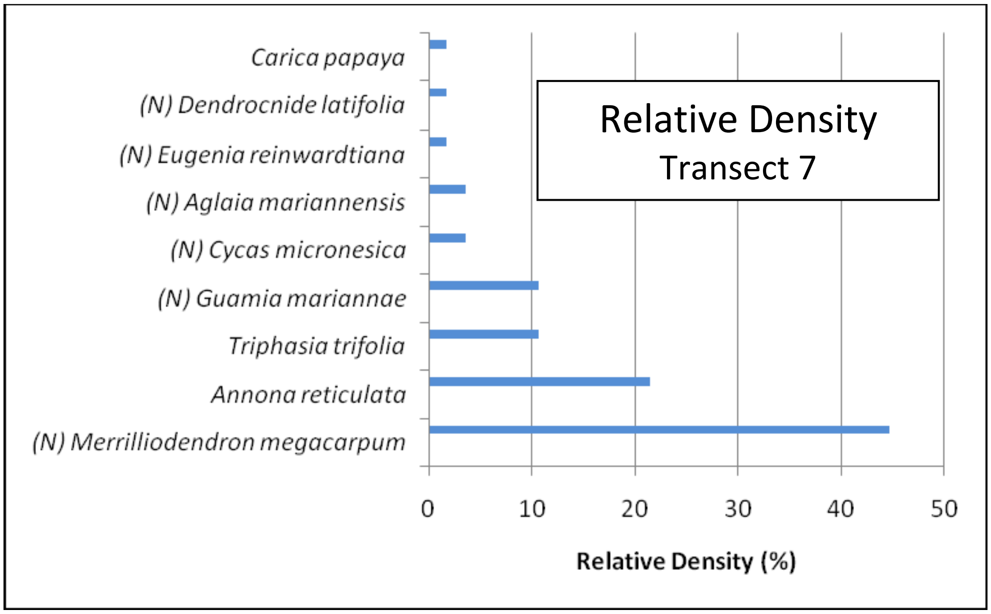
The northwestern sector of North Finegayan contains limestone forest along the western coast and upper plateau with the highest relative density (66%) of native tree species among the areas sampled (Figure 3.1-8). The two non-native species, *Annona squamosa* and *Cestrum diurnum*, comprised 12% of the relative density, while the endemic species, *Guamia* and *Aglaia*, comprised 28%. The forest in this area also had the highest relative density of native cycad trees (*Cycas micronesica*), with approximately 18%.



Note: (N) indicates native species; others are introduced.

Figure 3.1-8. Relative density (%) of trees in northwestern sector at North Finegayan.

The west-central sector of North Finegayan in the vicinity of Pugua Point (Transect 7) contains limestone forest with a native species density of 66% and a pronounced *Merrilliodendron megacarpum* component (Figure 3.1-9). *Merriolliodendron* is an indigenous species found in only a few localities on Guam because of its restricted habit. Non-native species comprised 34% of the relative density; *Annona*, *Triphasia*, and *Carica* are successful introductions that have long been naturalized in native forests. Endemic species (*Guamia* and *Aglaia*) accounted for 14% of the relative density. The native cycad, *Cycas micronesica*, had a low density of only 3%.



Note: (N) indicates native species; others are introduced.

Figure 3.1-9. Relative density (%) of trees in northwestern sector at North Finegayan.

The final area sampled in the North Finegayan annex was a coconut (*Cocos nucifera*) grove in the Haputo ERA embayment along the western coast (Figure 3.1-10). The area is located close to sea level below the limestone plateau of the main annex. Nonag (*Hernandia peltata*), an indigenous tree, had a relative density of about 22%; coconut palms comprised the remainder of the trees along this transect.

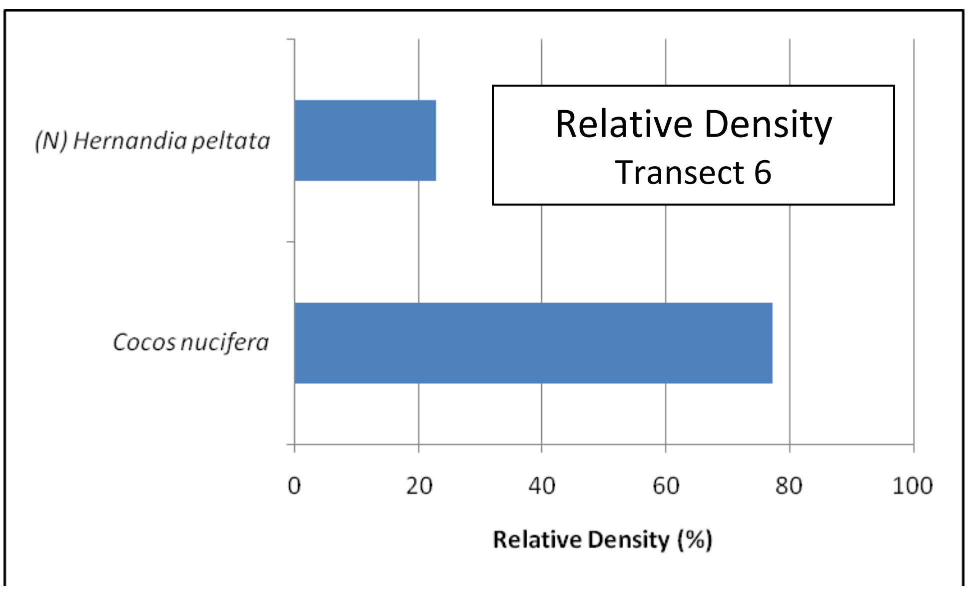


Figure 3.1-10. Relative density (%) of trees in southwestern sector at North Finegayan.

The percentage of native woody seedlings quantified along the transects exceeded 80% for Transects 4 and 8 in the northern and northwestern sectors on the upper plateau, and Transect 7 along the west-central coast (Figure 3.1-11). Elsewhere, the percentage was less than 60% native woody seedlings.

The mean woody seedling density for all transects at North Finegayan was slightly higher for native species (1.71 seedlings per SM) than for introduced species (1.12 seedlings per SM) (Figure 3.1-12).

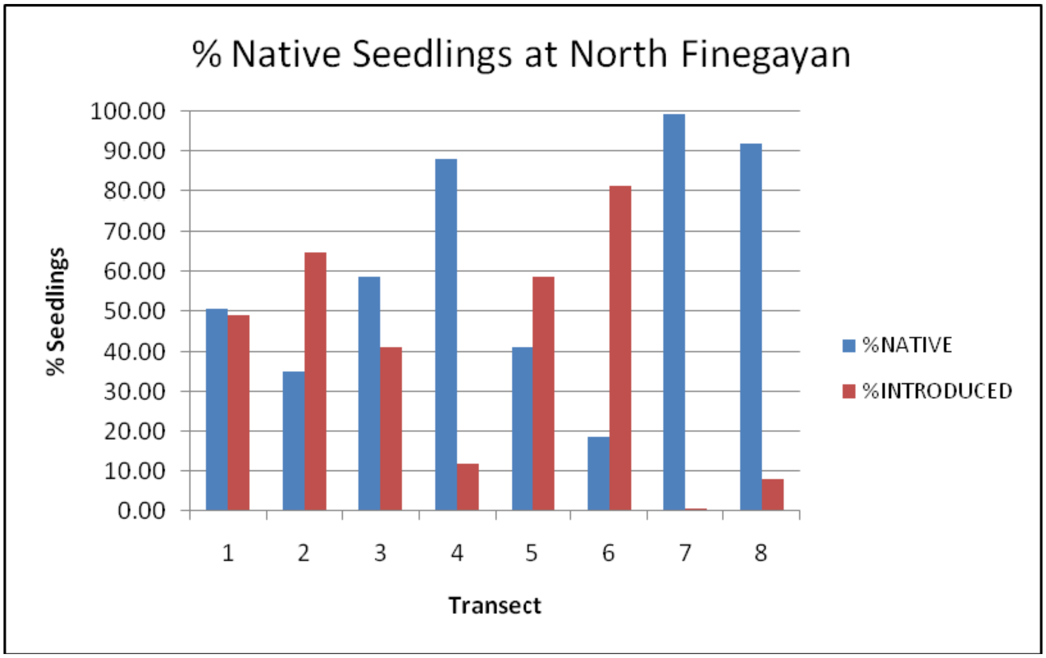


Figure 3.1-11. Native woody seedlings along all transects at North Finegayan.

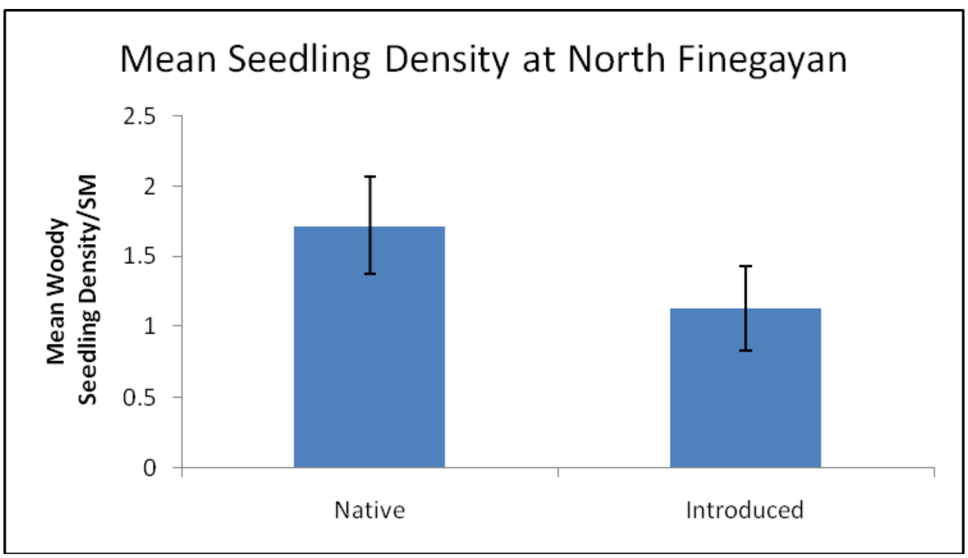


Figure 3.1-12. Mean density of woody seedlings along all transects at North Finegayan.

3.1.4 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat at North Finegayan. These include the ungulate activity, presence of erosion, the percent of native plant species, and overall species richness.

The species richness for tree species across all transects was calculated with a 95% confidence interval and is presented in Figure 3.1-13. Species richness for all transects at North Finegayan was 24 species (Figure 3.1-13).

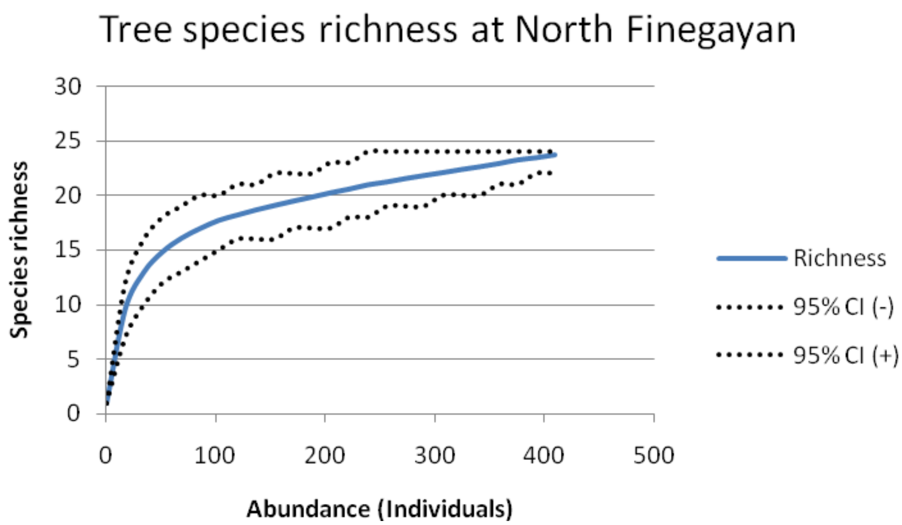


Figure 3.1-13. Species richness of trees along all transects at North Finegayan.

Analysis of individual transects revealed significantly lower species richness in the coconut grove of Transect 6 compared to all other sites (Figure 3.1-14; 95% confidence intervals not shown). This transect was in the lower plateau and lacked many of the woody species observed in the remaining seven transects. Similar species richness values were observed for Transect 5 in the northeastern sector, and Transect 8 in the northwestern sector, which are both on the upper plateau.

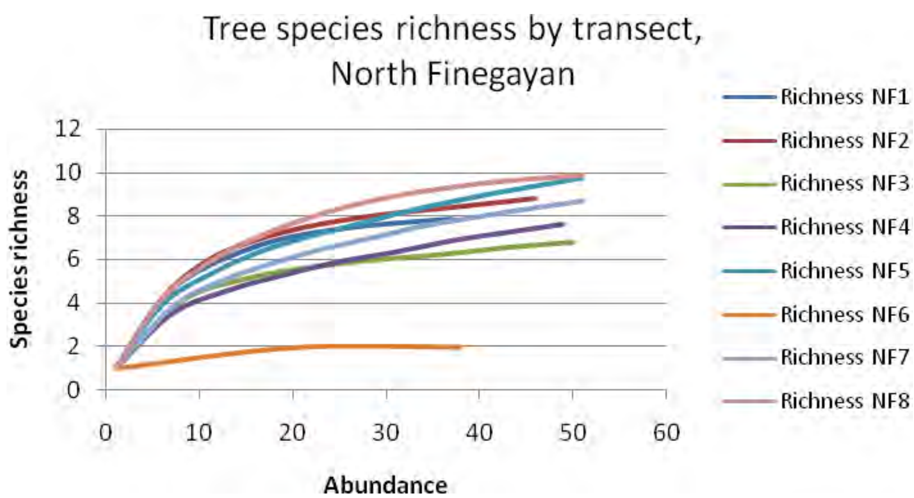


Figure 3.1-14. Species richness of trees along each transect at North Finegayan.

Ungulate activity was observed most frequently in the form of rubbings on tree trunks and browsing (Figure 3.1-15). Soil disturbance, such as wallows, was less frequently observed at North Finegayan.

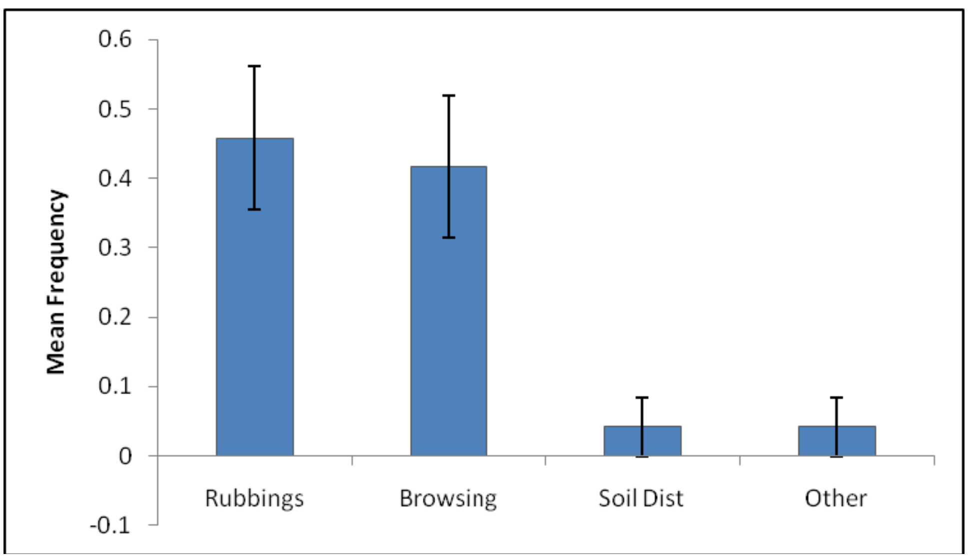


Figure 3.1-15. Mean frequency of ungulate activity along all transects at North Finegayan.

The ground cover along all transects at North Finegayan showed a high mean frequency of litter and relatively low mean frequencies of bare soil and rock (Figure 3.1-16).

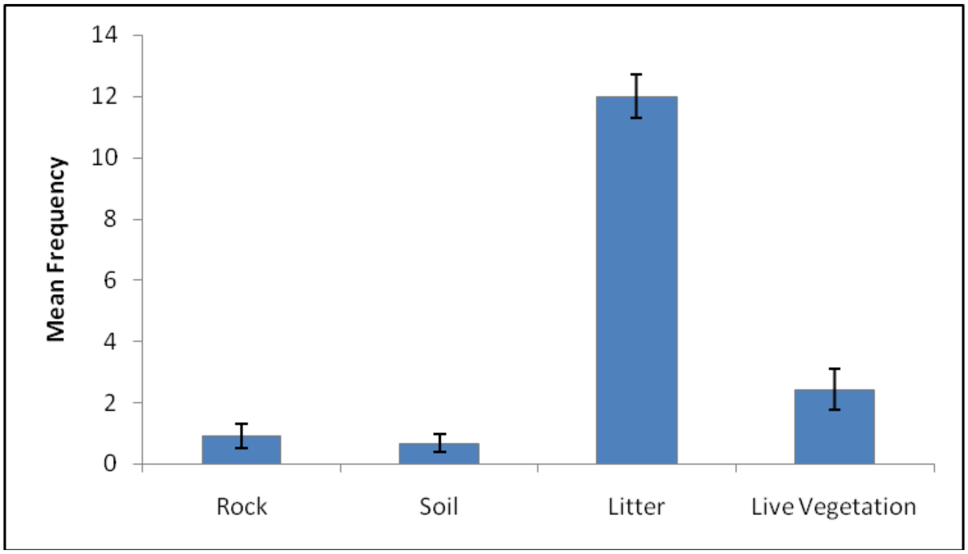


Figure 3.1-16. Mean frequency of ground cover along all transects at North Finegayan.

An example of the type of ungulate disturbance observed at North Finegayan is shown in Figure 3.1-17. Ungulates, most likely feral pigs, have toppled a fadang (*Cycas micronesica*) specimen, possibly to feed on the pith material in the trunk.

Figure 3.1-17. Ungulate damage to *Cycas micronesica*, Transect 8, North Finegayan.

3.1.5 Sensitive Species

3.1.5.1 Threatened and Endangered Species

None of the locally-listed or federally-listed endangered plants (see Table 2.2-1) were detected during the current survey in North Finegayan. BioSystems Analysis, Inc. (1989) did not detect *Heritiera longipetiolata* in their natural resources survey of Navy Finegayan, but noted that it is known to occur in the Haputo ERA.

The Haputo ERA provides habitat for the Pacific tree snail (*Partula radiolata*) and the last remaining colony of Mariana tree snails (*Partula gibba*) on Guam. These species are among the endemic tree snails locally-listed as threatened (*Partula radiolata*) or endangered (*Partula gibba*), and federally-listed as candidate species.

3.1.5.2 Species of Concern

Species of concern are those plants that have biological or cultural significance as determined by recognized authorities or regulatory agencies. The Guam Department of Agriculture/ Division of Aquatic and Wildlife Resources currently lists five plants among the Species of Greatest Conservation Need (SOGCN) for the island, based on certain criteria (see Table 2.2-1). Two SOGCN were observed at North Finegayan during the current survey: faniok (*Merrilliodendron megacarpum*) and fadang (*Cycas micronesica*). According to the *Guam Comprehensive Wildlife Conservation Strategy*, faniok is threatened by herbivory, typhoons, and development (Department of Agriculture, 2006). A faniok stand is present along Transect 7 close to sea level in the west-central sector of the installation. Fadang is typically distributed over limestone and volcanic substrates; however, populations islandwide are in decline from infestation by the Asian cycad scale (*Aulacaspis yasumatsui*) (Department of Agriculture, 2006). Fadang was quantified only on Transect 7 in the west-central sector, and Transect 8 in the northwestern sector of the upper plateau. These areas also had the most native tree species among those surveyed.

At North Finegayan, BioSystems Analysis, Inc. (1989) identified the following species of interest, which are rare or unusual but not subject to regulatory control or management at this time.

- *Balanophora indica* or chili-n-duendas is an endemic herb that is parasitic on the roots of autotrophic forest trees, such as *Cynometra* and *Guamia* (Stone, 1970).
- *Lycopodium phlegmaria*, or cordon de San Francisco, is an epiphytic club moss found in moist limestone forest sites at Finegayan.
- *Thelypteris truncata* is an indigenous fern of the Haputo ERA area.
- *Bulbophyllum longiflorum* is an indigenous orchid of the forest above Haputo ERA.
- *Geophila repens*, or tamanes-hating, is a native herb that has only been found at Haputo.
- *Merrilliodendron megacarpum*, or faniok, is an indigenous tree that occurs as a small stand south of Double Reef.

Of these, only *Merrilliodendron* was detected in the current survey.

The following species were identified within North Finegayan during the present survey.

- *Zeuxine fritzii* is an indigenous ground orchid found on the forest floor of Transects 3 and 5.
- *Nervilia aragoana* is an indigenous ground orchid found on the forest floor of Transects 3 and 5.

Although notable, these species are not subject to management controls or regulations on Guam.

3.2 South Finegayan

3.2.1 Location

South Finegyan is located adjacent and south of the Federal Aviation Administration (FAA) parcel, and east of the Guam Land Use Plan (GLUP) 77 parcel in northwestern Guam. The installation extends along Route 3 in Dededo. The land use is primarily residential.

3.2.2 Previous Studies

The previous vegetation studies at North Finegayan discussed under Section 3.1.2. did not encompass South Finegayan.

3.2.3 Quantitative Observations

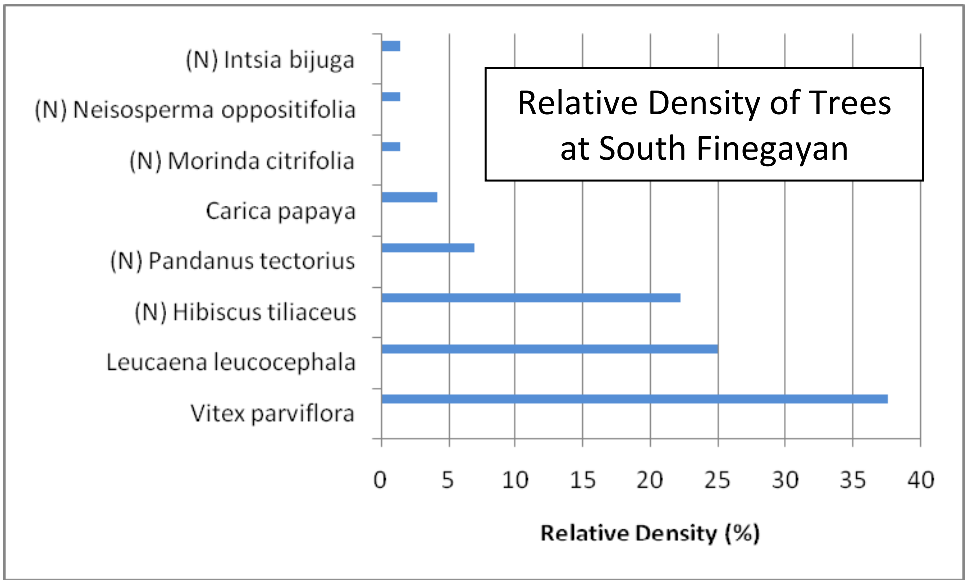
Surveys were performed along two transects in the central sector of South Finegayan (see Attachment A). The vegetation community is a disturbed limestone forest dominated by *Vitex parviflora*, tangantangan (*Leucaena leucocephala*) and pago (*Hibiscus tiliaceus*). The results of point-center quarter surveys are summarized in Table 3.2-1.

The relative density of tree species in South Finegyan (Figure 3.2-1) show the non-native *Vitex*, tangantangan (*Leucaena leucocephala*) and papaya (*Carica papaya*) comprised 67%. The remaining five native species comprised 33% of the density; none are endemic to the Marianas.

Table 3.2-1

SF-1 and SF-2, SOUTH FINEGAYAN, March 2008

SPECIES	STATUS	NO. TREES IN QTRS.	NO. SPECIES IN 100 SM	TOTAL BASAL AREA (sq. cm)	MEAN BASAL AREA (sq. cm)	ABSOLUTE DOMINANCE	ABSOLUTE FREQUENCY
Leucaena leucocephala	I	18	5.19	#VALUE!	44.50	230.93	50.00
Hibiscus tiliaceus	N	16	4.61	#VALUE!	77.39	356.97	38.89
Vitex parviflora	I	27	7.78	#VALUE!	361.34	2812.42	72.22
Pandanus tectorius	N	5	1.44	#VALUE!	52.54	75.73	22.22
Morinda citrifolia	N	1	0.29	#VALUE!	3.80	1.10	5.56
Neisosperma oppositifolia	N	1	0.29	#VALUE!	86.55	24.95	5.56
Carica papaya	I	3	0.86	#VALUE!	138.14	119.47	16.67
Intsia bijuga	N	1	0.29	#VALUE!	41.83	12.06	5.56



Note: (N) indicates native species; others are introduced.

Figure 3.2-1. Relative density (%) of trees at South Finegayan.

The density of trees in South Finegayan was approximately 21 trees per 100 SM, or 2,100 trees per hectare (Table 3.2-1). *Vitex parviflora* had the highest density (7.78 trees per 100 SM) and dominance among the trees surveyed. Five of the eight tree species (63%) surveyed are native to Guam. These include *Hibiscus tiliaceus*, *Pandanus tectorius*, *Morinda citrifolia*, *Neisosperma oppositifolia*, and *Intsia bijuga*.

The relative density of native trees was 33% for both transects at South Finegayan (Figure 3.2-2). The low native tree component may be attributed to past clearing activities at the site, which is adjacent to a fenced area enclosing what appears to be a hazardous waste remediation site.

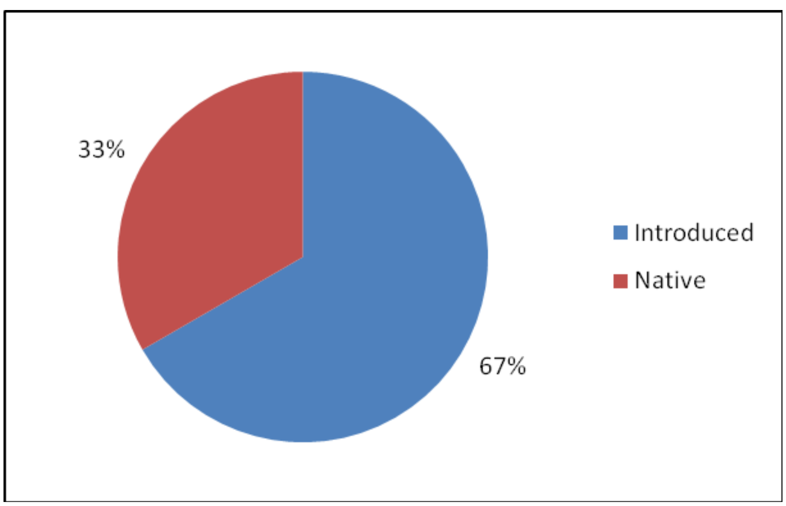


Figure 3.2-2. Relative density of native tree species at South Finegayan.

The mean woody seedling density at South Finegayan was lower for native species (1.46 seedlings per SM) than for introduced species (4.06 seedlings per SM) (Figure 3.2-3).

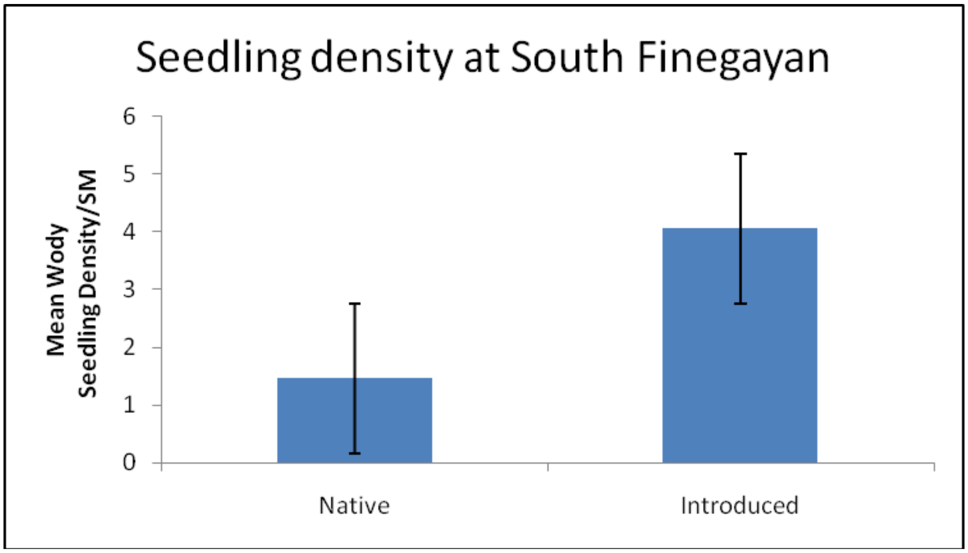


Figure 3.2-3. Seedling density of woody species at South Finegayan.

3.2.4 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat at South Finegayan. These include the ungulate activity, presence of erosion, the percent of native plant species, and overall species richness. The species richness for tree species at South Finegayan is presented in Figure 3.2-4.

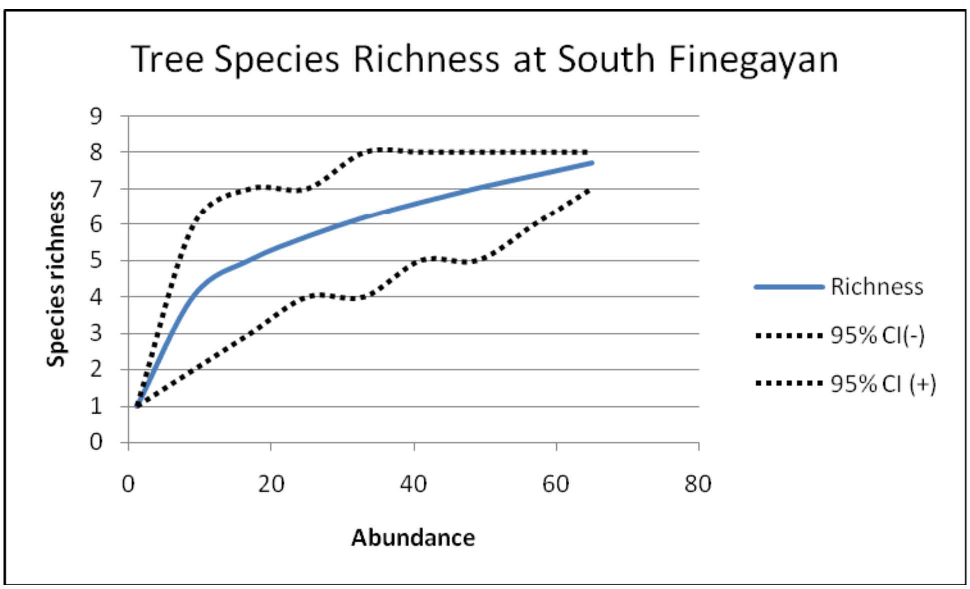


Figure 3.2-4. Species richness of trees at South Finegayan.

The ungulate activity at South Finegayan fell into two categories: rubbings and soil disturbance (Figure 3.2-5).

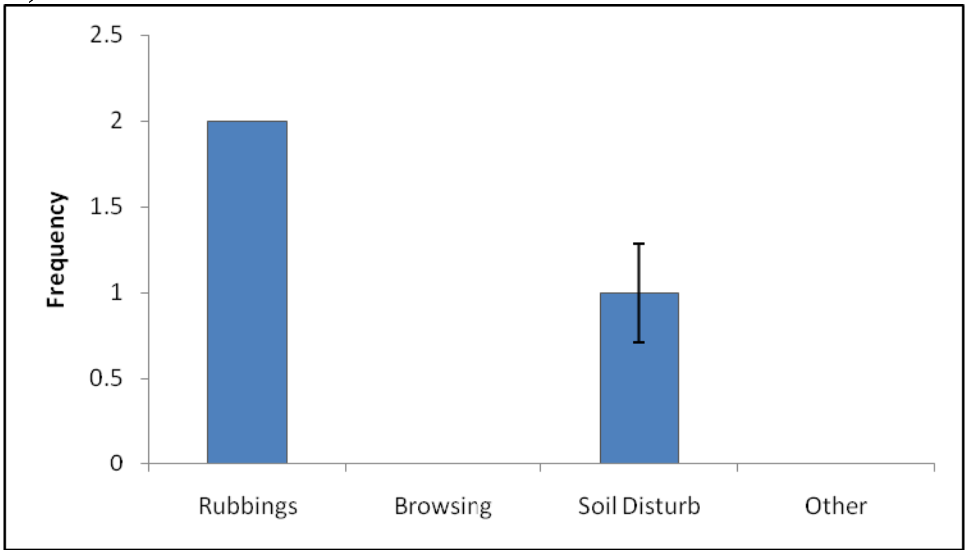


Figure 3.2-5. Mean frequency of ungulate activity at South Finegayan.

The ground cover at South Finegayan was primarily in the form of litter (Figure 3.2-6). Little live vegetation was detected.

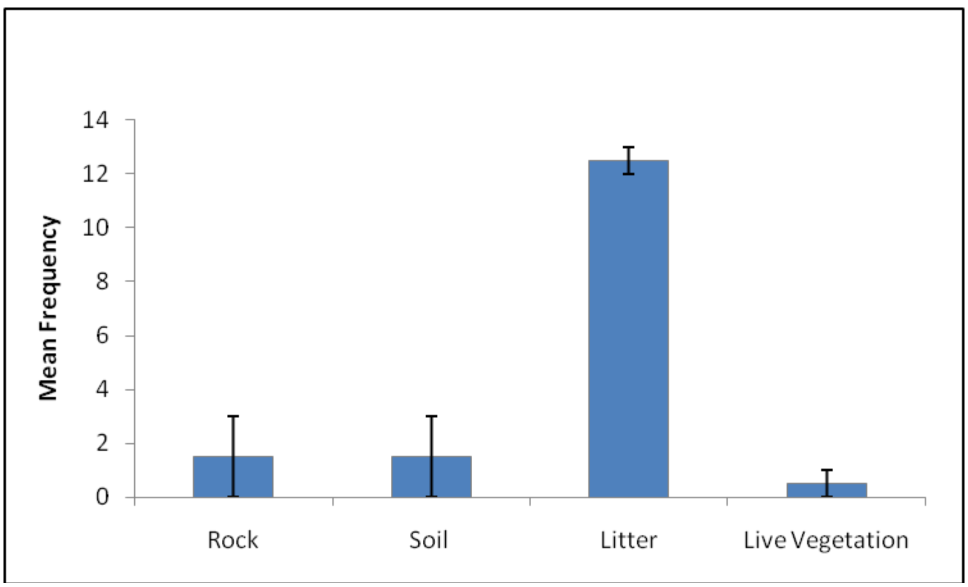


Figure 3.2-6. Mean frequency of ground cover at South Finegayan.

3.2.5 Threatened and Endangered Species and Species of Concern

No species listed as threatened or endangered, either by the Federal or local government, were observed along the transects at South Finegayan. Similarly, no species of concern were observed along the transects at South Finegayan.

3.3 Navy Barrigada

3.3.1 Location

Navy Barrigada is located in north-central Guam in the Municipality of Barrigada. The installation encompasses 1,848 acres with access from Route 15 on the west and Route 16 on the east. The primary land use is communication-related, with antenna fields and support facilities in the eastern and western sectors; a golf course is present in the southern sector of the installation.

Figure 3.3-1. *Cycas micronesica* in limestone forest along Transect 2, Navy Barrigada.

3.3.2 Previous Studies

The previous studies at Navy Barrigada include the BioSystems Analysis (1989) report that also documented the vegetation at Navy Finegayan. The report identified the following plant communities at Navy Barrigada: freshwater wetlands (4 acres), weeds with scattered shrubs (430 acres), cultivars (90 acres), tangantangan scrub forest (280 acres), limestone forest (350 acres), and degraded limestone forest (210 acres) (BioSystems Analysis, Inc., 1989).

3.3.3 Quantitative Observations

Much of Navy Barrigada comprises improved and unimproved roads, open fields and weedy vegetation, with the remaining forested areas mainly concentrated around Mt. Barrigada between two vast antenna fields. Surveys were performed along two transects in the north-central sector of Navy Barrigada (Attachment A): Transect 1 along an east-west axis near the toe of Mt. Barrigada, and Transect 2 along a north-south axis to the southwest of Transect 1 (Figure 3.3-1). Both transects were within limestone forest community mapped by BioSystems Analysis, Inc. (1989).

Tree density, dominance and frequency were quantified using the point-center quarter method and summarized for both transects (Table 3.3-1).

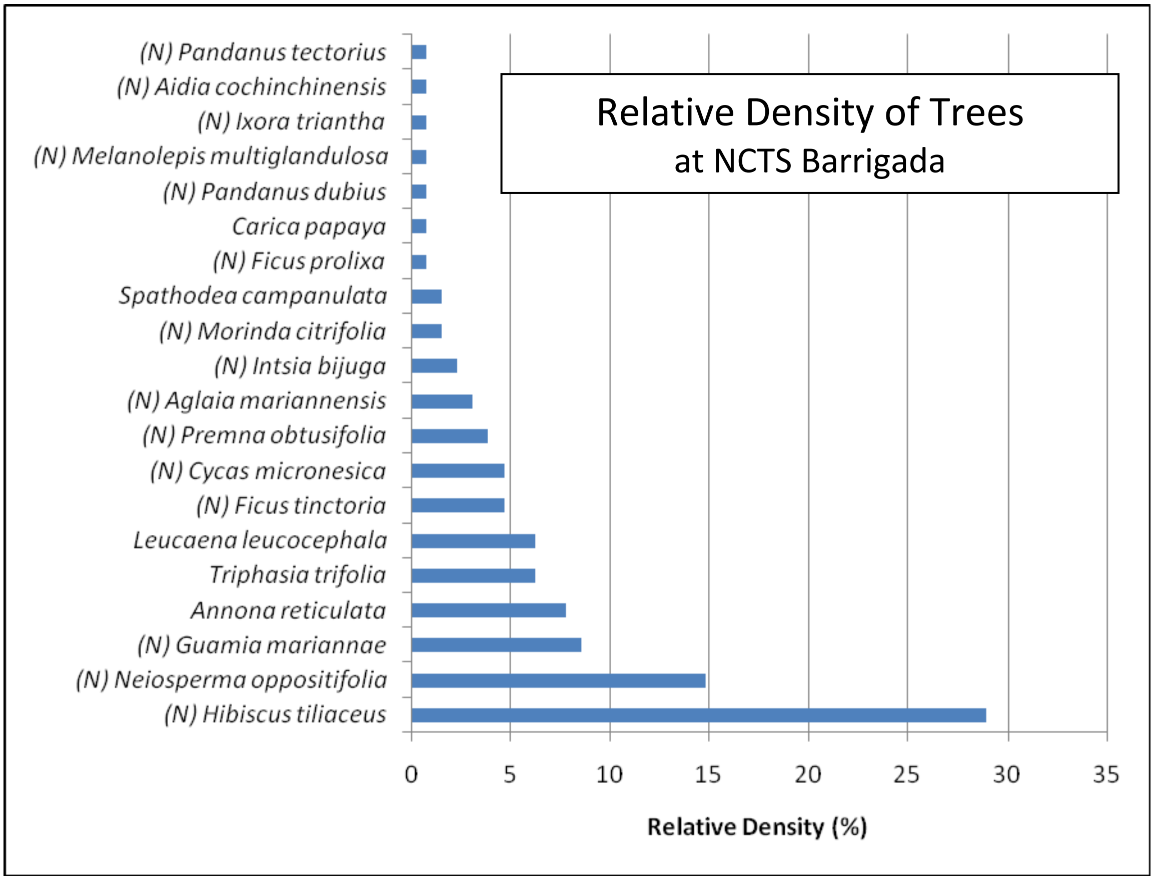
Table 3.3-1

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST NAVY BARRIGADA, FEBRUARY 2008							
SPECIES	STATUS	NO. TREES IN QTRS.	NO. SPECIES IN 100 SM	BASAL AREA (sq. cm)	MEAN BASAL AREA (sq. cm)	ABSOLUTE DOMINANCE	ABSOLUTE FREQUENCY
Hibiscus tiliaceus	N	37	12.59	2316.62	62.61	788.21	59.38
Neiosperma oppositifolia	N	19	6.46	1917.15	100.90	652.29	37.50
Guamia mariannae	N	11	3.74	615.38	55.94	209.38	25.00
Annona reticulata	I	10	3.40	479.28	47.93	163.07	18.75
Triphasia trifolia	I	8	2.72	396.80	49.60	135.01	18.75
Aglaia mariannensis	N	4	1.36	270.89	67.72	92.17	12.50
Ficus tinctoria	N	6	2.04	1046.92	174.49	356.20	9.38
Morinda citrifolia	N	2	0.68	54.67	27.33	18.60	3.13
Spathodea campanulata	I	2	0.68	225.08	112.54	76.58	3.13
Leucaena leucocephala	I	8	2.72	438.57	54.82	149.22	15.63
Ficus prolixa	N	1	0.34	3726.56	3726.56	1267.93	3.13
Cycas micronesica	N	6	2.04	1796.87	299.48	611.37	15.63
Carica papaya	I	1	0.34	116.84	116.84	39.75	3.13
Pandanus dubius	N	1	0.34	41.83	41.83	14.23	3.13
Melanolepis multiglandulosa	N	1	0.34	22.89	22.89	7.79	3.13
Ixora triantha	N	1	0.34	4.91	4.91	1.67	3.13
Premna obtusifolia	N	5	1.70	1070.45	214.09	364.21	12.50
Intsia bijuga	N	3	1.02	151.49	50.50	51.54	9.38
Aidia cochinchinensis	N	1	0.34	8.04	8.04	2.73	3.13
Pandanus tectorius	N	1	0.34	10.75	10.75	3.66	3.13

Twenty species were quantified along the transects. The highest dominance observed was for the banyan tree (*Ficus prolixa*), an overstory species with numerous aerial roots that contribute to its large footprint. The species with the second and third highest dominance were pago (*Hibiscus tiliaceus*) and fago (*Neisosperma oppositifolia*), which typically occupy the overstory. All three species are native to Guam. It is interesting that the seeded breadfruit or dugdug (*Artocarpus mariannensis*) was not quantified on these transects, although this was cited as a dominant species of the Navy Barrigada limestone forest by BioSystems Analysis, Inc. (1989). Dugdug may be more common on the slopes of Mt. Barrigada where the forest is more intact.

The point-center quarter observations revealed the highest frequencies were for pago (*Hibiscus tiliaceus*), followed by fago (*Neisosperma oppositifolia*) and paipai (*Guamia mariannae*). Paipai is a native forest understory species. Two introduced species, custard apple (*Annona reticulata*) and lemonchina (*Triphasia trifolia*), had the next highest frequency values. Although they are not native components, these species have become naturalized in other limestone forests around the island.

The overall density of trees was calculated at 43.55 trees per 100 SM. The native species pago (*Hibiscus tiliaceus*), fago (*Neisosperma oppositifolia*) and paipai (*Guamia mariannae*) had the highest three relative densities of approximately 29%, 14% and 9%, respectively (Figure 3.3-2).



Note: (N) indicates native species; others are introduced.

Figure 3.3-2. Relative density (%) of tree species, Navy Barrigada.

Native species had a combined relative density of approximatley 77%, far exceeding the relative density of introduced species for both transects at Navy Barrigada (Figure 3.3-3).

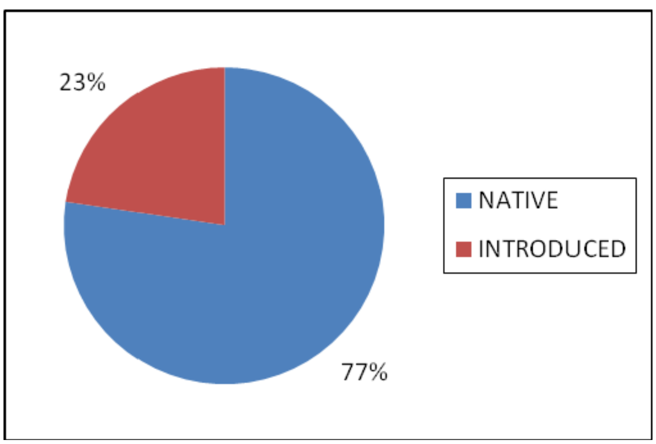


Figure 3.3-3. Relative density (%) of native and introduced tree species, Navy Barrigada.

A comparison of the woody seedling density revealed a higher density for Transect 2 (Figure 3.3-4). Both transects, however, showed markedly higher densities of native over introduced species.

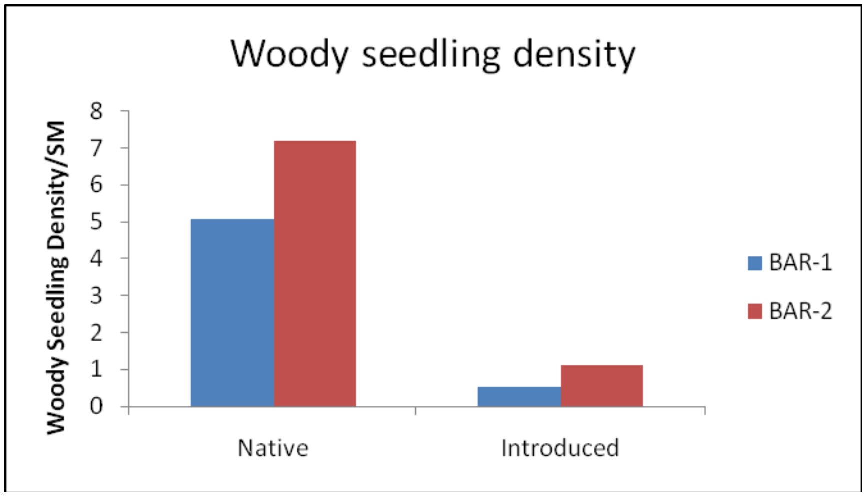


Figure 3.3-4. Density of woody seedlings along Transects 1 and 2, Navy Barrigada.

3.3.4 **Habitat Quality**

The habitat quality at Navy Barrigada may be described through the level of ungulate activity, percent of native species, and overall species richness.

Species richness calculated for the two transects was higher for Transect 2 (Figure 3.3-5). Nevertheless, the species richness × abundance curves for both transects had similar shapes and inflection points.

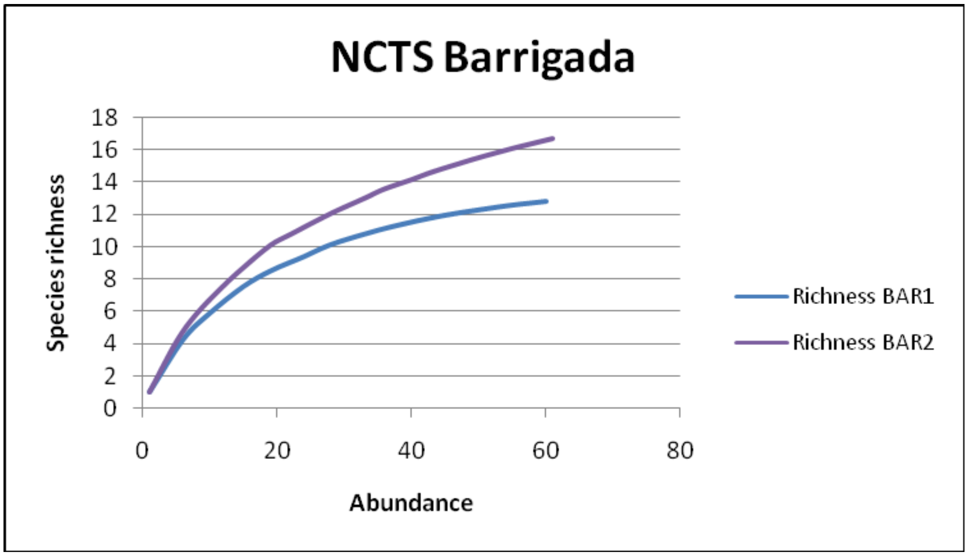


Figure 3.3-5. Species richness for Transects 1 and 2, Navy Barrigada.

There was no ungulate activity quantified at the transect stations during the survey. The ground cover observations revealed a high frequency of leaf litter (Figure 3.3-6). Bare soil, rock and live vegetation had relatively low mean frequencies.

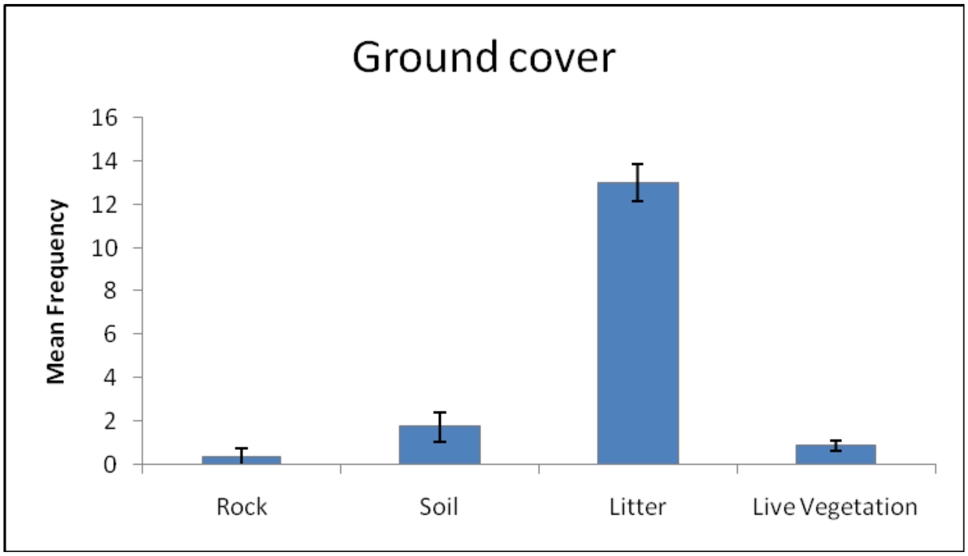


Figure 3.3-6. Mean frequency of ground cover along all transects, Navy Barrigada.

3.3.5 Threatened and Endangered Species and Species of Concern

3.3.5.1 Threatened and Endangered Species

Figure 3.3-7. *Partula radiolata* on *Neisosperma* leaf at Transect 2, Navy Barrigada.

BioSystems Analysis, Inc. (1989) identified no threatened or endangered species at Navy Barrigada. Likewise, no plant species listed as threatened or endangered were identified within Navy Barrigada during the current survey.

Live specimens of the Pacific tree snail (*Partula radiolata*) were found on fago (*Neisosperma oppositifolia*) along Transect 2 in the central sector (Figure 3.3-7). The Pacific tree snail is listed as threatened on the local endangered species list.

3.3.5.2 Species of Concern

BioSystems Analysis, Inc. (1989) reported that no species or habitats of concern were found at Navy Barrigada. The current survey found one species of concern, fadang (*Cycas micronesica*), which is considered a SOGCN by the local Department of Agriculture. Fadang was found along Transects 1 and 2, with densities of 3.81 and 0.61 trees per 100 SM, respectively. Specimens were not in good health and often topped by epiphytes, such as bird's nest fern (*Asplenium nidus*) (see Figure 3.3-1). BioSystems Analysis, Inc. (1989) cited fadang among the dominant species in the limestone forest at Navy Barrigada.

Figure 3.3-8. *Eulophia graminea* on Transect 1, Navy Barrigada.

The presence of other uncommon species found in the current survey was also noted. These include *Nervilia aragoana* (Orchidaceae), an indigenous ground orchid, and *Eulophia graminea* (Orchidaceae), a possibly introduced ground orchid (Figure 3.3-8).

3.4 Andersen South

3.4.1 Location

The Andersen South Housing Area, commonly known as Andy South, is an approximately 2,432-acre area located in the northeastern sector of Guam, inland and adjacent to Route No. 15. The official name is the Marianas Bonins Command (MARBO) Annex. Andy South comprises residential units in the southern sector, and scattered infrastructure facilities in the remaining areas; however, the majority of the Annex is undeveloped.

3.4.2 Quantitative Observations

Figure 3.4-1. *Averrhoa bilimbi* stand along Transect 3, Andersen South.

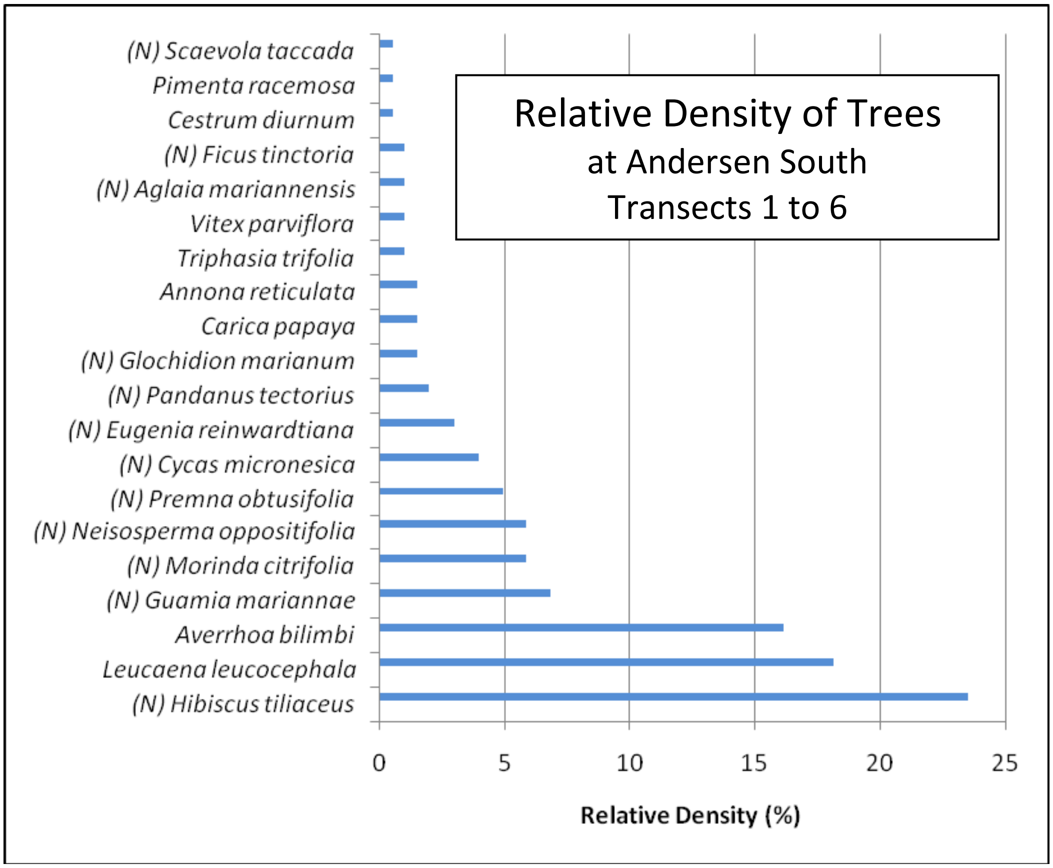
Quantitative surveys were performed along 6 transects in the forested sectors. Transects 1 through 3 were within the central area (Figure 3.4-1), Transect 4 was in the southwestern sector, and Transects 5 and 6 were in the northwestern sector (Attachment A).

The point-center quarter survey results are summarized in Table 3.4-1. The overall density for the six transects was calculated at 21.96 trees per 100 SM. The native pago (*Hibiscus tiliaceus*) is an important species in these forests. Pago had the highest relative density (approximately 24%) (Figure 3.4-2) and highest frequency among species, with specimens quantified on five of the six transects. Pago was also the third most dominant species at Andy South, following the introduced pickle tree (*Averrhoa bilimbi*) and endemic paipai (*Guamia mariannae*). *Averrhoa* and another introduced species, tangantangan (*Leucaena leucocephala*), followed pago with the next highest frequencies at approximately 33 each. *Averrhoa* was common along the transects in the central sector (see Figure 3.4-2); however, it was recorded on every transect at Andy South. Aside from pickle tree, other non-native species in the survey, such as papaya (*Carica papaya*) and custard apple (*Annona reticulata*), produce edible fruits that are likely dispersed by ungulate activity.

Table 3.4-1

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST
AS-1 THROUGH AS-6, ANDERSEN SOUTH, MARCH 2008

SPECIES	STATUS	NO. TREES IN QTRS.	NO. SPECIES IN 100 SM	TOTAL BASAL AREA (sq. cm)	MEAN BASAL AREA (sq. cm)	ABSOLUTE DOMINANCE	ABSOLUTE FREQUENCY
Averrhoa bilimbi	I	33	3.55	5575.11	168.94	600.16	33.33
Guamia mariannae	N	14	1.51	4677.56	334.11	503.54	21.57
Hibiscus tiliaceus	N	48	5.17	4139.79	86.25	445.65	49.02
Leucaena leucocephala	I	37	3.98	3742.11	101.14	402.84	33.33
Morinda citrifolia	N	12	1.29	3551.99	296.00	382.37	19.61
Premna obtusifolia	N	10	1.08	3211.63	321.16	345.73	11.76
Pimenta racemosa	I	1	0.11	1734.07	1734.065	186.67	1.96
Neisosperma oppositifolia	I	12	1.29	1585.69	132.14	170.70	17.65
Carica papaya	I	3	0.32	1328.73	442.91	143.04	3.92
Cycas micronesica	N	8	0.86	1117.92	139.74	120.34	11.76
Pandanus tectorius	N	4	0.43	475.32	118.83	51.17	7.84
Vitex parviflora	I	2	0.22	415.12	207.56	44.69	3.92
Glochidion marianum	N	3	0.32	328.50	109.50	35.36	3.92
Annona reticulata	I	3	0.32	127.84	42.61	13.76	3.92
Eugenia reinwardtiana	N	6	0.65	103.11	17.18	11.10	5.88
Cestrum diurnum	I	1	0.11	91.56	91.56	9.86	1.96
Aglaia mariannensis	N	2	0.22	43.36	21.68	4.67	3.92
Triphasia trifolia	I	2	0.22	16.89	8.45	1.82	3.92
Ficus tinctoria	I	2	0.22	10.31	5.15	1.11	1.96
Scaevola taccada	N	1	0.11	4.91	4.91	0.53	1.96

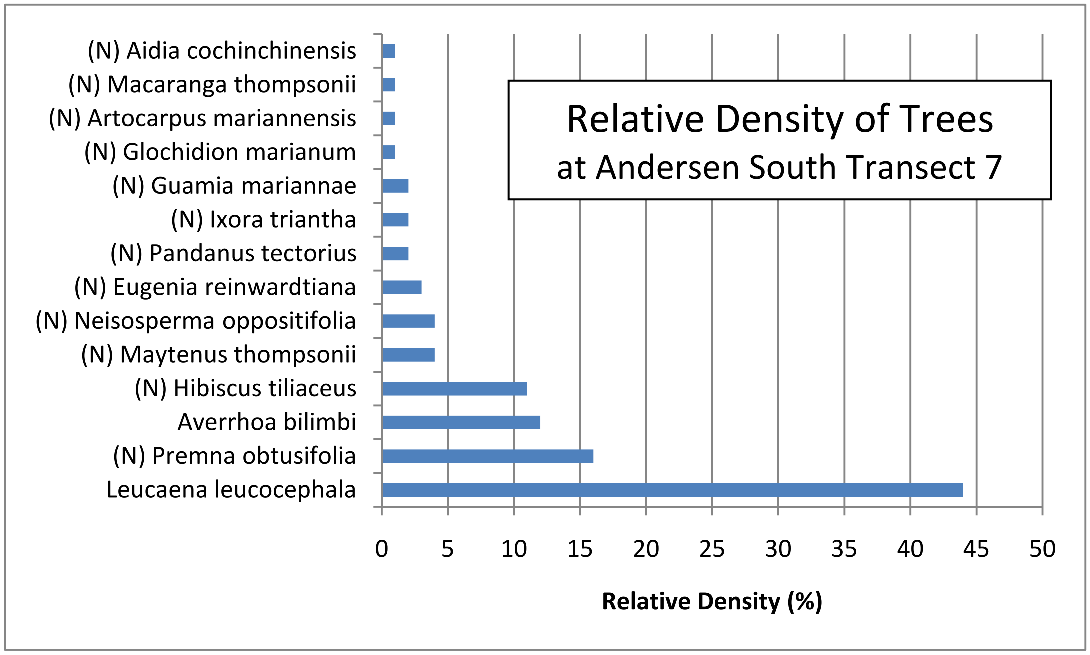


Note: (N) indicates native species; others are introduced.

Figure 3.4-2. Relative density (%) of tree species at Andersen South (Transects 1 to 6).

Of the 20 tree species quantified on the transects, 12 species are native to Guam (Figure 3.4-2). These native species had a collective relative density of 60% at Andy South (Figure 3.4-3). *Vitex parviflora* is a rapidly spreading introduction that is becoming dominant in many of Guam's forests (Department of Agriculture, 2006); however, *Vitex* accounted for less than 2% of the relative density at Andy South with only two specimens quantified on the transects. These specimens had mean basal area of 207 sq. cm, which places them among the larger trees in the forest. The introduced bay-rum tree (*Pimenta racemosa*), a relative of allspice (*P. dioica*), was encountered in the northwestern sector. Although only one specimen was quantified at Andy South (Transect 5), it was fairly large with a basal area of over 1,700 sq. cm. Bay-rum can be invasive, particularly in southern Guam.

One species that was noticeably absent or in low numbers at Andy South was dugdug or dokdok, the native seeded breadfruit (*Artocarpus mariannensis*). A few trees were seen but not surveyed on Transect 4. Dugdug is a characteristic species of native limestone forests in northern Guam (Fosberg, 1960). Specimens of native breadfruit were observed in other sectors of the Annex (i.e., east of Transect 1) that were not included in the sampled areas. The recruitment and distribution of seeded breadfruit at Andy South may be affected by typhoons and ungulate activity, as in other areas of the island.



Note: (N) indicates native species; others are introduced.

Figure 3.4-3. Relative density (%) of tree species at Andersen South Transect 7.

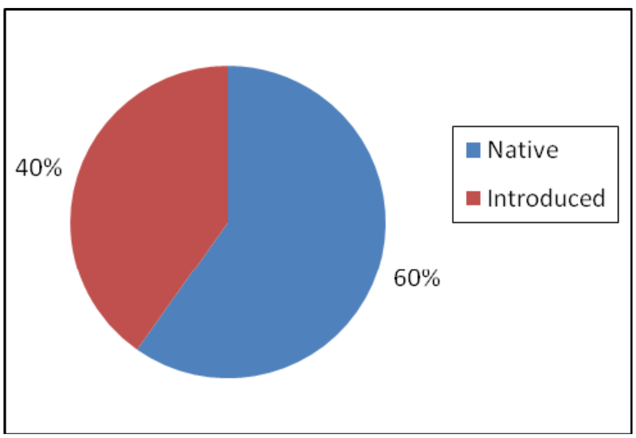


Figure 3.4-3. Relative density of native tree species at Andersen South, Transects 1 to 6.

Plots conducted at stations along the six transects quantified more native than introduced seedlings of woody species (Figure 3.4-4). Native species had a mean density of approximately 4 seedlings/SM; in comparison, introduced species had a mean density of less than 2 seedlings/SM.

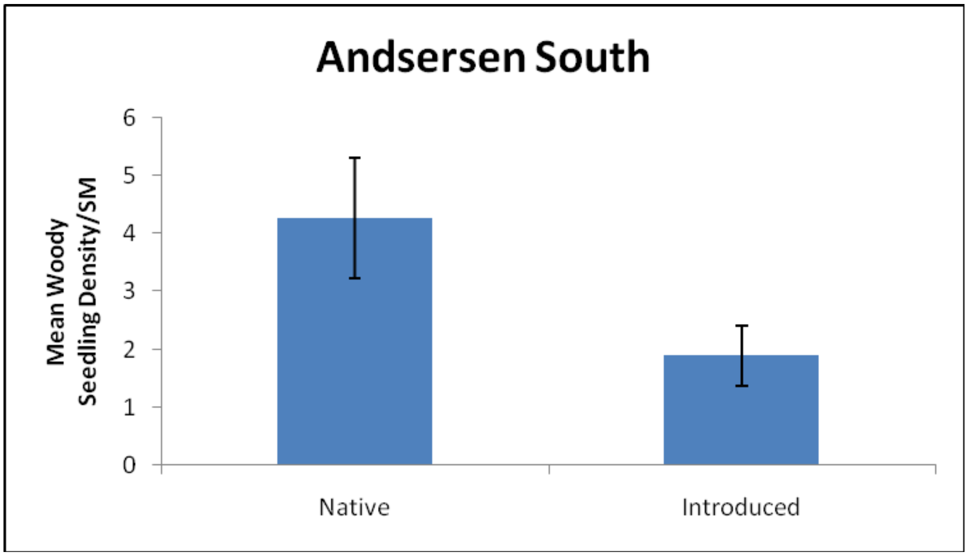


Figure 3.4-4. Mean density of woody seedlings along all transects at Andersen South.

3.4.3 Habitat Quality

The habitat quality at Andersen South may be described through the level of ungulate activity, percent of native species, and overall species richness.

Among the six transect, the calculated species richness was highest for Transect 4 (Figure 3.4-5). Although more points were sampled for Transect 4, rarefaction indicates that it does have a higher species richness than transects with fewer samples. The overall species richness curve for the combined transects is shown in Figure 3.4-6. The forest along Transect 4 is the most intact among the six areas sampled in terms of canopy. The native species ratio is also higher than other Andy South transects, with 10 of the 14 tree species either native or endemic to Guam or the Marianas.

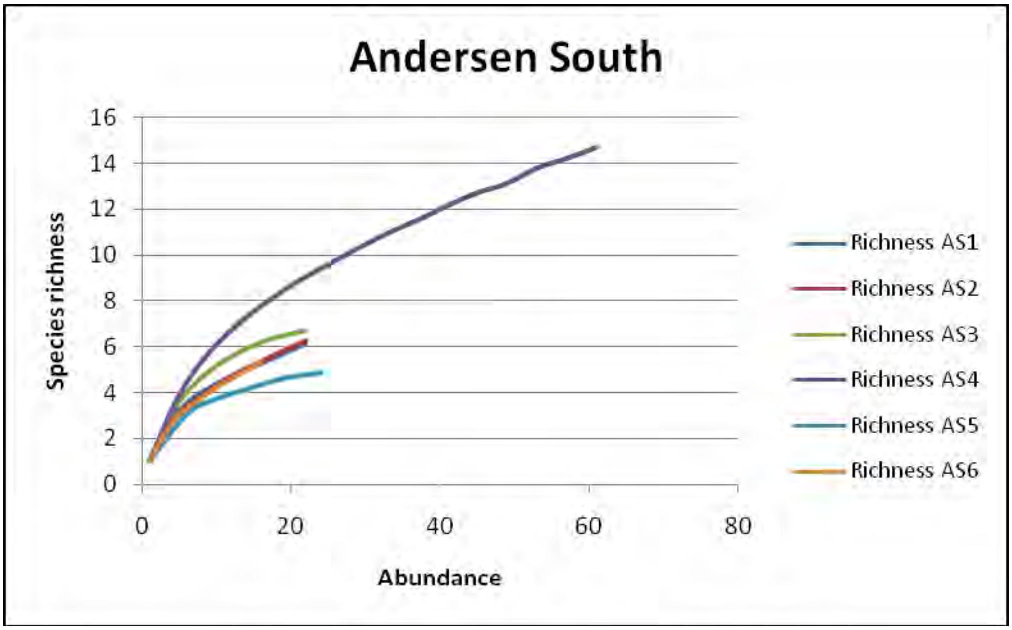


Figure 3.4-5. Species richness of trees along each transect at Andersen South.

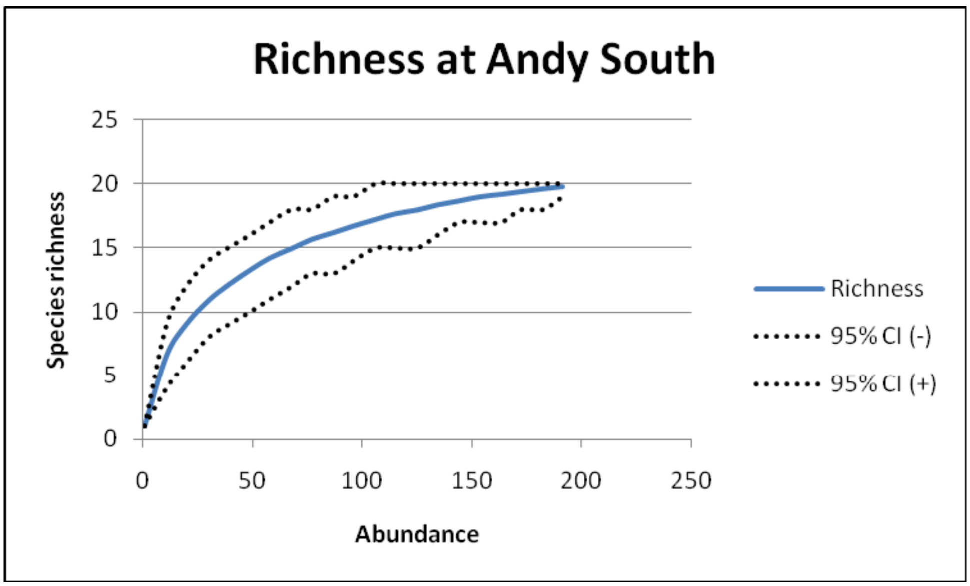


Figure 3.4-6. Species richness of trees along all transects at Andersen South.

The ground cover at Andersen South was quantified for all transects (Figure 3.4-7). Calculations showed leaf litter had the highest mean frequency (11.7) among the four categories of cover. Transects in the central sector of the Annex had high levels of leaf litter mostly beneath pickle tree (*Averrhoa bilimbi*) stands.

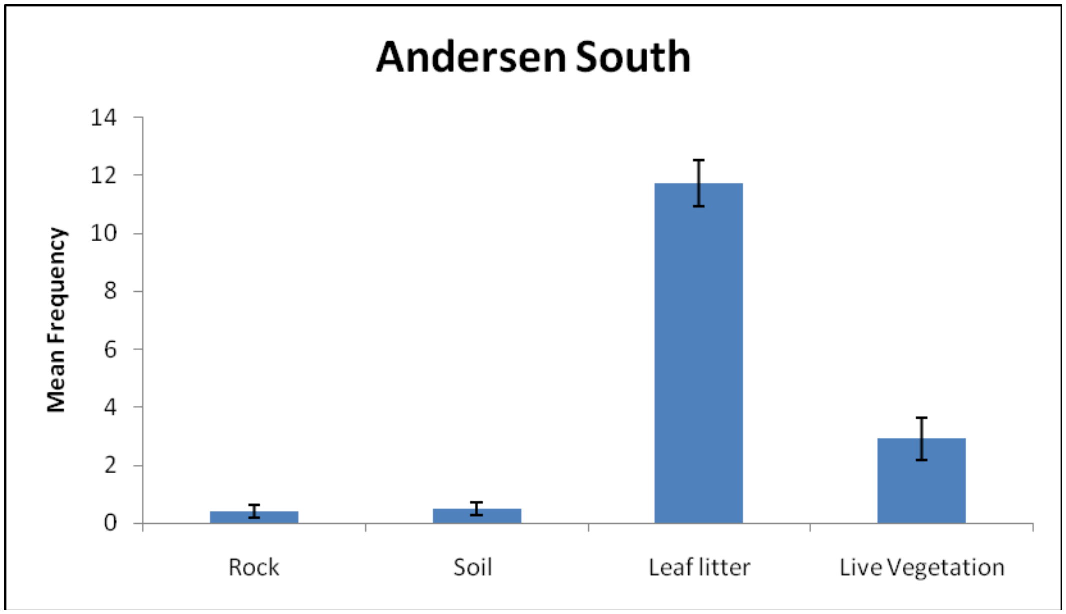


Figure 3.4-7. Mean frequency of ground cover along all transects at Andersen South.

The measure of ungulate activity for all transects revealed that rooting and rubbings were the most common observations, with mean frequencies of 0.59 and 0.50, respectively (Figure 3.4-8).

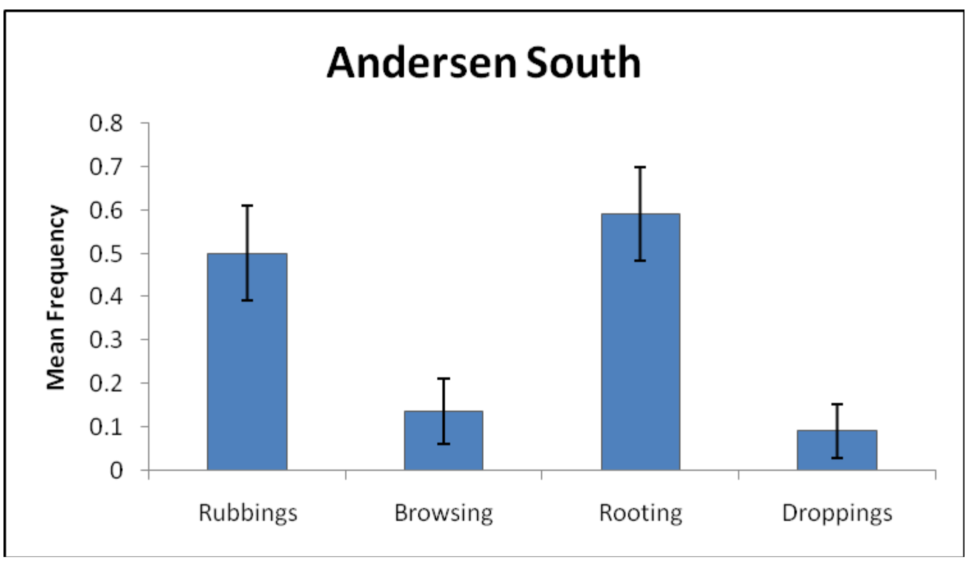


Figure 3.4-8. Mean frequency of ungulate activity along all transects at Andersen South.

3.4.4 Threatened and Endangered Species and Species of Concern

3.4.4.1 Threatened and Endangered Species

No species listed as threatened or endangered were identified within Andersen South during the current survey.

Figure 3.4-9. *Cycas micronesica* along Transect 4, Andersen South.

3.4.4.2 Species of Concern

The only species of concern identified within Andersen South during the current survey was the native cycad or fadang (*Cycas micronesica*). The Department of Agriculture's Division of Aquatic and Wildlife Resources lists fadang among the island's Species of Greatest Conservation Need (SOGCN) because of the threat from the introduced Asian cycad scale (Department of Agriculture, 2006). Both healthy and injured cycads were noted in the survey. Seven specimens were quantified, with the highest density of cycads observed on Transect 4 (3.61 trees per 100 SM) (Figure 3.4-9).

Figure 3.4-10. *Nervilia aragoana* in understory of Transect 4, Andersen South.

Incidental species that are not regulated or managed under local or federal law were also noted on the transects. These include water root orchid or saiyaihayon (*Nervilia aragoana*) (Figure 3.4-10), and (*Zeuxine fritzii*), an inconspicuous ground orchid (Figure 3.4-11).

Figure 3.4-11. *Zeuxine fritzii* in understory of Transect 5, Andersen South.

3.5 Naval Munitions Site

3.5.1 Location

The Naval Munitions Site (NMS) is located in southwestern Guam in the municipality of Agat. NMS is approximately 8,800 acres in size and was formerly known as Naval Magazine and as Ordnance Annex. The site encompasses ordnance storage and disposal, potable water supply infrastructure, and vast areas of watershed and natural communities.

Figure 3.5-1. *Pandanus*-dominated ravine forest along Transect 1, NMS.

3.5.2 Previous Studies

Several studies have been conducted in NMS that address the plant communities. BioSystems Analysis, Inc. (1989) performed vegetation studies at NMS that characterized the plant communities and identified species of concern. The following plant communities were identified at NMS: limestone forest (1,767 acres); degraded limestone forest (220 acres); ravine forest (3,091 acres); degraded ravine forest (927 acres); savanna (2,063 acres); and freshwater wetland (86 acres).

3.5.3 Quantitative Observations

Quantitative surveys were performed in 2008 and 2009 along transects in ravine forest, limestone forest, and a savanna grassland community (Transect 2). Ravine forest and limestone forest in the northeastern sector were sampled along Transects 4, 5 and 6, which traversed or were in the vicinity of stream channels. Transect 7 sampled ravine forest in the north-central sector near active and former operations areas. Ravine forest was also sampled in the western portion of NMS along Transects 1 and 3, which both cross stream channels. In the southern sector of NMS, Transects 8 and 11 sampled the ravine forest and coconut grove surrounding the Explosive Ordnance Disposal (EOD) Range. The faniok (*Merrilliodendron megacarpum*) forest around Mt. Almagosa was sampled in Transect 9. Transect 10 sampled ravine forest along the Sadog Gagu River, which drains into Fena Reservoir.

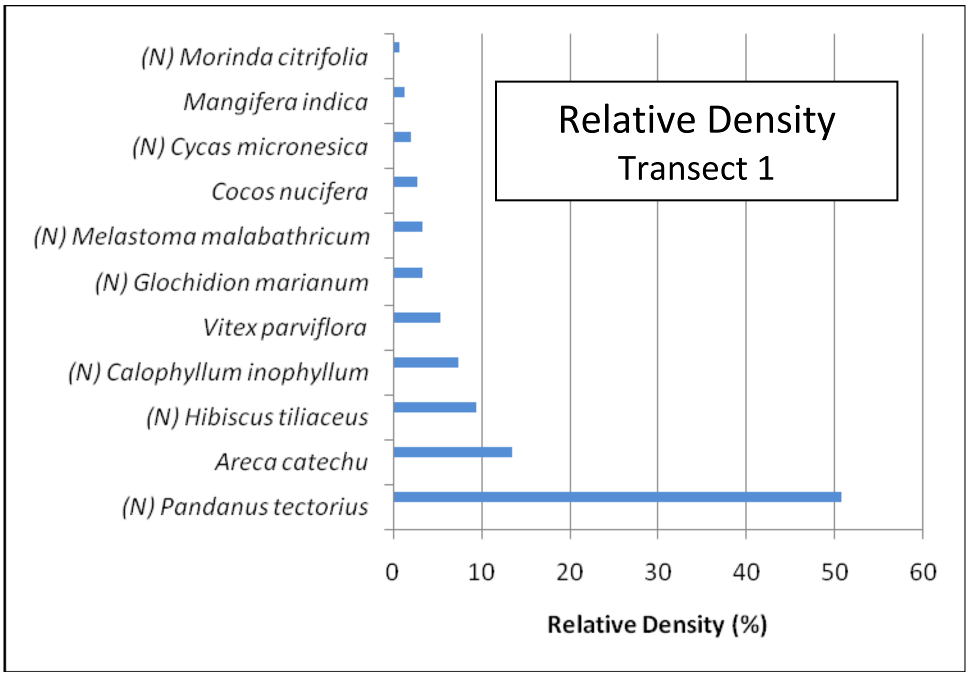
Transect 1 was the longest and traversed the most variable terrain of the seven transects conducted in northern NMS. The overall density for this transect was calculated at approximately 1,203 trees per hectare. The native kafu or screwpine (*Pandanus tectorius*) had the highest relative density (over 50%) and was the most dominant species among the 11 tree species encountered on the transect (Table 3.5-1 and Figure 3.5-1).

Table 3.5-1

POINT-CENTER QUARTER METHOD RESULTS FOR RAVINE FOREST NMS-1, NAVAL MUNITIONS SITE, APRIL 2008

SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm²)	MEAN BASAL AREA (cm²)	ABSOLUTE COVER (m²/ha)	ABSOLUTE FREQUENCY
Pandanus tectorius	N	609.59	9929.16	132.39	8.07	83.78
Vitex parviflora	I	65.02	2181.61	272.70	1.77	10.81
Glochidion marianum	N	40.64	2139.01	427.80	1.74	13.51
Mangifera indica	I	16.26	1977.70	988.85	1.61	2.70
Cocos nucifera	I	32.51	1934.33	483.58	1.57	8.11
Areca catechu	I	162.56	1286.06	64.30	1.05	32.43
Cycas micronesica	N	24.38	979.81	326.60	0.80	8.11
Calophyllum inophyllum	N	89.41	425.19	38.65	0.35	18.92
Hibiscus tiliaceus	N	113.79	375.18	26.80	0.30	18.92
Morinda citrifolia	N	8.13	38.47	38.47	0.03	2.70
Melastoma malabathricum	N	40.64	34.76	6.95	0.03	8.11

Key to Status: N = native; I = introduced.



Note: (N) indicates native species; others are introduced.

Figure 3.5-2. Relative density (%) of trees along Transect 1, NMS

Native species accounted for approximately 70% of the relative density among the eleven tree species quantified along Transect 1 (Figure 3.5-3).

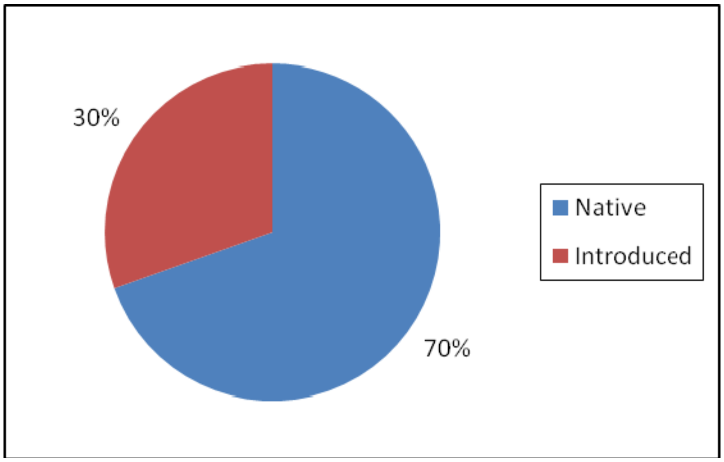
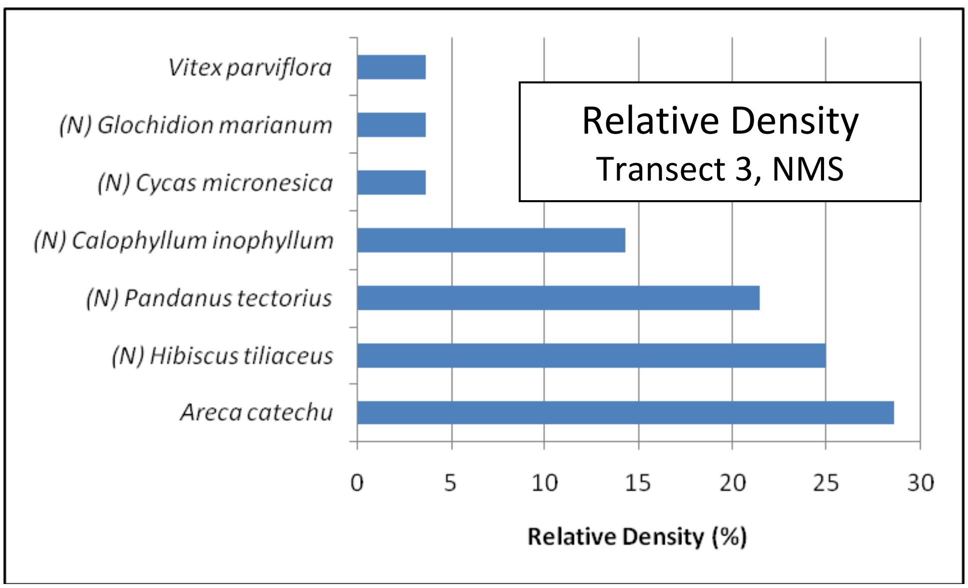


Figure 3.5-3. Relative density of native tree species in Transect 1.

The ravine forest sampled in Transect 3 had a density of approximately 1,700 trees per hectare. Betelnut palms (*Areca catechu*), which are thought to be an aboriginal introduction, had the highest relative density (29%) among the seven species on the transect. Aside from betelnut and *Vitex parviflora*, the transect comprised native species that accounted for approximately 67% of the relative density (Figure 3.5-4).



Note: (N) indicates native species; others are introduced.

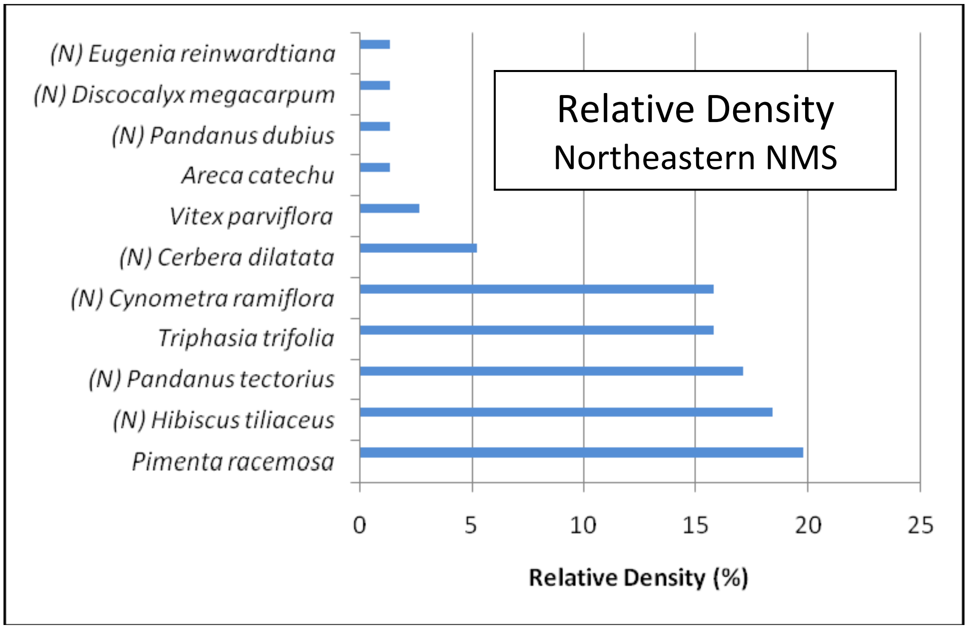
Figure 3.5-4. Relative density (%) of trees along Transect 3, NMS.

The transects in the northeastern sector (Transects 4 through 6) revealed a calculated density of approximately 5,261 trees per hectare (Table 3.5-2). The native kafu (*P. tectorius*) had the highest cover and third highest relative density (about 17%) among the 11 tree species in the transects (Table 3.5-2, Figure 3.5-5). The introduced and often invasive bay-rum (*Pimenta racemosa*) had the highest relative density (about 20%), followed closely by native pago (*H. tiliaceus*) with about 19%. Both native gulos (*Cynometra ramiflora*) and introduced lemonchina (*Triphasia trifolia*) had densities of about 16%. These five species each had relative densities exceeding 15%; in contrast, on Transect 1 the relative density of kafu was slightly more than 50% and the densities of the remaining species were less than 14%.

Table 3.5-2

POINT-CENTER QUARTER METHOD RESULTS FOR RAVINE FOREST NMS-4, NMS-5, NMS-6, NAVAL MUNITIONS SITE, MARCH 2008						
SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm^2)	MEAN BASAL AREA (cm^2)	ABSOLUTE COVER (m^2/ha)	ABSOLUTE FREQUENCY
Pandanus tectorius	N	899.91	1381.09	106.24	9.56	31.58
Hibiscus tiliaceus	N	969.14	637.31	45.52	4.41	31.58
Cynometra ramiflora	N	830.69	467.45	38.95	3.24	31.58
Triphasia trifolia	I	830.69	408.91	34.08	2.83	21.05
Cerbera dilatata	N	276.90	212.49	53.12	1.47	5.26
Pimenta racemosa	I	1038.36	167.13	11.14	1.16	31.58
Vitex parviflora	I	138.45	63.78	31.89	0.44	10.53
Areca catechu	I	69.22	62.18	62.18	0.43	5.26
Pandanus dubius	N	69.22	38.47	38.47	0.27	5.26
Eugenia reinwardtiana	N	69.22	19.63	19.63	0.14	5.26

Key to Status: N = native; I = introduced.



Note: (N) indicates native species; others are introduced.

Figure 3.5-5. Relative density (%) of trees along Transects 4, 5 and 6, NMS.

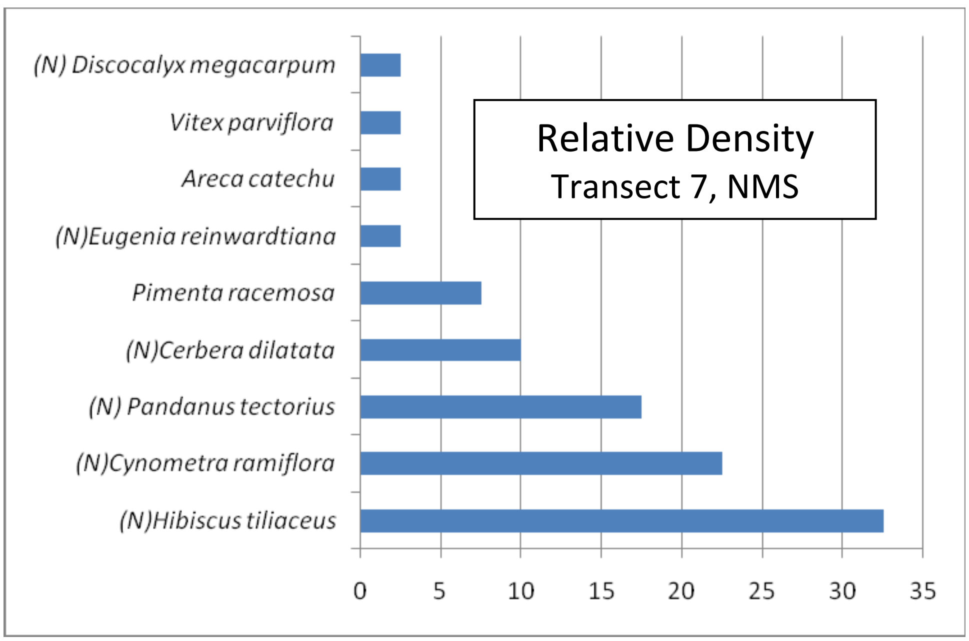
The ravine forest sampled along Transect 7 had a calculated density of approximately 1,791 trees per hectare (Table 3.5-3). The four highest relative densities were for species native to Guam (i.e., *Hibiscus tiliaceus*, *Cynometra ramiflora*, *Pandanus tectorius*, and *Cerbera dilatata*), which had relative densities ranging from about 33% to 10% (Figure 3.5-6). Introduced species accounted for less than 13% of the relative density among the nine species on the transect.

Table 3.5-3

POINT-CENTER QUARTER METHOD RESULTS FOR RAVINE FOREST
NMS-7, NAVAL MUNITIONS SITE, MARCH 2008

SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm²)	MEAN BASAL AREA (cm²)	ABSOLUTE COVER (m²/ha)	ABSOLUTE FREQUENCY
Cerbera dilatata	N	179.09	0.00	842.76	15.09	20
Pandanus tectorius	N	313.41	0.00	79.83	2.50	50
Hibiscus tiliaceus	N	582.04	0.00	31.86	1.85	50
Cynometra ramiflora	N	402.95	0.00	23.51	0.95	40
Areca catechu	I	44.77	0.00	132.67	0.59	10
Pimenta racemosa	I	134.32	0.00	6.62	0.09	20
Vitex parviflora	I	44.77	0.00	12.56	0.06	10
Eugenia reinwardtiana	N	44.77	0.00	6.60	0.03	10
Discocalyx megacarpum	N	44.77	0.00	6.60	0.03	10

Key to Status: N = native; I = introduced.



Note: (N) indicates native species; others are introduced.

Figure 3.5-6. Relative density (%) of trees along Transect 7, NMS. Native species are indicated by (N).

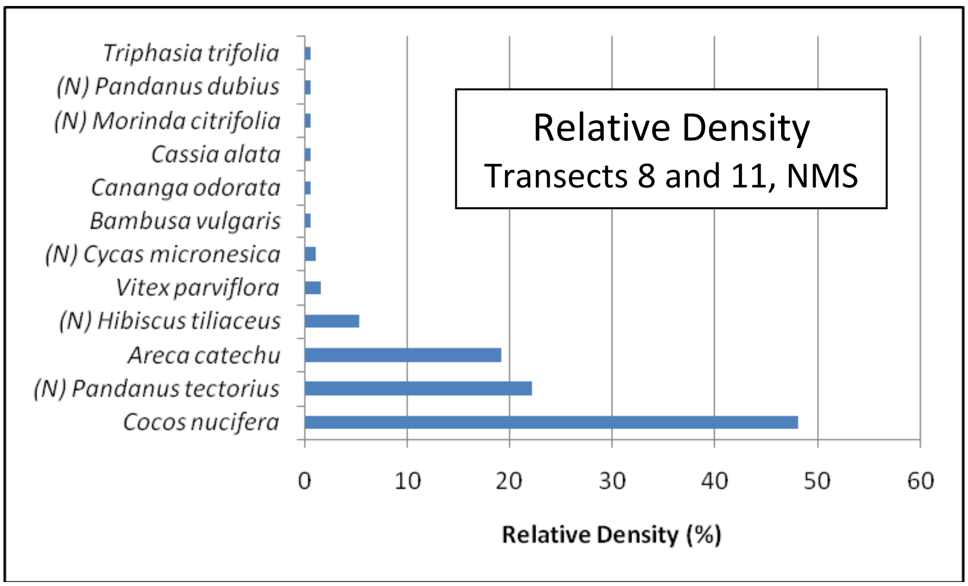
The ravine forest in the southwestern sector of the annex was sampled along Transects 8 and 11, located south and west of the EOD Range, respectively. The survey revealed an overall density of about 1,500 trees per hectare. Coconut (*Cocos nucifera*) and betelnut palms were dominant with native kafu (*Pandanus tectorius*) in terms of density, dominance and frequency (Table 3.5-4). The remaining species had low relative densities (Figure 3.5-7). The native cycad or fadang

(*Cycas micronesica*) was represented by two specimens with a mean basal area of 630 cm²; both trees were sampled on Transect 8.

Table 3.5-4

POINT-CENTER QUARTER METHOD RESULTS FOR RAVINE FOREST NMS-8 AND NMS-11, NAVAL MUNITIONS SITE, DEC. 2008						
SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm²)	MEAN BASAL AREA (cm²)	ABSOLUTE COVER (m²/ha)	ABSOLUTE FREQUENCY
Cocos nucifera	I	723.02	52974.40	529.74	38.30	69.23
Pandanus tectorius	N	332.59	4026.92	87.54	2.91	53.85
Areca catechu	I	289.21	2868.03	71.70	2.07	40.38
Vitex parviflora	I	21.69	1558.74	519.58	1.13	3.85
Cycas micronesica	N	14.46	1261.93	630.96	0.91	3.85
Hibiscus tiliaceus	N	79.53	359.91	32.72	0.26	11.54
Cananga odorata	I	7.23	289.38	289.38	0.21	1.92
Triphasia trifolia	I	7.23	66.44	66.44	0.05	1.92
Bambusa vulgaris	I	7.23	46.54	46.54	0.03	1.92
Cassia alata	I	7.23	36.30	36.30	0.03	1.92
Morinda citrifolia	N	7.23	35.24	35.24	0.03	1.92
Pandanus dubius	N	7.23	15.90	15.90	0.01	1.92

Key to Status: N = native; I = introduced.



Note: (N) indicates native species; others are introduced.

Figure 3.5-7. Relative density (%) of trees along Transects 8 and 11, NMS.

The limestone forest in the valley and slopes surrounding Mt. Almagosa was sampled on Transect 9 (Table 3.5-5). The overall density was calculated at approximately 2,637 trees per hectare. The forest is characterized by the dominant faniok (*Merrilliodendron megacarpum*) trees that comprised over 63% of the relative density (Figure 3.5-8). Faniok had an absolute cover of 21.31 m²/ha, well above any other species on the transect. Since faniok has a limited distribution on Guam, this is an uncommon forest type with few known stands, such as at the

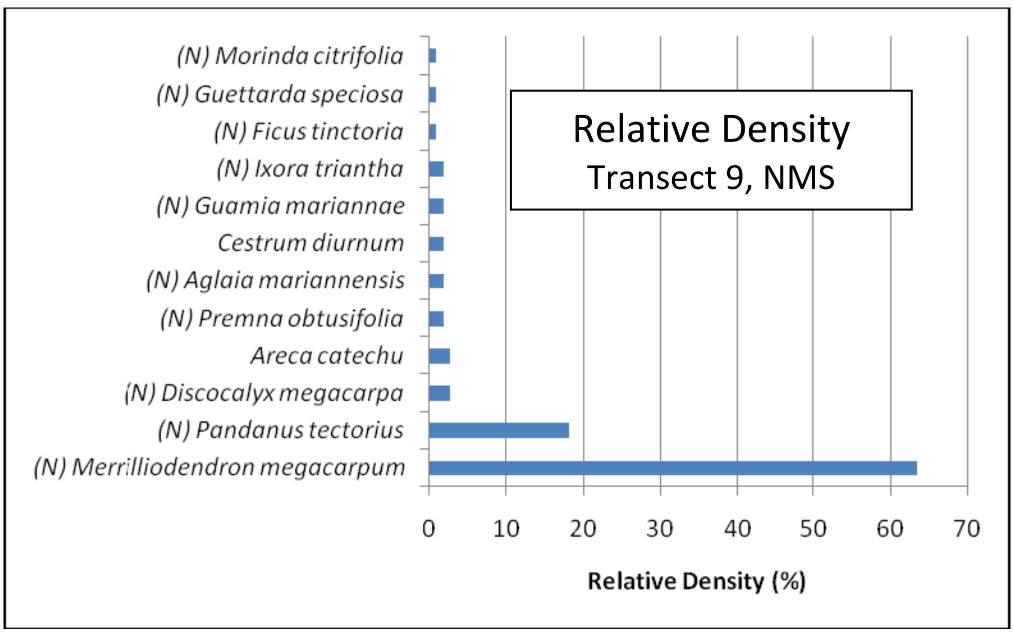
Haputo ERA in North Finegayan and near Mt. Jumullong-Manglo. Kafu (*Pandanus tectorius*) trees are an important component after faniok, forming dense, impenetrable patches where the canopy is open and fragmented. In areas where the canopy is more intact, the humid understory encourages the growth of lush ferns and mosses that blanket the dissected limestone karst. The uncommon terrestrial fern *Heterogonium pinatum*, and ground orchid *Calanthe triplicata*, are found in this area, with its unusual juxtaposition of high limestone ridges and freshwater springs.

Table 3.5-5

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST
NMS-9, NAVAL MUNITIONS SITE, DEC 2008

SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm²)	MEAN BASAL AREA (cm²)	ABSOLUTE COVER (m²/ha)	ABSOLUTE FREQUENCY
Merrilliodendron megacarpum	N	1673.73	8402.10	127.30	21.31	76.92
Pandanus tectorius	N	481.83	1093.07	57.53	2.77	30.77
Areca catechu	I	76.08	255.79	85.26	0.65	11.54
Morinda citrifolia	N	25.36	254.34	254.34	0.64	3.85
Aglaia mariannensis	N	50.72	224.82	112.41	0.57	3.85
Ficus tinctoria	N	25.36	162.53	162.53	0.41	3.85
Premna obtusifolia	N	50.72	119.12	59.56	0.30	7.69
Guettarda speciosa	N	25.36	103.82	103.82	0.26	3.85
Guamia mariannae	N	50.72	80.61	40.31	0.20	3.85
Cestrum diurnum	I	50.72	78.37	39.18	0.20	7.69
Ixora triantha	N	50.72	33.17	16.58	0.08	7.69
Discocalyx megacarpa	N	76.08	15.05	5.02	0.04	11.54

Key to Status: N = native; I = introduced.



Note: (N) indicates native species; others are introduced.

Figure 3.5-8. Relative density (%) of trees along Transect 9, NMS.

Native species comprised 95% of the relative density of tree species along Transect 9 (Figure 3.5-9). The remaining 5% comprised two introduced but naturalized species, betelnut (*Areca catechu*) and tintanchina (*Cestrum diurnum*), which are long-established on Guam (Stone, 1970).

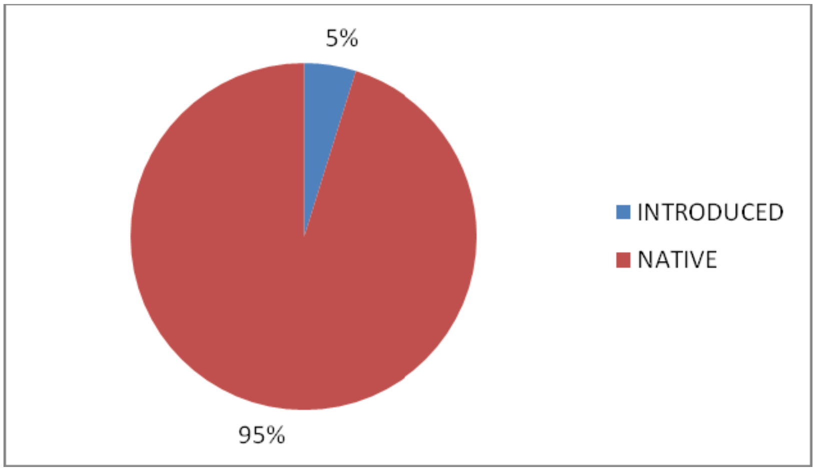
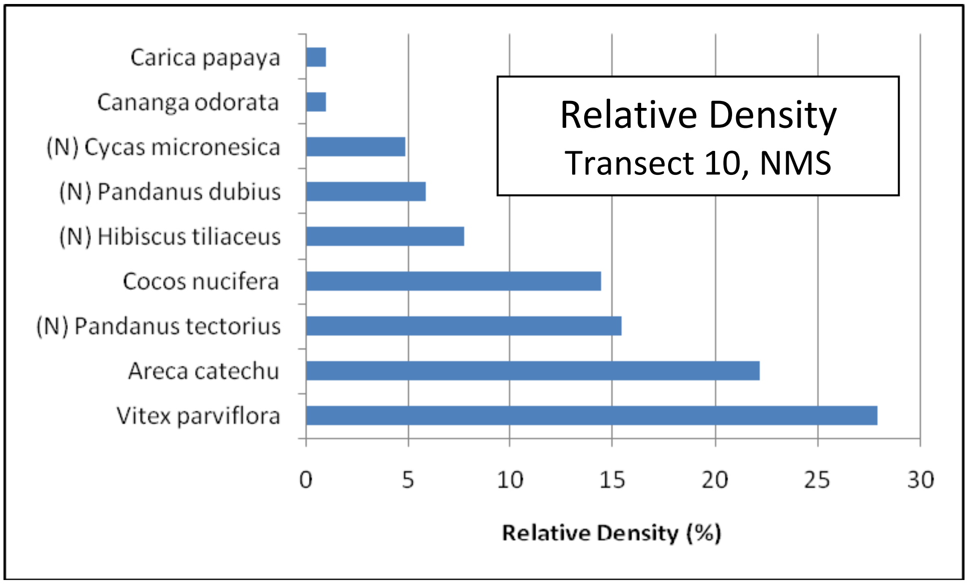


Figure 3.5-9. Relative density of native tree species along Transect 9, NMS.

Transect 10 sampled the ravine forest along theSadog Gagu River in the southern sector of the annex. Point-center quarter results revealed an overall tree density of approximately 1,474 trees per hectare. Two introduced and naturalized species, coconut (*Cocos nucifera*) and *Vitex parviflora*, outranked all other species with cover values of 13.46 m²/ha and 8.02 m²/ha, respectively (Table 3.5-6). *Vitex* also had the highest relative density (28%), followed by the betelnut palm or pugua (*Areca catechu*) (22%) (Figure 3.5-10). The overall relative density of native species was approximately 34% (Figure 3.5-11), which is lower than the densities observed in ravine forest transects in the northern sectors of the annex.

Table 3.5-6

POINT-CENTER QUARTER METHOD RESULTS FOR RAVINE FOREST NMS-10, NAVAL MUNITIONS SITE, DEC 2008						
SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm²)	MEAN BASAL AREA (cm²)	ABSOLUTE COVER (m²/ha)	ABSOLUTE FREQUENCY
Cocos nucifera	I	212.71	9488.12	632.54	13.46	42.31
Vitex parviflora	I	411.25	5657.10	195.07	8.02	50.00
Pandanus tectorius	N	226.89	1917.52	119.84	2.72	38.46
Cycas micronesica	N	70.90	1208.79	241.76	1.71	15.38
Areca catechu	I	326.16	1155.85	50.25	1.64	42.31
Pandanus dubius	N	85.09	537.38	89.56	0.76	11.54
Hibiscus tiliaceus	N	113.45	405.92	50.74	0.58	15.38
Cananga odorata	I	14.18	268.67	268.67	0.38	3.85
Carica papaya	I	14.18	122.66	122.66	0.17	3.85



Note: (N) indicates native species; others are introduced.

Figure 3.5-10. Relative density (%) of trees along Transect 10, NMS.

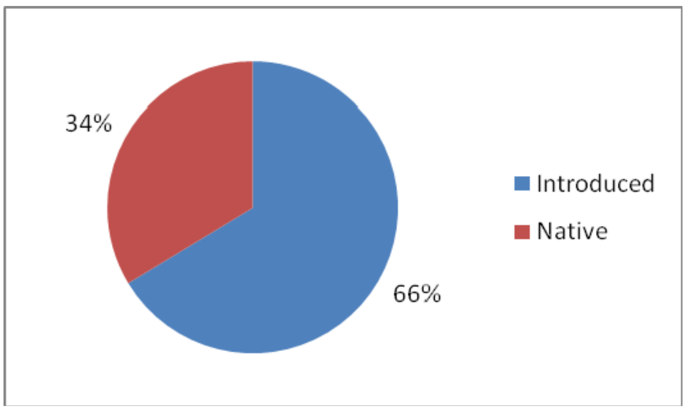


Figure 3.5-11. Relative density of native tree species in Transect 10.

Plots performed in the northern NMS revealed a lower native woody seedling desnity of approximately 1.83 seedlings per square meter compared with introduced seedlings, which had a denstiy of about 2.44 seedlings per square meter (Figure 3.5-12). Transect 4 in the northeastern sector had a particularly high desnity of bay-rum (*Pimenta racemosa*) seedlings, which contributed to the higher overall desnsity of introduced seedling species. Bay-rum appears to be thriving in the northeastern sector, possibly in part because of its prolific seed production.

The southern sector of NMS had a native woody seedling density of about 17.19 seedlings per square meter (Figure 3.5-13). This was higher than the density of introduced seedlings of approximately 1.06 seedlings per square meter. Native mapunao (*Aglaia mariannensis*) trees were prolific seedling producers on Transect 9, which contributed to the higher native seedling density in southern NMS.

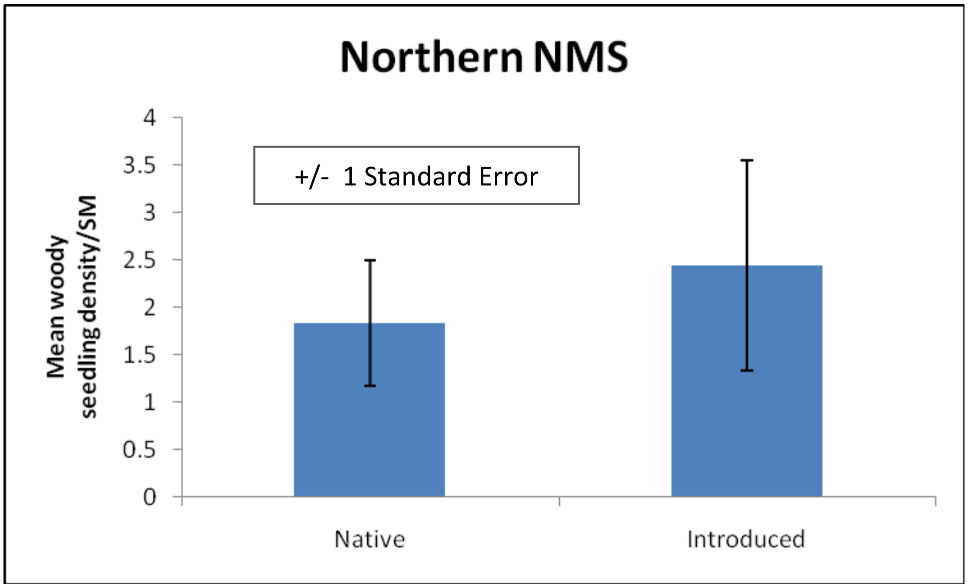


Figure 3.5-12. Mean density of woody seedlings along Transects 1 through 7, NMS.

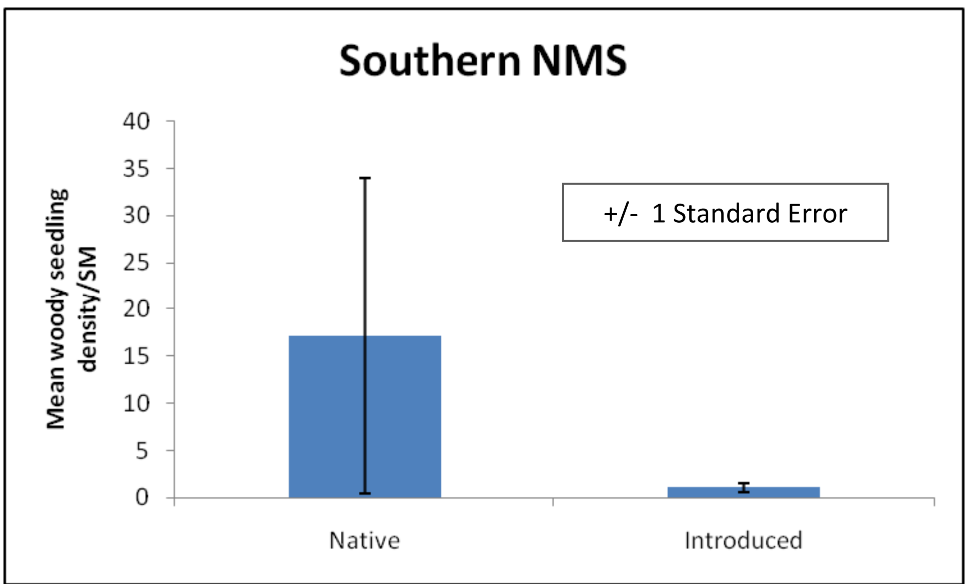


Figure 3.5-13. Mean density of woody seedlings along Transects 8 through 11, NMS.

3.5.4 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat at Naval Munitions Site. These include ungulate activity, the presence of erosion, percent of native plant species, and overall species richness. Among the transects sampled in northern NMS, species richness was highest for Transect 5, followed by Transects, 7, 1, 6, 3 and 4, respectively (Figure 3.5-14). Transect 1 and Transect 7 appear to have similar points of inflection; rarefaction would indicate that richness is similar among these transects although fewer samples were obtained for Transect 7.

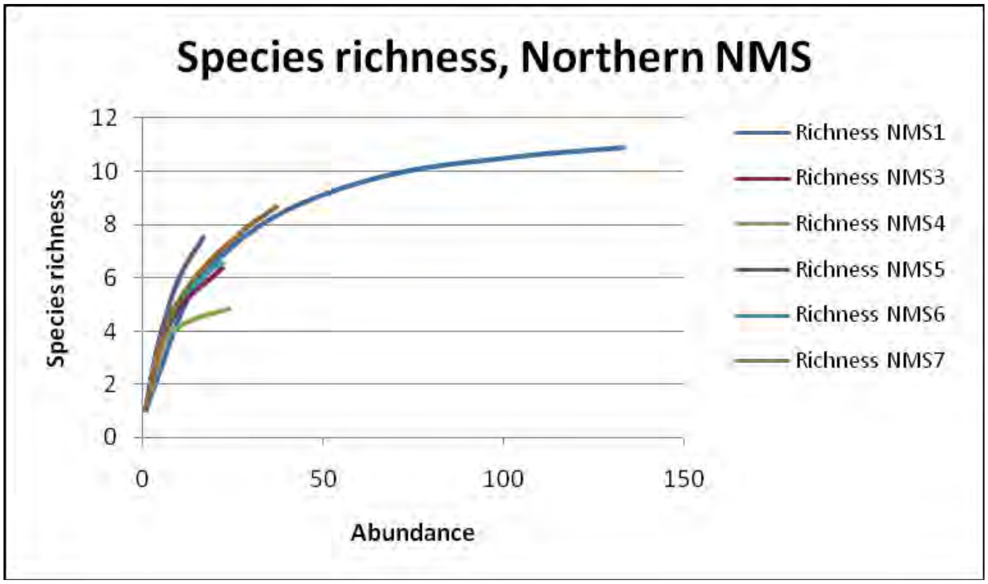


Figure 3.5-14. Species richness of trees along transects at northern NMS.

Species richness curves indicate a higher species richness for Transect 9 in the *Merrilliodendron* forest than for other transects in southern NMS (Transects 8, 10, and 11) (Figure 3.5-15). Transect 9 also had the highest relative density of native versus introduced species among all transect at NMS (Table 3.5-7).

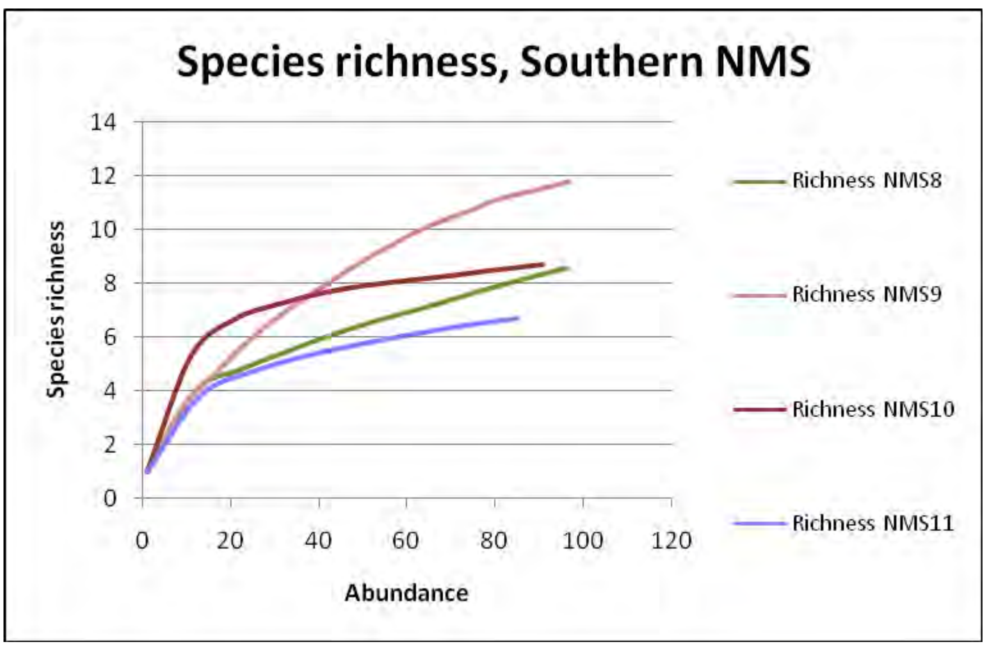


Figure 3.5-15. Species richness of trees along Transects 8 through 11, NMS.

Overall, the lowest species richness in the southern NMS was along Transect 11 in the ravine forest west of the EOD Range, which contained only 7 tree species. This forest contains a high proportion of coconut (*Cocos nucifera*) (approximately 55% of the relative density) among mostly kafu (*Pandanus tectorius*), betelnut (*Areca catechu*), and pago (*Hibiscus tiliaceus*) trees. In the northern NMS, the lowest species richness was observed along Transect 4 (see Figure 3.5-14); only 5 species were sampled on this transect, which contained similar relative densities of native and introduced species.

Table 3.5-7

SUMMARY OF RELATIVE DENSITY OF TREE SPECIES AT NMS

Transect	% Native	% Introduced	Total species
1	69.59	30.41	11
3	67.86	32.14	7
4	46.43	53.57	5
5	40.00	60.00	8
6	89.29	10.71	7
7	87.50	12.50	9
8	25.93	74.07	9
9	95.00	5.00	12
10	66.35	33.65	9
11	33.00	67.00	7

Ungulate activity was quantified at stations along Transects 1 through 11 (Figures 3.5-16 and 3.5-17). Soil disturbance, such as rooting, had the highest mean frequency, followed by browsing. Erosion, vegetation damage and other disturbance from wild pigs (*Sus scrofa*), deer (*Cervus unicolor*), and carabao (*Bubalis bubalis*) are considered major problems at the annex. The ungulate activity was especially conspicuous along Transect 11 in southern NMS, where active wallows, rooting and live feral pigs were observed.

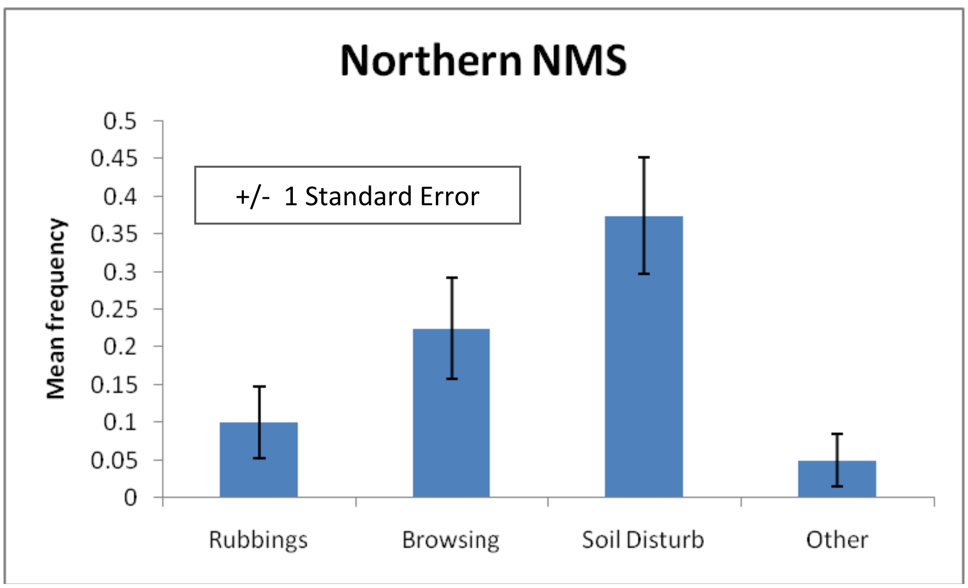


Figure 3.5-16. Mean frequency of ungulate activity along Transects 1 through 7.

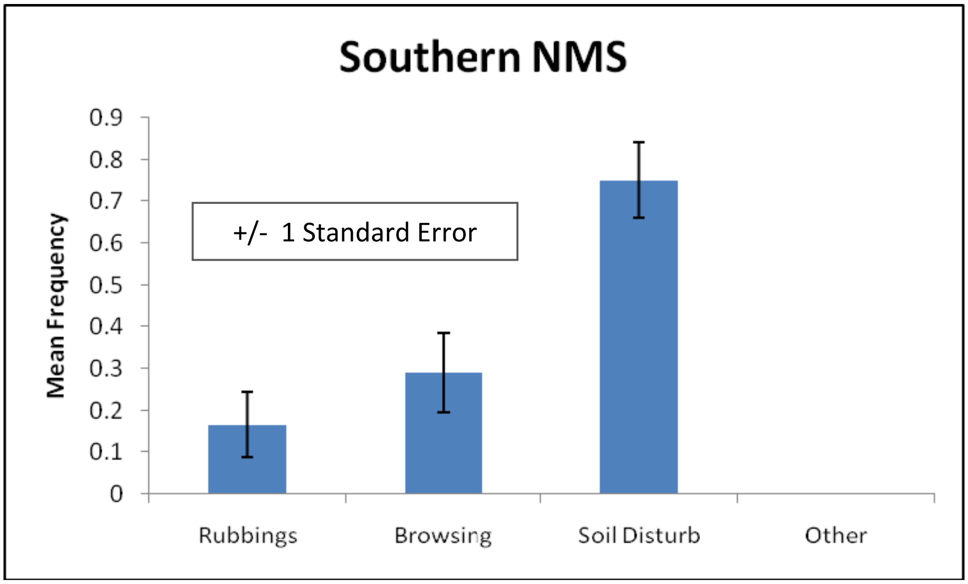


Figure 3.5-17. Mean frequency of ungulate activity along Transects 8 through 11.

The ground cover quantified along Transects 1 through 11 revealed that leaf litter had the highest mean frequency among the four cover classes in the northern and southern NMS (Figures 3.5-18 and 3.5-19). The lowest mean frequency in both areas of NMS was for bare rock, although this cover class had a slightly higher frequency in southern NMS.

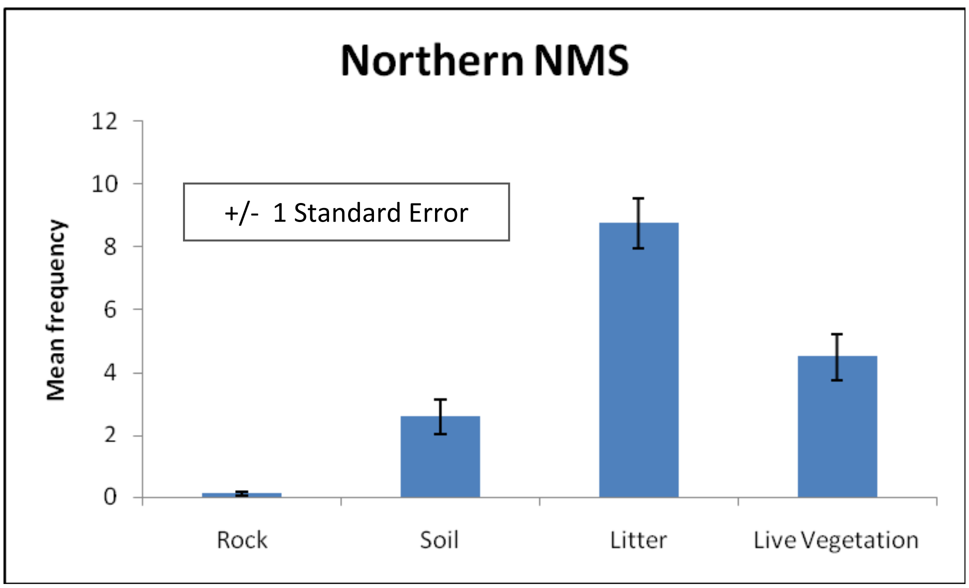


Figure 3.5-18. Mean frequency of ground cover along along Transects 1 through 7, NMS.

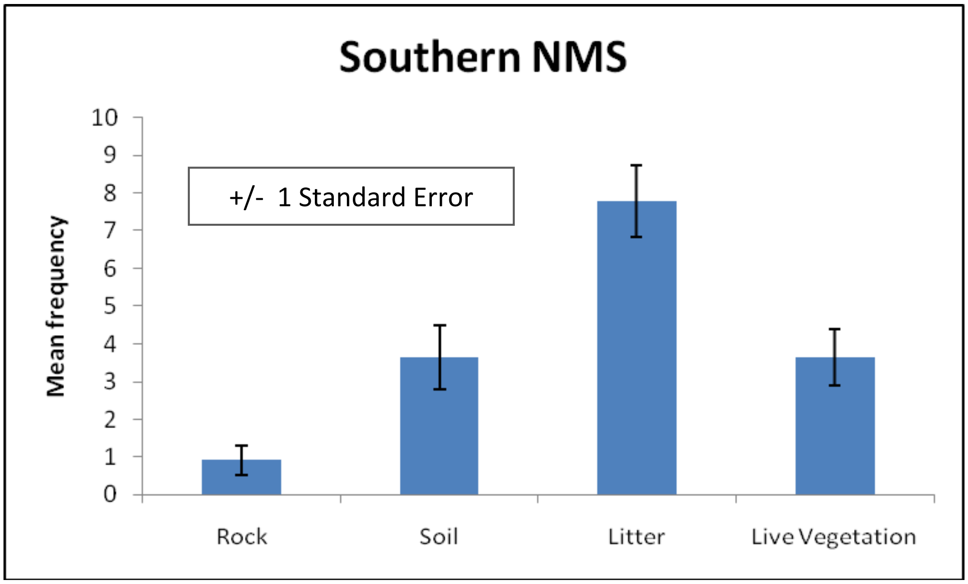


Figure 3.5-19. Mean frequency of ground cover along along Transects 8 through 11, NMS.

3.5.5 Threatened and Endangered Species and Species of Concern

3.5.5.1 Threatened and Endangered Species

The only federally or locally listed species identified at NMS by BioSystems Analysis, Inc. (1989) was the tree fern tsatsa (*Cyathea lunulata*), which is locally protected as an endangered species. No tree ferns or other listed species were observed at NMS during the current survey.

Figure 3.5-20. Faniok (*Merriolliodendron megacarpum*) forest along Transect 9, NMS.

3.5.5.2 Species of Concern

BioSystems Analysis, Inc. (1989) cited the presence of several rare but unprotected species at NMS. These are listed below:

- *Thelypteris warburgii*, a fern indigenous to Guam and Papua New Guinea that occurs only at NMS along the Bonya, Tolaeyuus and Maemong Rivers.
- *Eria rostiflora*, an epiphytic orchid found only at NMS.
- *Coelogyne guamensis*, an epiphytic orchid found locally only at NMS.
- *Nervilia platychila*, a ground orchid found locally only at NMS.
- *Maesa* sp., a tree found locally only at NMS.
- *Fagraea berteriana*, a native tree found locally only at NMS.

- *Merrilliodendron megacarpum*, a native tree with limited distribution on Guam (Figure 3.5-20).

The current survey found *Thelypteris warburgii* near Transects 5 and 6, with only one plant at each site (Figure 3.5-21). *T. warburgii* is also considered a species of concern by the U.S. Fish and Wildlife Service (USFWS, 2005). *Merrilliodendron megacarpum* was quantified in the forest stands along Transect 9 around Mt. Almagosa (see Figure 3.5-20). A few specimens of *Fagraea berteriana* were observed along Transects 1 and 9, some of which were flowering and fruiting.

Figure 3.5-21. ***Thelypertis warburgii*** **along Bonya River, NMS.**

Figure 3.5-22. ***Tuberolabium guamensis*** **along Transect 5, NMS.**

The following uncommon species were also noted along transects at NMS, although they are not regulated or managed by the federal or local authorities: *Heterogonium pinnatum*, a terrestrial fern; *Hedyotis laciniata*, an endemic herb of the savannas; *Tuberolabium* (*Trachoma*) *guamensis*, an endemic epiphytic orchid found on Guam and Rota (Figure 3.5-22; and *Luisia teretifolia*, an indigenous epiphytic orchid found on Guam and Rota (Figure 3.5-23).

The Guam Department of Agriculture lists fadang (*Cycas micronesica*) among the six plant species of greatest conservation need (SOGCN) (Department of Agriculture, 2006). This was the only SOGCN observed during the current survey. In the northern sector of NMS, fadang had a relative density of less than 4% on Transects 1 and 3; it was not sampled on other transects in northern NMS. On transects in the southern sector of NMS, fadang appeared only on Transects 8 and 10, where it had relative densities of approximately 2% and 4%, respectively.

Figure 3.5-23. ***Luisia teretifolia*** **along Transect 7, NMS.**

3.6 Orote Peninsula

3.6.1 Location

The Orote Peninsula extends into the Philippine Sea, forming the southern boundary of Outer Apra Harbor. The steep escarpments overlooking the ocean and strict security associated the Navy's ammunition wharf (Kilo Wharf) have kept the Peninsula relatively inaccessible to unauthorized persons and feral ungulates.

Figure 3.6-1. Limestone karst topography of Orote Peninsula. Native fadang (*Cycas micronesica*) and umumu (*Pisonia grandis*) trees are shown in the center and left of the photo, respectively.

3.6.2 Previous Studies

BioSystems Analysis Inc. (1988) described the limestone forest that lines the southern and western cliffs of Orote Peninsula as the largest in the Apra Harbor complex, with the best forest located in the western sector of the Peninsula. The study identified *Tristiropsis acutangula*, *Neisosperma oppositifolia*, *Ficus prolixa*, and *Heritiera longipetiolata*, among others, as the dominants in the limestone forest. The Peninsula has also undergone studies associated with the development of the ammunition wharf (VTN Pacific, 1983) and its extension (Department of the Navy, 2007) on the northern coast of the Peninsula. The vegetation survey for the extension of Kilo Wharf identified upland forests and strand vegetation; the upland forests were further categorized as native limestone forest, disturbed limestone forest, halophytic-xerophytic scrub, tangantangan (*Leucaena leucocephala*) secondary forest, and coconut (*Cocos nucifera*) forest (I Tano', 2006). The overall forest density in the vicinity of the wharf was calculated as 92 trees per 100 m², or approximately 9,200 trees per ha. Tangantangan (*Leucaena leucocephala*) had the highest density and frequency; the dominants based on biomass were *Pisonia grandis* and *Calophyllum inophyllum*.

3.6.3 Quantitative Observations

Surveys were performed along a transect in the upper plateau to the west of the old runway in the southern sector of Orote. The area has a rugged limestone karst topography (Figure 3.6-1). Based on the transect results, the overall density in this sector of Orote is approximately 5,030 trees per hectare (Table 3.6-1). The limestone forest was characterized by native fago (*Neisosperma oppositifolia*) trees, which comprised 28% of the relative density (Figure 3.6-2), or approximately 1,414 trees per ha. The next highest densities were for the well-established but non-native trees tangantangan (*Leucaena leucocephala*) and lemonchina (*Triphasia trifolia*), with densities of 16% and 14%, respectively. Collectively, these introduced species, including papaya (*Carica papaya*), comprised 33% of the relative density. The remaining 73% of the relative density comprised native species, including the Mariana Islands endemic species *Aglaia mariannensis* and *Tabernaemontana rotensis*.

Table 3.6-1

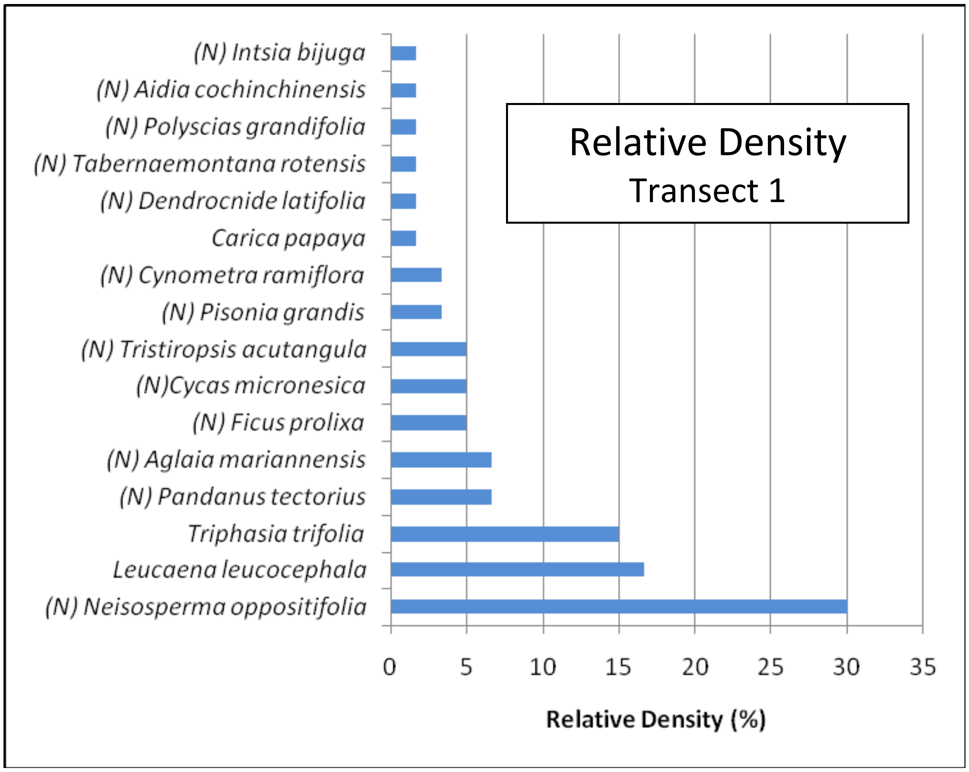
POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST
OROTE PENINSULA, FEBRUARY 2008

SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm²)	MEAN BASAL AREA (cm²)	ABSOLUTE COVER (m²/ha)	ABSOLUTE FREQUENCY
Ficus prolixa	N	235.78	2651.70	883.90	20.84	12.50
Pisonia grandis	N	157.19	2060.95	1030.47	16.20	12.50
Tristiropsis acutangula	N	235.78	2027.03	675.68	15.93	18.75
Neisosperma oppositifolia	N	1414.67	717.11	39.84	5.64	56.25
Cycas micronesica	N	235.78	454.71	151.57	3.57	18.75
Aglaia mariannensis	N	314.37	364.22	91.06	2.86	18.75
Pandanus tectorius	N	314.37	362.43	90.61	2.85	25.00
Leucaena leucocephala	I	785.93	332.52	33.25	2.61	37.50
Triphasia trifolia	I	707.33	135.84	15.09	1.07	37.50
Carica papaya	I	78.59	66.44	66.44	0.52	6.25
Intsia bijuga	N	78.59	59.57	59.57	0.47	6.25
Polyscias grandifolia	N	78.59	41.46	41.46	0.33	6.25
Tabernaemontana rotensis	N	78.59	26.96	26.96	0.21	6.25
Cynometra ramiflora	N	157.19	19.82	9.91	0.16	12.50
Dendrocnide latifolia	N	78.59	18.09	18.09	0.14	6.25
Aidia cochinchinensis	N	78.59	10.17	10.17	0.08	6.25

Key to Status: N = native; I = introduced.

Absolute cover or dominance was highest for native *Ficus prolixa* (20.84 m²/ha), *Pisonia grandis* (16.20 m²/ha), and *Tristiropsis acutangula* (15.93 m²/ha); each had total basal areas exceeding 2,000 cm². These species occupy the uppermost canopy of the forest. In comparison, non-native *Leucaena leucocephala*, *Triphasia trifolia*, and *Carica papaya*, which occupy the forest understory, had relatively modest absolute cover values below 3 m²/ha.

Absolute frequency was led by native fago (*Neisosperma oppositifolia*), a mid to upper canopy tree, with a value of 56.25. The naturalized species, *Triphasia trifolia* and *Leucaena leucocephala*, had the next highest absolute frequencies at 37.50 each. *Leucaena* is well-distributed on Orote Peninsula, forming buffers between the periphery of the forest and cleared areas. *Leucaena* had a density of 59.23 trees per 100 m² (5,923 trees per ha) and an absolute frequency of 75 in forests sampled near the Kilo Wharf extension project on the northern coast of the Peninsula (I Tano', 2006).



Note: (N) indicates native species; others are introduced.

Figure 3.6-2. Relative density (%) of trees at Orote Peninsula.

The woody seedling composition in plots at Orote consisted of about 84% native seedlings, with a seedling density of 4.04 seedlings per m² (Figure 3.6-3). Introduced seedlings comprised approximately 15%, with a density of 0.76 seedlings per m².

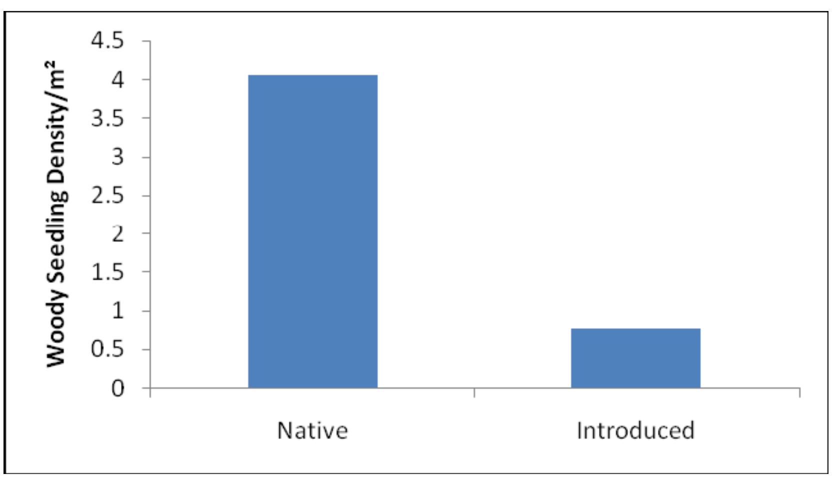


Figure 3.6-3. Density of native and introduced woody seedlings at Orote Peninsula.

The native woody seedling density seemed to reflect the higher relative density of native tree species quantified in the point-center quarter transect.

3.6.4 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat at the Route 15 study area. These include ungulate activity, the presence of erosion, percent of native plant species, and overall species richness. The species richness curve does not show a definite asymptote to indicate that richness has leveled off (Figure 3.6-4).

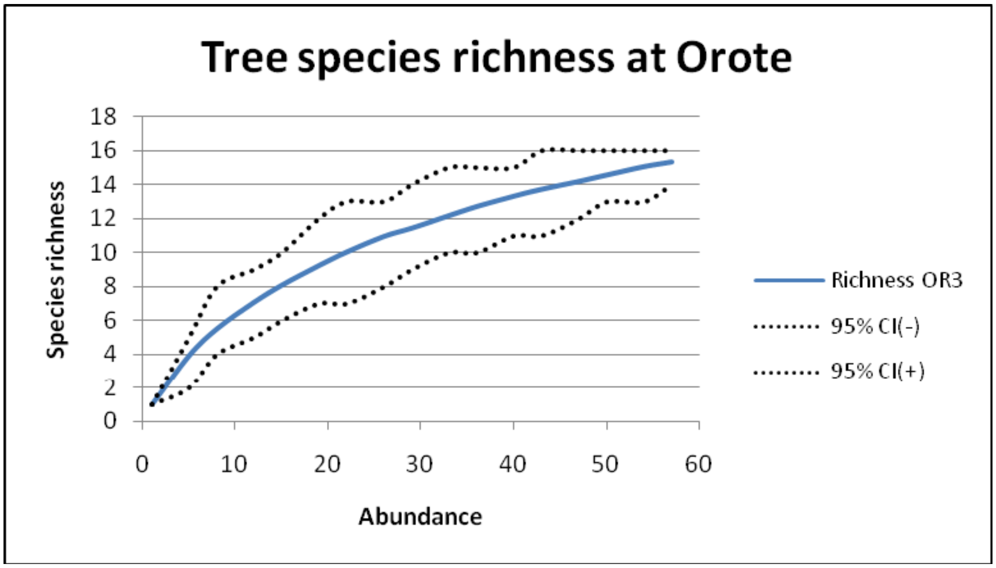


Figure 3.6-4. Species richness of trees at Orote Peninsula.

The mean frequency of ground cover in four categories was calculated based on quadrats (Figure 3.6-5). The categories of rock and vegetative litter had close mean frequencies; live vegetation was very low and no bare soil was observed in quadrats.

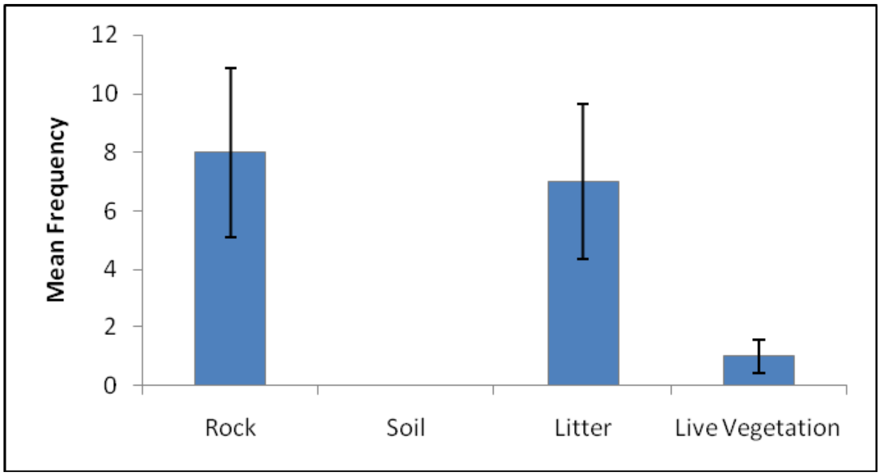


Figure 3.6-5. Mean frequency of ground cover at Orote Peninsula.

Orote Peninsula is considered free of ungulates because of its topography and relative isolation. Nonetheless, the area was surveyed for soil disturbance or other activity attributed to ungulates; however, no ungulate sign was recorded at Orote Peninsula along the vegetation transect.

3.6.5 Threatened and Endangered Species and Species of Concern

3.6.5.1 Threatened and Endangered Species

Guam's only federally-listed plant species, the fire tree or trongkon guafi (*Serianthes nelsonii*), is known to occur only at the northern tip of the island (USFWS, 1993). BioSystems Analysis, Inc. (1988) identified ufa halomtano (*Heritiera longipetiolata*) as the only listed species within Orote Peninsula. *Heritiera* is listed as an endangered species by the Government of Guam under the Endangered Species Act of Guam (5 GCA, Chapter 63), and is also considered a Species of Greatest Conservation Need (Department of Agriculture, 2006). The areas below the Spanish Steps and Orote cliffline contain significant numbers of ufa halomtano (BioSystems Analysis, Inc. 1988). The survey for the extension of Kilo Wharf documented seven live individuals (including one seedling) on the cliff south of the Wharf (I Tano', 2006). No specimens of *Heritiera* were found in the present survey, which sampled the forest on the southern region of the Peninsula opposite the ammunition wharf.

3.6.5.2 Notable Species and Species of Concern

The following species of concern were identified within Orote Peninsula during the current survey:

Figure 3.6-6. *Tabernaemontana rotensis* at Orote.

- *Tabernaemontana rotensis* (Apocynaceae) is an endemic tree with distribution limited to the islands of Guam and Rota. The species was proposed for federal listing under the U.S. Endangered Species Act; however, this candidacy status was removed in 2004. *Tabernaemontana* is considered a Species of Greatest Conservation Need by the Government of Guam (Department of Agriculture, 2006). Herbivory and insect infestations are thought to be the major threats to this species. *Tabernaemontana* was not detected by BioSystems Analysis (1988) or during the survey for the extension of Kilo Wharf (I Tano', 2006). One live specimen was encountered in the current vegetation survey (Figure 3.6-6), which appeared to be a healthy tree with a basal area of 26.96 cm². No flowers, fruits, or seedlings were observed.
- *Pisonia grandis* (Nyctaginaceae) is an indigenous tree considered important to the recovery of the Micronesian kingfisher (*Halcyon cinnamomina cinnamomina*) as nesting habitat. A density of 157 trees per ha was calculated for the survey at Orote.

- *Cycas micronesica* (Cycadaceae) is listed by the Guam Department of Agriculture as a Species of Greatest Conservation Need (SOGCN). This native cycad is under threat by an introduced insect, the Asian scale (*Aulacaspis yasumatsui*).

Although they are not regulated or managed by the local or federal governments, several notable species were observed at Orote and are discussed below.

- *Tristiropsis acutangula* (Balsalminaceae) is an indigenous tree of limited distribution on Guam. Orote had the highest density of *Tristiropsis* (approximately 236 trees per ha) among all DOD and non-DOD lands investigated in the current survey.
- *Zeuxine fritzii* (Orchidaceae) is an indigenous ground orchid found on forest floors. Feral pigs are known threats through their rooting activities.
- *Streblus pendulinus* (Moraceae) is a shrub or small tree indigenous to Guam (Figure 3.6-7). *Streblus* was not detected on any other transects on DOD or non-DOD lands in the current survey.

3.7

Figure 3.6-7. *Streblus pendulinus* at Orote.

Route 15

3.7.1 Location

The Route 15 study area encompasses three contiguous parcels: Lot 7161-R1 (252.54 acres) in the north; Andersen South MARBO Command "C", Andersen Administrative Annex (AJJW) (395.08 acres) located adjacent and south of this lot; and Lot 7164 (377.17 acres) located adjacent and east of both parcels along the northeastern coast of Guam. The study area is bound by the Pacific Ocean on the east and Route 15 on the west. The Andersen South Housing Area (also known as MARBO Base Command B-R5 or MARBO Annex) is located to the west of the site across Route 15. The northern parcel is actively quarried in support of on-going long-term construction of the Guam Raceway Park, a multi-sport venue with a completed drag racing strip and motocross track. Extensive sections of Lot 7161-R1 have been cleared and graded, and much of the intact forest is limited to the coastal plateau, and northern and southern peripheries. The southern parcel is mostly undeveloped with a network of overgrown jeep trails among the second growth forest. This parcel is administered by Guam Economic Development Authority (GEDCA) on behalf of the Guam Ancestral Lands Commission. The eastern parcel (Lot 7164) lies below the northern and southern parcels. Agricultural leaseholders actively farm assorted citrus and other fruit species on a portion of this lower limestone plateau.

Figure 3.7-1. View of lower plateau sampled in Transect 3, Route 15.

3.7.2 Previous Studies

The northern parcel was previously surveyed as part of the environmental impact assessment prepared by Duenas and Associates, Inc. (2000) for the existing Guam Raceway Park. The study identified 115 vascular plant species in three plant communities: primary/secondary limestone forest (158 acres), disturbed vegetation/grasslands (33 acres), and halophytic/xerophytic scrub on cliff faces. Sixteen of the species documented in Lot 7161-R1 are endemic to the Mariana Islands (Duenas and Associates, Inc., 2000). Quantitative data was collected in the study along three 200-meter transects using the point-center quarter method. The data revealed absolute densities of live trees of 50.3, 57.8 and 61.54 trees per 100 square meters, in the northern, central and southern sectors, respectively (Duenas and Associates, Inc., 2000). For comparison with the current survey, these values were converted to 5,030, 5,748, and 6,154 trees per hectare, respectively.

3.7.3 Quantitative Observations

Surveys were performed along three transects in the limestone forest communities of the Route 15 parcels. Transect 1 was located in the northeastern sector of Lot 7161-R1 along a north-south axis; Transect 2 was located on the GEDCA parcel to the south along a north-south axis; and Transect 3 was located along a north-south axis in Lot 7164 on the plateau below Transect 2 (Figure 3.7-1).

Figure 3.7-2. ***Eugenia reinwardtiana*****, or a'abang, in the limestone forest of the lower plateau, Lot 7164.**

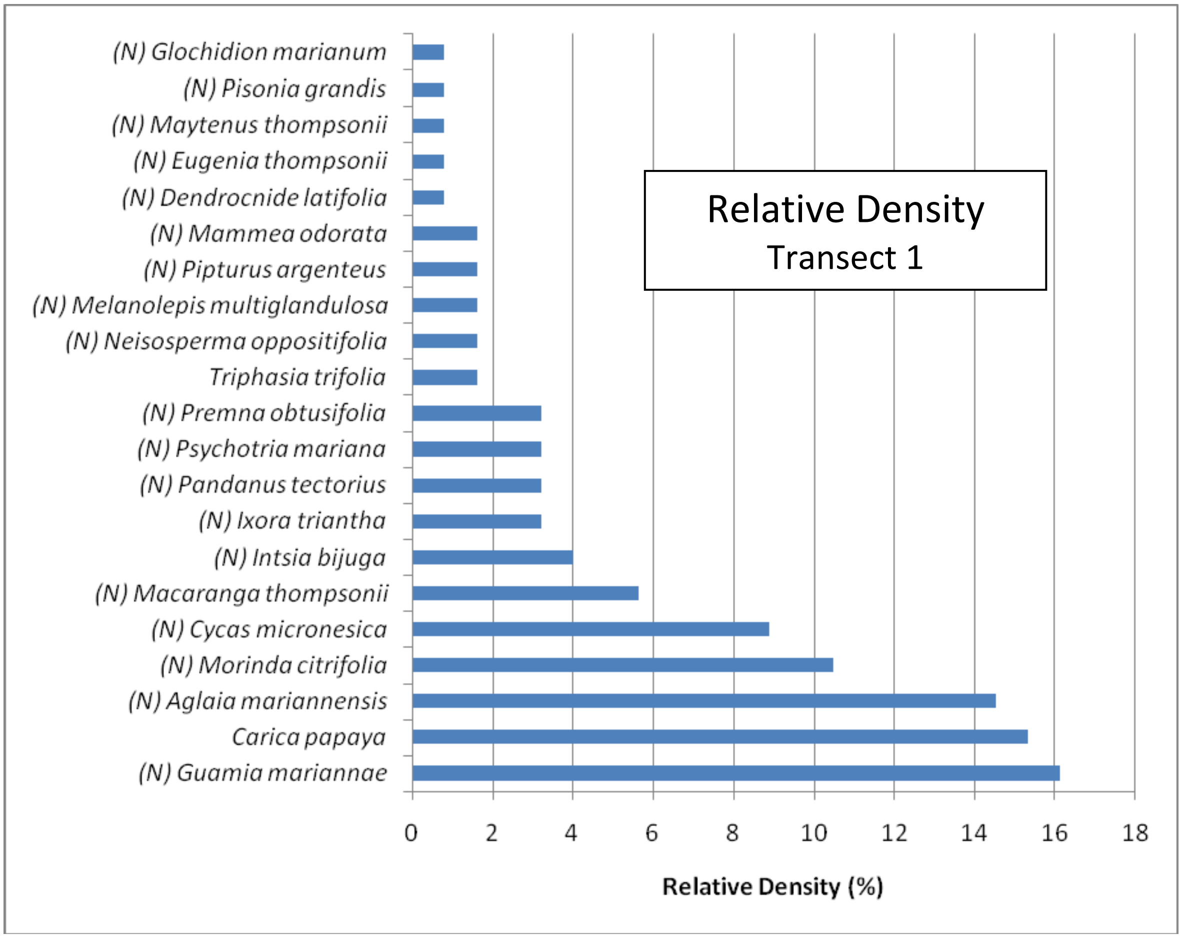
The quantitative observations from the point-center quarter survey along Transect 1 revealed an absolute density of approximately 3,148 trees per hectare in Lot 7161-R1. Native fadang (*Cycas micronesica*) and ifil (*Intsia bijuga*), and introduced papaya (*Carica papaya*) were the most dominant species, with absolute cover values from 3.73 to 5.33 m² per hectare (Table 3.7-1). Pengua (*Macaranga thompsonii*), a species endemic to the Marianas, was the next most dominant species with an absolute cover of 3.08 m² per hectare. This tree is a broad-leaved canopy species ranging from 5 to 12 m tall (Raulerson and Rinehart, 1991). Pengua appeared on all three transects. Fadang had the highest total basal area (2,100 cm²); however, sizeable specimens of ifil, a native hardwood, were also present. Ifil had the highest mean basal area (293 cm²) based on five specimens sampled on the transect.

The relative density was highest for paipai (*Guamia mariannae*), papaya, and mapunao (*Aglaia mariannensis*), with relative densities of approximately 16%, 15% and 14.5%, respectively (Figure 3.7-3). These species also had the highest absolute frequencies, indicating that they are well-distributed along the transect.

Table 3.7-1

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST TRANSECT 1, RT. 15, DECEMBER 2008						
SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm^2)	MEAN BASAL AREA (cm^2)	ABSOLUTE COVER (m^2/ha)	ABSOLUTE FREQUENCY
Cycas micronesica	N	279.30	2100.84	190.99	5.33	29.03
Carica papaya	I	482.43	1599.16	84.17	4.06	35.48
Intsia bijuga	N	126.95	1468.32	293.66	3.73	16.13
Macaranga thompsonii	N	177.74	1211.87	173.12	3.08	19.35
Aglaia mariannensis	N	457.03	1178.10	65.45	2.99	38.71
Pandanus tectorius	N	101.56	629.89	157.47	1.60	9.68
Guamia mariannae	N	507.82	504.54	25.23	1.28	45.16
Mammea odorata	N	50.78	466.33	233.16	1.18	6.45
Morinda citrifolia	N	330.08	459.05	35.31	1.17	29.03
Premna obtusifolia	N	101.56	382.75	95.69	0.97	12.90
Psychotria mariana	N	101.56	329.43	82.36	0.84	12.90
Eugenia thompsonii	N	25.39	218.93	218.93	0.56	3.23
Pisonia grandis	N	25.39	172.46	172.46	0.44	3.23
Pipturus argenteus	N	50.78	125.46	62.73	0.32	6.45
Dendrocnide latifolia	N	25.39	63.59	63.59	0.16	3.23
Glochidion marianum	N	25.39	58.06	58.06	0.15	3.23
Ixora triantha	N	101.56	53.40	13.35	0.14	9.68
Neisosperma oppositifolia	N	50.78	44.41	22.20	0.11	6.45
Melanolepis multiglandulosa	N	50.78	28.36	14.18	0.07	3.23
Maytenus thompsonii	N	25.39	12.56	12.56	0.03	3.23
Triphasia trifolia	I	50.78	7.26	3.63	0.02	6.45

Key to Status: N = native; I = introduced.



Note: (N) indicates native species; others are introduced.

Figure 3.7-3. Relative density (%) of trees at Rt. 15 Parcel.

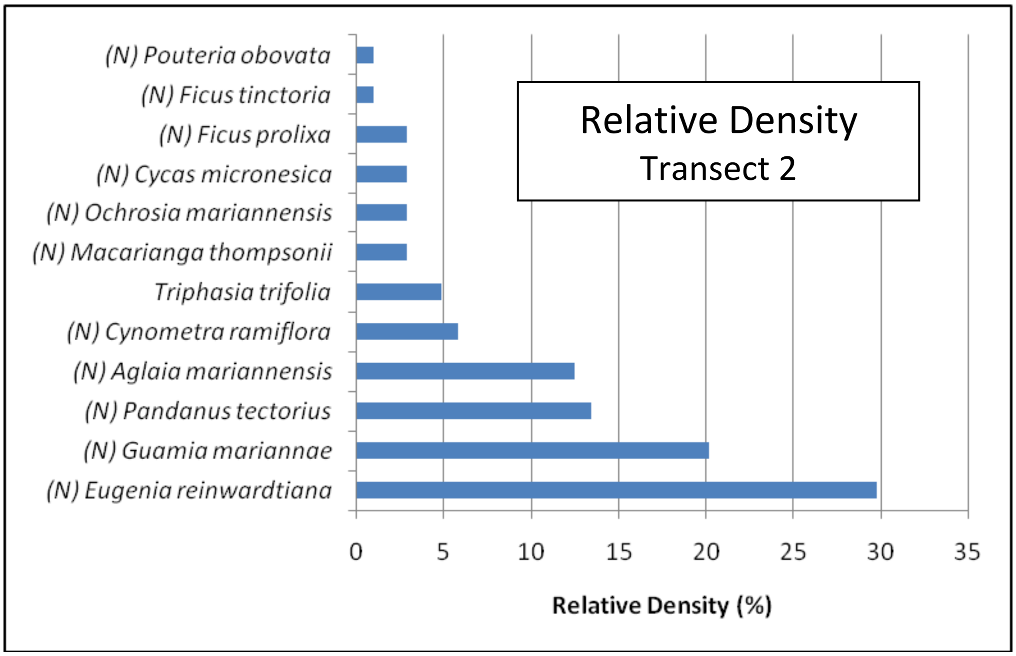
The forest in the southern GEDCA parcel had an absolute density of 4,566 trees per hectare. This was the highest overall density among the three transects in the Route 15 project area. On this transect, the native a'abang (*Eugenia reinwardtiana*) was dominant with an absolute cover of 8.19 m² per hectare and an absolute density of 1,321 trees per hectare (Table 3.7-2). A'abang was also well-dispersed, and had the highest frequency (57.69) among the 12 species on the transect. Pengua (*Macaranga thompsonii*) had an even higher absolute cover (5.13 m² per hectare) than in Transect 1, although absolute density was lower at 131.73 trees per hecatare. The relative density of trees was highest for a'abang at nearly 30%, followed by paipai (*Guamia mariannae*) and kafu (*Pandanus tectorius*) at 20% and 13%, respectively (Figure 3.7-4). Fadang (*Cycas micronesica*) had a lower absolute density (131.73 trees per hectare), absolute cover (218.61 cm²), and absolute frequency (7.69) than in Transect 1 (see Table 3.7-1, Figure 3.7-3).

Table 3.7-2

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST TRANSECT 2, RT. 15, DECEMBER 2008

SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm²)	MEAN BASAL AREA (cm²)	ABSOLUTE COVER (m²/ha)	ABSOLUTE FREQUENCY
Eugenia reinwardtiana	N	1361.19	1865.37	60.17	8.19	57.69
Pandanus tectorius	N	614.73	1551.13	110.79	6.81	30.77
Macarianga thompsonii	N	131.73	1169.42	389.81	5.13	11.54
Guamia mariannae	N	922.09	779.91	37.14	3.42	53.85
Cycas micronesica	N	131.73	655.83	218.61	2.88	7.69
Aglaia mariannensis	N	570.82	646.02	49.69	2.84	30.77
Ficus prolixa	N	131.73	201.22	67.07	0.88	7.69
Cynometra ramiflora	N	263.46	189.81	31.64	0.83	19.23
Ochrosia mariannensis	N	131.73	86.95	28.98	0.38	11.54
Ficus tinctoria	N	43.91	56.72	56.72	0.25	3.85
Triphasia trifolia	I	219.55	36.76	7.35	0.16	15.38
Pouteria obovata	N	43.91	12.56	12.56	0.06	3.85

Key to Status: N = native; I = introduced.



Note: (N) indicates native species; others are introduced.

Figure 3.7-4. Relative density (%) of trees along Transect 2, Route 15.

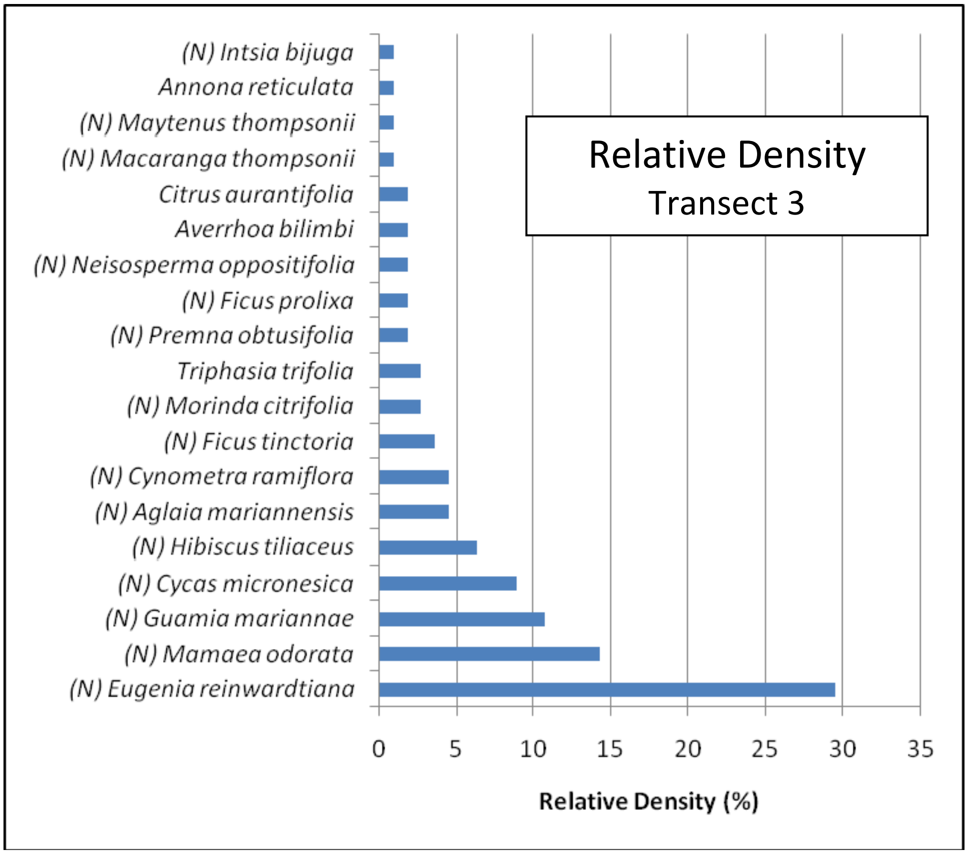
Transect 3, on the lower plateau of Lot 7164, was closest to sea level among the three transects in the project area, but was further inland from the halophytic/xerophytic plant community along the coast. The absolute density was approximately 3,183 trees per hectare. As with Transect 2, a'abang (*Eugenia reinwardtiana*) was a dominant component, with the highest absolute density (937.92 trees per hectare), absolute cover (6.84 m² per hectare), and absolute frequency (67.86) (Table 3.7-3).

Table 3.7-3

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST
TRANSECT 3, RT. 15, DECEMBER 2008

SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm²)	MEAN BASAL AREA (cm²)	ABSOLUTE COVER (m²/ha)	ABSOLUTE FREQUENCY
Eugenia reinwardtiana	N	937.92	2407.77	72.96	6.84	67.86
Cycas micronesica	N	284.22	1973.40	197.34	5.61	32.14
Neisosperma oppositifolia	N	56.84	1676.52	838.26	4.76	7.14
Ficus tinctoria	N	113.69	1638.75	409.69	4.66	3.57
Premna obtusifolia	N	56.84	1210.86	605.43	3.44	7.14
Mamaea odorata	N	454.75	1103.45	68.97	3.14	39.29
Intsia bijuga	N	28.42	961.63	961.63	2.73	3.57
Macaranga thompsonii	N	28.42	720.70	720.70	2.05	3.57
Aglaia mariannensis	N	142.11	486.38	97.28	1.38	17.86
Hibiscus tiliaceus	N	198.95	400.85	57.26	1.14	14.29
Morinda citrifolia	N	85.27	275.64	91.88	0.78	10.71
Averrhoa bilimbi	I	56.84	268.04	134.02	0.76	3.57
Guamia mariannae	N	341.06	243.99	20.33	0.69	35.71
Cynometra ramiflora	N	142.11	228.23	45.65	0.65	14.29
Ficus prolixa	N	56.84	96.94	48.47	0.28	3.57
Citrus aurantifolia	I	56.84	66.33	33.17	0.19	3.57
Triphasia trifolia	I	85.27	50.91	16.97	0.14	3.57
Maytenus thompsonii	N	28.42	9.62	9.62	0.03	3.57
Annona reticulata	I	28.42	7.54	7.54	0.02	3.57

Key to Status: N = native; I = introduced.



Note: (N) indicates native species; others are introduced.

Figure 3.7-5. Relative density (%) of trees along Transect 3, Route 15.

The mean woody seedling density was calculated for the three transects at Route 15 (Figure 3.7-6). Native seedlings exceeded mean density of 6 seedlings per m², compared with a mean density of approximately 1 seedling per m² for non-native species.

Native seedlings outranked introduced seedlings in every transect (Figure 3.7-7), especially in Transect 1. Non-native seedlings were nearly equivalent with native seedlings along Transect 3, which can be attributed to the presence of naturalized introductions, such as *Triphasia trifolia*, pickle tree (*Averrhoa bilimbi*), and custard apple (*Annona reticulata*), and some cultivated species, such as sweetsop (*Annona squamosa*) and citrus trees.

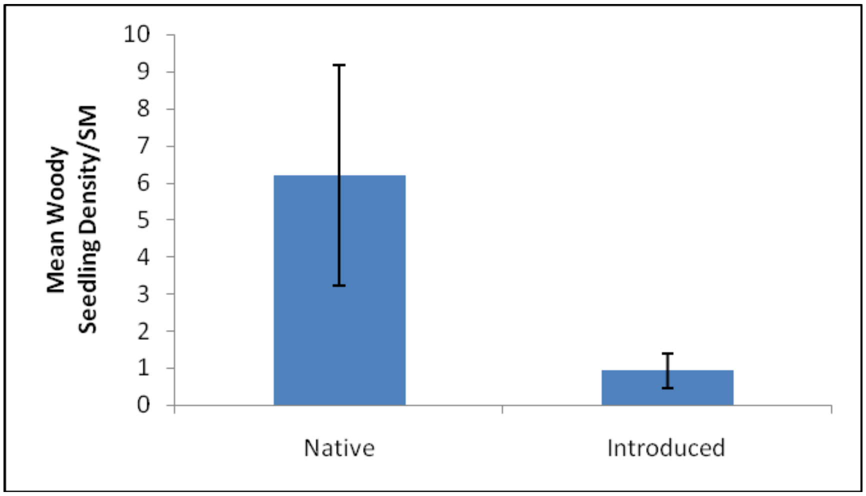


Figure 3.7-6. Mean woody seedling density for all transects, Route 15 (± 1 S.E.).

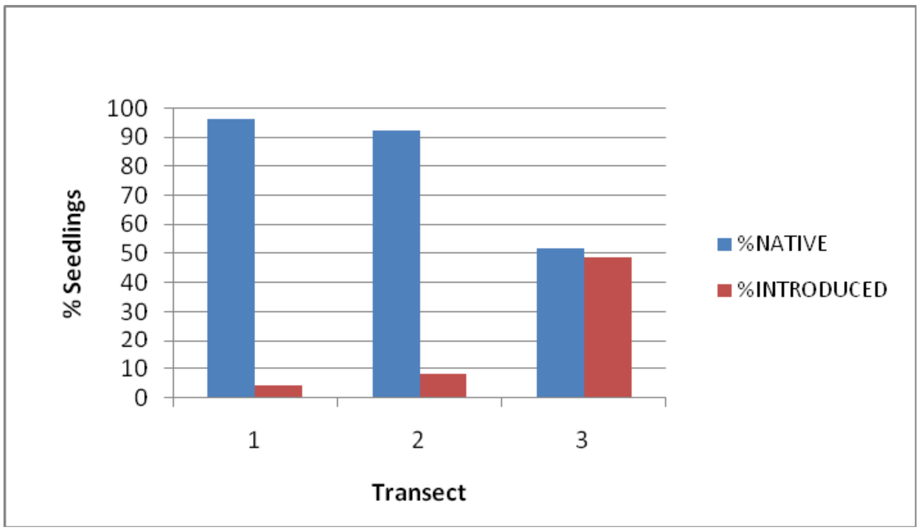


Figure 3.7-7. Percentage of native seedlings for each transect, Route 15.

3.7.4 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat at the Route 15 study area. These include ungulate activity, the presence of erosion, percent of native plant species, and overall species richness. Species richness curves for Transects 1 and 3 indicate higher richness for these areas than Transect 2 in the GEDCA parcel south of Lot 7161-R1 (Figure 3.7-8).

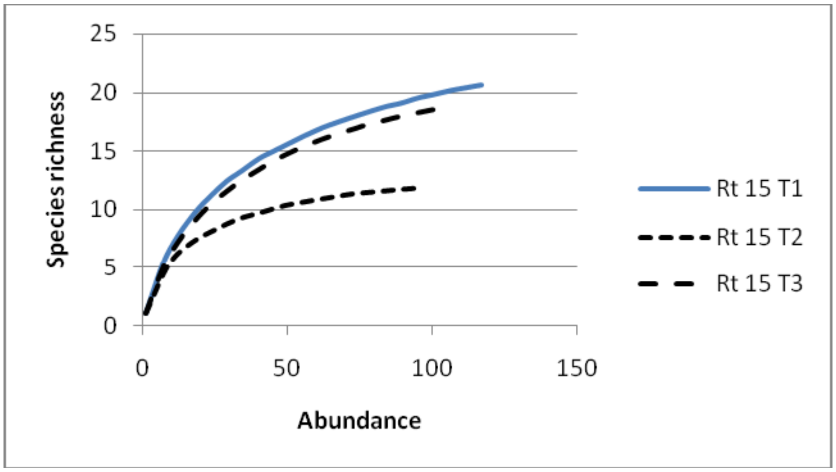


Figure 3.7-8. Species richness of trees along all transects at Route 15.

Leaf and vegetative litter had the highest frequency (8.7) among the four categories of ground cover quantified on the three transects (Figure 3.7-9). Live vegetation (3.9), rock (2.3), and soil (1.0) had significantly lower frequencies. Limestone rock outcrops were prevalent along all three transects as a natural feature of the terrain.

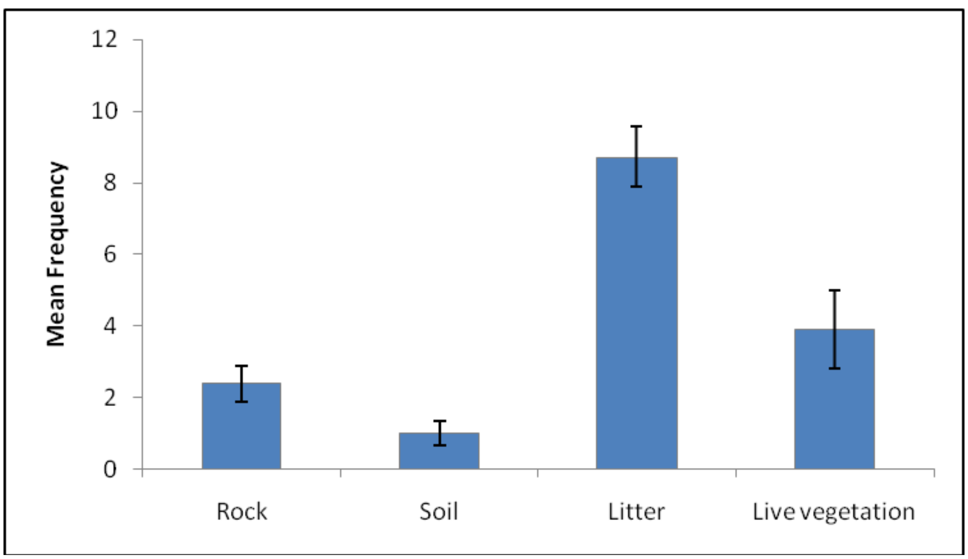


Figure 3.7-9. Mean frequency of ground cover along all transects at Route 15 (± 1 S.E.).

Ungulate activity along all three transects was highest in the form of soil disturbance (0.4), such as rooting or wallows (3.7-10). Rubbing and signs of browsing had similar frequencies approaching 0.2, while other signs, such as scat, were least observed with a frequency of around 0.1.

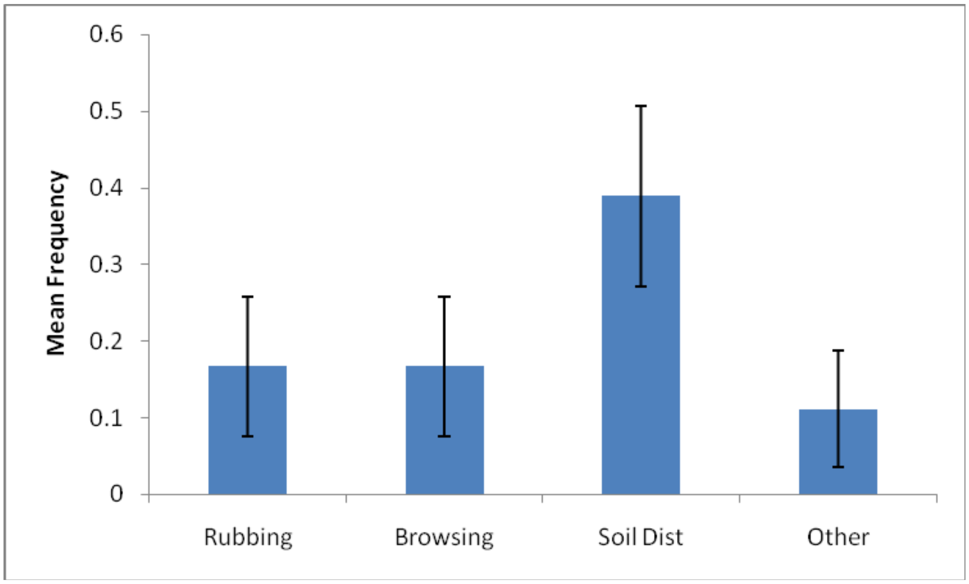


Figure 3.7-10. Mean frequency of ungulate activity along all transects at Route 15 (± 1 S.E.).

3.7.5 Threatened and Endangered Species and Species of Concern

3.7.5.1 Threatened and Endangered Species

The previous survey in Lot 7161-R1 identified 22 ufa halomtano (*Heritiera longipetiolata*) trees, with 184 associated seedlings (Duenas and Associates, Inc., 2000). This species is endemic to the Marianas and is listed as endangered by the Government of Guam, which considers ungulate damage, typhoons, and infrequent flowering as major threats to the viability of the population (Department of Agriculture, 2006). Other threats appear to be present, since several of the trees in Lot 7161-R1 were infested with termites or ants, or were parasitized by other plants, such as strangling fig (*Ficus* spp.) (Duenas and Associates, Inc., 2000). Several trees were left intact within a designated conservation area at the Guam Raceway Park as a required condition of the Department of Agriculture.

Figure 3.7-11. *Cycas micronesica* with *Nephrolephis acutifolia* epiphytes, Transect 1, Route 15.

No ufa halomtano trees were observed on the present transects in Lot 7161-R1 and Lot 7164; a single specimen was found near Transect 2 in the adjacent GEDCA parcel. The tree was mostly dead except for a 7 cm diameter branch near the base. The main trunk had a diameter at breast height (dbh) of 37 cm.

3.7.5.2 Species of Concern and Notable Species

The following species of concern were identified within the Route 15 parcels.

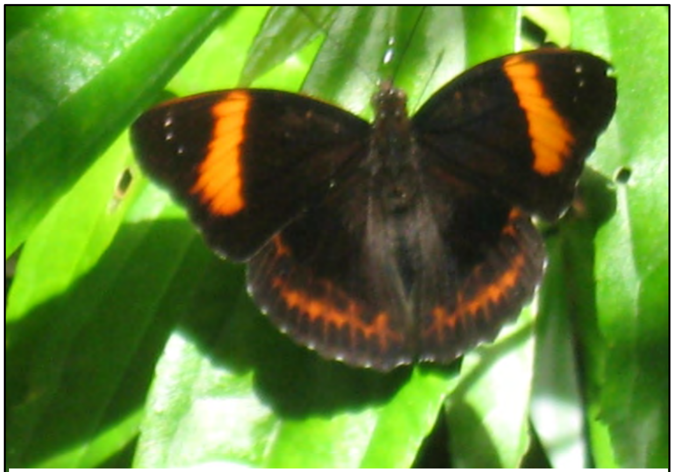


Figure 3.7-12. *Hypolimnas octocula* on Transect 2, Route 15.

Cycas micronesica (Figure 3.7-11) is considered a Species of Greatest Conservation Need (SOGCN) by the Government of Guam (Department of Agriculture, 2006). The islandwide populations are threatened by an introduced scale insect, *Aulocapsis yasumatsui*.

Elatostema calcareum (Urticaceae) and *Procris pedunculata* (Urticaceae) are indigenous succulent herbs that grow in limited habitats over limestone rock outcrops in moist limestone forest. These plants serve as host species for the Mariana eight-spot butterfly (*Hypolimnas octocula*), which is listed as a species of concern by the U.S. Fish and Wildlife Service (USFWS). One butterfly was found along Transect 2 in the GEDCA parcel (Figure 3.7-12).

Other species were noted, although they are not managed or protected by the local or federal governments.

Zehneria (*Melothria*) *guamensis* (Cucurbitaceae) is a rare endemic vine. The species was found in one small area of Lot No. 7161-R1 (Figure 3.7-13).

Figure 3.7-13. *Zehneria* (*Melothria*) *guamensis* with distinctive orange fruits, Transect 1, Route 15.

3.8 Former FAA Parcel

3.8.1 Location

The former FAA parcel (Lot Radio Station (R) Finegayan-1) is located adjacent and north of the Navy South Finegayan housing area in the Municipality of Dededo, Guam. The 678-acre property was the former site of the Federal Aviation Authority (FAA) Headquarters, but has since been returned to the Government of Guam (Guam Ancestral Lands Commission), and is currently administered by the Guam Economic Development and Commerce Authority (GEDCA). The parcel extends northwest from Route 3 to the western coastline encompassing Ague Point.

3.8.2 Quantitative Observations

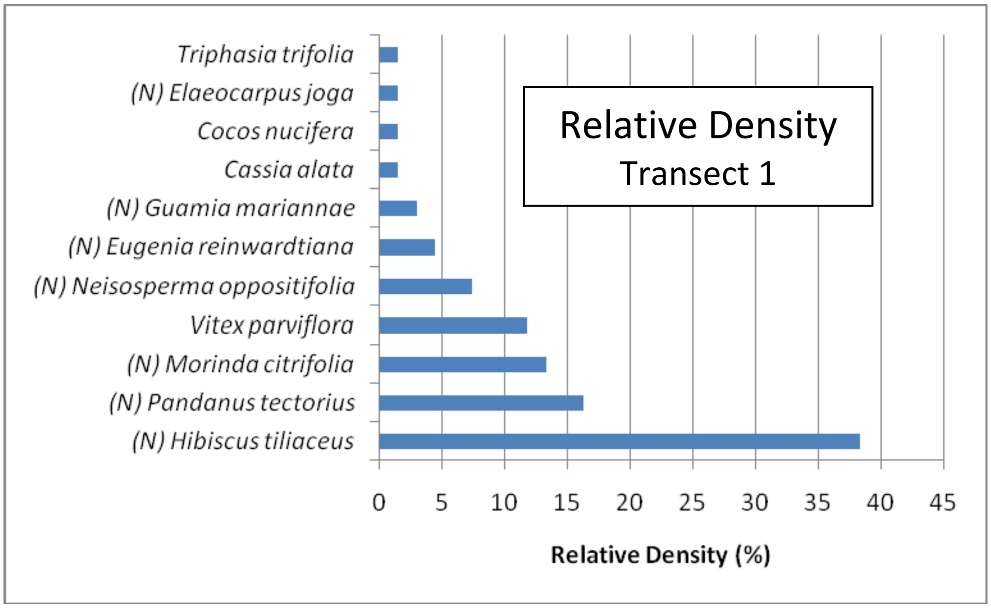
Quantitative surveys were performed using the point-center quarter method along three transects in the FAA parcel. Transect 1 was located along a north-south axis in the eastern sector and Transects 2 and 3 were located along a northwest-southeast axis in the central-southern sector.
Overall tree density among the three transects was lowest in the eastern sector with approximately 1,798 trees/ha and a total absolute cover of 25.85 m²/ha (Table 3.8-1). *Hibiscus tiliaceus*, or pago, was dominant with the highest density (687.44 trees/ha) and absolute frequency (58.82); however, this native species had a modest absolute cover of 2.03 m²/ha. Pago occurred as a mid-canopy species and comprised approximately 38% of the relative density among the 11 tree species encountered on the transect (Figure 3.8-1). Native species had a higher relative density (approximately 84%) than introduced species (approximately 16%). Aside from pago, kafu (*Pandanus tectorius*), lada (*Morinda citrifolia*) and *Vitex parviflora* had relative densities greater than 10%. Kafu and lada are native mid-canopy species; non-native *Vitex* occupied the upper canopy. Yoga (*Eleocarpus joga*), a native emergent canopy species, had the highest total basal area (4,126 cm²) and absolute cover (10.91 m²/ha), although only one specimen was encountered. *Eleocarpus* was not encountered along the other transects.

Table 3.8-1

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST
TRANSECT 1, FAA PARCEL, DECEMBER 2008

SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm²)	MEAN BASAL AREA (cm²)	ABSOLUTE COVER (m²/ha)	ABSOLUTE FREQUENCY
Elaeocarpus joga	N	26.44	4126.16	4126.16	10.91	5.88
Vitex parviflora	I	211.52	2337.49	292.19	6.18	41.18
Morinda citrifolia	N	237.96	785.25	87.25	2.08	41.18
Hibiscus tiliaceus	N	687.44	766.06	29.46	2.03	58.82
Cocos nucifera	I	26.44	637.62	637.62	1.69	5.88
Pandanus tectorius	N	290.84	498.48	45.32	1.32	35.29
Neisosperma oppositifolia	N	132.20	304.42	60.88	0.80	17.65
Eugenia reinwardtiana	N	79.32	227.14	75.71	0.60	11.76
Guamia mariannae	N	52.88	51.94	25.97	0.14	11.76
Cassia alata	I	26.44	35.24	35.24	0.09	5.88
Triphasia trifolia	I	26.44	5.72	5.72	0.02	5.88

Key to Status: N = native; I = introduced.



Note: (N) indicates native species; others are introduced.

Figure 3.8-1. Relative density (%) of trees along Transect 1, FAA parcel.

Transect 2 in the central-southern sector had the highest density among the transects, with 2,856.98 trees/ha and a total absolute cover of 24.86 m²/ha (Table 3.8-2). Both pago (*Hibiscus tiliaceus*) and kafu prevailed over other species with densities of 546.19 trees/ha and absolute frequencies of 47.06. These species, and paipai (*Guamia mariannae*) and fago (*Neisosperma oppositifolia*), had relative densities exceeding 10% (Figure 3.8-2). Overall, native species had a higher relative density (about 82%) than introduced species (about 18%), which was similar to the proportion observed in the eastern sector along Transect 1. Two species, paipai and mapunao (*Aglaia mariannensis*), are endemic to the Mariana Islands.

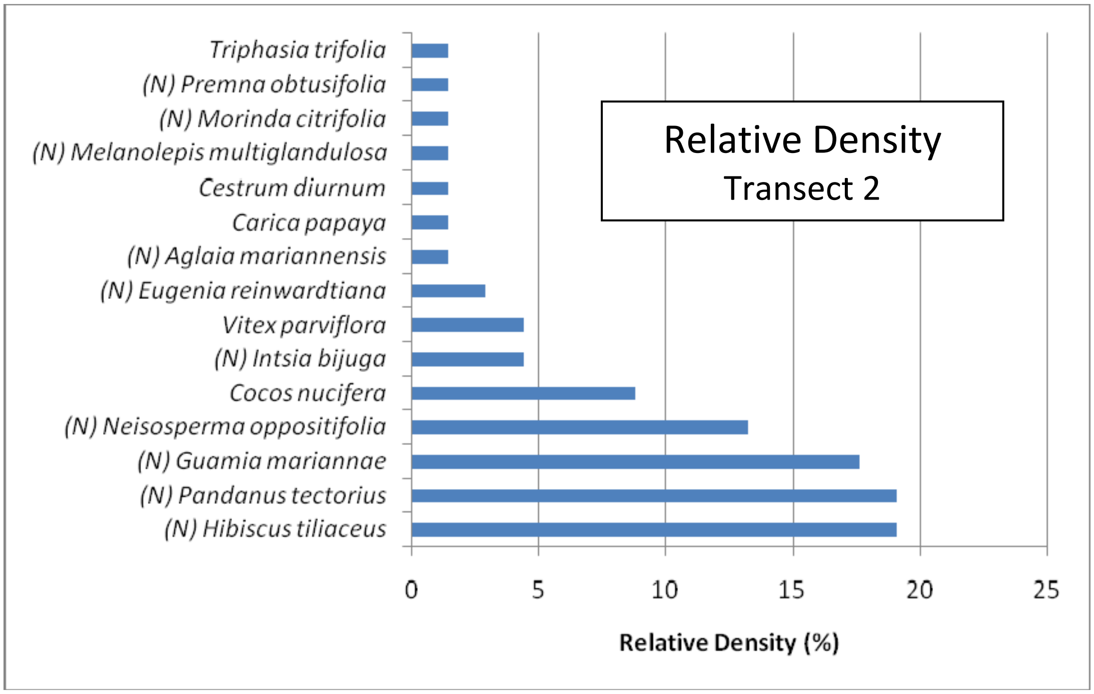
Coconut (*Cocos nucifera*) was dominant overall in absolute cover (12.75 m²/ha), followed by kafu, fago and ifil (*Intsia bijuga*). *Vitex parviflora* was less dominant than in Transect 1 in density (126 trees/ha) and absolute cover (0.93 m²/ha). The mean basal area of *Vitex* (73.91cm²) was also the lowest observed among the transects.

Table 3.8-2

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST
TRANSECT 2, FAA PARCEL, DECEMBER 2008

SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm²)	MEAN BASAL AREA (cm²)	ABSOLUTE COVER (m²/ha)	ABSOLUTE FREQUENCY
Cocos nucifera	I	252.09	3034.26	505.71	12.75	17.65
Pandanus tectorius	N	546.19	802.61	61.74	3.37	47.06
Neisosperma oppositifolia	N	378.13	786.81	87.42	3.31	35.29
Intsia bijuga	N	126.04	406.21	135.40	1.71	11.76
Vitex parviflora	I	126.04	221.72	73.91	0.93	17.65
Hibiscus tiliaceus	N	546.19	194.10	14.93	0.82	47.06
Guamia mariannae	N	504.17	151.66	12.64	0.64	35.29
Premna obtusifolia	N	42.01	118.76	118.76	0.50	5.88
Carica papaya	I	42.01	88.20	88.20	0.37	5.88
Morinda citrifolia	N	42.01	52.78	52.78	0.22	5.88
Eugenia reinwardtiana	N	84.03	20.07	10.04	0.08	5.88
Triphasia trifolia	I	42.01	13.85	13.85	0.06	5.88
Aglaia mariannensis	N	42.01	11.34	11.34	0.05	5.88
Cestrum diurnum	I	42.01	10.17	10.17	0.04	5.88
Melanolepis multiglandulosa	N	42.01	4.52	4.52	0.02	5.88

Key to Status: N = native; I = introduced.



Note: (N) indicates native species; others are introduced.

Figure 3.8-2. Relative density (%) of trees along Transect 2, FAA parcel.

Transect 3 had an overall tree density of 1,868.79 trees/ha and a total absolute cover of 41.24 m^2/ha (Table 3.8-3). The overall absolute cover was the highest among the three transects. Pago was consistently dominant among the transects, with the highest individual density (632.09 trees/ha) on Transect 3, and a relative density of about 33% (Figure 3.8-3). Pago (*Hibiscus tiliaceus*) also had the highest frequency among the seven species on Transect 3. Collectively, native species had a relative density of about 62%, which was the lowest proportion of native species among the three transects.

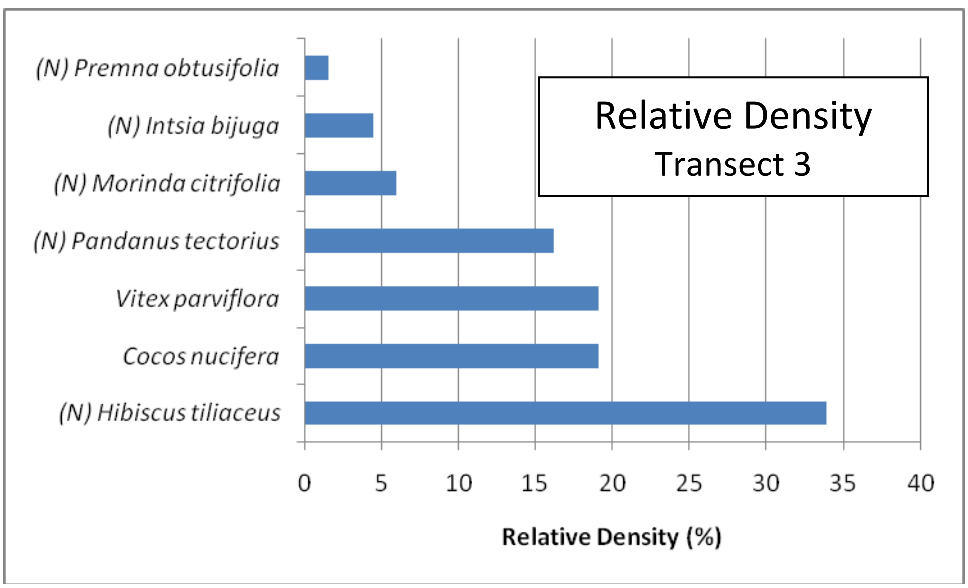
Coconut comprised the bulk of absolute cover (20.52 m/ha) on Transect 3; both density (357 trees/ha) and absolute cover were higher than in Transect 2. *Vitex parviflora* had the next highest absolute cover, and was as equally well-distributed along the transect as coconut with an absolute frequency of 41.18.

Table 3.8-3

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST TRANSECT 3, FAA PARCEL, DECEMBER 2008

SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm^2)	MEAN BASAL AREA (cm^2)	ABSOLUTE COVER (m^2/ha)	ABSOLUTE FREQUENCY
Cocos nucifera	I	357.27	7470.79	574.68	20.53	41.18
Vitex parviflora	I	357.27	5764.55	443.43	15.84	41.18
Intsia bijuga	N	82.45	525.32	175.11	1.44	17.65
Pandanus tectorius	N	302.30	507.47	46.13	1.39	35.29
Hibiscus tiliaceus	N	632.09	375.67	16.33	1.03	64.71
Premna obtusifolia	N	27.48	319.72	319.72	0.88	5.88
Morinda citrifolia	N	109.93	41.62	10.41	0.11	17.65

Key to Status: N = native; I = introduced.



Note: (N) indicates native species; others are introduced.

Figure 3.8-3. Relative density (%) of trees along Transect 3, FAA parcel.

The mean woody seedling density was significantly higher for native species (2.7 seedlings/m²) than for non-native species (0.3 seedlings/m²) (Figure 3.8-4). The proportion of native to introduced seedlings was similar for Transects 1 and 2, and slightly lower for Transect 3 (Figure 3.8-5). The seedling density reflects the higher native component observed in the relative tree densities along the transects.

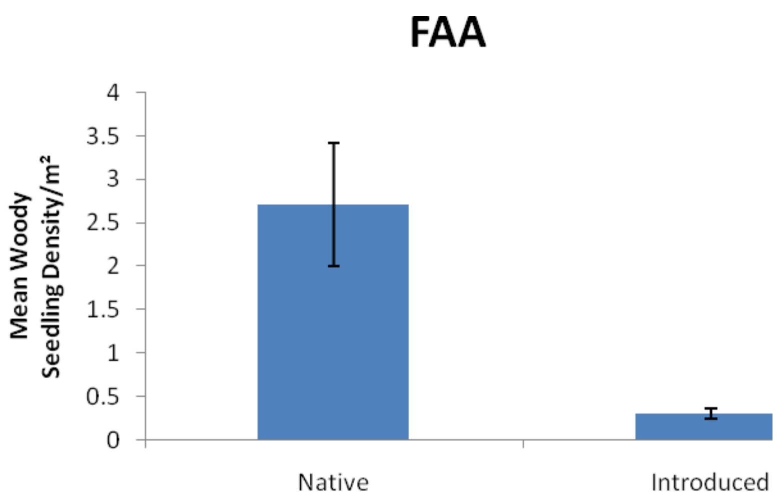


Figure 3.8-4. Mean woody seedling density for all transects, FAA parcel (± 1 S.E.).

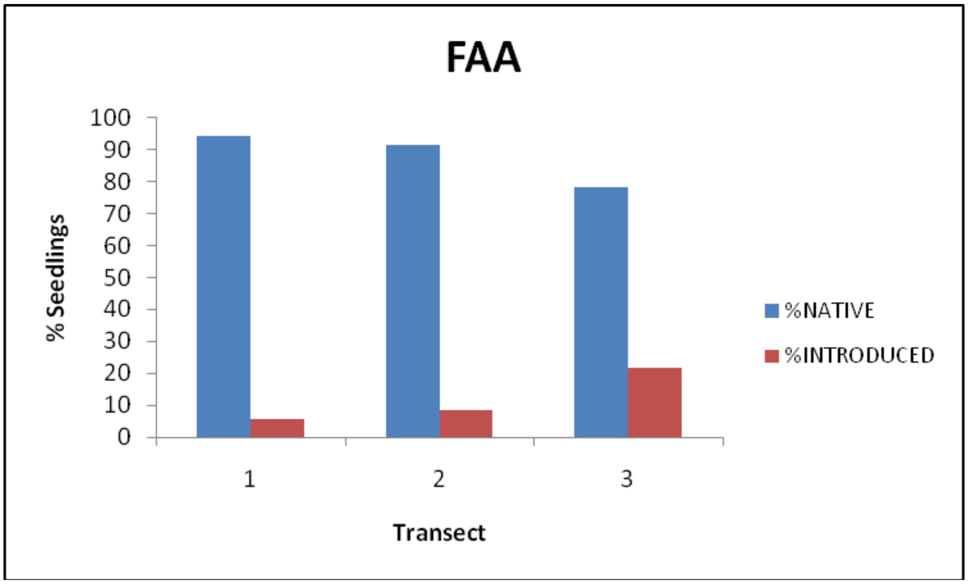


Figure 3.8-5. Percentage of native seedlings for each transect, FAA parcel.

3.8.3 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat in the former FAA parcel. These include ungulate activity, the presence of erosion, percent of native plant species, and overall species richness. Species richness curves indicate the highest tree species richness among the transects was along Transect 2, while Transect 3 had the lowest richness (Figure 3.8-6).

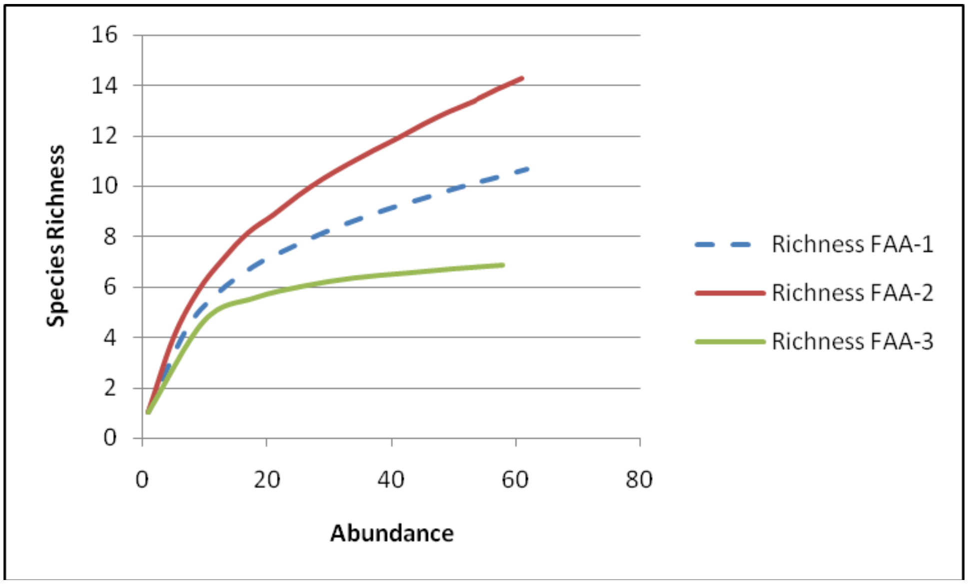


Figure 3.8-6. Species richness of trees along all transects at FAA parcel.

Leaf and vegetative litter comprised the highest mean frequency (5.6) among the four ground cover categories in the survey (Figure 3.8-7). Live vegetation had a similar frequency (5), while the limestone substrate and rocky terrain was reflected in the moderate frequency for rock (3.75). The lowest mean frequency was for bare soil (1.6).

Ungulate activity was encountered most frequently as soil disturbance, such as pig wallows and rooting (Figure 3.8-8). The mean frequency for soil disturbance appeared to be significantly higher than for rubbing and browsing on vegetation. Other signs of ungulate activity, such as scat, were not observed on the transects.

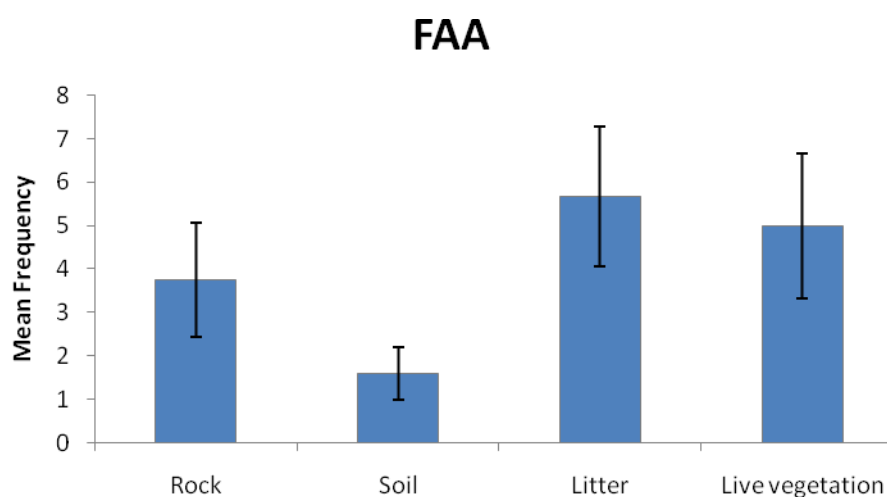


Figure 3.8-7. Mean frequency of ground cover along all transects at FAA (± 1 S.E.).

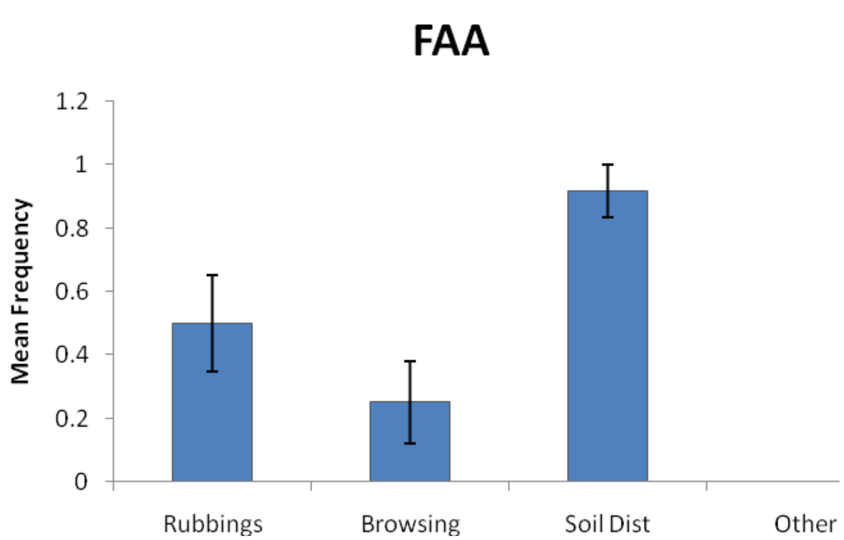


Figure 3.8-8. Mean frequency of ungulate activity along all transects at FAA (± 1 S.E.).

3.8.4 Threatened and Endangered Species and Species of Concern

No locally or federally listed threatened or endangered species were identified within former FAA parcel in the current survey. Likewise, no species of concern were identified within the study site.

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ATTACHMENT A

MAPS OF TRANSECTS

Figure 2. NCTS South Finegayan

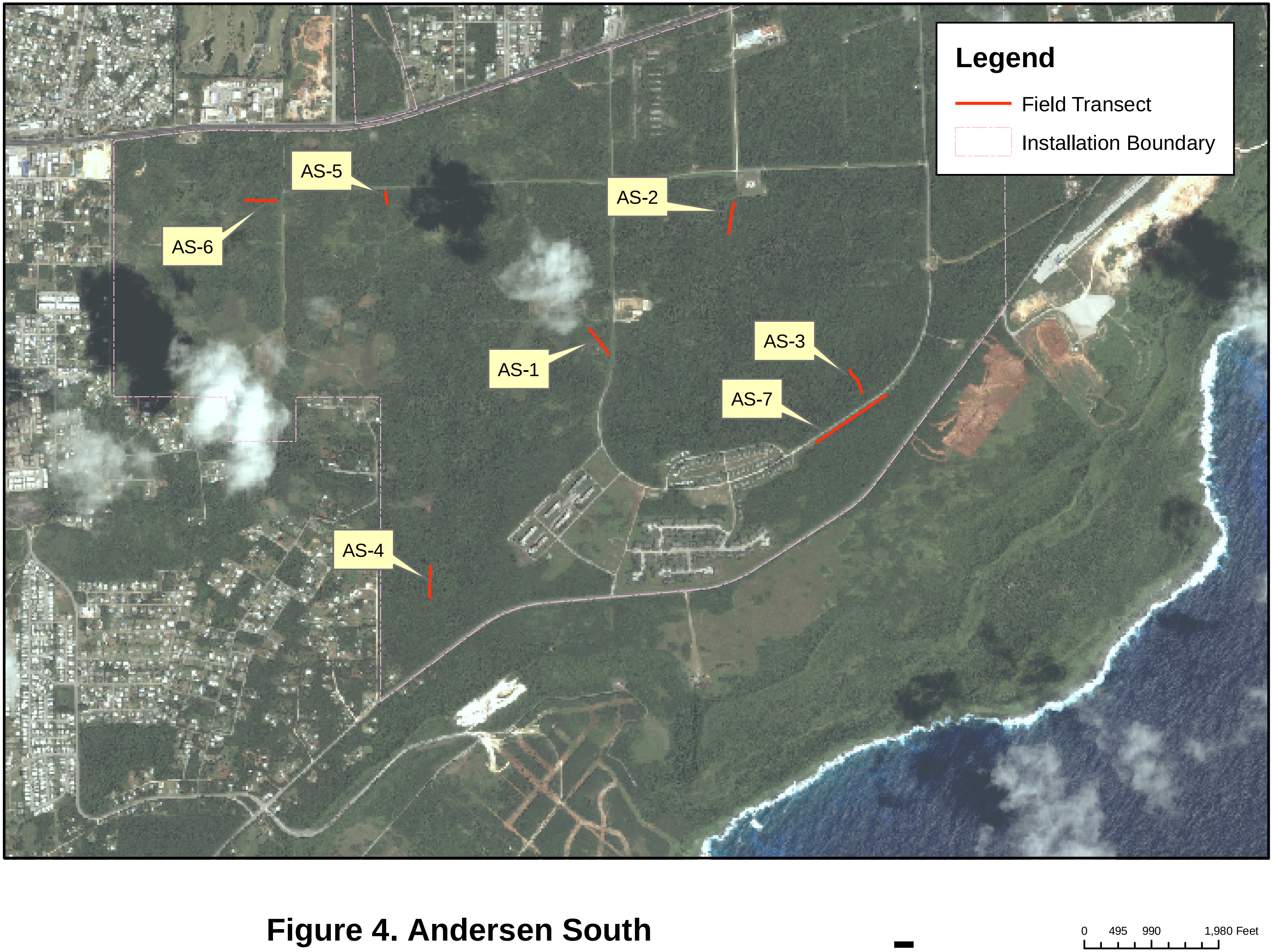


Figure 4. Andersen South

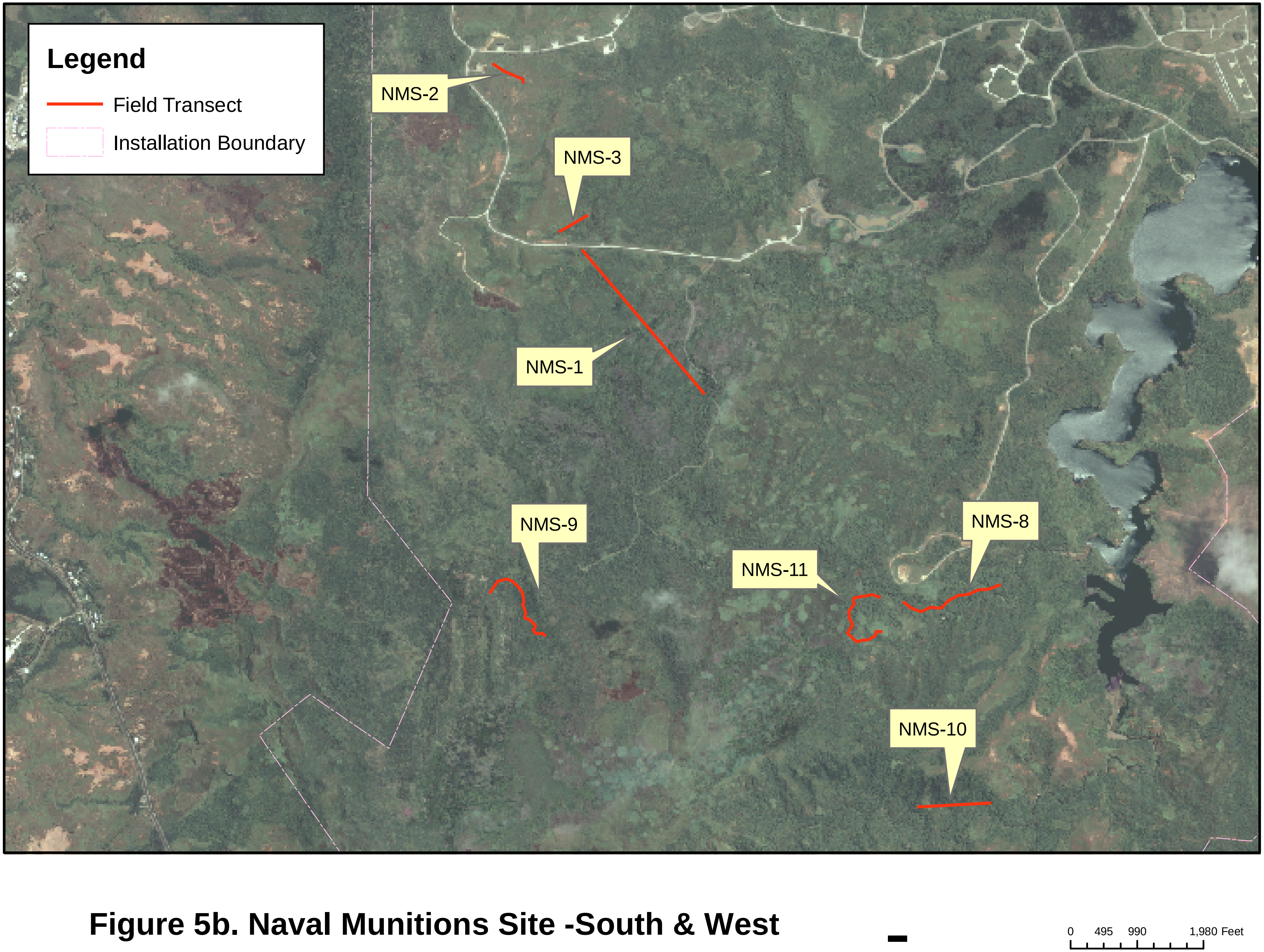


Figure 5b. Naval Munitions Site -South & West

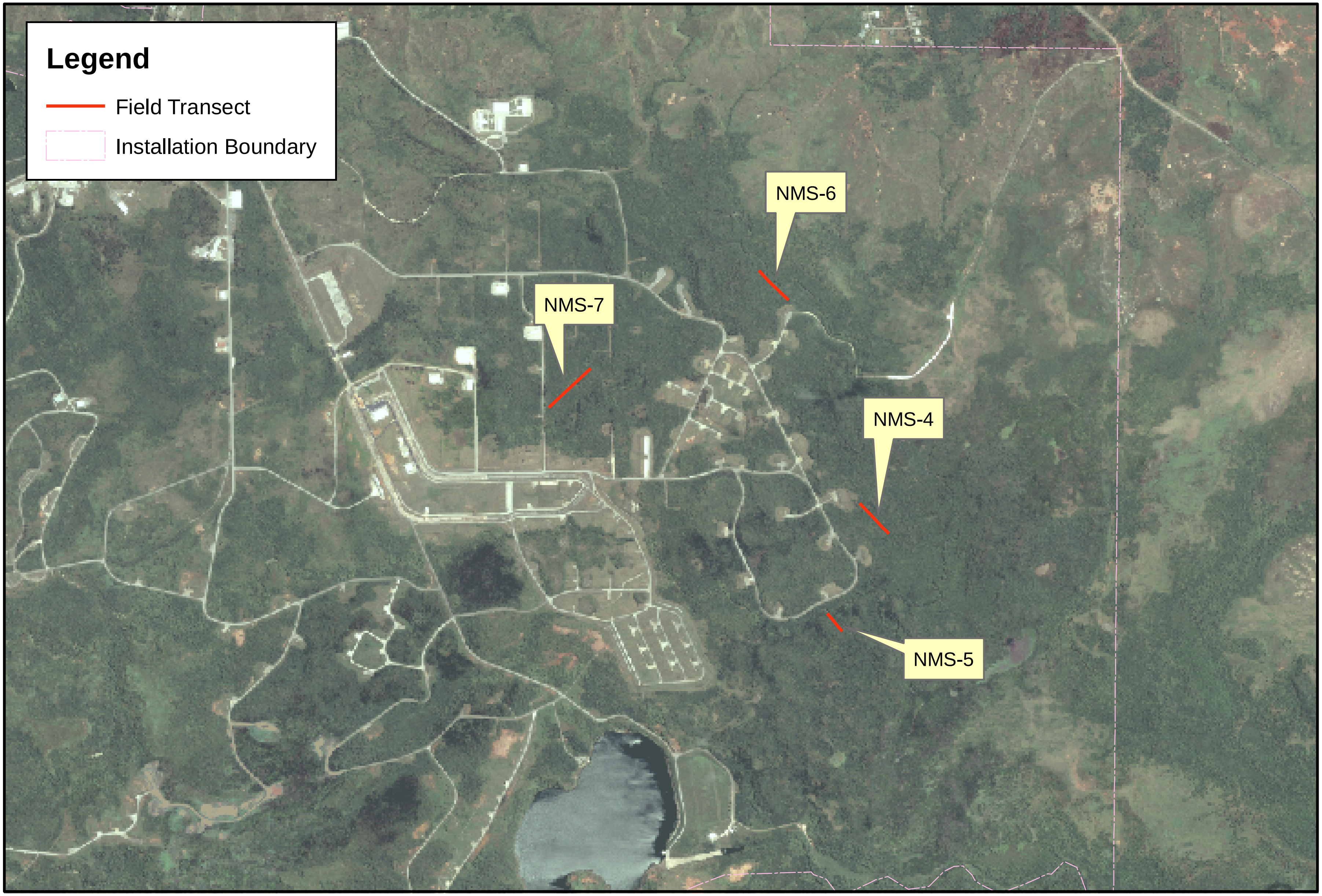
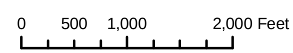


Figure 5a. Naval Munitions Site - East



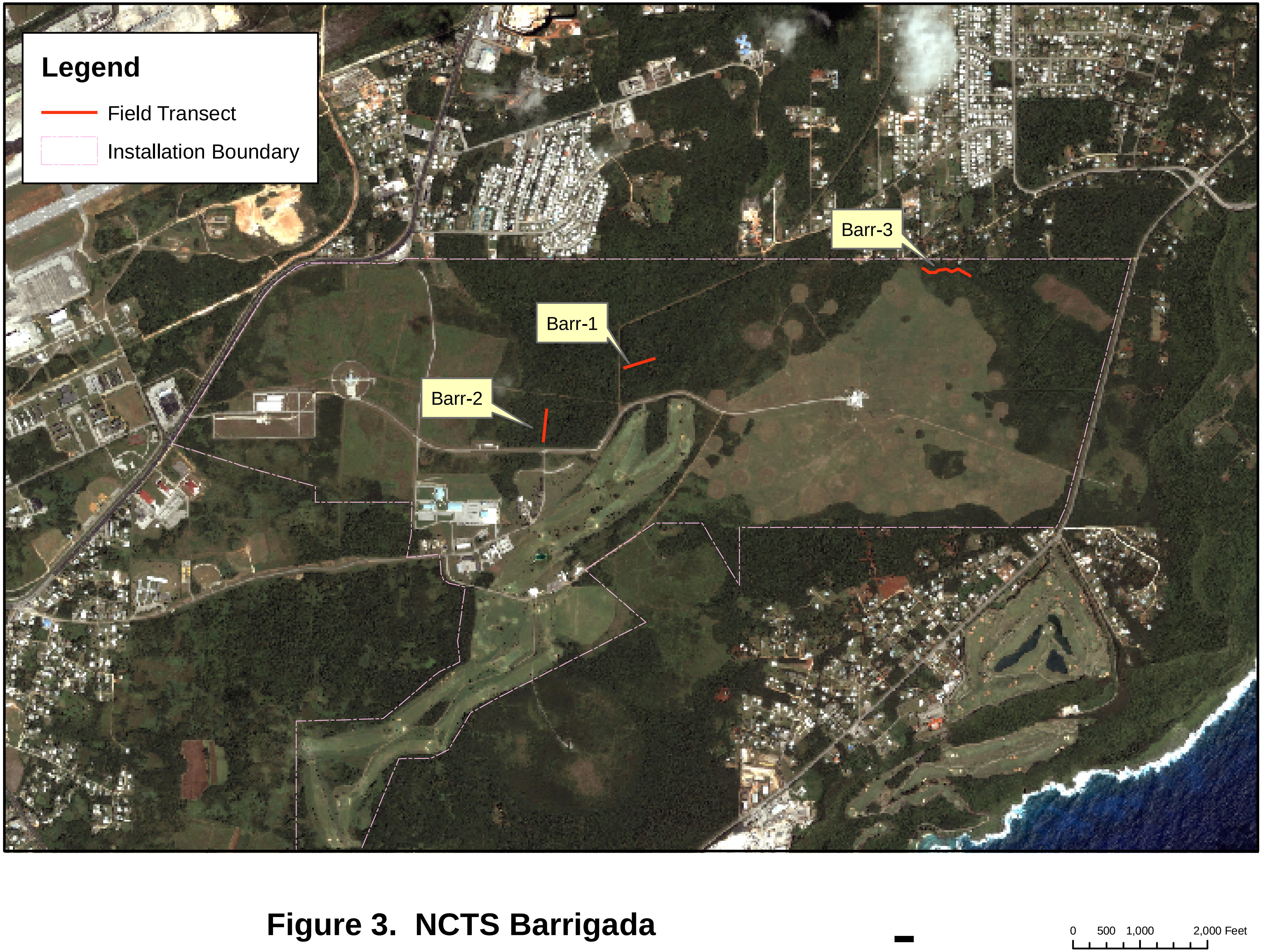


Figure 3. NCTS Barrigada

Figure 6. Orote

Figure 8. Former FAA Parcel

Guam Vegetation Surveys in Support of the Military Buildup EIS at Various Locations on Guam

Proposed Access Route to the Naval Magazine Site

Prepared for:

TEC Joint Venture

Prepared by:

TEC Inc.

Honolulu, Hawaii

Contract N62742-06-D-1870, TO 016 with Modifications 1,2, and 5

April 2010

Table of Contents

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1.0 Introduction

Vegetation field surveys have been conducted in support of the Guam Military Buildup EIS. This report documents qualitative surveys conducted and additional survey transects that were completed as followup to cover several additional areas after the initial set of transects that are described in another report. Qualitative surveys were conducted primarily to confirm or refine mapping of vegetation communities, targeting primary (relatively undisturbed) limestone forest and forest dominated by *Merrilliodendron mega-carpum*, a relatively uncommon forest type on Guam that is typically dominated by the species and is a known host plant for endangered tree snails. The surveys were also intended to document any Federal- or Guam-listed or rare plant species. Surveys were conducted at NCTS Finegayan, NMS Almagosa Basin, Access Road to NMS, and the Route 15 upper plateau lands (Firing Range Option A lands being considered in the EIS). At Andersen AFB the specific task was to document the presence of host plants for butterfly species that are candidates for listing under the Endangered Species Act (ESA). The primary host plant species targeted were two species that are hosts for the Marianas eight-spot butterfly (*Hypolimnas octocula mariannensis*) with limited distribution: *Procris pedunculata* and *Elatostema calcareum*. The Marianas wandering butterfly (*Vagrans egistina*) is the second candidate species and its known host plant is *Maytenus thompsonii*, a plant that is relatively common in primary and disturbed limestone forests.

The rare plant species that are not listed species are those identified in the Guam Comprehensive Wildlife Conservation Strategy as species of conservation concern (CWCS; Guam DAWR 2006). The native cycad identified in the CWCS (*Cycas circinalis* [*C. micronesica*]) was not evaluated in detail because it is relatively common but threatened by disease. The rare species evaluated and the listed species are as follows:

- *Cyathia lunulata* – Listed in the CWCS.
- *Cycas circinalis (C. micronesica*) – Listed in the CWCS.
- *Heritiera longipetiolata* – Guam-endangered.
- *Merrilliodendron mega-carpum* – Listed in the CWCS.
- *Serianthes nelsonii* – Federal- and Guam-endangered.
- *Tabernaemontana rotensis* – Listed in the CWCS (this species was determined by USFWS to be the same as *T. pandacaqui* [69 Federal Register 18499-18500]).

In addition to these species, other species that are thought to be uncommon based on the field experience of the botanists conducting the surveys are noted in the description of each site.

2.0 Methods

Qualitative general pedestrian surveys were conducted over several periods by three biologists (Glenn Metzler and Malia Kipapa of TEC Inc. and Claudine Camacho of Duenas, Camacho & Associates, Inc.). Surveys were conducted at NCTS Finegayan, NMS Almagosa Basin, Access Road to NMS, the Route 15 upper plateau lands (Firing Range Option A lands being considered in the EIS), and Andersen AFB. The survey periods for each site are listed under each site. Surveys consisted of walking transect lines in areas where specific vegetation communities were uncertain or where edges of certain mapped community types were uncertain, or in areas where specific activities are proposed (NMS Access Road where a new road is proposed and Andersen AFB were new utility lines are proposed). Transect lines, although depicted on maps as straight lines for clear visual depiction, were typically not straight lines but did follow generally the transect lines shown on the accompanying figures. Observation points are identified on figures and represent a general area for which vegetation is described in the text.

Quantitative surveys along 3 separate transects, one each at NCTS Finegayan, Anderson South, and Navy Barrigada. Methods included a point-quarter survey and plots. Methods are further described in the vegetation report in Appendix C and transect locations are shown in the Natural Resources Report to which this document is appended to.

Plants specifically searched for during all surveys are listed species or noted as species of conservation concern. Also searched for were the ERA candidate butterfly species host plants, with less emphasis on *Maytenus thompsonii* since it is a relatively common plant in most primary and disturbed limestone habitats. Plant names referred to in the text are the names listed by Raulerson (2006).

3.0 Results

3.1 Key Findings

One plant species listed as endangered by the Government of Guam, the tree *Heritierata longipetiolata*, was observed at the Route 15 site. These trees have been previously reported by Duenas and Associates (2000). They identified a total of 22 mature trees and 184 seedlings. No attempt was made to relocate all the individuals but some of them were observed in the present study. One species noted as a species of conservation concern in the Guam Wildlife Conservation Strategy (Guam DAWR 2006), the tree *Tabernaemontana rotensis*, was noted along one transect at Andersen AFB. *Merrilliodendron mega-carpum,* designated a species of conservation concern, is typically present in stands or patches and a total of 10 acres (4 hectares) were mapped at NMS. Another species noted as a species of conservation concern, the cycad *Cycas circinalis* (*C. micronesica*), was observed in numerous limestone forest locations.

Note: All figures showing sites and survey locations for the qualitative studies are provided at the end of this report. Transect locations for the quantitative vegetation descriptions along transects are shown in the Natural Resources Report to which this document is appended to.

Table 1. Presence of Plant Species in Survey Areas

Site Transects	*Cyathea lunulata*	*Cycas circinalis (C. micro-nesica*	*Heritiera longipet-iolata*	*Merrill-iodendron meg-carpum*	*Serian-thes nelsonii*	*Tabernae-montana rotensis*	*Maytenus thompsonii*	*Procris pedunculata or Elatostema calcareum*
Andersen AFB	-	X	-	-	-	X	X	-
NCTS Finegayan*	-	X	-	-	-	-	X	-
Route 15 Plateau	-	X	X	-	-	X	X	X
NMS	-	X	-	X	-	-	-	-
NMS Access Rd.	-	X	-	X	-	-	-	-
Potts Jct	-	-	-	-	-	-	-	-
NCTS Fin T-9	-	-	-	-	-	-	-	-
Andy South T-7	-	-	-	-	-	-	x	-
Navy Barr T-3	-	-	-	-	-	-	-	-

*excluding Haputo ERA

3.2 Route 15

Surveyors: Glenn Metzler (all dates) and Malia Kipapa (2008 only) for transects A-M; G. Metzler and Claudine Camacho (transects N-Q only).

Dates of Survey: December 5-10, 2008; January 19, 2010.

Summary – Several *Heritiera longipetiolata* trees and samplings were observed in one area and a single *Tabernaemontana rotensis* was observed. Primary limestone forest is prevalent in the cliffline area and this survey established a line separating primary limestone forest from secondary (disturbed) limestone forest. Near the cliffline rocky ground and outcrops become more common and the habitat is less disturbed and invaded by non-indigenous species. In the southern portions, the forest floor and limestone outcrops are moss-covered and have succulent herbs and ground orchids such as *Nervilia aragoana* and *Zeuxine fritzii*. Current quarry operations (as of January 2010) were removing primary limestone forest in the northern part of the survey area.

<u>Reference Figure 1. Route 15 North.</u>

Rt15-A, cleared area with scattered patches of trees and shrubs.

Rt15-A. Disturbed primarily open land with *Morinda citrifolia*, *Carica papaya*, *Pennisetum polystachion*, and *Nephrolepis hirsutula*. There are scattered patches of natives including a few *Cycas circinalis*.

Rt15-B. Native forest of *Neisosperma oppositifolia*, *Eugenia thompsonii*, *Aglaia mariannensis*, *Macarganga thompsonii*, *Pisonia grandis*, *Intsia bijuga*, *Casuarina equisetifolia*, and *Elaeocarpus joga*. At the cliffline is *Ficus prolixa*, *Hedyotis foetida*, *Bikkia tetandra*, *Allophyllus timoriensis*, *Thuarea involuta*, and *Cycas circinalis*. A few non-indigenous species including *Bidens alba* and *Passiflora suberosa*.

Rt15-C. The entire transect is cleared with small patches of native vegetation with indigenous native trees and shrubs of *Morinda citrifolia*, *Neisosperma oppositifolia*, and *Macaranga thompsonii* that are now being invaded by non-indigenous species such as *Bidens alba* and woody species such as *Carica papaya* and *Triphasia triflora* and the indigenous *Hibiscus tiliaceous*. Open areas are dominated by non-indigenous grasses and *Bidens alba*, *Stachytarpheta* spp, *Mikania scandens*, and *Cardiospermum halicacabum*.

Rt15-B, cliffline area with predominately indigenous woody plants, native cycad and non-indigenous herbs.

Rt15-B, quarry operations in January 2010 up to the cliffline.

Rt15-D. Similar to transect C.

Rt15E. This location is native forest up to the cliffline with dominants including *Macaranga thomsonii*, *Aglaia mariannensis*, *Eugenia reinwardiana*, and *Pisonia grandis* (ranging to 12 inch diameter).

Rt15-F. This is an area of predominately native vegetation with some cleared patches and lanes, with edges of native forest being invaded by *Carica papaya*, various non-indigenous herbs and vines, and indigenous *Hibiscus tiliaceus*. Vegetation outside of the cleared lanes is a diverse primary limestone forest including *Pandanus tectorius*, *Neisosperma oppositifolia*, *Macaranga thompsonii*, *Ficus tinctoria*, *Intsia bijuga*, *Aglaia mariannensis*, *Guamia mariannae*, *Eugenia reinwardtiana and E. thompsonii*, *Cycas circinalis* (to 15-20 feet tall), *Dendrocnide latifolia*, and abundant native ferns. A single *Tabernaemontana rotensis* tree was observed. The shrub *Maytenus thompsonii*, host for the Mariana wandering butterfly (*Vagrans egestina*), was observed but was not abundant. The substrate is estimated as 75% limestone rocks or rock outcrops.

Rt15-F, primary limestone forest with high diversity.

Rt15-G. Native vegetation is dominant including *Aglaia mariannensis*, *Guamia marianae*, *Macaranga thompsonii*, *Eugenia reinwardtiana*.

Rt15-H. This area is disturbed to the cliffline and dominated by the non-indigenous species *Bidens alba* and *Triphasia triflora*, and the indigenous *Hibiscus tiliaceous*.

Rt15-C, cleared areas with patches of native vegetation being taken over by invasives.

<u>Reference Figure 2. Route 15 Central.</u>

Rt15-I, transect disturbed up to cliffline; vegetation at cliffline is primarily native with stunted trees.

Rt15-I. This area consists of larger remnant forest patches with roads and clearings intermixed. Cleared area dominated by the herbaceous *Bidens alba* with some scattered native trees such as *Ficus tinctoria* and *Hibiscus tiliaceous* in edge areas. At the northwestern corner of the transect is a population of *Heritiera longipetiolata* with at least several remaining large trees and several saplings observed. This population was previously documented in an EIS prepared for the raceway in 2000 (Duenas and Associates 2000). Other species in this diverse forest are *Ficus tinctoria*, *Mammea odorata*, *Pandanus tectorius*, *Guamia mariannae*, *Aglaia mariannensis*, *Pisonia grandis*, and *Eugenia reinwardtiana*. Near the cliff is a stunted *Ficus prolixa* forest festooned with the non-indigenous vine

Cuscuta campestris. Entire area is mapped as primary limestone forest because that is the predominant vegetation.

Rt15-K, *Pisonia grandis* with fern epiphytes.

Rt15-J. Edge of forest at open field that is dominated by grasses, *Triphasia triflora*, and the native pioneer species, *Hibiscus tiliaceous*, *Psychotria mariana*, and *Flagellaria indica*. The vegetation transitions quickly into relatively undisturbed primary limestone forest.

Rt15-K. Primary limestone forest dominated by *Neisosperma oppositifolia*, *Eugenia reinwardtiana*, *Aglaia mariannensis*, *Guamia mariannensis* with a few large *Pisonia grandis* trees.

<u>Reference Figure 3. Route 15 South.</u>

Rt15-L. Scrub forest at field edge with non-indigenous *Triphasia trifolia* and *Leucaena leucocephala* and in more open areas *Lantana camara* and *Bidens alba*; native pioneers or edge species present including *Hibiscus tiliaceous*, *Wikstromia elliptica*, and *Ochrosia mariannensis*.

Rt15-M. Primary limestone forest of *Macaranga thompsonii*, *Ficus* spp, *Neisosperma oppositifolia*, *Eugenia reinwardtiana*, *Cynometra ramiflora*, *Ochrosia mariannensis*, *Intsia bijuga* and a few *Barringtonia asiatica*. *Maytenus thompsonii* was also observed.

Rt15-L, edge of primary limestone forest with mix of native and non-native species.

Rt15-N. Field-grass edge with *Pennisetum polystachion* and a few scattered *Psychotria mariana* and *Morinda citrifolia*.

Rt15-O. Primary limestone forest near cliff edge including *Mammea odorata*, *Ficus prolix*, *Premna obtusifolia*, *Pandanus tectorius*, and small *Cycas circinalis*, but becomes progressively more invaded towards the open field. Cliffline species *Bikkia tetrandra*, *Allophyllus timoriensis*, and *Xylosma nelsonii.*

Rt15-N, forest field edge.

Rt15-O, native limestone forest with mix of native species including *Mammea odorata*.

Rt15-P. Native species dominate similar to Rt15-O but with larger *Cycas circinalis*, *Mammea odorata* and some large *Pisonia grandis*. Also in this forest are *Eugenia reinwardtiana* and *Intsia bijuga*, Fern species are present such as as *Asplenium polyodon* and *Polypodium scolopendria*, and vines such as *Jasminum marianum*) and *Flagellaria indica*. There is heavy pig damage in some areas of the forest in less rocky areas away from the cliffline. Most *Cycas circinalis* are dying.

Rt15-Q. This is a mixed shrub community of woody species with indigenous and invasive, non-indigenous species. There is much *Hibiscus tiliaceous* and non-indigenous species including *Triphasia trifolia*, *Lantana camara*, and the herbaceous *Eupatorium odoratum* (*Chromolaena odorata*) and large area with heavy *Coccinea grandis* vine infestation. Pig damage is very heavy in places.

Rt15-P, pig damage.

3.3 NCTS Finegayan

Surveyors: Glenn Metzler (all dates) and Malia Kipapa (2008 only).

Dates of Surveys: December 9, 2008; January 15, 2010 (Fin Central only).

Summary – No listed or rare species were observed. A small patch of the host plant for the Mariana eight-spot butterfly (*Hypolimnas octocula mariannensis*), *Procris pedunculata* was observed scattered in one area of cockscomb limestone in a few patches. The cockscomb limestone area also has some large *Cycas circinalis* to nearly 20 feet in height.

Reference Figure 4. NCTS Finegayan North.

Fin-A. Transect traverses a disturbed limestone forest of mixed native and invasive species with a heavily browsed understory and openings. A few large *Ficus tinctoria* and *Artocarpus mariannensis* are scattered at various locations. Species in the forest include *Vitex parviflora*, *Neisosperma oppositifolia*, *Hibiscus tiliaceus*, *Morinda citrifolia*, *Pandanus tectorius*, and *Cycas circinalis*.

Fin-A, disturbed limestone forest with scattered emergent trees and open areas.

Reference Figure 5. NCTS Finegayan Central.

Fin-B, large *Cycas circinalis* on limestone.

Fin-B. An area of cockscomb limestone, very uneven. Abundant *Cycas circinalis* present, some large to nearly 20 feet in height. Mixed diverse canopy and understory, primarily indigenous species such as *Neisosperma oppositifolia*, *Macaranga thompsonii*, *Guamia mariannae*, *Aglaia mariannensis*, *Pandanus dubius*, *Eugenia reinwardtiana*, and a few *Dendrocnide latifolia.* Scattered non-indigenous species are also present. Herbaceous species on the rocky substrate includes scattered patches of *Procris pedunculata*.

Fin-C. Approximate boundary between primary limestone forest and secondary (disturbed) limestone forest with the disturbed vegetation primarily *Annona reticulata*, *Triphasia triflora*, *Cestrum diurnum*, and *Stachytarpheta* spp and the primary limestone forest dominated by a mix of indigenous species as noted above .

Fin-D. There is a large sinkhole depression just to the north, approximately 100 or more feet in diameter with a large *Artocarpus mariannensis* down in the bottom. The boundary between primary and secondary limestone forest includes similar species to those described above with the addition of *Leucaena leucocephala* along the edge of the access road.

Reference Figure 6. NCTS Finegayan South.

Fin-E. The overstory is dominated by *Vitex parviflora* with scattered *Premna obtusifolia*, *Neisosperma oppositifolia*, and *Intsia bijuga*. An occasional specimen of indigenous *Elaeocarpus joga* or *Artocarpus mariannensis* trees. The understory is of mixed species, predominantly native including *Neisosperma oppositifolia*, *Guamia marianae*, and *Pandanus tectorius* or *Pandanus dubious*. *Maytenus thompsonii* was also noted. Occasional clearings dominated by herbaceous invasive species including *Eupatorium odoratum* (*Chromolaena odorata*), *Mikania scandens* and other invasive vines, and the native swordfern *Nephrolepis hirsutula*.

Fin-E, opening in disturbed forest with non-native herbaceous vegetation and a large *Eleaocarpus joga*.

Fin-F. The vegetation is similar to Fin-E but with a more rocky substrate.

Photo 13. Fin-G, *Vitex parviflora* dominanted canopy with substrate of mixed moss-covered rock and soil.

Fin-G. The forest is primarily a *Vitex parviflora* canopy with an understory of *Neisosperma oppositifolia*, *Aglaia mariannensis*, *Guamia marianae*, and *Eugenia reinwardtiana*. The substrate is mixed areas of soil and rock.

Fin-H. The area is heavily disturbed with much bare ground, including a very large pig wallow approximately 20 feet x 8 feet. The area is dominated by *Cestrum diurnum*, *Hibiscus tiliaceous* (the primary indigenous species), *Triphasia trifolia*, *Annona reticulata*, and *Mikania scandens*. There is scattered *Neisosperma oppositifolia*.

<u>Reference Figure 7. NCTS Finegayan East.</u>

Fin-H, large pig wallow in open area of the forest.

Fin-I. Vegetation in this area near a borrow pit is similar to many other areas on NCTS Finegayan. The forest canopy is generally closed and dominated by *Vitex parviflora* with some large individual trees. There are scattered large *Artocarpus mariannensis* (to approximately 18 inch diameter with prominent buttresses) and an occasional *Elaeocarpus joga*. One large *Barringtonia asiatica* was also observed. Other species in the canopy or subcanopy are *Morinda citrifolia*, *Hibiscus tiliaceous*, *Pandanus dubious*, *Pandanus tectorius*, *Ficus tinctoria*, and *Neisosperma oppositifolia*. Understory woody species that are prevalent include the indigenous species *Guamia mariannae*, *Hibiscus tiliaceous*, and *Eugenia reinwardtiana* and *Eugenia palumbis* (in patches) and the invasive *Triphasia trifolia*. *Piper guahamense* was common in the understory as were ferns, both terrestrial and ephytic, including *Polypodium* spp., *Pteris tripartita*, and *Pteris vittata*. Some areas had abundant moss-covered rock. Vines included *Jasminum marianum* and *Flagellaria indica* and a single specimen of *Dischidia puberula*, an uncommon species, was also observed. Along the utility line right-of-way in this area were numerous *Maytenus thompsonii*, many of which were noted in flower and fruit. Some *M. thompsonii* were also observed in the forest.

Fin I, an emergent *Artocarpus mariannensis* in a surrounding disturbed limestone forest.

3.4 Naval Munitions Site

Surveyors: Glenn Metzler (December 08 and January 2010) and Malia Kipapa (December 08 only).

Dates of Surveys: December 19, 2008 and January 20, 2010.

Summary – Three separate *Merrilliodendron mega-carpum* stands were mapped totaling 10 acres (4 hectares). In addition numerous other smaller scattered patches of *Merrilliodenron* were noted in the area. Several uncommon species were observed including *Dishidia puberula* and *Coelogyne guamense*, the latter an orchid species found primarily in the branches of large trees on high limestone ridges and found on Guam, Rota, and Palau (Raulerson and Rinehart 1992).

Reference Figure 8. Naval Munitions Site Almagosa.

NMS-A. Edge of *Merrilliodendron* forest in rocky outcrop understory including ferns and *Freycinetia reineckei*.

Merrilliodendron forest is a relatively uncommon forest type on Guam with known stands in the Haputo ERA, Hiilan Point, Mt. Lamlam, Mt. Tenjo (Guam DAWR 2006), within the Almagosa basin and surrounding areas of NMS, and a small patch located along the proposed western access road to NMS (see Access Road description in Section 3.5 of this report). Other stands may be present in other areas on Guam, particularly on private lands where there have been few studies. The *Merrilliodendron* trees at Haputo ERA and the Lost Pond area are known hosts of tree snails that are Guam-listed species and are candidate species for listing under the Endangered Species Act. *Merrilliodendron* forest patches appear to be scattered throughout the Alamagosa basin area but there are only a few known larger *Merrilliodendron* areas that are hereafter described as stands (see Figure 7). No tree snails were observed in a cursory visual examination in these forests but a thorough search was not conducted.

NMS-B , northern end of Merrilliodendron Stand A and open areas between trees.

NMS-B. This location is near the northern limit of the largest *Merrilliodendron* stand where there are more openings in the canopy and species such as *Pandanus* spp. and *Hibiscus tiliaceus* become more prevalent. Elevation is generally increasing.

NMS-C. The terrain becomes more varied in this area with areas of dissected limestone with crevasses 6 feet or more deep. Based on observations to the south, some water may drain from the large wetland into this area. The

NMS-C, near edge of *Merrilliodendron* stand, an area with highly dissected limestone.

vegetation is also more varied with *Pandanus* spp., *Discocalyx megacarpa*, *Guettarda speciosa*, *Cycas circinalis,* and *Ficus* spp. and ferns such as *Microlepia speluncae*. A specimen of an uncommon vine, *Dischidia puberula*, was observed in the area.

NMS-D. This location is quite open and beyond the edge of the *Merrilliodenron* stand. A specimen of the somewhat uncommon shrub *Drypetes dolichocarpa* was noted in this area. *Fagrea berteriana*, an uncommon tree, was also noted at scattered locations in the general area.

NMS-E. This location is near the eastern edge of a smaller *Merrilliodendron* stand. This edge is on the west-facing slope of a north-south ridge with slopes estimated at 25-40 degrees. This west-facing slope is lush with ground cover of fern species and rock outcrops covered in thick moss. On the side of this ridge near the southern edge of the *Merrilliodendron* stand in one area is a large group of *Coelogyne guamense*, an epiphytic orchid species typically found primarily in the branches of large trees on high limestone ridges (Raulerson and Rinehart 1992), so not often observed. The western edge of this smaller stand is not as clearly defined as the sloped eastern edge because there are more openings and less dominance by *Merrilliodendron*.

NMS-E, the epiphytic orchid *Coleogyne guamense*.

NMS-E, West facing slope at the edge of the *Merrilliodendron* stand with diverse vegetation.

NMS-E, from the ridgetop looking southwest. towards cliffs, probably limestone and with heavy vegetation.

NMS-E, from the ridgetop looking southeast with savanna vegetation and a large wetland in the basin.

NMS-F, edge of *Merrilliodendron* forest with some openings and dead cycad.

NMS-F. This location is near the western edge of this smaller *Merrilliodendron* stand. There are numerous openings in the canopy. The pattern of vegetation and some dead cycads indicates a possibility that fires occurred which created the openings.

NMS-G. This area has another small *Merrilliodendron* stand as well as other small scattered patches of this species not within the stand to the north and south. Scattered in this area are a few large *Artocarpus mariannensis*, standing out well above any of the surrounding vegetation, which is fairly low in stature at about 15-25 feet.

NMS-H. This area is somewhat open and weedy with numerous invasives such a s*Eupatorium odoratum* (*Chromolaena odorata*), grasses, *Mikania scandens*, and other vines. The native vine *Stictocardia tiliaefolia* is common and the dominant trees include the palms *Cocos nucifera* and *Areca catechu* and *Pandanus* spp.

NMS-H, View looking southwest over ravine forest with open canopy dominated by *Cocos nucifera* and a mix of other species.

NMS-I. Patches of *Merrilliodendron* were noted in this area on the east-facing slope above where Almagosa spring emerges.

NMS-J. A brief visual survey along the trail to Mt. Lamlam noted several scattered patches of forest dominated by *Merrilliodendron* in this area. These areas were not investigated in detail but may cover up to several acres.

Reference Figure 9. Naval Munitions Site EOD.

NMS-EOD-1. Canopy on slopes dominated by *Vitex parviflora* with patches of *Cocos nucifera*.

EOD-1. This area is off to the left of the road going into the EOD site. It had a canopy nearly completely dominated by *Vitex parviflora* with much young *Cocos nucifera* in the understory and some of the canopy dominated by *Cocos nucifera*. Other areas of the understory were sparse.

EOD-2, 3. This area consists of ravine forest. The trees on the upper slopes in this entire area are almost entirely the invasive tree *Vitex parviflora* and they tend to occur in small groves interspersed by openings. These trees, particularly the numerous larger specimens (up to 2 feet in diameter), often host the ephiphytic orchid *Dendrobium guamense* and common epiphytic ferns, typically the common species such as the small *Pyrrosia lanceolata and Polypodium punctatum*. Even within the forested areas the canopy is thin with much sunlight and an understory of mixed indigenous and non-indigenous woody and herbaceous species.

EOD-2. Looking southwest over a ravine forest dominated by *Vitex parviflora* on slopes (entire view) and *Cocos nucifera* and *Pandanus* spp. near valley bottoms.

EOD-3. *Vitex parviflora* dominates the canopy with some trees attaining large size.

3.5 NMS Access Road

Surveyors: Glenn Metzler and Claudine Camacho.

Date: July 2, 2009.

Summary – The proposed access road would follow an existing foot trail that traverses savanna vegetation with a few stands of forest in minor valleys. The area surveyed was within approximately 75 feet of either side of the trail. *Merrilliodendron mega-carpum* forest was present and dominated a portion of the small forest on either side of the trail at the highest forest stand encountered along the trail. As discussed in Section 3.3, this forest type is not common on Guam. On both sides of the trail the *Merrilliodendron* forest did not appear to extend much, if any, beyond the survey corridor. No threatened or endangered or rare species were observed.

Reference Figure 10. NMS Access Road.

AccessRd-A. This is a forested patch with openings and dominated by tangantangan and *Hibiscus tiliaceous* with scattered *Cocos nucifera*. *Panicum maximum* and *Saccharum officianarum* dominate in openings and the surrounding area and herbaceous weeds such as *Bidens alba*, *Elephantopus mollis*, and *Mikania scandens* are in the understory along with indigenous *Piper guahamense* and *Flagellaria indica*.

AccessRd-A, view of typical terrain and vegetation along the trail; the initial forested patch is dominated by *Leucaena leucocephala*.

AccessRd-B. Forest stand of mixed indigenous and non-indigenous trees and shrubs.

AccessRd-B. This area is a strip of ravine forest oriented north-south with a diverse mix of indigenous and non-indigenous species. Indigenous trees and shrubs include *Premna obtusifolia*, *Guettarda speciosa*, *Ficus tinctoria*, *Pandanus dubious*, *Morinda citrifolia*, *Glochidion marianum*, *Aglaia mariannensis*, and *Phyllanthus marianus*. *Leucaena leucocephala* and *Triphasia triflora* are the dominant invasive woody species. Epiphytes are common including various common ferns and some specimens of the endemic orchid *Dendrobium guamense*. The understory contains indigenous ferns including *Thelypteris guamensis*, *Antrophyum plantagineum*, and *Nephrolepis biserrata*, and the indigenous vines *Freycinetia reineckei*, *Jasminum marianum*, and *Entada pursaetha*. Grasses and sedges present included the indigenous *Miscanthus floridus*, *Centotheca lappacea*, *Isachne miliacea*, *Scleria polycarpa*, and various non-indigenous grasses.

AccessRd-C. West end of highest elevation forest stand.

AccessRd-C. This is the western portion of a north-south oriented strip of ravine forest. This western portion is somewhat open and includes a mix of indigenous and non-indigenous species but dominated by *Leucaena leucocephala*. Indigenous species present are primarily those that do well in disturbed conditions such as *Morinda citrifolia* and *Flagellaria indica*.

AccessRd-D. This is the eastern portion of a north-south oriented strip of ravine forest. This is the location with a statue of the Virgin Mary placed on a ledge of a limestone outcrop. On either side of the existing trail in the eastern portion of the forested strip the vegetation is dominated by *Merrilliodendron mega-carpum*. The cleared width of the trail through this area ranges from approximately 15-20 feet. The area containing the *Merrilliodendron* forest is estimated at less than 1 acre. The dominant tree/shrub in much of this forest near the trail is *Leucaena leucocephala*. *Areca catechu* and *Triphasia triflora* are other common invasive trees or shrubs. Indigenous trees and shrubs include *Premna obtusifolia*, *Pandanus dubious* and *P. tectorius*, *Glochidion marianum*, *Hibiscus tiliaceous*, and a few *Cycas circinalis*. Low shrubs include *Discocalyx megacarpa* (in fruit) and *Medinilla medinilliana*. Epiphytes are common including various common ferns and some specimens of the endemic orchid *Dendrobium guamense*. Ferns on the ground or on rock walls include *Thelypteris gretheri*, *Thelypteris torresiana*, *Tectaria crenata*, and *Nephrolepis biserrata*. The indigenous vines *Freycinetia reineckei*, and *Flagellaria indica* are common. There are few grasses and sedges. Edges of the forest patch are dominated by *Leucaena leucocephala*. Soil disturbance from pigs in this forest is light.

AccessRd-D. *Merrilliodendron* forest with limestone rock outcrops.

AccessRd-E. This is savanna dominated by *Miscanthus floridulus*, *Saccharum officinarum*, and *Pennisetum polystachion*. *Elephantopis mollis* is a common invasive species along trails. Mixed in with grasses in places are non-indigenous *Pueraria phaseoloides*, *Buchnera floridana*, and the indigenous fern *Blechnum orientale*.

AccessRd-E. Top of ridges are primarily savanna.

3.6 Andersen AFB Utility Lines

Surveyors: Glenn Metzler and Claudine Camacho.

Date: January 14, 2010.

Summary – A primary purpose of this survey was to determine if there were any host plants for the two Federal candidate butterfly species *Hypolimnas octocula mariannensis* and *Vagrans egistina*. These host plants, *Elatostema calcareum, Procris pedunculata*, and *Maytenus thompsonii*, were not observed on any of these transects. Transects were in disturbed limestone forests ranging from highly degraded to somewhat degraded with a primarily indigenous understory. Two *Tabernaemontana rotensis* trees were observed on Transect B in flower and fruit. Several trees of the uncommon *Geniostoma micranthum*, and endemic species, were observed on transect C. On January 28, during surveys by others, a fruit bat was observed during the daytime roosting in a Guamia tree.

AAFB-A, degraded limestone forest with *Vitex parviflora* that has been blown over with resprouts.

Reference Figure 11. Andersen AFB Utility Line Transect A.

AAFB-Transect A. The forest on this transect is highly degraded. Substrate is primarily soil with less than 10 percent mossy rock. The primary invasive species are *Vitex parviflora* (some to 2 feet diameter), many of which have been blown over to horizontal with vertical resprouts, and *Averrhoa bilimbi*. Epiphytic ferns on these trees are all common species. Native (or early introduced) trees present in some abundance are *Pandanus tectorius* and *Cocos nucifera*. The *Pandanus* was generally heavily browsed and the understory in general was very open in this forest.

Reference Figure 12. Andersen AFB Utility Line Transects B and C.

AAFB-B, typical vegetation on the transect.

AAFB-B. Transect B traverses a low-stature (generally less than 20 feet) disturbed limestone forest with a few old downed or partially dead large *Intsia bijuga* trees, dominated primarily by indigenous species. The very southwestern end, after crossing the cleared lane, is a taller forest dominated by *Vitex parviflora* with *Pandanus tectorius* in the understory and a highly disturbed soil from pig damage and almost no herbs. The low-stature forest contained small openings typically dominated by *Eupatorium odoratum* (*Chromolaena odorata*). The forest was dominated by *Premna obtusifolia*, *Pandanus tectorius*, *Guamia mariannae*, *Aglaia mariannensis*, and *Neisosperma oppositifolia,* with an abundance of the indigenous herbaceous vine *Stictocardia tiliaefolia*, the woody vine *Jasminum marianum,* and common epiphytic ferns and the less common *Vittaria incurvata* present. *Intsia bijuga* was also quite common as was *Discocalyx megacarpa*, some of which were in fruit. Heavily browsed *Pandanus* leaves were noted and there were areas of high soil disturbance from pig rooting. Two *Tabernaemontana rotensis* trees were noted and both were either in flower or fruit. One of these trees had numerous (15-20) small saplings underneath that were heavily browsed. On January 28 during other surveys a fruit bat was observed roosting in a *Guamia* tree near the northeast end of the transect. Numerous butterflies were noted on this transect and included 3 common species: *Papilio polytes*, *Euploea eunice*, and *Eurema blanda*.

AAFB-Transect B, *Tabernaemontana rotensis* flowers.

AAFB-Transect B, *Tabernaemontana rotensis* sapling that is heavily browsed.

AAFB-C, *Geniostoma micranthum* in flower and fruit.

AAFB-C. The transect is located adjacent to the road. The forest consisted of a *Vitex parviflora* dominated canopy with a somewhat dense understory or sometimes canopy of *Hibiscus tiliaceous*, *Guamia mariannae*, *Aglaia mariannensis*, *Pandanus tectorius*, *Premna obtusifolia*, *Ficus tinctoria*, and *Neisospema oppositifolia*. Other species noted included *Pyschotria mariana*, *Guettarda speciosa*, and the somewhat uncommon *Geniostoma micranthum* in flower and fruit. Herbaceous species included *Piper guahamense*, several common fern species, the ground orchids *Nervillia aragoana* and *Zeuxine fritzii*, and the vine *Stictocardia tiliaefolia*.

3.7 Potts Junction

Surveyors: Glenn Metzler and Claudine Camacho.

Date: July 8, 2009.

Summary – The Potts Junction site is dominated by a highly disturbed shrub/grassland vegetation community with few native species. Much of the site is low vegetation including *Bidens alba*, *Passiflora suberosa*, and *Fimbristylis cymosa* with patches of grass including *Pennisetum purpureum*, *Pennisetum polystachion*, and *Saccharum spontaneum*. There are patches of trees or shrubs including *Buddleja asiatica*, *Spathodea campanulata*, *Hibiscus tiliaceus*, and *Leucaena leucocephala* and some patches of the fern *Pteris vittata*. There are some *Cocos nucifera* trees near the boundary with the Starts Golf Course.

3.8 NCTS Finegayan Transect 9

Surveyors: Glenn Metzler and Claudine Camacho.

Date: July 7, 2009.

Summary - The point-center quarter survey results for Transect NF-9 are summarized in Table 2. The overall density for this transect was calculated at 1,435 trees per hectare. Only four species of tree were encountered throughout the survey. The introduced *Vitex parviflora* was the most dominant species encountered along this transect, and the only introduced species observed. *Vitex parviflora* had a relative density of 55% (Figures 1and 2) and a relative dominance of 93%. *Hibiscus tiliaceus* and *Pandanus tectorius*, together, had a

North Finegayan Transect 9.

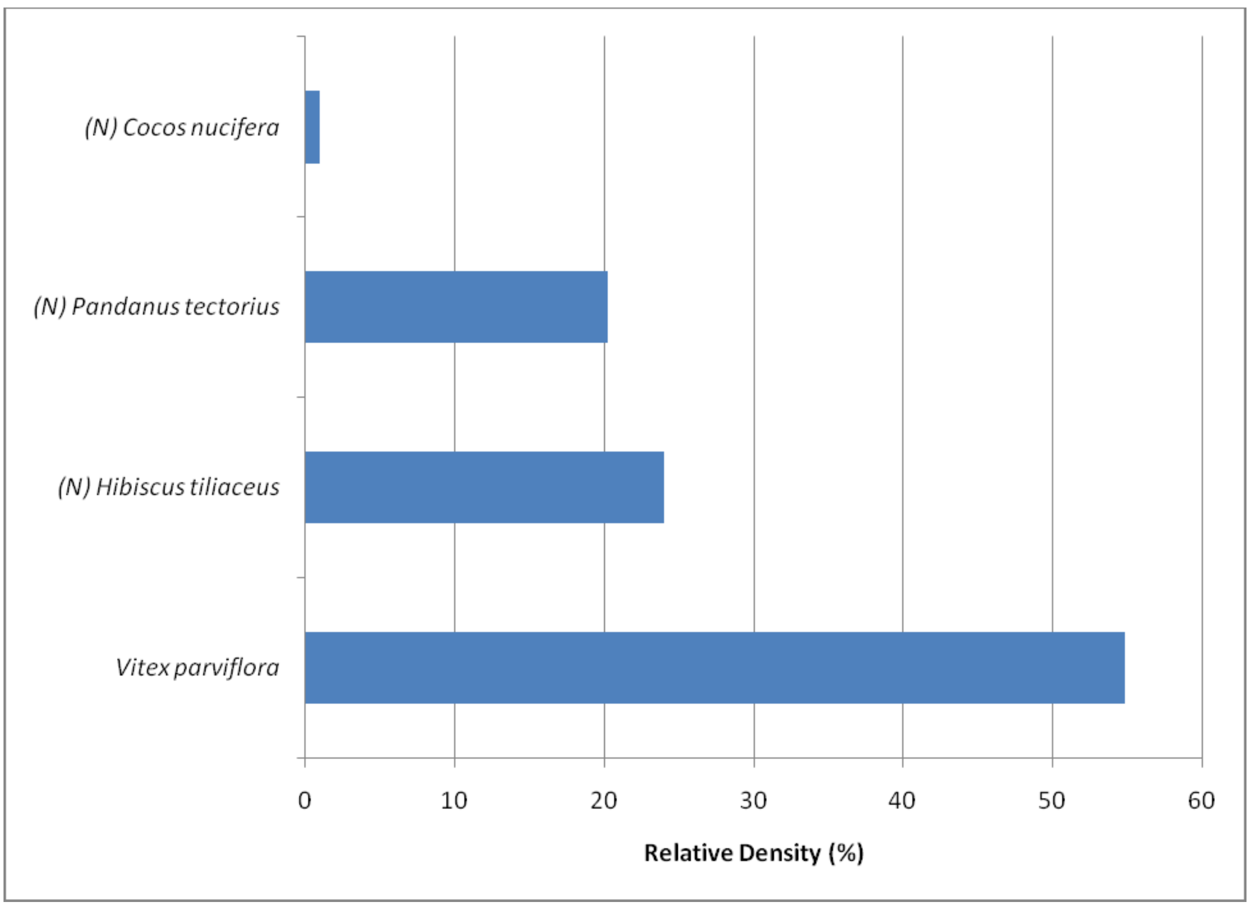
relative density of 44%, yet only accounted for approximately 6% of the relative dominance within the transect. One individual of *Cocos nucifera* was encountered. The tree species richness for Transect NF-9 is presented in Figure 3.

Table 2. Summary of forest at NF-9, Finegayan.

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST NF-9 NCTS Finegayan, JULY 2009						
SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm^2)	MEAN BASAL AREA (cm^2)	ABSOLUTE COVER (m^2/ha)	ABSOLUTE FREQUENCY
Vitex parviflora	I	786	19101.11	335.11	26.34	219.23
Hibiscus tiliaceus	N	345	709.44	28.38	0.98	96.15
Pandanus tectorius	N	290	596.03	28.38	0.82	80.77
Cocos nucifera	N	14	206.02	206.02	0.29	3.85

Key to Status: N = native; I = introduced

Figure 1. Relative Density (%) of Trees at NF-9, Finegayan



Note: (N) indicates native species; others are introduced.

Figure 2. Relative density of native tree species along NF-9, Finegayan

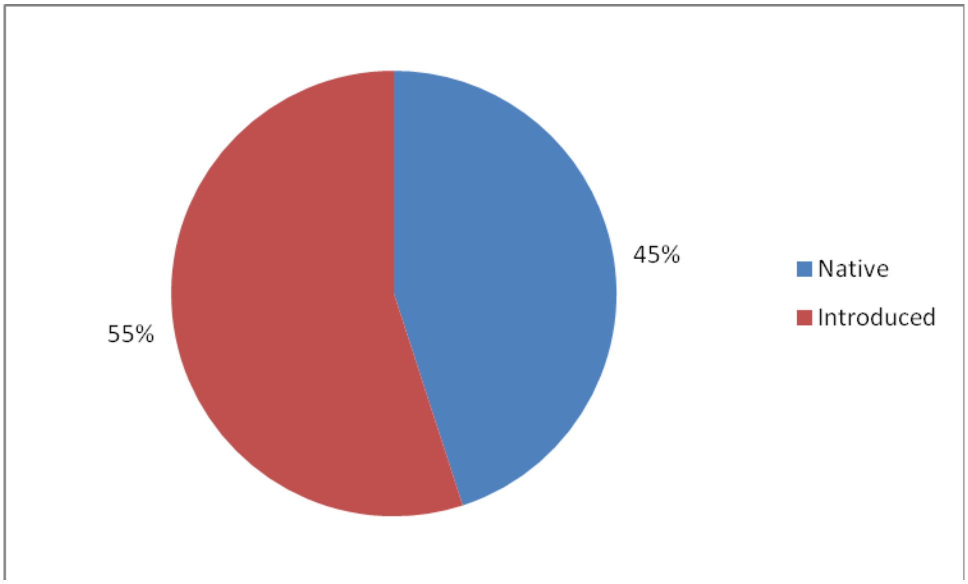


Figure 3. Species Richness of Trees at NF-9, Finegayan

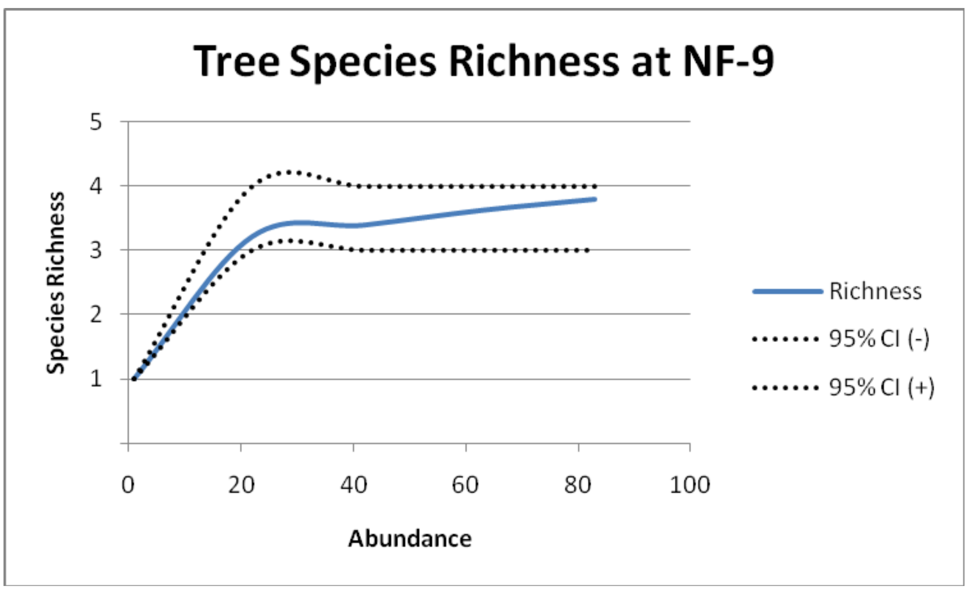


Table 3. Woody Seedling Species Encountered in Plots at NF-9, Finegayan

Woody Seedling Species (<2cm dbh)						
	0m	*100m*	*200m*	*300m*	*400m*	*500m*
Cocos nucifera			9	2		
Flagellaria indica					1	1
Glochidion marianum				1		
Hibiscus tiliaceus	3			3	9	
Leucaena leucocephala				2		
Morinda citrifolia	2	13		21	8	21
Pandanus tectorius	3	1			9	5
Triphasia trifolia				3	1	
Vitex parviflora	2	1	6	23	4	3
Totals	10	15	15	55	32	30

Table 4. Non-Woody Seedling Species Presence in Plots at NF-9, Finegayan

Non-Woody Seedling Species (Presence/Absence)						
	0m	*100m*	*200m*	*300m*	*400m*	*500m*
Belvisia	1	1	1	1	1	1
Davalia			1			1
Nephrolepis acutifolia				1		
Nephrolepis hirsutula	1	1	1	1	1	1
Polypodium punctatum		1		1		1
Polypodium scolopendria				1	1	1
Pteris tripartita					1	1
Pyrrosia	1	1	1	1		1
Achyranthes aspera					1	
Axonopus compressus		1	1			1
Cassia leschenaultiana	1	1	1			
Centosteca lappacea	1					
Chromolaena odorata		1	1	1	1	1
Cyperus kyllingia			1			
Cyperus ligularis			1			
Desmodium triflorum			1			
Hyptis capitata		1				
Hyptis pectinata			1	1		
Mikania	1	1	1	1	1	1
Momordica charantia				1	1	1
Nervillia aragoana		1			1	
Oplismenus			1	1	1	1
Passiflora suberosa	1	1	1	1	1	
Piper guahamense					1	1
Sida rhombifolia			1			
Spermacoce						1
Stachytarpheta jamaicensis			1			
Stichtocardia tiliaefolia				1	1	
Taeniophyllum		1	1			
Urena lobata			1			
Zeuxine fritzii	1					
Total Seedlings	8	12	18	13	13	14

Note: "1" indicates presence within plots

Table 5. Ground Cover at NF-9, Finegayan.

Meters from start	Rock	Soil	Leaf litter	Live vegetation	Total
0		1	15		16
100			14	2	16
200			10	6	16
300			11	5	16
400			15	1	16
500			13	3	16
Frequency	0	1	78	17	

3.9 Andersen South Transect 7

Surveyors: Glenn Metzler and Claudine Camacho.

Date: January 12, 2010.

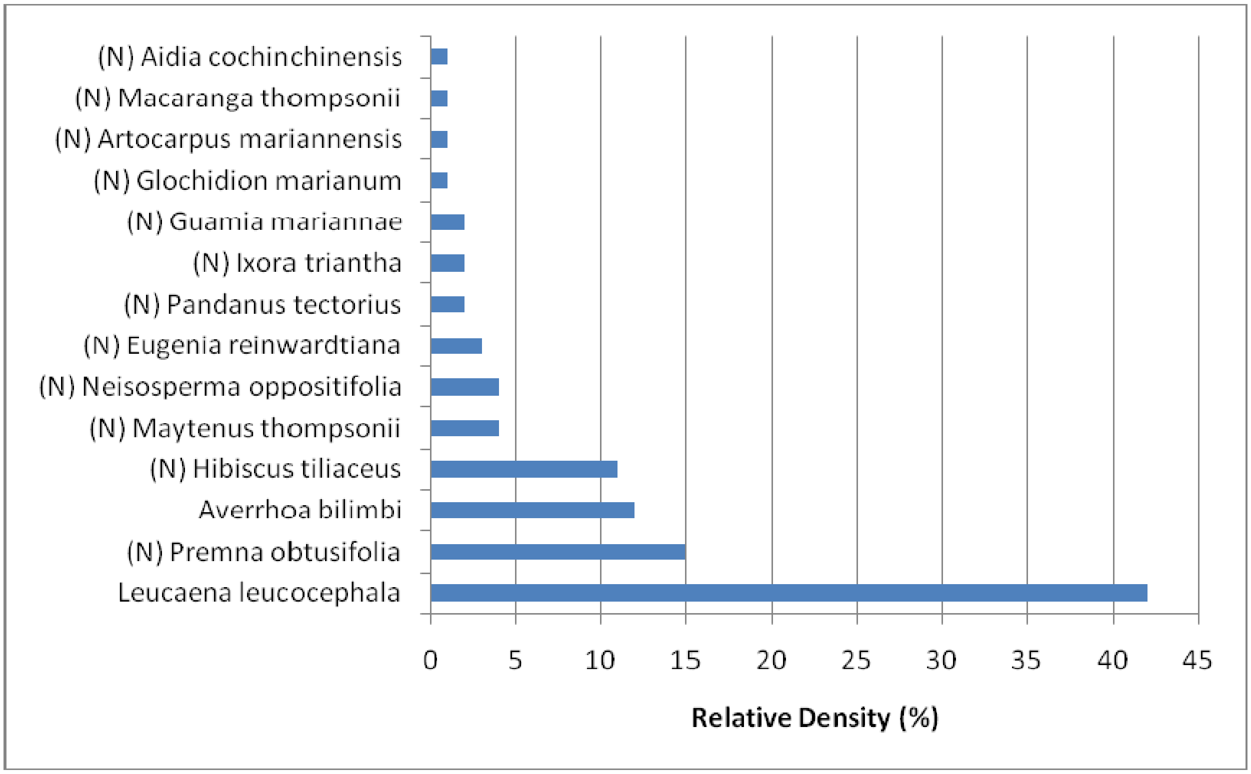
Summary - The point-center quarter survey results for Transect AS-7 are summarized in Table 6. The overall density for this transect was calculated at 3,300 trees per hectare. Fourteen species of tree were encountered throughout the survey. The introduced *Leucaena leucocephala* had the highest relative density (approximately 42%) of all species (Figure 4). Tangantangan and *Averrhoa bilimbi* were the only introduced tree species encountered in this survey, yet accounted for approximately 54% of the relative density (Figure 5) and 41% of the relative dominance of all species combined. *Premna obtusifolia* was the most encountered native tree species and had the highest relative density (approximately 15%) of all native species. The tree species richness for AS-7, Anderson South is presented in Figure 6.

Table 6. Summary of forest at Transect AS-7, Anderson South.

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST AS-7, ANDERSEN SOUTH, JAN. 2010						
SPECIES	STATUS	NO. TREES/ HECTARE	TOTAL BASAL AREA (sq. cm)	MEAN BASAL AREA (sq. cm)	ABSOLUTE DOMINANCE	ABSOLUTE FREQUENCY
Leucaena leucocephala	I	1434	4548.01	103.36	1482.33	84.62
Premna obtusifolia	N	521	3873.21	242.08	1262.39	42.31
Averrhoa bilimbi	I	391	634.61	52.88	206.84	19.23
Hibiscus tiliaceus	N	359	254.19	23.11	82.85	23.08
Maytenus thompsonii	N	130	46.83	11.71	15.26	15.38
Neisosperma oppositifolia	N	130	353.27	88.32	115.14	11.54
Eugenia reinwardtiana	N	98	105.43	35.14	34.36	7.69
Pandanus tectorius	N	65	51.03	25.51	16.63	7.69
Ixora triantha	N	65	41.33	20.67	13.47	7.69
Guamia mariannae	N	65	54.65	27.33	17.81	7.69
Glochidion marianum	N	33	16.61	16.61	5.41	3.85
Artocarpus mariannensis	N	33	2418.00	2418.00	788.10	3.85
Macaranga thompsonii	N	33	280.41	280.41	91.39	3.85
Aidia cochinchinensis	N	33	78.29	78.29	25.52	3.85

Key to Status: N = native; I = introduced

Figure 4. Relative Density (%) of Trees at AS-7, Anderson South.



Note: (N) indicates native species; others are introduced.

Figure 5. Relative density of native tree species at AS-7, Anderson South.

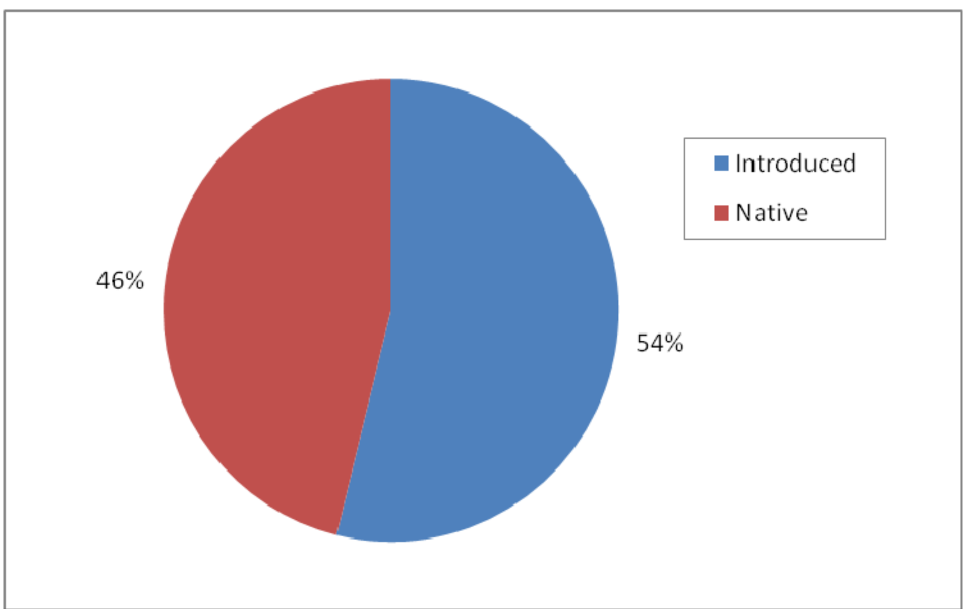


Figure 6. Species Richness of Trees at AS-7, Anderson South.

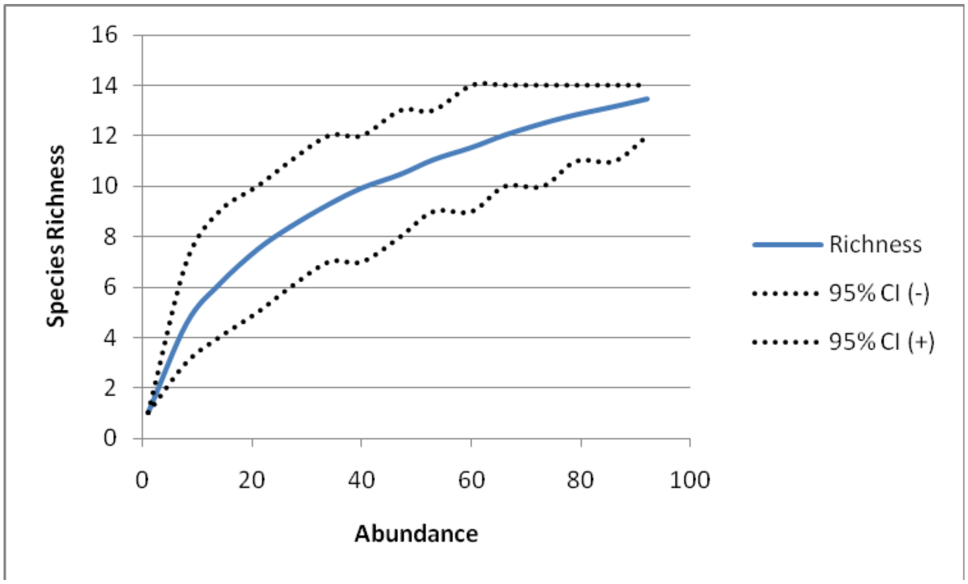


Table 7. Woody Seedling Species Encountered in Plots at AS-7, Anderson South.

Woody Seedling Species (<2cm dbh)						
	0m	*100m*	*200m*	*300m*	*400m*	*500m*
Aglaia mariannensis						*2*
Averrhoa bilimbi	*4*	*6*			*1*	*2*
Carica papaya						*1*
Colubrina asiatica	*4*					
Discocalyx megacarpa						*1*
Eugenia reinwardtiana				*1*		*1*
*Flagellaria indica (climbing)**	*80*	*61*	*100*	*100*	*100*	*100*
Guamia mariannae				6	2	15
*Ixora triantha***	6	3	1		15	4
Jasminum marianum	2		1	1		
Leucaena leucocephala	6	4	2			
Morinda citrifolia	11	16			1	2
Neisosperma oppositifolia		1	14	2	3	
Pandanus tectorius			3			8
Pouteria obovata	2			1		
Premna obtusifolia	2					
Triphasia trifolia	3	4	6	2	4	4
Ximenia americana	3					
Total Seedlings	123	95	127	113	126	140

*Notes: * Counts of 100 were terminated at 100 but exceeded that number.*

*** Some or all of this species may be Aidia cochinchinenis - definitive determination could not be made for the seedlings.*

Table 8. Non-Woody Seedling Species Presence in Plots at AS-7, Anderson South.

Non-Woody Seedling Species (Presence/Absence)						
	0m	*100m*	*200m*	*300m*	*400m*	*500m*
Asplenium nidus						1
Davalia		1				
Nephrolepis biserrata	1	1	1		1	1
Polypodium punctatum	1	1		1	1	1
Polypodium scolopendria	1	1			1	1
Pyrrosia	1	1				
Achyranthes aspera	1					
Caesalpinia			1			1
Chromolaena odorata		1				1
Mikania		1				1
Passiflora suberosa	1	1				1
Zeuxine fritzii	1	1	1			6
Total Seedlings	7	9	3	1	3	14

Note: "1" indicates presence within plots

Table 9. Ground Cover at AS-7, Anderson South

Meters from start	**Rock**	**Soil**	**Leaf litter**	**Live vegetation**	**Total**
0		2	10	4	16
100		4	8	4	16
200	1	11	4		16
300		12	3	1	16
400		6	7	3	16
500	3	2	8	3	16
Frequency	4	37	40	15	

3.10 Navy Barrigada Transect 3

Surveyors: Glenn Metzler and Claudine Camacho.

Date: January 13, 2010.

Barrigada Transect 3.

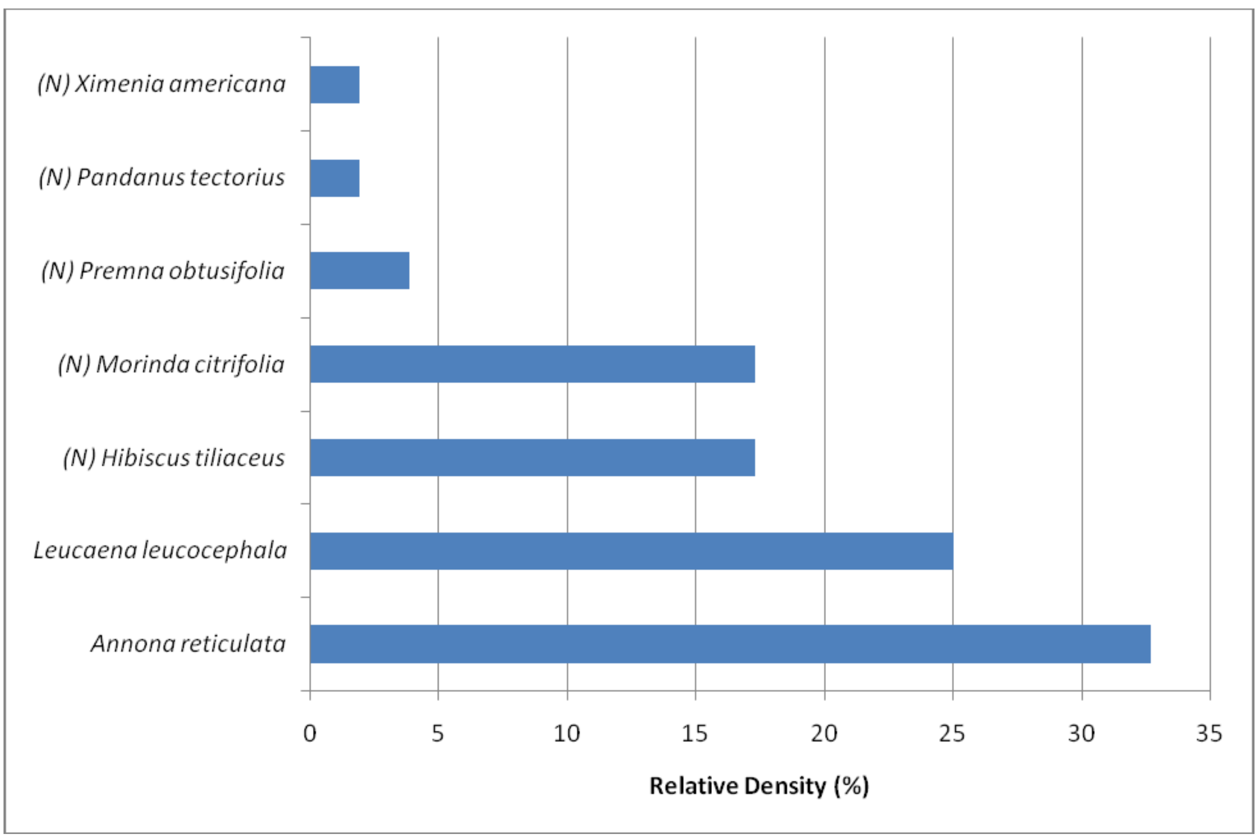
Summary - The point-center quarter survey results for Transect T-3 are summarized in Table 10. The overall density for this transect was calculated at 4,632 trees per hectare. Seven species of tree were encountered throughout the survey. The introduced *Annona reticulata* and *Leucaena leucocephala* had the two highest relative densities of all species observed (Figure 7), and were the only introduced species encountered throughout the survey. Together, these two species accounted for approximately 58% of the relative density (Figure 8) and 47% of the relative dominance. *Hibiscus tiliaceus* was the most encountered native tree species and had the highest relative density (approximately 17%) and relative dominance (approximately 31%) of all native species. The tree species richness for Transect T-3 is presented in Figure 9.

Table 10. Summary of Forest at Transect 3, NCTS Barrigada

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST T-3 Barrigada, January 2010						
SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm²)	MEAN BASAL AREA (cm²)	ABSOLUTE COVER (m²/ha)	ABSOLUTE FREQUENCY
Annona reticulata	I	1514	645.47	37.97	5.75	130.77
Leucaena leucocephala	I	1158	264.98	20.38	2.36	100.00
Hibiscus tiliaceus	N	802	597.74	66.42	5.33	69.23
Morinda citrifolia	N	802	254.96	28.33	2.27	69.23
Premna obtusifolia	N	178	106.54	53.27	0.95	15.38
Pandanus tectorius	N	89	23.75	23.75	0.21	7.69
Ximenia americana	N	89	26.41	26.41	0.24	7.69

Key to Status: N = native; I = introduced

Figure 7. Relative Density (%) of Trees at Transect 3, NCTS Barrigada



Note: (N) indicates native species; others are introduced.

Figure 8. Relative density of native tree species along Transect 3, NCTS Barrigada.

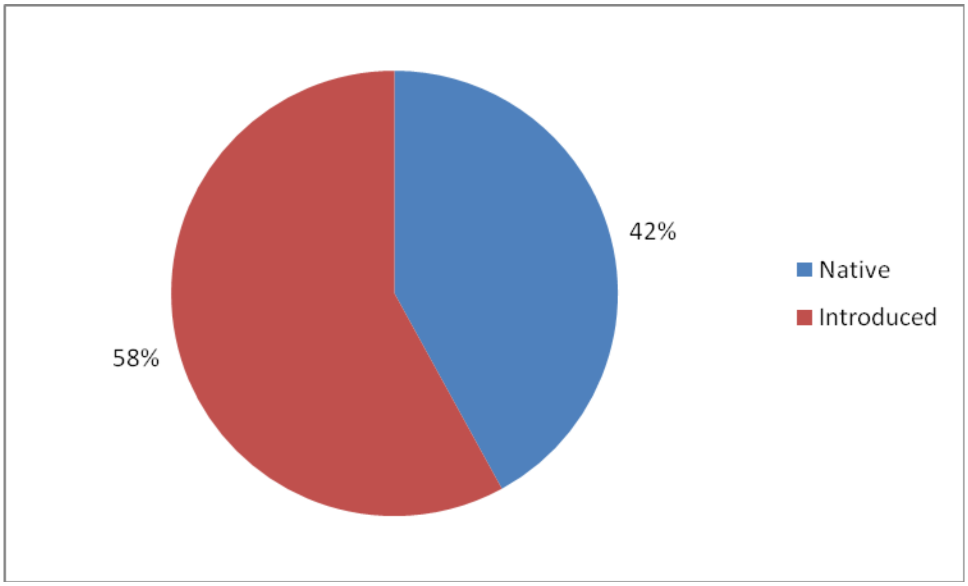


Figure 9. Species Richness of Trees at Transect 3, NCTS Barrigada

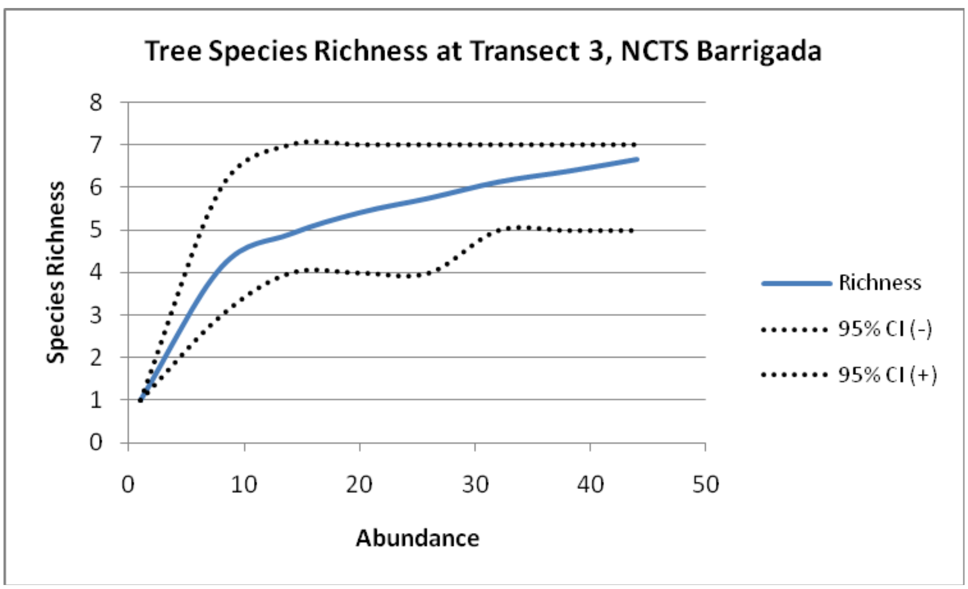


Table 11. Woody Seedling Species Encountered in Plots at Transect 3, NCTS Barrigada

Woody Seedling Species (<2cm dbh)			
	40m	*140m*	*240m*
Annona reticulata			3
Averrhoa bilimbia			1
Carica papaya	1		
Colubrina asiatica		60	
Flagellaria indica	20		39
Guamia mariannae			1
Ixora triantha	1		
Jasminum marianum	2		50
Lantana camara		5	
Leucaena leucocephala	67	73	11
Morinda citrifolia	16	12	9
Pandanus tectorius		1	
Psidium guajava		3	
Triphasia trifolia	3		
Ximenia americana		14	2
Unknown Tiliaceae sp.		6	
Totals	110	174	116

Table 12. Non-Woody Seedling Species Presence in Plots at Transect 3, NCTS Barrigada.

Non-Woody Seedling Species (Presence/Absence)			
	40m	*140m*	*240m*
Achyranthes aspera		*1*	*1*
Mikania scandens	1	1	1
Nephrolepis acutifolia	1		
Nephrolepis biserrata			1
Nephrolepis hirsutula		1	
Passiflora suberosa	1	1	1
Polypodium punctatum	1	1	1
Polypodium scolopendria	1	1	1
Pyrrosia lanceolata		1	1
Chromolaena odorata		1	1
Momordica charantia	1		
Stichtocardia tiliaefolia	1	1	
Total Seedlings	7	8	7

Note: "1" indicates presence within plots

Table 13. Ground Cover at Transect 3, NCTS Barrigada.

Meters from start	Rock	Soil	Leaf litter	Live vegetation	TOTAL
40	2	4	6	4	16
140		10	6		16
240		2	10	4	16
Frequency	2	16	22	8	

4.0 References

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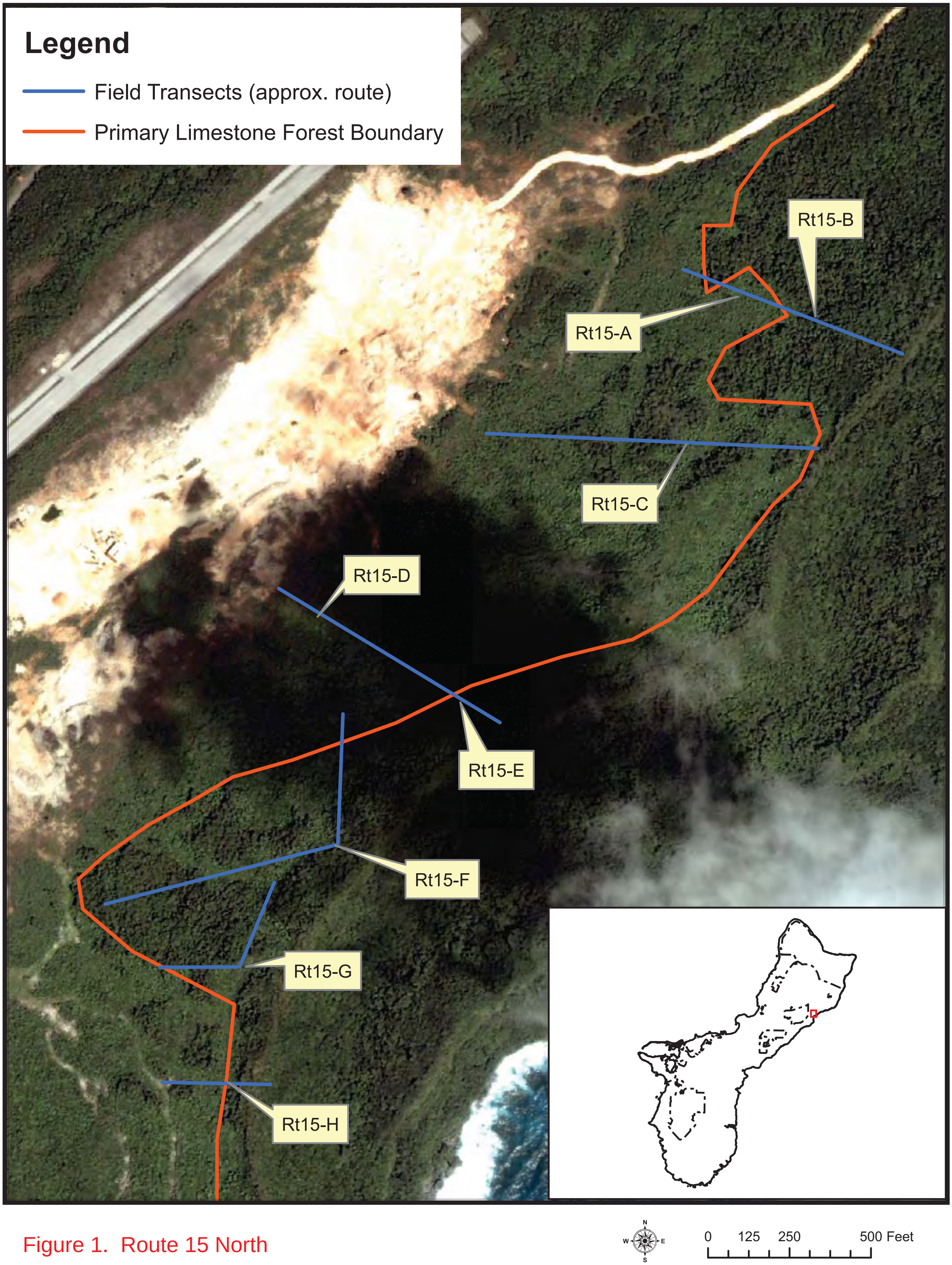


Figure 1. Route 15 North

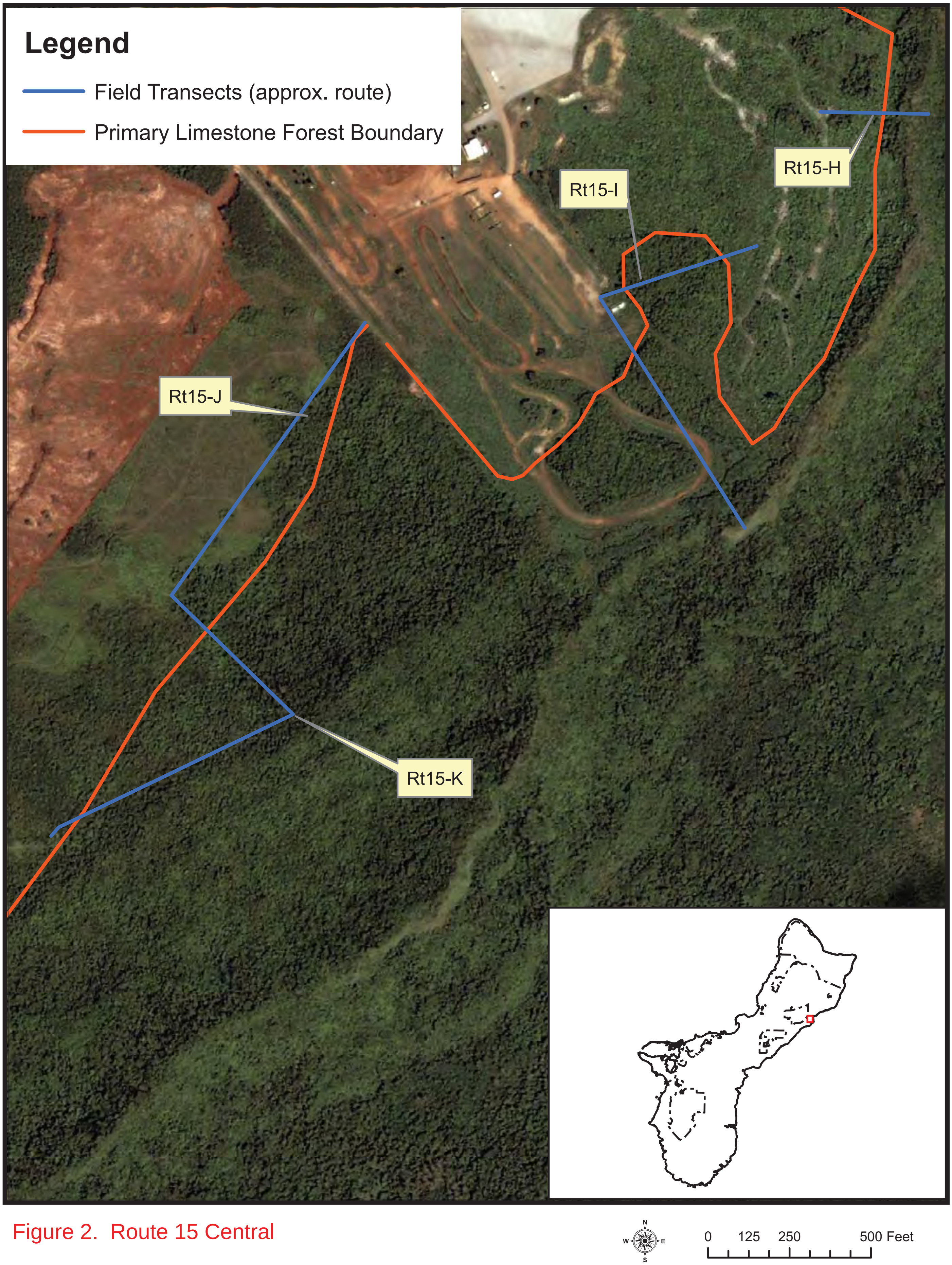


Figure 2. Route 15 Central

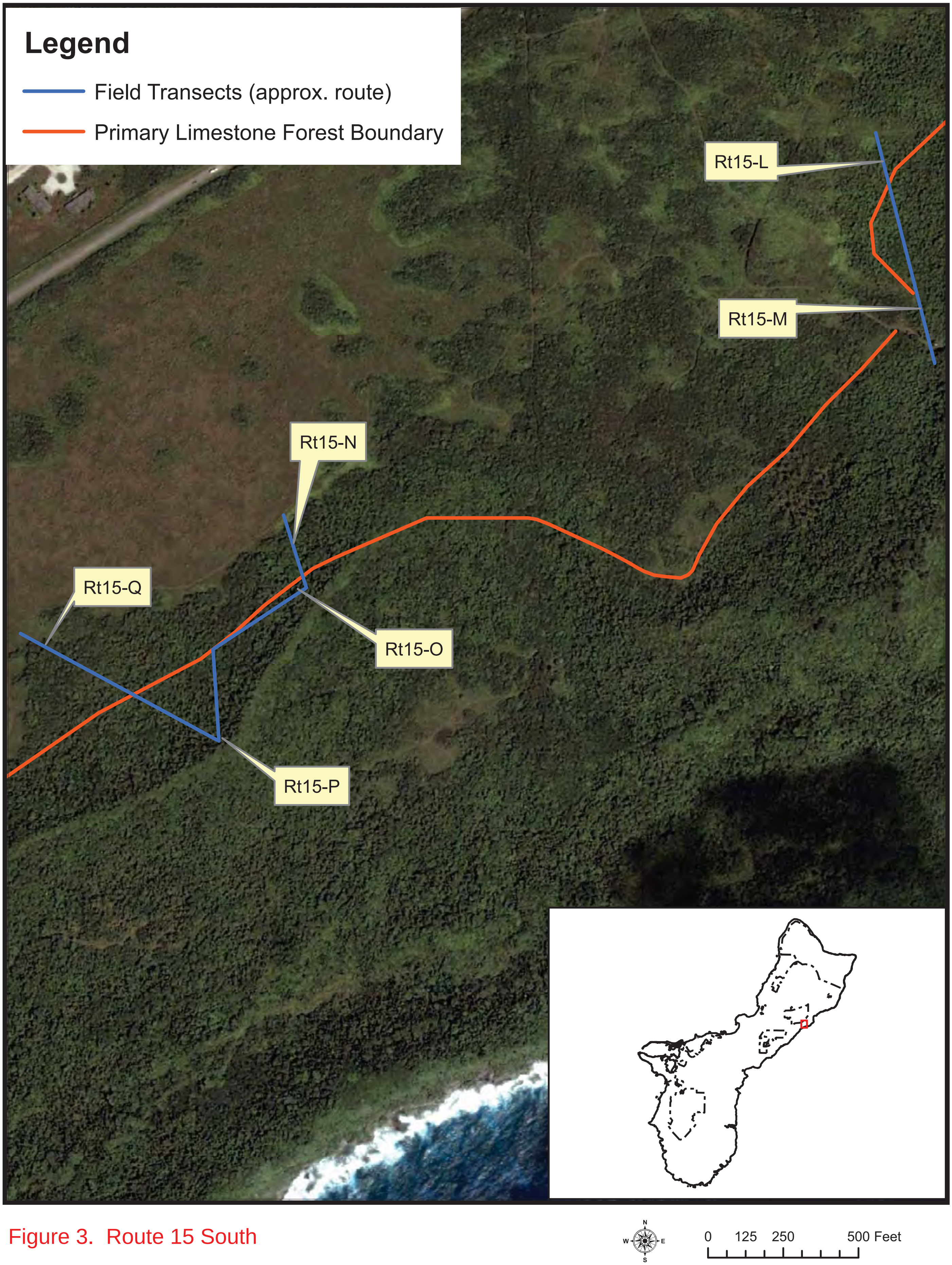


Figure 3. Route 15 South

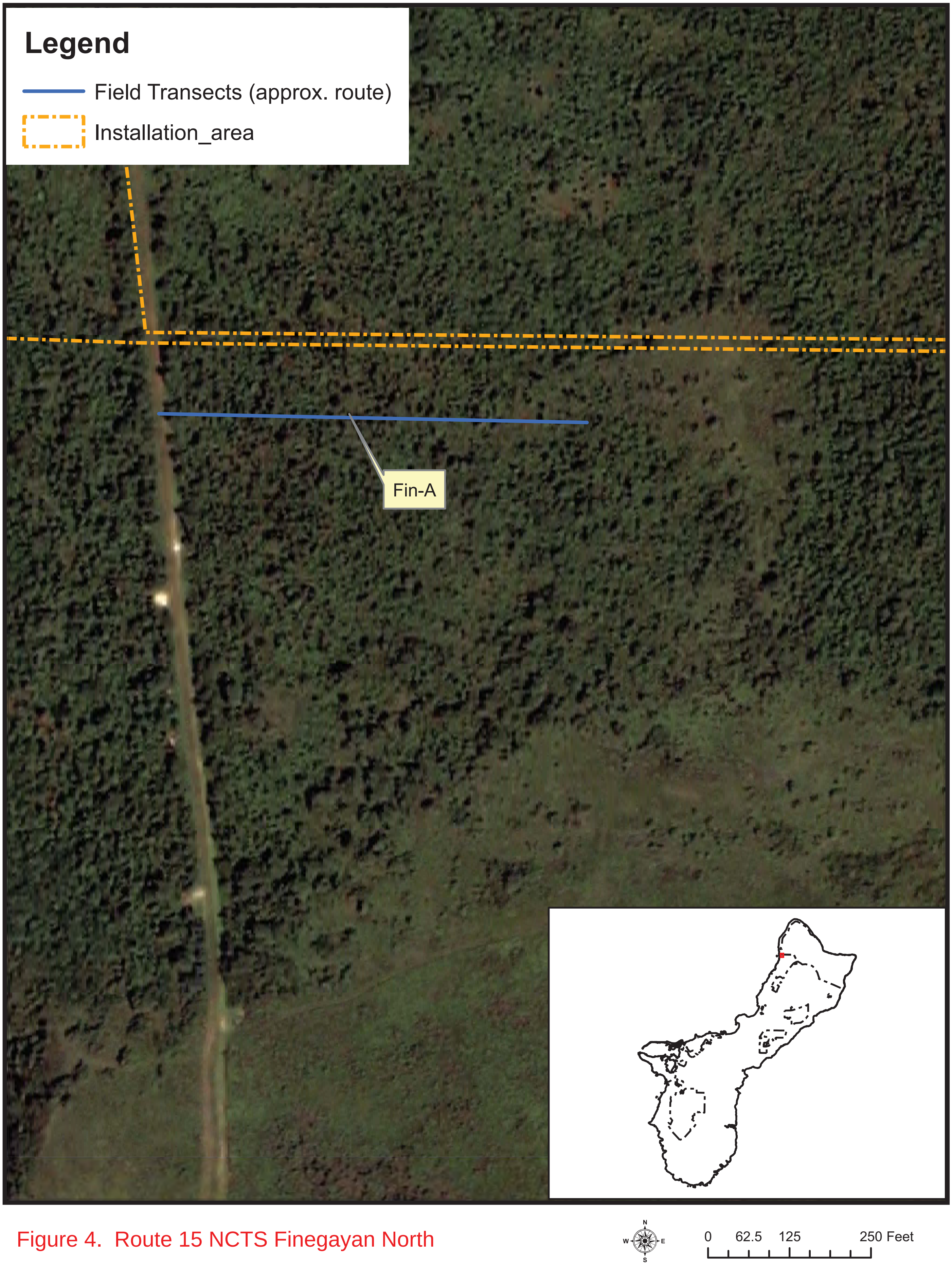


Figure 4. Route 15 NCTS Finegayan North

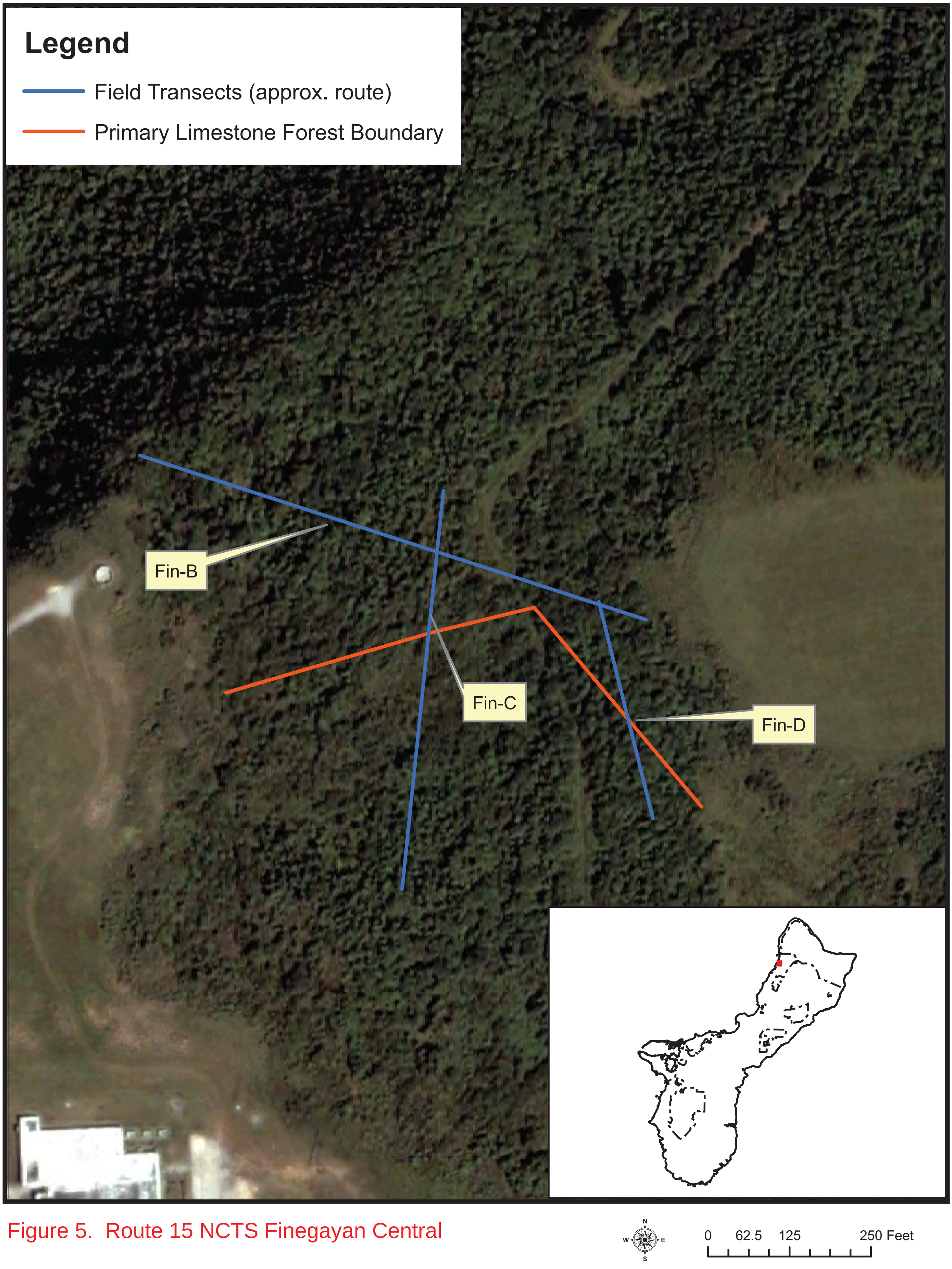


Figure 5. Route 15 NCTS Finegayan Central

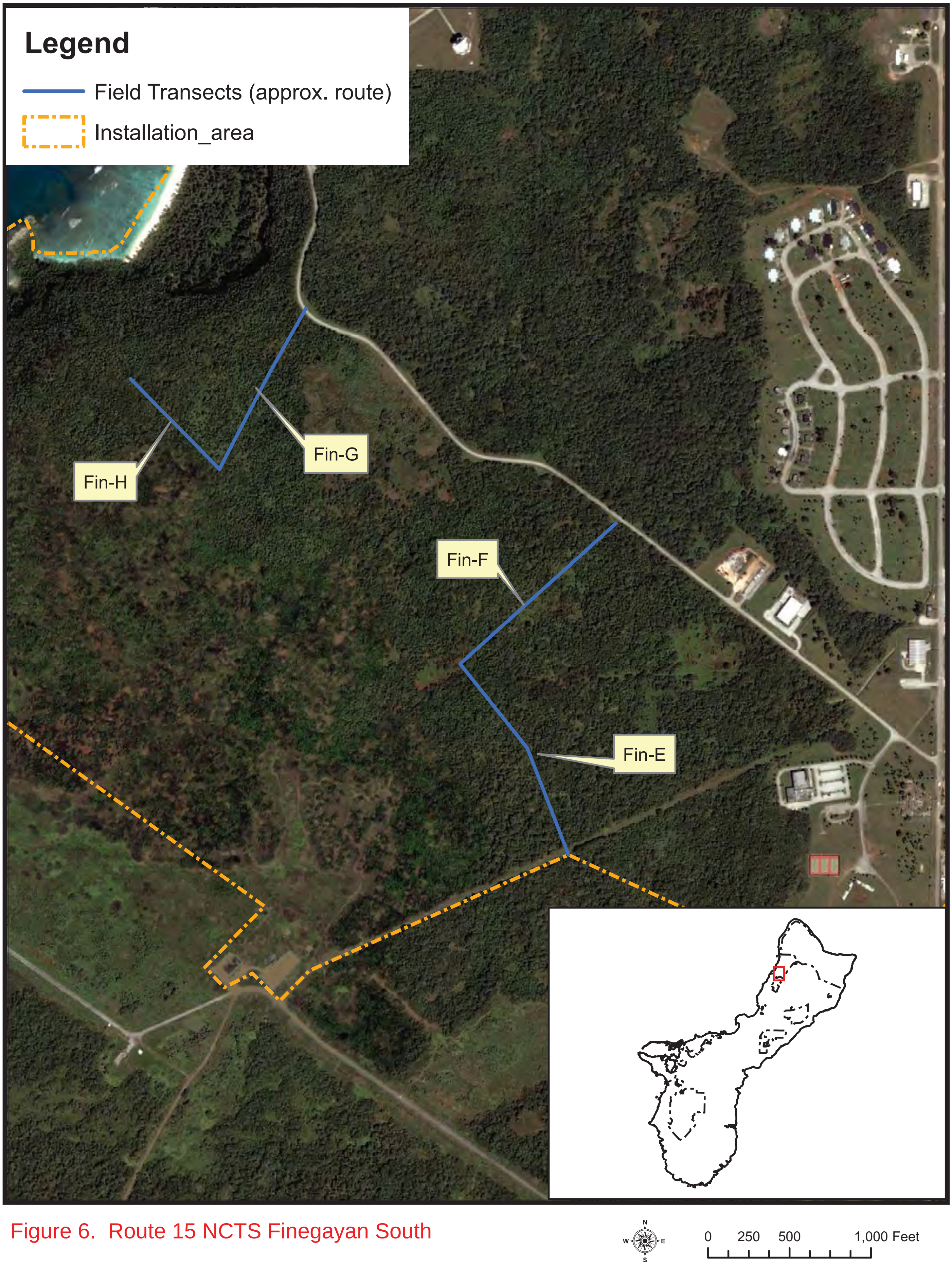


Figure 6. Route 15 NCTS Finegayan South

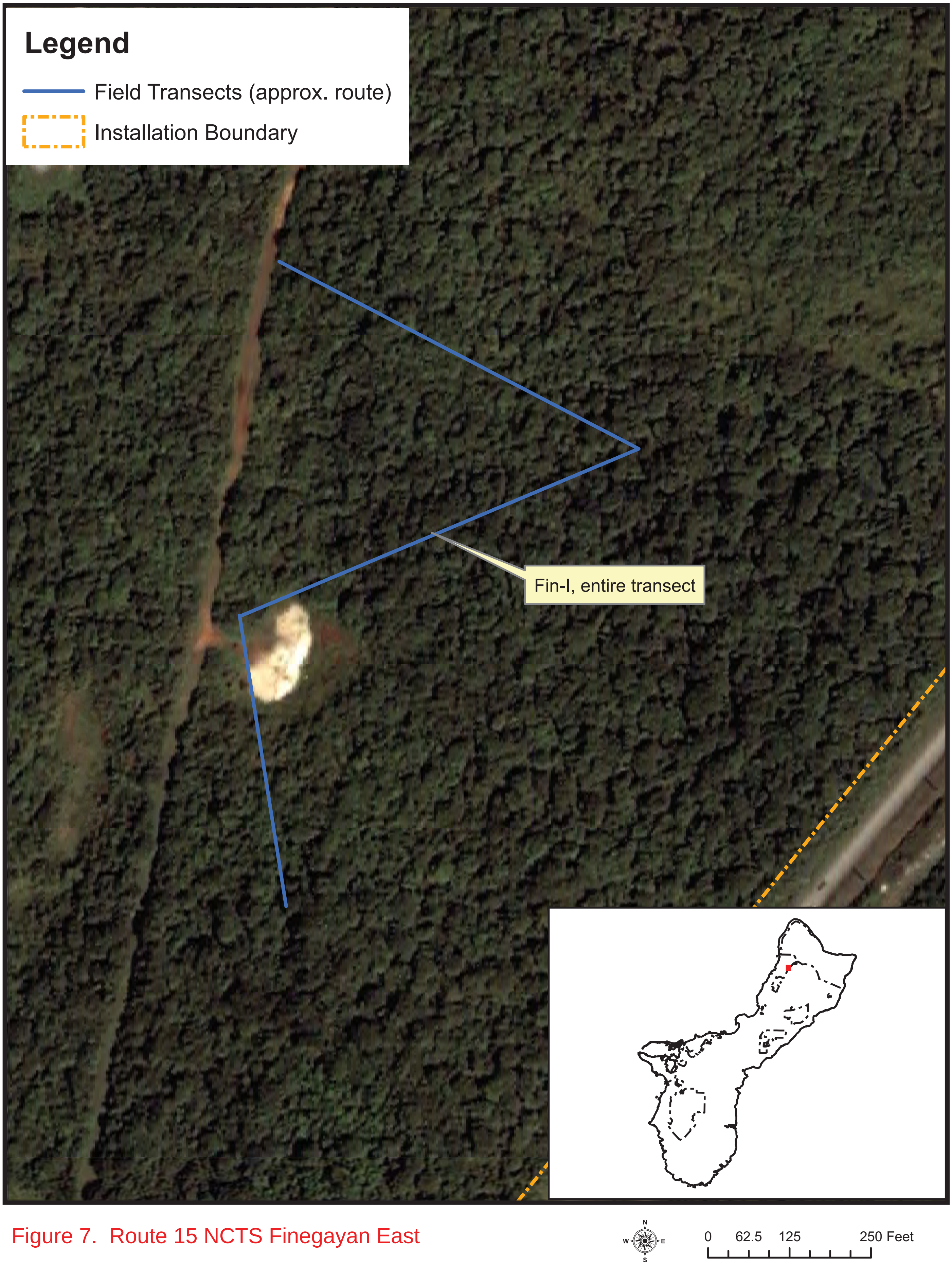


Figure 7. Route 15 NCTS Finegayan East

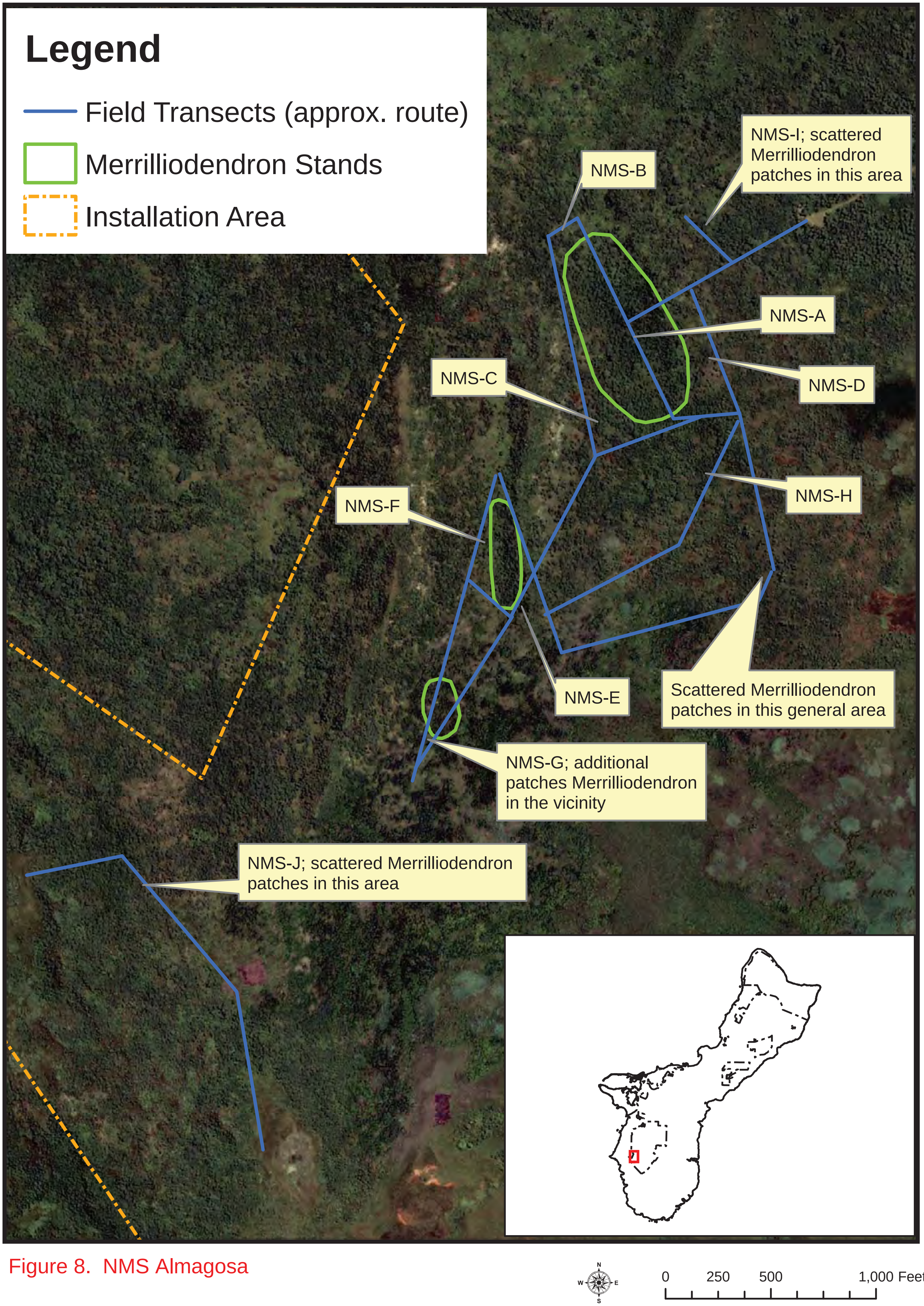


Figure 8. NMS Almagosa

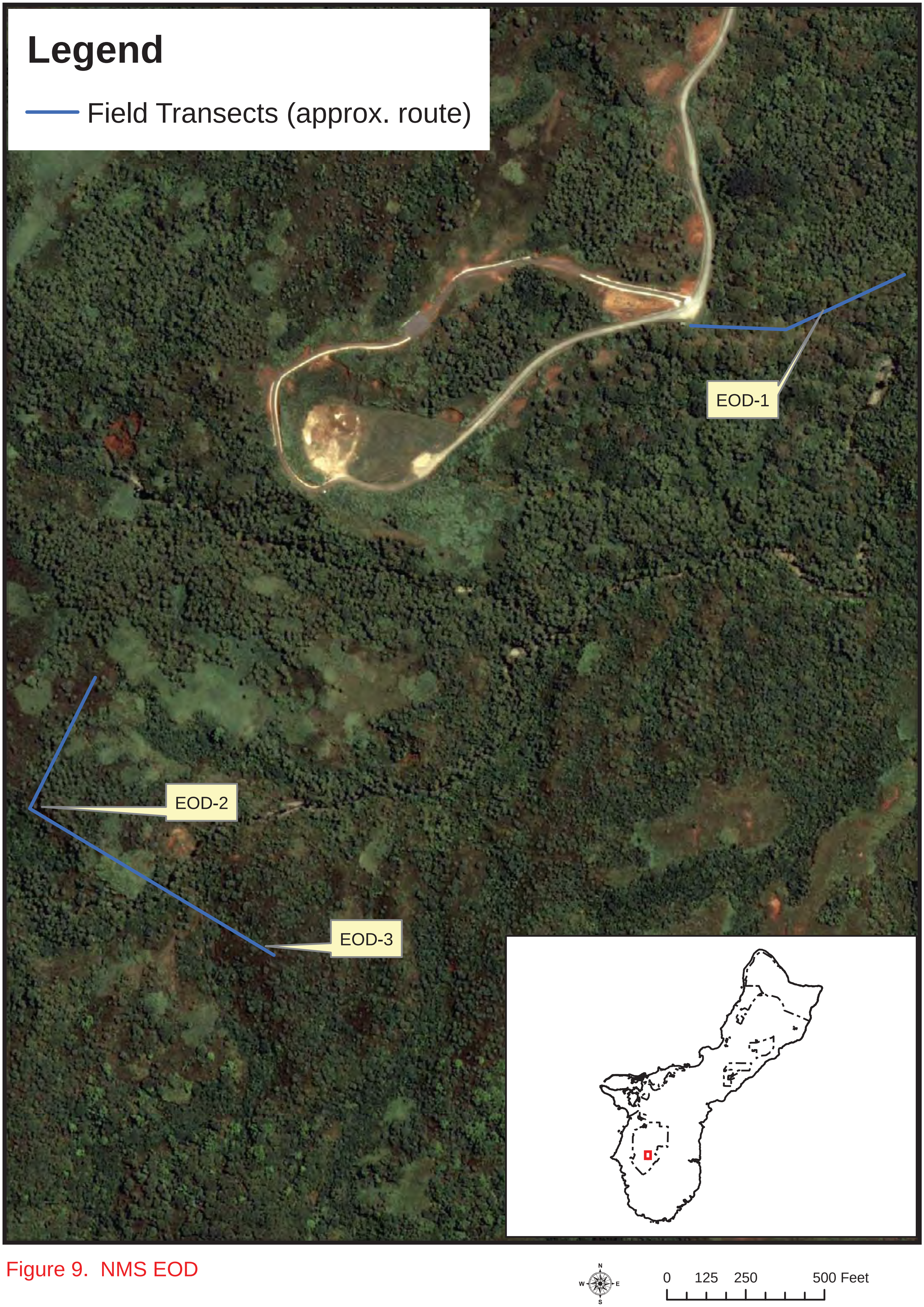


Figure 9. NMS EOD

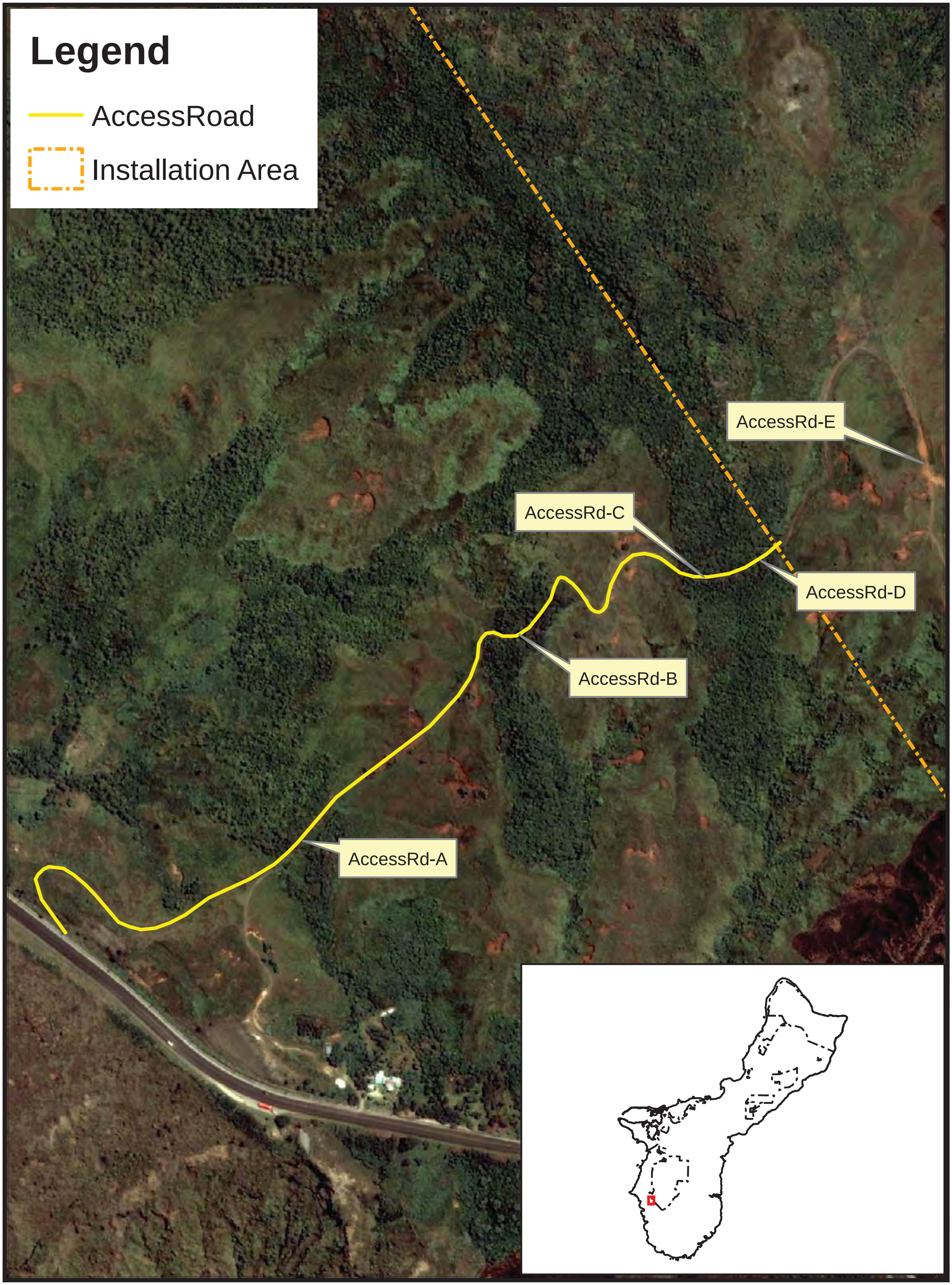
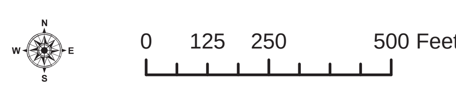


Figure 10. NMS Access Road



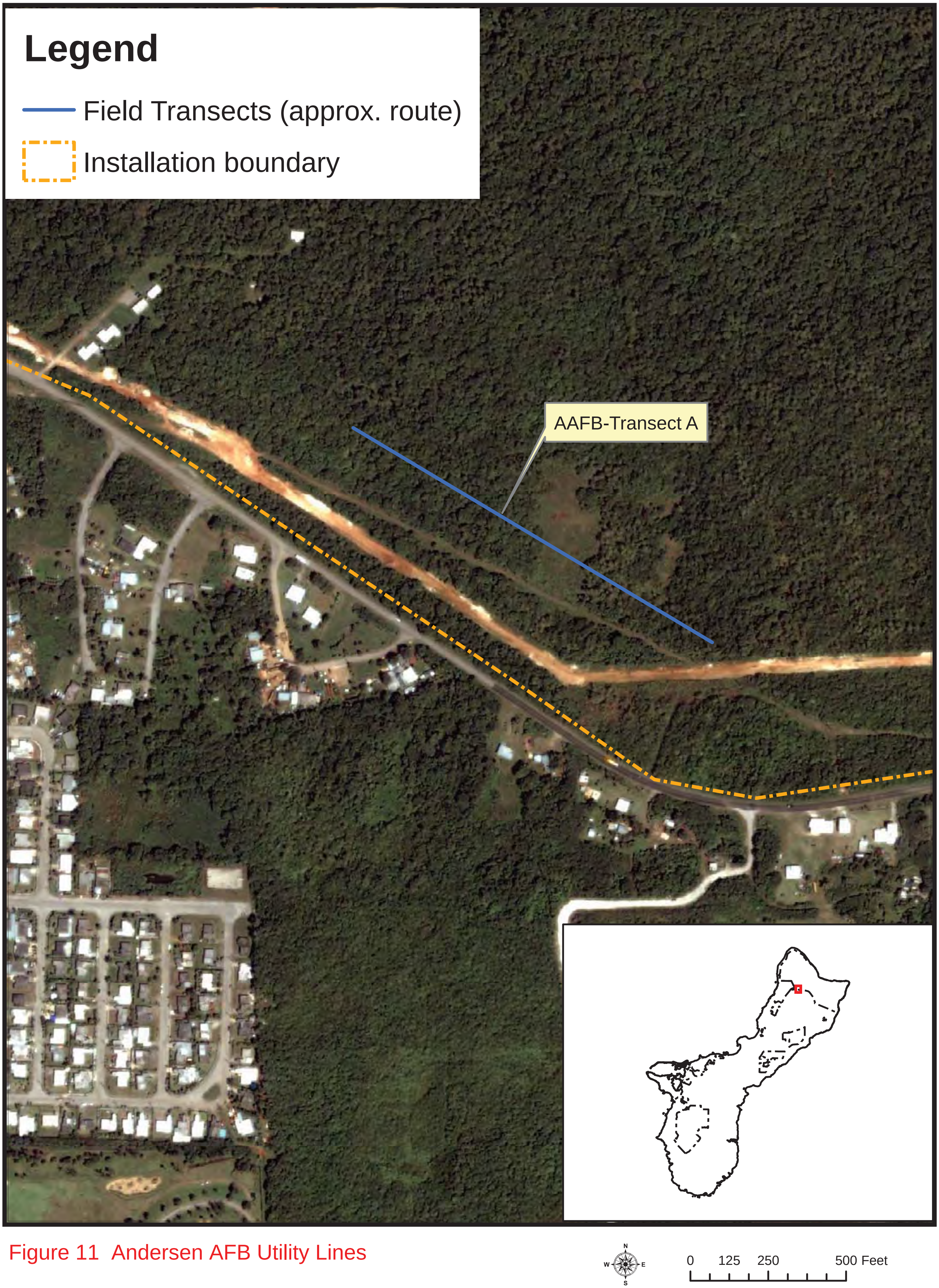


Figure 11 Andersen AFB Utility Lines

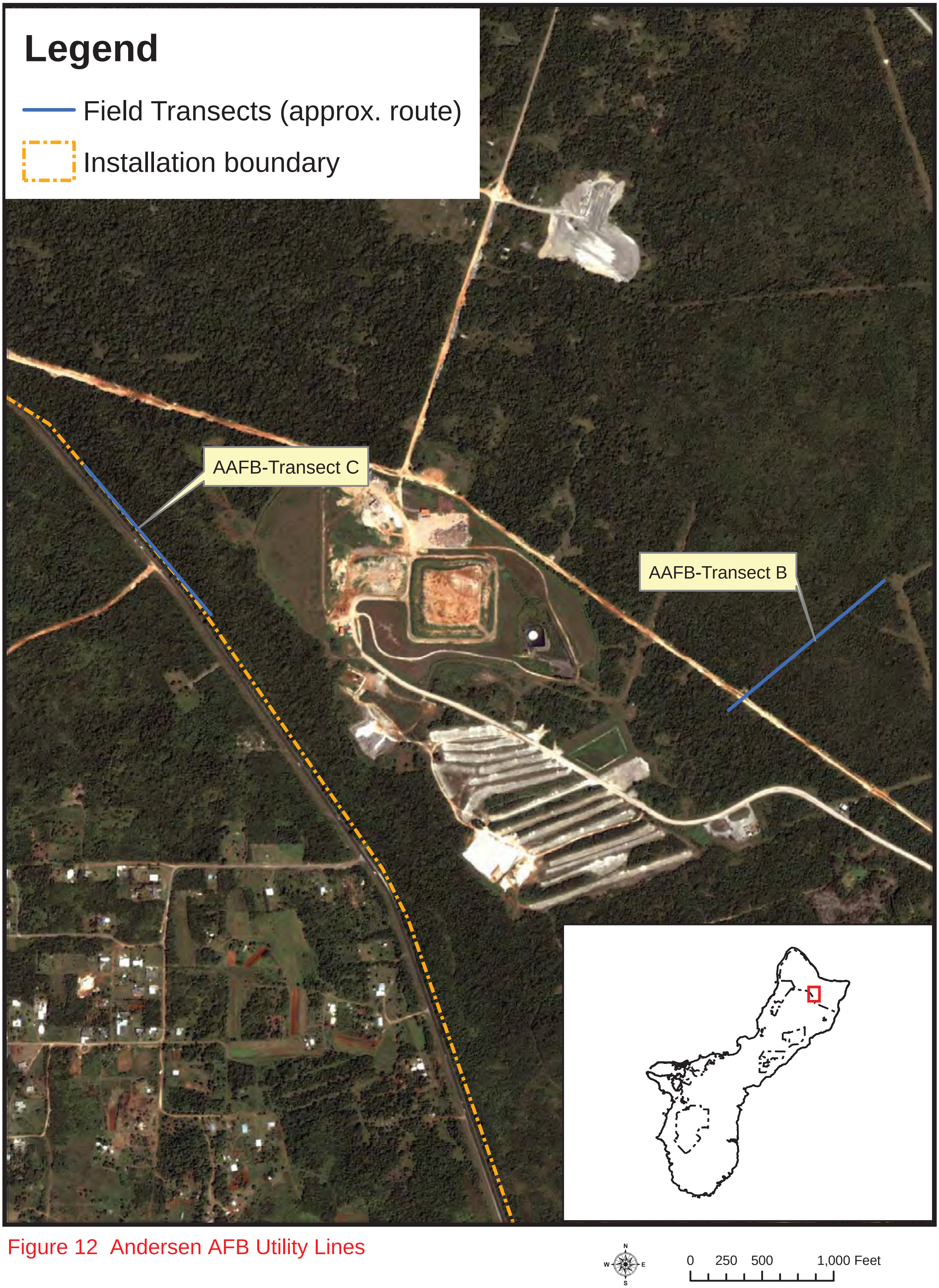


Figure 12 Andersen AFB Utility Lines

APPENDIX E
Butterfly Surveys

Butterfly Survey Report. Andersen Air Force Base, Andersen South, and Navy Barrigada. AECOM. June 28, 2010; and

Survey for the Mariana eight spot butterfly, *Hypolimnas octocula marianensis* (Lepidoptera: Nymphalidae), in the Pagat Route 15 area of Yigo Village, Guam. NAVFAC Pacific, Pearl Harbor, HI August 2009.

BUTTERFLY SURVEY REPORT

Andersen Air Force Base

Andersen South

Navy Barrigada

June 28, 2010

Department of the Navy
Naval Facilities Engineering Command,
258 Makalapa Drive, Suite 100
Pacific Pearl Harbor, HI 96860-3134

AE Services for Environmental Planning to Support Strategic Forward Basing Initiatives
Contract Number N62742-06-D-1870, TO 0016

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1 Introduction

Under a NAVFAC contract for AE Services for Environmental Planning to Support Strategic Forward Basing Initiatives and in support of the "Marine Corps Relocation Initiative to Various Locations on Guam", the TEC JV received Task Order 0016 with subsequent modifications 1 & 2 and TO 0007 Mod 04 for Natural Resource (NR) Surveys on Guam. The basis for this assignment is to provide the necessary data to support the Environmental Impact Statement (EIS) for the Joint Guam Program Office actions relating to the relocation of the Marines by filling existing data gaps identified in the Final Natural Resources Survey and Assessment Report of Guam and Certain Islands of the Northern Mariana Islands (NAVFAC 2007).

As part of the natural resource surveys, investigations for the presence of the Mariana Eight-Spot Butterfly (*Hypolimnas octucula mariannensis*) and the Mariana wandering butterfly (*Vagrans egistina*) were conducted on three DoD parcels on Guam: Andersen Air Force Base (AAFB), Andersen South and Navy Barrigada. Both species are candidate species for listing by the United States Fish and Wildlife Service (USFWS) under the Endangered Species Act of 1973 (USFWS, 2010). The Mariana Wandering Butterfly is also considered a Species of Greatest Conservation Need (GDAWR, 2005).

1.1 Mariana Eight-Spot Butterfly

The Mariana Eight-Spot Butterfly (Photo 1) is a nymphalid butterfly, feeds upon two host plants, *Procris pedunculata* and *Elatostema calcareum*, which are indigenous succulent herbs that grow in limited habitats over limestone rock outcrops in moist limestone forest. The buttefly is endemic to the islands of Guam and Saipan, and the species is now known from ten populations on Guam. This species is currently threatened by predation and parasitism. The Mariana Eight-Spot Butterfly has extremely high mortality of eggs and larvae due to predation by alien ants and wasps. Because the threat of parasitism and predation by nonnative insects occurs range-wide and can cause significant population declines to this species, they are high in magnitude. The threats are imminent because they are ongoing (USFWS, 2010).

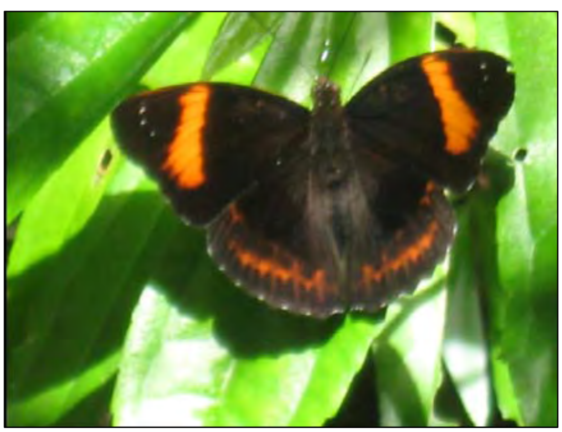

Photo 1 Mariana Eight-Spot Butterfly (*Hypolimnas octucula mariannensis*)

Surveys on the Rt 15 properties (Figure 1) identified the host plants: *Elatostema calcareum* (Urticaceae) and *Procris pedunculata* (Urticaceae) and observed Mariana Eight-Spot Butterfly along Transect 2. Also, evidence of eggs was found in other locations throughout the investigated areas (Figure 1).

1.2 Mariana Wandering Butterfly

A very rare butterfly, endemic to the islands of Guam and Rota. Although, historically found on Guam and CNMI (Rota), the species now occurs with any certainty only on Rota (USFWS, 2010a).

Body color is primarily orange and black, with black bordering the wings. A large orange irregular shape extends from the forewings to the hindwings. Females and males are similar in body color and size. Larvae feed on a plant species (*Maytenus thompsonii*) that is endemic to the Mariana Islands. Adults are good fliers and can move considerable distances (USFWS, 2008).

2 Methods

During September 28– October 2, 2009 and January 25-31, 2010 a butterfly survey was conducted on three transects at Andersen AFB, one transect on Andersen South, and one transect on Navy Barrigada. The butterfly survey consisted of two methods: timed counts and baited traps. Descriptions of these methods are provided in the sections below.

2.1 Timed Counts

Timed counts were conducted along linear transects within each of the three parcels. At every 30-m, two scientists would stand back-to-back and enumerate the 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 (Figure 2) and one transect was located on Andersen South (Figure 3) and Navy Barrigada (Figure 4).

2.1.1 Andersen AFB

On AAFB, the butterfly survey occurred on Transects 5, 6, and 7 (Figure 2), which are all located in the southern portion of AAFB. Each transect was 400 m in length. The transects were located in forested areas with a canopy of 6-12 m in height with moderate to dense undergrowth. On Transect 5, between 130 m and 190 m, an open area dominated by herbaceous vegetation, grasses, and a few small isolated trees results in a break in the forest canopy.

2.1.2 Andersen South

On Andersen South, the butterfly survey was conducted on Transect 7 (Figure 3), which is 500-m long and located in a forested area. The forest canopy is approximately 10 m in height, with moderate to heavy undergrowth. The undergrowth often occurred in the form of smaller saplings and numerous vines.

2.1.3 Navy Barrigada

On Navy Barrigada, the butterfly survey was conducted on Transect 3, which measured 250-m in length (Figure 4). The transect is located in a forested area with a canopy of approximately 6-8 m in height with several small clearings on and/or near the transect. The forested area is located adjacent to a large, maintained grass field associated with communication towers. The survey began approximately 15 m from the forest's edge.

2.2 Baited Traps

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 (Photo 2). At the end of the trapping period, which lasted approximately 6 hours, the traps were checked, and captured butterflies were noted and then released.

Photo 2 Butterfly Trap. The bait is placed in the white dish. Butterflies land on the edge of the dish and consume the bait. When the butterflies initiate their next flight they instinctively fly upwards and become trapped in the mesh cylinder.

2.2.1 Andersen AFB

Two baited traps were placed on each transect (Transects 5, 6, and 7) in the morning and retrieved in the late afternoon. On Transect 5, the traps were placed within a forested area in the beginning of the transect (September and January) and a second trap was placed within a clearing in the September survey and near the end of the transect in the January survey. On Transect 6 and Transect 7, the traps were placed in forested areas at the beginning and the end of each transect in both the September and January surveys.

2.2.2 Andersen South

Butterfly traps were set at the 0 and 470 meter mark on Transect 7. The baited traps were placed on each transect during daylight hours.

2.2.3 Navy Barrigada

Two baited traps were placed on Transect 3 during daylight hours. The trap was placed at the start of the transect, and at approximately the 60 meter mark near a clearing.

3 Results

3.1 Description of Species Observed

A total of six butterfly species were identified during the surveys. The descriptions of the species are based on Schreiner and Haus, 1997.

- Lemon Emigrant, *Catopsilia pomona*. The species is found in the Marianas and Palau. The larvae feed on various species of *Cassia* sp. The species is often found in moist open areas and engages in migratory flights.

- Monarch, *Danaus plexippus*. This species' range includes the America, Australia and numerous pacific Islands – including the Marianas. In Micronesia, the species feeds on *Asclepias curassavica* and crown flower, *Caltopis gigantean*. The species is a known migrant capable of flying thousands of miles.

- Blue-branded King Crow, *Euploea Eunice*. This species' range extends from India to Micronesia. The larvae feed on *Ficus* sp., edible figs, and oleander. They are often sighted hanging on aerial roots of fig trees, other vegetation, or structures.

- Blue Moon, *Hypolimnas bolina*. This species ranges from Madagascar to New Zealand; moreover, the species is considered the most widely distributed butterfly in the world. The species is recorded as taking migratory flights from Australia to New Zealand.

- Common Evening Brown, *Melanitis leda*. In the Pacific, the Common Evening Brown butterfly occurs within the Marianas and Caroline Island Chains. On Guam, the species has been found on corn, Guinea grass, and Napier grasses. The larvae also feed on grasses.

- Common Mormon, *Papilio polytes*. This species is found throughout southeast Asia, Philippines, Palau, Yap, and the Marianas Islands; although, the species is thought to be a recent arrival to the Marianas. The butterflies are attracted to salt and frequently found at puddles. Food plants include citrus and other Rutaceae plants.

The Mariana Eight-Spot Butterfly and the Mariana Wandering Butterfly were not observed on any transect.

3.2 Timed Counts

Tables 1, 2, and 3 identify the number of individuals and species observed within the various sampling plots on AAFB, Andersen South, and Navy Barrigada, respectively.

3.2.1 Andersen AFB

In September 2009, the Common Mormon and Blue-banded King Crow were the two most common butterflies sighted and comprised 46 and 43.6 percent of the total sightings at AAFB, respectively (Table 1). Approximately 62 percent (57 of 92 sightings) of the total sightings of the Blue-banded King Crow occurred within two plots along Transect 5 associated with a road cut.

In January 2010, the Blue-banded King Crow and the Common Mormon were the two most common butterflies sighted, comprising 64.5 and 24.5 percent of the total sightings, respectively. Similar to the September findings, a majority of the total sightings on the Blue-banded King Crow (152 of 160 [95 percent]) occurred within the first 120 m of Transect 5.

The January sightings total of 282 individuals is approximately one-third higher than the September total of 211. Although there were two additional species sighted in September (Blue Moon and Monarch), the total number of individuals of these two species was only three. All of the species sighted are widely distributed in the Mariana Islands.

3.2.2 Andersen South

Table 2 identifies the numbers of individuals and species observed within the various sampling plots on Andersen South in September 2009 and February, 2010. None of the species that werte observed on Andersen South are considered endangered or threatened and all are widely distributed in the Mariana Islands.

On Andersen South the Common Mormon was the most numerous sighted butterfly in both September 2009 and January 2010, comprising 88.8 and 56.3 percent of the total sightings, respectively. The numbers of butterflies sighted, on average, also decreased between September and January. This reduction in abundance may be the result may be the result of natural cycles in butterfly population, the relatively short observation periods involved, or other factors.

3.2.3 Navy Barrigada

On Navy Barrigada, the Common Mormon was the most frequently observed butterfly in September and January, comprising 73.2 and 52.5 percent of the total sightings, respectively (table 3). The numbers of individuals and species showed little variation between September and January.

Table 1											
Butterfly Sightings on AAFB											
Transect	September 2009						January 2010				
	Meter Dist. On Transect	Species					Meter Dist. On Transect	Species			
		Common Mormon	Blue-banded King Crow	Lemon Emigrant	Blue Moon	Monarch		Common Mormon	Blue-banded King Crow	Lemon Emigrant	
5	10		1				0		40		
	40						30	1	9		
	70	1	4				60		28		
	100	2	6				90	1	24		
	130	2	29	2	2		120		51		
	160	3	28	4		1	180	2			
	190						220	1	1		
	230						250	1			
	260						280	3			
	290	1					310	3	1		
	320	1					340	2	2		
	350						370	2			
	380	2					400	2	4		
	TOTAL SIGHTINGS	12	68	6	2	1	TOTAL SIGHTINGS	18	160		
	Percent of Sightings	13.48	76.40	6.74	2.25	1.12	Percent of Sightings	10.1	89.8	0	
6	0										
	30						20	1			
	60	2					50	2		1	
	90	8	2	3			80	2			
	120	8		1			110	2	1		
	150	3		2			140	1			
	180	5		1			170	3		6	
	210		3	1			200	3		3	

Table 1

Butterfly Sightings on AAFB

Transect	September 2009						January 2010			
	Meter Dist. On Transect	Species					Meter Dist. On Transect	Species		
		Common Mormon	Blue-banded King Crow	Lemon Emigrant	Blue Moon	Monarch		Common Mormon	Blue-banded King Crow	Lemon Emigrant
	240	1		3			230	2		7
	270	2					260		1	
	300	3		1			290	2		1
	330	2					320	2		4
	360	6					350	2		6
	390	5	17				380	3	1	1
	TOTAL SIGHTINGS	45	22	12	0	0	TOTAL SIGHTINGS	25	3	29
	Percent of Sightings	56.96	27.85	15.19	0.00	0.00	Percent of Sightings	43.9	5.3	50.9
7	0	2		1			0	3		
	30						30	2	1	
	60	1					60	2	2	
	90	1					90	5		
	120	3					120	1		
	150	2					150	2	4	
	180	3	2				180	1	6	
	210	4					210	4	1	
	240	4					240	1	1	
	270						270	4		1
	300	8					300	2		
	330	6					340		1	
	360	4					370			
	390	2					400		3	
	TOTAL SIGHTINGS	40	2	1	0	0	TOTAL SIGHTINGS	27	19	1

Table 1											
Butterfly Sightings on AAFB											
Transect	September 2009						January 2010				
	Meter Dist. On Transect	Species					Meter Dist. On Transect	Species			
		Common Mormon	Blue-banded King Crow	Lemon Emigrant	Blue Moon	Monarch		Common Mormon	Blue-banded King Crow	Lemon Emigrant
	Percent of Sightings	93	5	2	0	0	Percent of Sightings	61.36	36.36	2.27

Table 2							
Butterfly Sightings Andersen South							
September 2009				January 2010			
Meter Dist. On Transect	Species			Meter Dist. On Transect	Species		
	Common Mormon	Blue-banded King Crow	Lemon Emigrant		Common Mormon	Blue-banded King Crow	Lemon Emigrant
0	3			0	3	3	
20	4			30		1	
40	2			60			
60	4			90	3		1
80	4	1	2	120	3	1	
100			1	150	1		
120	6			180			
140	16			210	2		
160	10	1		240	1	1	1
180	2			270		2	
200	4			300			
220	4			330		1	
240	4			360	1		
260	1			390	2		
280	3			420	1	2	
300	3	2		450	1		
320	3		1	480		1	
340	4						
360	3						
380	3	2	1				
400	2						
420	1		1				
440	3						
460	1						
480	3						
500	2						
TOTAL SIGHTINGS	95	6	6	TOTAL SIGHTINGS	18	12	2
Percent of Sightings	88.79	5.61	5.61	Percent of Sightings	56.3	37.5	6.3

Table 3 Butterfly Sightings at Navy Barrigada – September 2009 and January 2010								
Survey Plot - Meter Distance on Transect	Species			Survey Plot - Meter Distance on Transect	Species			
	Common Mormon	Blue-banded King Crow	Blue Moon		Common Mormon	Blue-banded King Crow	Blue Moon	Common Evening Brown
0	2	6		0	2	6		1
30	2	2		30	3			
60	7			60	2	1		
90	7	2	1	90	7		1	
120	3			120	1	2		
150	2			150	4	3		
180	2			180		4		
210	1			210				
240	4			240	2	1		
TOTAL SIGHTINGS	30	10	1	TOTAL SIGHTINGS	21	17	1	1
Percent of Sightings	73.2	24.4	2.4	Percent of Sightings	52.5	42.5	2.5	2.5

3.3 Baited Traps

3.3.1 Andersen AFB

No butterflies were captured in the baited traps on AAFB in September 2009. In January 2010, one Blue-banded King Crow was captured in a trap on Transect 6.

3.3.2 Andersen South

Butterfly traps were set at the 0 and 470 meter mark on the transect. The baited traps were placed on each transect during daylight hours. No butterflies were captured on Andersen South during the butterfly surveys.

3.3.3 Navy Barrigada

Two individuals of Common Evening Brown butterfly were captured in September 2009. In January 2010, one Common Evening Brown was captured.

4 Summary

Six butterfly species were observed or trapped as part of this study. Table 4 identifies species observed within the various transects on AAFB, Andersen South, and Navy Barrigada. None of the six species are considered endangered or threatened and are fairly well-distributed throughout Guam and portions of the Mariana Islands (Schreiner and Nafus, 1997). The number of sightings of butterflies within forested areas was generally low. Sightings typically increased dramatically in areas dominated by grasses or wooded areas with less understory vegetation.

Table 4
Butterfly Species Identified at AAFB, Andersen South, and Navy Barrigada

Species	AAFB Transects			Andersen South	Navy Barrigada
	5	6	7		
Blue-branded king crow	x	x	x	x	x
Blue Moon*	x				x
Common Mormon	x	x	x	x	x
Common Evening Brown**					x
Lemon Emigrant	x	x	x	x	
Monarch	x				

Notes: *Observed several times along the road on Andersen South.
**Although not observed on the transects or during the survey, the species was observed on AAFB and Andersen South.

The Mariana Eight-Spot Butterfly and Mariana Wandering Butterfly were not observed on any transect. Moreover, the host plants for the Mariana Eight-Spot Butterfly were also not observed on AAFB, Andersen South, or Navy Barrigada. The plant (*Maytenus thompso*nii) for the Marianas Wandering Butterfly was observed on Andersen South.

5 References:

GDAWR. 2005. Guam Comprehensive Wildlife Conservation Strategy (GCWCS). Department of Agriculture, Guam. Guam Division of Aquatic and Wildlife Resources. September 26, 2005.

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USFWS, 2010a Species Profile on Mariana Wandering Butterfly (*Vagrans egistina*). Website accessed April, 2010. http://www.fws.gov/ecos/ajax/docs/candforms_pdf/r1/I0R8_I01.pdf

Survey for the Mariana eight spot butterfly, *Hypolimnas octocula marianensis* (Lepidoptera: Nymphalidae), in the Pagat Route 15 area of Yigo Village, Guam

August 2009

Prepared by Cory Campora and Stephan Lee
NAVFAC Pacific

Summary

Surveys were performed for all life stages of the Mariana eight spot butterfly, *Hypolimnas octocula marianensis* Fruhstorfer, and its two documented host plant species along three transects (Rt 15 North, Rt 15 South, and Pagat Cave) in the Pagat area south of Route 15, in the southern corner of Yigo Village, Guam during the time period from July 15 to July 24, 2009. Host plants of *H. octocula marianensis* were sparse except for two areas, one on the Rt 15 North transect and one on the Rt 15 South transect, which contained large groups of both plant species. One adult *H. octocula marianensis* was seen in the large host plant area on the Rt 15 North transect. Other life stages (e.g. egg, larvae, pupae) were found on host plants in all three transects, however, without rearing these stages to the adult form they cannot be identified with complete certainty as *H. octocula marianensis*. Geographic locations are provided for all locations of *H. octocula marianensis* and host plants.

Introduction

Hypolimnas octocula marianensis Fruhstorfer, also known as the Mariana eight spot butterfly or forest flicker, is one of eight subspecies in the *Hypolimnas octocula* complex (Tennent 2006) and is currently classified as a candidate species for listing as endangered by United States Fish and Wildlife Service (FWS). It is reported to occur on the islands of Guam and Saipan (Tennent 2006); however, it may have been extirpated from Saipan (Hawley and Castro 2008, Schreiner and Nafus 1997). The status of *H. octocula marianensis* on Guam is also unclear. It was described as scarce during a 1936 Lepidoptera survey, with only one specimen collected from the Piti area (Swezey 1942). According to the Guam Agricultural Experiment Station collection, three specimens were collected at Hilaan Point in 1975, one specimen was collected from Anderson Air Force Base in 1982, and two more specimens were collected from Hilaan Point in 2001 (GDAWR 2005). Results from surveys conducted in 1996 for the FWS by Schreiner and Nafus indicated that there were 10 populations of the butterfly on Guam (Hawley and Castro 2008). The locations of these populations were as follows: Fadian Cove (1), Hilaan (2), Mangilao golf course (2), Orote (1), Pagat (2), and Tweeds Cove (2). No quantitative estimates of population sizes were provided, but it was noted that the highest number of individuals seen in one day was six (USFWS 2008). The two known host plants of *H. octocula marianensis* are *Elatostema calcareum* and *Procris pedunculata*

(Schreiner and Nafus 1997). Both host plants are from the family Urticaceae and occur in wet, native forest areas with exposed limestone karst.

The current survey was conducted in the Pagat area south of Route 15, near the Guam International Raceway in the southern corner of Yigo Village. One adult *H. octocula marianensis* was observed in this area during recent biological surveys for the Guam and Common Wealth of the Northern Mariana Islands (CNMI) Military Relocation Environmental Impact Statement (EIS) (M. Moese, personal communication, 5 Jan. 2009). The purpose of this survey was to gather more information on *H. octocula marinensis* in this area.

Methods

Two primary transects used were used to survey the butterfly and host plants. These were established by biologists from TEC Inc. and SWCA Environmental Consultants and are referred to as Route 15 North and Route 15 South. A third transect, the trail leading to Pagat Cave, was surveyed only once. Personnel participating in the surveys consisted of two entomologists from NAVFAC Pacific and one biologist from NAVFAC Marianas. All transects were surveyed during the period from 15 to 24 July, 2009. Surveys were generally conducted from late morning (~ 9:00-10:00 am) to late afternoon (~ 2:00-4:00 pm); however on 17 July the survey was conducted one hour before and after sunrise (~ 5:30 am to 7:30 am) and one hour before and after sunset (~ 7:00 pm to 9:00 pm) to determine if larvae were active during these time periods. A handheld GPS (Garmin GPSMap60Csx) was used to track all movement and record geographical locations of host plants and all observed life stages of *H. octocula marianensis*.

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.

Results

Two areas were identified which contained numerous plants of both host plant species. These areas were near the beginning of the Route 15 North and Route

15 South transects and are shown respectively (sites N01 and S03) in Figures 1 and 2. A description of the search effort in these areas is provided in Table 1. Other host plants sighted on occurred in small isolated groups and were represented as discrete points in Figures 1, 2, and 3. All host plant locations are listed in Table 1, and images of host plants are included as appendix A.

Sightings of *H. octocula marianensis* are listed in Table 2, and displayed in Figures 1, 2, and 3. No butterflies of any species were observed at the bait pans. With the exception of the site on the Pagat Cave trail where three larvae were found, all sightings occurred within sites N01 and S03. One adult male *H. octocula marianensis* was seen and photographed within N01. The following day, an identical butterfly was seen at the same location and was presumed to be the same individual. There was a possible sighting of an adult female *H. octocula marianenis* within S03, but it passed quickly out of sight and could not be positively identified. A total of 7 *Hypolimnas* larva were found at 5 different locations on both *E. calcareum* and *P. pecunculata*. *Hypolimnas* eggs were found only on *E. calcareum*, with a total of 19 eggs at 5 different locations. One viable *Hypolimnas* chrysalis was found on *E. calcareum* within site N01, and three empty *Hypolimnas* chrysalides were found on *P. pedunculata* within site S03.

Discussion

Results from this survey and others conducted in the Pagat area of Route 15 indicate that there are at least two areas of habitat that are supporting *H. octocula marianenis*. The sighting of the adult butterfly within N01 during the current survey and the sighting of the adult butterfly in the vicinity of S03 by TEC Inc. (M. Moese, personal communication, 5 Jan 2009) are evidence that the species is present in these two areas. The site on the lower shelf down by Pagat Cave may represent a third area with *H. octocula marianensis*, but it cannot be confirmed without the presence of adults. These findings support the results from surveys conducted in 1996 by Schreiner and Nafus who reported 2 populations of *H. octocula marianensis* in the Pagat area (USFWS 2008). Whether or not the two confirmed areas support a single population or two separate populations is unclear. The habitat sites on the north and south transects are separated by approximately 1.5 kilometers. The Pagat Cave Trail site is approximately 1.5 kilometers from the south transect site and 3 kilometers from the north transect site, but it was at a much lower elevation than the other two sites. The cave trail site was on the lower island shelf at about 82 meters above sea level compared to approximately 166 m and 185 m above sea level for the north and south transect sites. If it is assumed that the larva found near Pagat cave were *H. octocula marianenis*, it would seem more likely that they would represent a separate population from the butterflies seen at the other two sites.

Unfortunately there is some uncertainty regarding the identification of immature life stages of *H. octocula marianensis*. These stages are not easily distinguishable from other *Hypolimnas* species unless they are successfully reared to the adult form. While the larva found on *E. calcareum* and *P. pedunculata* fit Schreiner and Nafus' (1997) description (black with reddish orange spines and a black head), there are two other *Hypolimnas* species*, H. anomala* and *H. bolina*, which look similar during their immature stages. Schreiner and Nafus (1997) describe *H. anomala* larva as black with black spines and greasy in appearance when they are younger, and black with orange spines when they are older. *Hypolimans bolina* is described as similar to *H. anomla* but with a "diffuse brownish orange stripe down each side". The younger larvae also differ from *H. anomala* in that they have orange spines rather than black and they do not have a greasy appearance (Schreiner and Nafus 1997). All larva seen during the current survey were black or blackish gray with black heads and orange spines. Differentiating these from *H. anomala* is not easy since the amount of red in the orange spines is listed as the primary distinguishing factor (Schreiner and Nafus 1997) and is difficult to characterize. Based on Schreiner and Nafus' (1997) descriptions, it would seem unlikely that these larva were *H. bolina* since there was no evidence of a lateral stripe. However, they cannot be completely discounted as *H. bolina* because images of larva were also sent to Chris Samson, a lepidopterist who has worked with *H. octocula* complex (Sampson 1986), and his opinion was that some of them could be *H. bolina* or *H. anomala*, while others could be *H. octocula marianensis* (C. Samson and J. Tennent, personal communication, 21 July 2009).

Images of larvae were also sent to Ilse Schreiner, a former entomologist at the University of Guam and coauthor of Butterflies of Micronesia (Schreiner and Nafus 1997). Her comment was that while it is difficult to identify the immature stages, if they were on either of the known host plants, then they were probably *H. octocula marianensis* (I. H. Schreiner, personal communication, 17 July 2009). The only host plant listed for *H. anomala* is *Pipturus argenteus* (Wright et al. 1977, Schreiner and Nafus 1997). *Hypolimnas bolina* has also not been documented to feed on *E. calcareum* or *P. pedunculata*, but, unlike *H. anomala*, it has an extensive list of foodplants, including other species of *Elatostema* (Wright et al. 1977, Parsons 1991). It is consequently not implausible that *H. bolina* could be found on *E. calcareum*. Adult butterflies of both *H. anomala* and *H. bolina* were seen flying within the large host plant areas on the north and south transects; however, they were not common. The most common butterfly species seen flying in these areas were *Euploea eunice* (Danaidae) and *Papilio polytes* (Papilionidae).

Eggs of *H. bolina*, *H. anomala*, and *H.octocula marianensis* are also very similar in appearance and very difficult, if not impossible, to differentiate in the field (C. Samson and J. Tennent, personal communication, 21 July 2009). It is interesting to note, however, that out of 19 *Hypolimnas* eggs found during this survey, all of them were black (Appendix B, Images 7, 10, 11, and 13) except for two, which were green (Appendix B, image 12). Healthy, viable eggs should be green in color, and eggs which have been parasitized are black (I. H. Schreiner, personal communication, 17 July 2009). Egg parasitism of *H. bolina* and *H. anomala*. on Guam was reported by Donald Nafus in 1993 (Nafus 1993); however, it was found that *H. bolina* was parasitized more frequently during the egg stage than *H. anomala* . The majority of egg parasitism on both butterfly species was carried out by three parasitoids: 1) *Telenomus* sp. 2) *Oencyrtus* sp. and 3) *Trichogramma chilonus*. This study did not include Guam's endemic nymphalid species (*Vagrans egista* (Latreille and Godart)) and subspecies (*H. octocula marianensis*), however, given that the three parasitoids listed above show a lack of host specificity, it is highly probably that the native nymphalids are also attacked.

The adult *H. octocula marianensis* that were observed on July 22 and 23 were probably the same individual. The butterflies were identical in appearance and were seen roosting in the same location on the same tree at approximately the same time. On both occasions the butterfly remained in the upper, sunlit canopy and spent the majority of its time perched. This is consistent with behavior documented for *H. octocula elsina* on New Caledonia: "*Octocula* favors well-developed rainforest, emerging from the undergrowth to sun itself on leaves, especially in the morning. It is very much commoner on the wetter, eastern side of New Caledonia (Holloway and Peters 1976)." The pattern and coloration of this butterfly alone do not provide enough information to assess the gender of the butterfly - male and female *H. octocula marianensis* are very similar in appearance, unlike other subspecies show strong sexual dimorphism (Wright et al. 1977, Schreiner and Nafus 1997). However, judging from the behavior it displayed, it was probably a male. Males are generally less active and fly about with no obvious sense of purpose while females are much more businesslike, flying from hostplant to hostplant in their quest to oviposit (I. H. Schreiner, personal communication, 17 July 2009). It also appeared to exhibit some territorialism, never flying far from its roost and chasing other butterflies which entered its air space.

In summary, there is at least one population of the Mariana eight spot butterfly in the Pagat area. There are two areas that contain relatively high numbers of both host plants for the butterfly, and which appear to be sustaining the butterfly population. Any negative impact on these areas would have a direct effect on the butterfly population. The population in these areas already appears to be under stress from parasitization, and any further pressures from habitat degradation could potentially be very damaging. Other areas of habitat for *H. octocula marianensis*, similar to the Pagat Cave trail site, may exist on the lower limestone shelf; however, these would probably support separate populations from the Route 15 area. Additional surveys would be required to identify these habitat areas at lower elevations.

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Table 1. *Hypolimnas octocula marianensis* host plant sites and search effort.

Site	Transect & Coordinates	Elev (ft)	Species	Date & Time Searching for *H. octocula*	Date & No. People[1] Searching for *H. octocula*	Total Search Time (m)	Notes
N01	Rt 15 North N/A[2]	545	*Elatostema calcareum* and *Procris pedunculata*	15JUL09 0948-1033 20JUL09 0900-1015 22JUL09 1030-1220 23JUL09 1000-1100	15JUL09 2 (CC, SL) 20JUL09 3 (CC, SL, MS) 22JUL09 2 (CC, MS) 23JUL09 2 (CC, SL)	290	Mostly *P. pedunculata*, some *E. calcareum*. (Appendix A, images 1-3, 5, 7-10)
N02	Rt 15 North N13 30.759 E144 53.660	563	*Procris pedunculata*	15JUL09 1100-1105	15JUL09 2 (CC, SL)	5	Small group of plants in a patch of limestone forest just after a cleared area.
N03	Rt 15 North N13 30.763 E144 53.661	570	*Procris pedunculata*	15JUL09 1130-1135	15JUL09 2 (CC, SL)	5	Small group of plants in a patch of limestone forest just after a cleared area.
N04	Rt 15 North N13 30.794 E144 53.640	576	*Procris pedunculata*	15JUL09 1150-1153	15JUL09 1 (CC)	3	Small group of plants
N05	Rt 15 North N13 30.809 E144 53.633	565	*Procris pedunculata*	15JUL09 1200-1203	15JUL09 1 (CC)	3	Small group of plants
S01	Rt15 South N13 30.144 E144 53.202	593	*Elatostema calcareum*	16JUL09 0950-0955	16JUL09 2 (CC, SL)	5	Small group of plants
S02	Rt15 South N13 30.143 E144 53.199	603	*Procris pedunculata*	16JUL09 0955-1000	16JUL09 2 (CC, SL)	5	Small group of plants
S03	Rt 15 South N/A[2]	N/A[3]	*Elatostema calcareum* and *Procris pedunculata*	16JUL09 1002-1138 17JUL09 0538-0745 17JUL09 1900-2034 20JUL09 1430-1545 21JUL09 1000-1200 22JUL09 1245-1315 23JUL09 1120-1220 23JUL09 1430-1600 24JUL09 1000-1115	16JUL09 2 (CC, SL) 17JUL09 2 (CC, SL) 17JUL09 2 (CC, SL) 20JUL09 2 (CC, MS) 21JUL09 2 (CC, MS) 22JUL09 2 (CC, MS) 23JUL09 2 (CC, SL) 23JUL09 2 (CC, SL) 24JUL09 2 (CC, SL)	767	Very large stands of *E. calcareum* and *P. pedunculata*. (Appendix A, images 4, 6, and 11)

Site	Transect & Coordinates	Elev (ft)	Species	Date & Time Searching for *H. octocula*	Date & No. People[1] Searching for *H. octocula*	Total Search Time (m)	Notes
S04	Rt 15 South N13 30.123 E144 53.147	615	*Elatostema calcareum*	16JUL09 1207-1220	16JUL09 2 (CC, SL)	13	Small group of *E. calcareum.*
S05	Rt 15 South N13 30.115 E144 53.110	600	*Procris pedunculata*	16JUL09 1220-1227	16JUL09 2 (CC, SL)	7	Small group of *P. pedunculata*.
S06	Rt 15 South N13 30.095 E144 53.092	600	*Elatostema calcareum*	16JUL09 1240-1245	16JUL09 2 (CC, SL)	5	Small group of *E. calcareum.*
S07	Rt 15 South N13 30.100 E144 53.079	600	*Elatostema calcareum*	16JUL09 1247-1252	16JUL09 2 (CC, SL)	5	Small group of *E. calcareum.*
S08	Rt 15 South N13 30.106 E144 53.091	589	*Elatostema calcareum*	16JUL09 1342-1400	16JUL09 2 (CC, SL)	8	Small group of *E. calcareum*.
S09	Rt 15 South N13 30.164 E144 53.183	-	N/A[4]	24 JUL09 1100-1130	24 JUL09 1 (CC)	30	Used binoculars to search top of canopy covering site S03.
P01	Pagat Cave Trail N13 29.524 E144 52.643	268	*Elatostema calcareum*	22JUL09 1550-1610	22JUL09 1 (CC)	20	Medium sized group of *E. calcareum*. (Appendix A, image 12)

[1]CC = Cory Campora, SL = Stephan Lee, MS = Maria Santos
[2]This site consists of a large area and cannot be defined accurately by a single point.
[3]Elevation was variable within this area.
[4]This site was an observation point for looking at upper canopy.

Table 2. Observed life stages of *Hypolimnas octocula marianensis*.

Date & Time	Site	Transect & Coordinates	Elev (ft)	Life Stage (quantity)	Host Plant	Weather - Cloud Cover (%):Wind (1-3):Rain (Y/N)	Notes
15JUL09 1050	N01	Rt 15 North N13 30.819 E 144 53.651	545	Chrysalis (1)	*Elatostema calcareum*	20:1:N	Signs of feeding on leaves *E. calcareum* near the chrysalis. (Appendix B, image 1.)
16JUL09 1030	S03	Rt 15 South N13 30.157 E144 53.164	615	Larvae (1)	*Procris pedunculata*	70:2:N	Late instar, actively feeding during part of the time it was observed, large green frass pellets seen nearby. (Appendix B, images 2-4.)
16JUL09 1138	S03	Rt 15 South N13 30.132 E144 53.164	621	Larvae (1)	*Elatostema calcareum*	70:2:N	Late instar. (Appendix B, images 5 and 6.)
16JUL09 1135	S03	Rt 15 South N13 30.132 E144 53.164	621	Egg (3)	*Elatostema calcareum*	70:2:N	Located in same location as larvae, but on a separate plant. All three eggs were black. (Appendix B, image 7.)
17JUL09 1915	S03	Rt 15 South N13 30.141 E144 53.167	580	Chrysalis (2)	*Procris pedunculata*	80:0:Y	Both chrysalides were empty.
17JUL09 0630	S03	Rt 15 South N13 30.141 E144 53.167	580	Egg (4)	*Elatostema calcareum*	80:0:Y	All four eggs were black.
17JUL09 0550	S03	Rt15 South N13 30.134 E144 53.160	609	Larvae (1)	*Procris pedunculata*	80:0:Y	Very late instar, actively feeding. (Appendix B, image 8.)
17JUL09 1955	S03	Rt15 South N13 30.138 E144 53.165	589	Larvae (1)	*Elatostema calcareum*	10:0:N	Very late instar, actively feeding, large green frass pellets seen nearby. (Appendix B, image 9.)
20JUL09 0915	N01	Rt 15 North N13 30.819 E144 53.651	545	Egg (5)	*Elatostema calcareum*	80:1:N	Near the same plant we found the chrysalis 15 July. (Appendix B, images 10 and 11.)
21JUL09 1130	S03	Rt 15 South N13 30.140 E144 53.167	607	Egg (6)	*Elatostema calcareum*	70:1:N	Two eggs green, 4 eggs black. (Appendix B, images 12 and 13.)

Date & Time	Site	Transect & Coordinates	Elev (ft)	Life Stage (quantity)	Host Plant	Weather - Cloud Cover (%):Wind (1-3):Rain (Y/N)	Notes
21JUL09 1027	S03	Rt 15 South N13 30.143 E144 53.163	624	Chrysalis (1)	*Procris pedunculata*	70:1:N	Empty. (Appendix B, image 14.)
22JUL09 1130	N01	Rt 15 North N13 30.818 E144 53.653	567	Adult (1)	N/A (*Macaranga thompsonii*)	80:0:N	Was flying up in a small clearing within the canopy, but seemed to prefer resting on the leaves of the *M. thompsonii*. (Appendix B, images 15 and 16.)
22JUL09 1600	P01	Pagat Cave Trail N13 29.524 E144 52.643	268	Larvae (3)	*Elatostema calcareum*	50:1:N	One late instar, two earlier instars.
23JUL09 1145	S03	Rt 15 South N13 30.156 E144 53.174	620	Chrysalis (1)	*Procris pedunculata*	20:2:N	Empty.
23JUL09 1045	N01	Rt 15 North N13 30.818 E144 53.653	567	Adult (1)	N/A (*Macaranga thompsonii*)	30:2:N	Was in the same location as the adult butterfly seen on 22 July – appeared to be the same individual. (Appendix B, image 17.)
24JUL09 1050	S03	Rt 15 South N13 30.129 E144 53.159	606	Egg (1)	*Elatostema calcareum*	20:2:N	Egg was black.

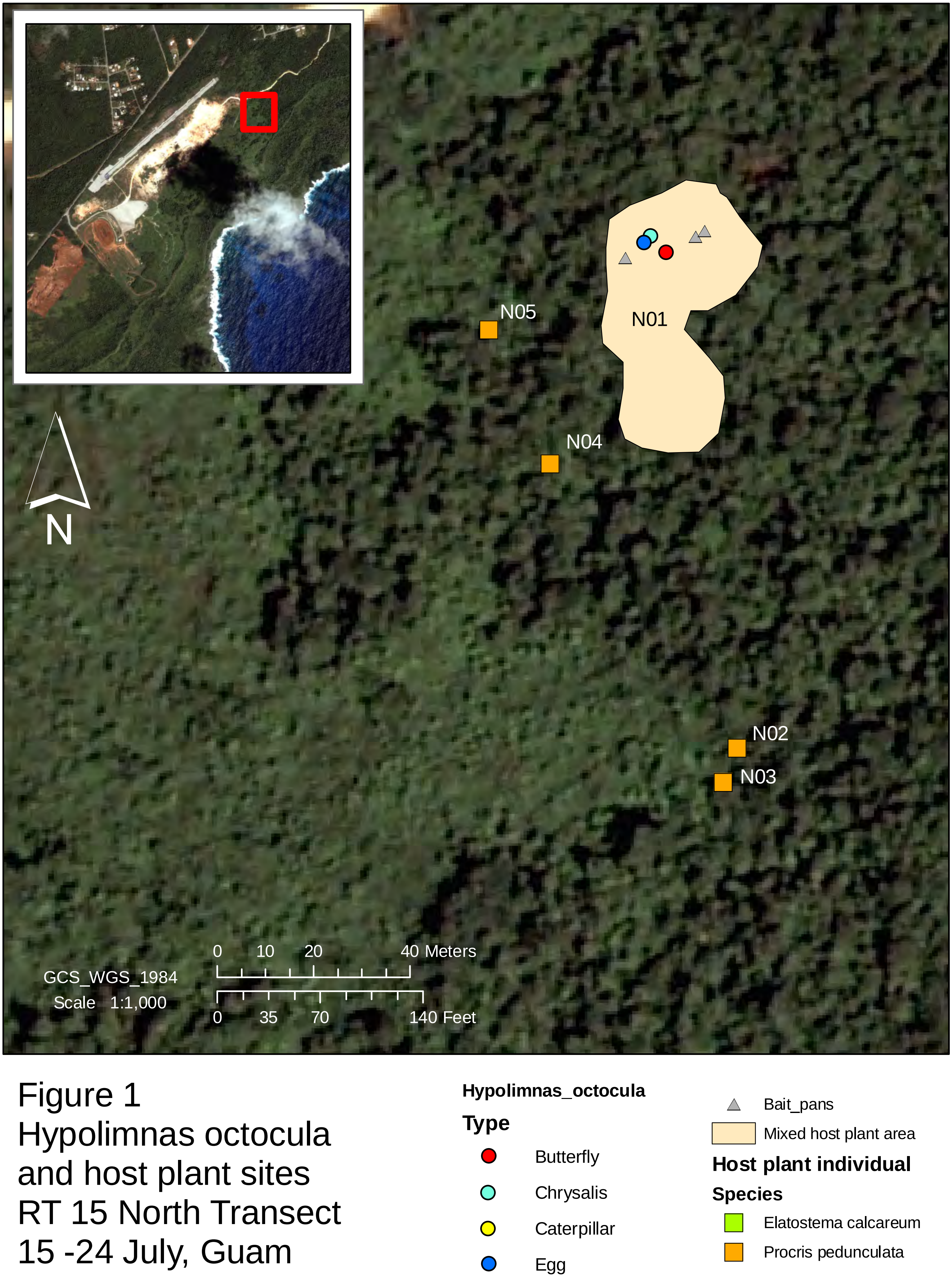


Figure 1
Hypolimnas octocula
and host plant sites
RT 15 North Transect
15 -24 July, Guam

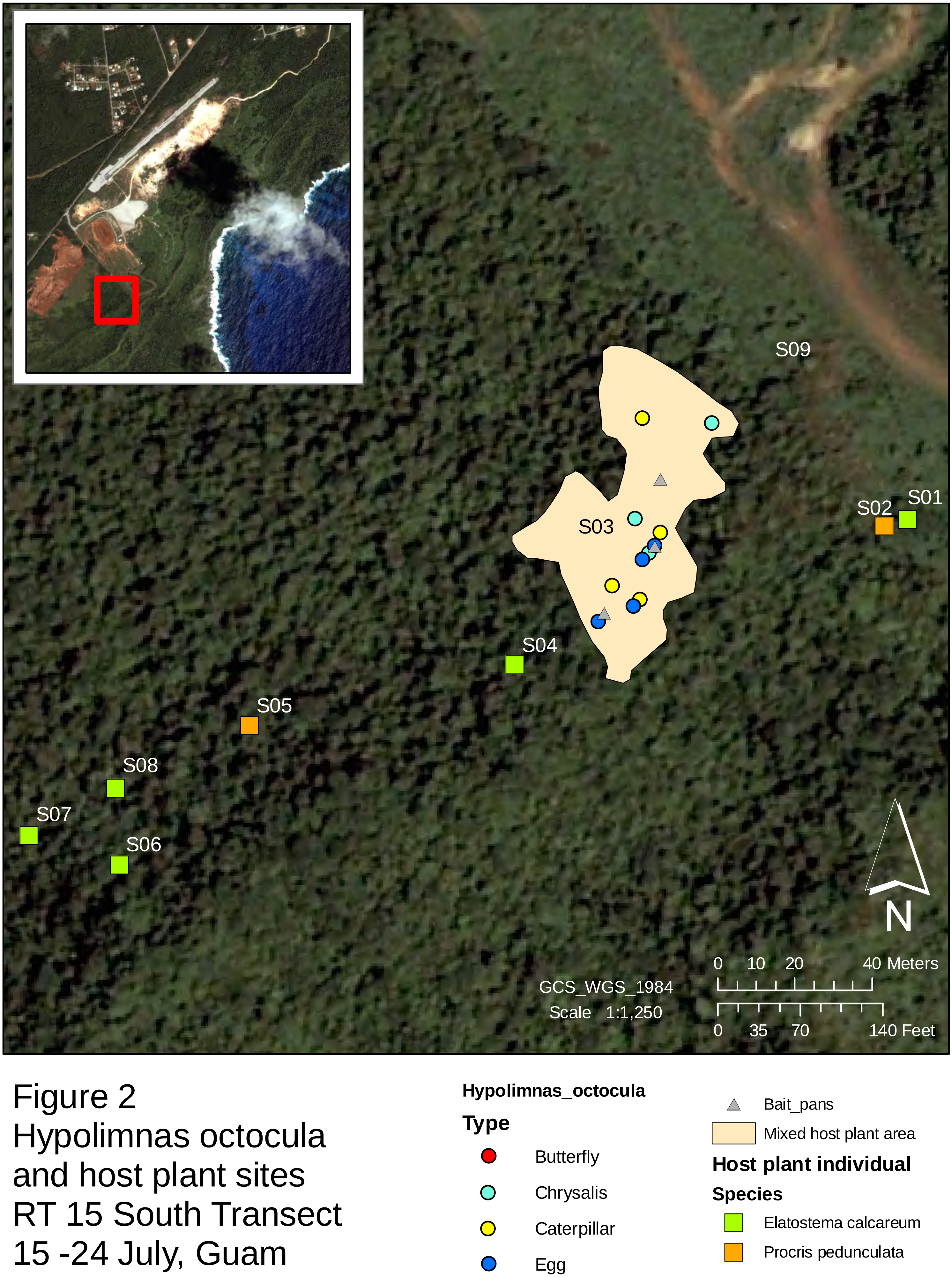


Figure 2
Hypolimnas octocula
and host plant sites
RT 15 South Transect
15 -24 July, Guam

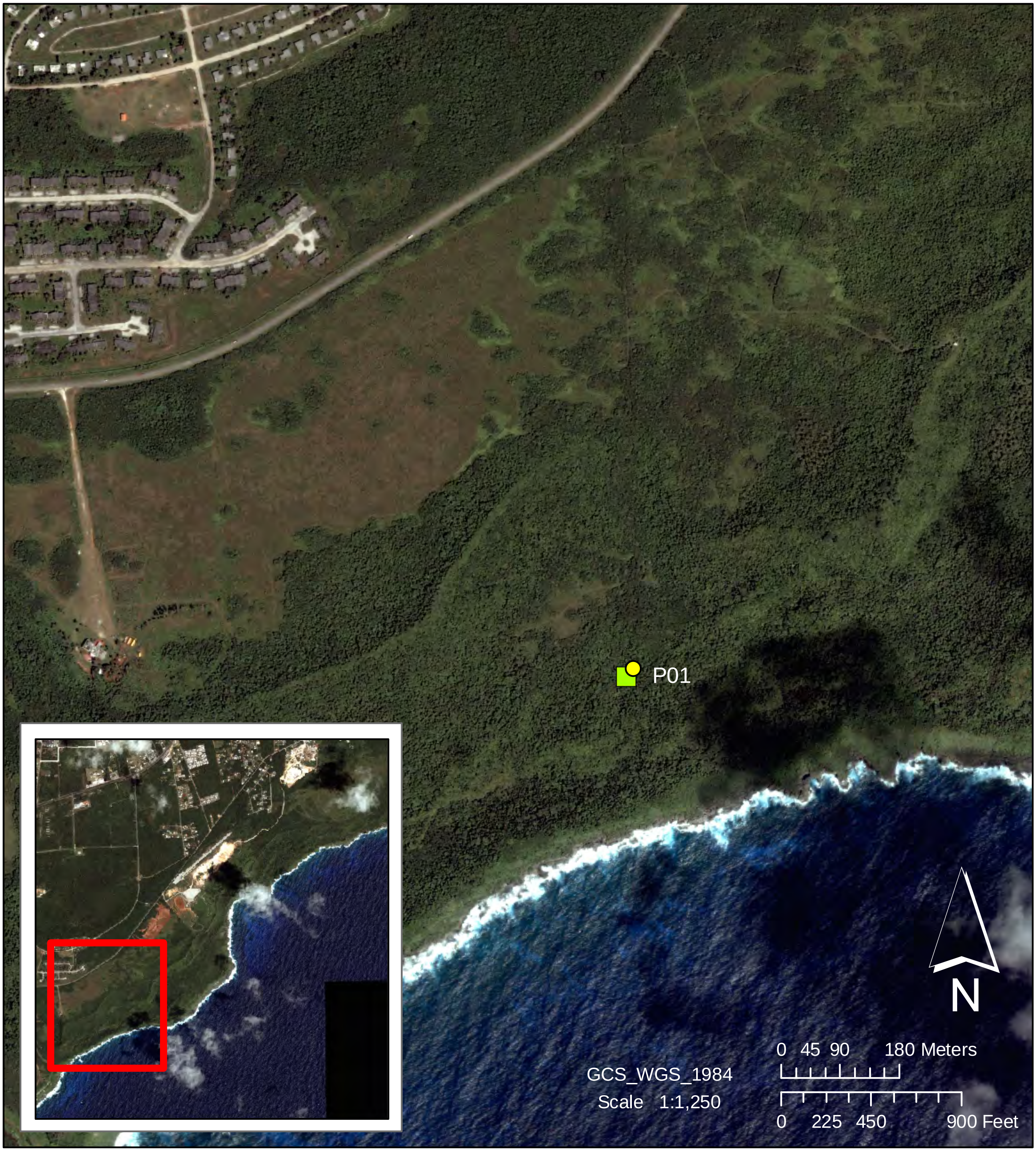


Figure 3
Hypolimnas octocula
and host plant sites
RT 15 Pagat Cave Trail
15 -24 July, Guam

Hypolimnas_octocula

Type

- Butterfly
- Chrysalis
- Caterpillar
- Egg

Host plant individual

Species

- Elatostema calcareum
- Procris pedunculata

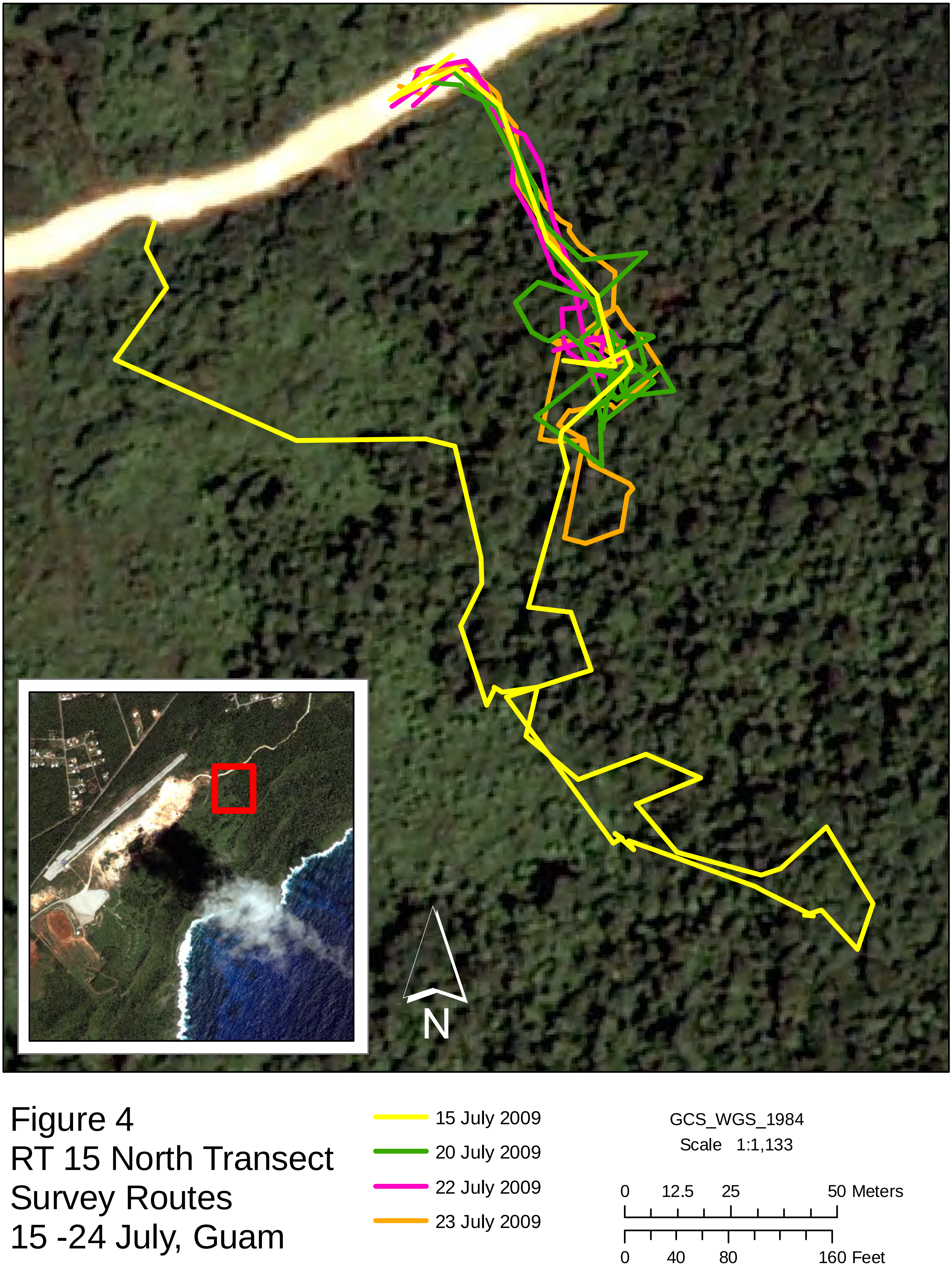


Figure 4
RT 15 North Transect
Survey Routes
15 -24 July, Guam

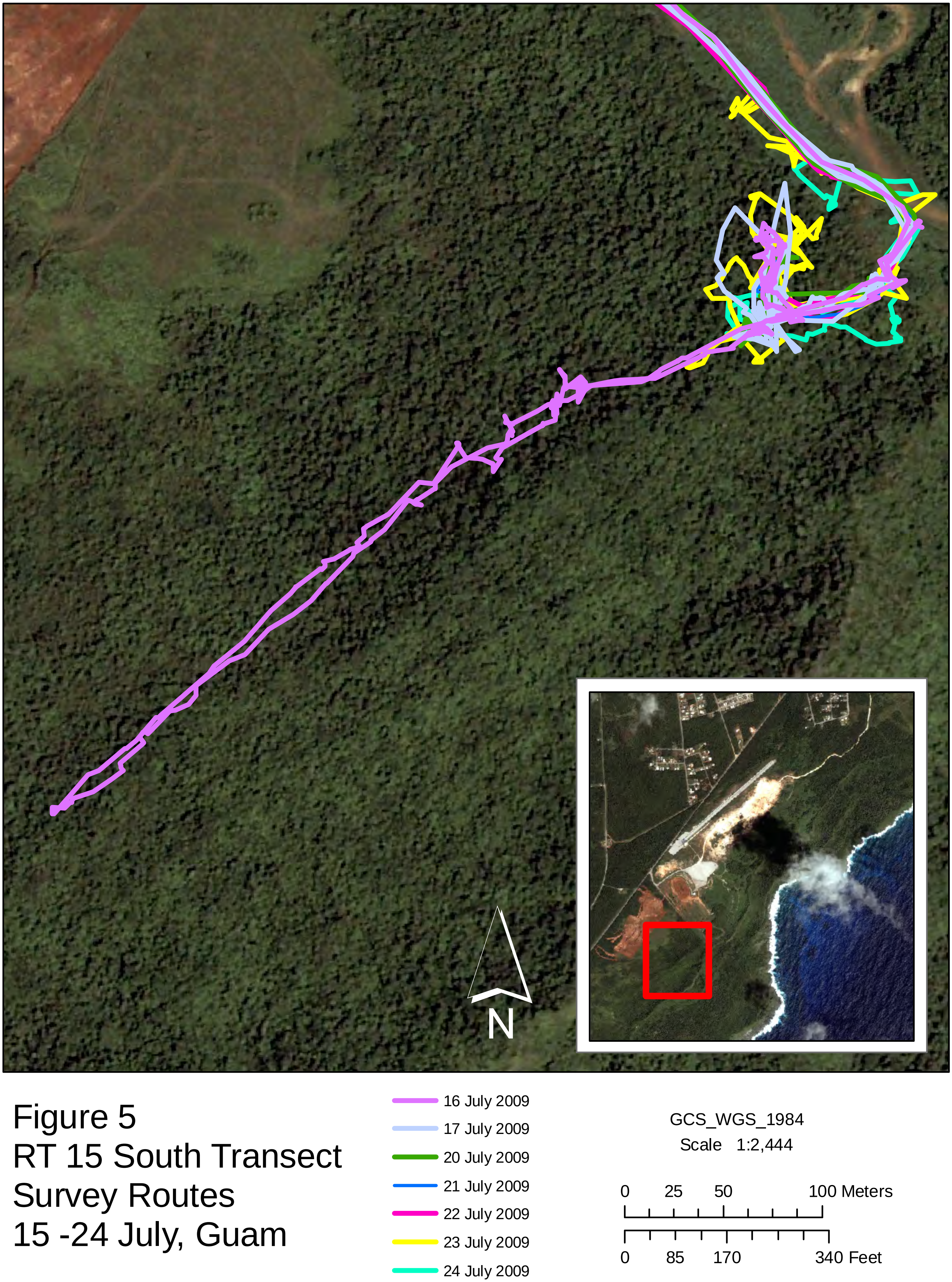


Figure 5
RT 15 South Transect
Survey Routes
15 -24 July, Guam

Figure 6
RT 15 Pagat Cave Trail
Survey Route
15 -24 July, Guam

22 July 2009

GCS_WGS_1984
Scale 1:6,200

0 62.5 125 250 Meters
0 210 420 840 Feet

Appendix A
Host Plant Images

1. Leaves of *Elatostema calcareum*. (Rt 15 North transect, site N01, 15 July 2009)

2. Leaves of *Procris pedunculata*. (Rt 15 North transect, site N01, 15 July 2009)

3. *Procris pedunculata*. (Rt 15 North transect, site N01, 15 July 2009)

4. *Elatostema calcareum*. (Rt 15 South transect, site S03, 16 July 2009)

5. Flowers of *Procris pedunculata*. (Rt 15 North transect, site N01, 15 July 2009)

6. Flowers of *Elatostema calcareum*. (Rt 15 South transect, site S03, 16 July 2009)

7. ***Procris pedunculata*. (Rt 15 North transect, site N01, 15 July 2009)**

8. ***Procris pedunculata*. (Rt 15 North transect, site N01, 15 July 2009)**

9. *Elatostema calcareum*. (Rt 15 North transect, site N01, 15 July 2009)

10. *Procris pedunculata*. (Rt 15 North transect, site N01, 15 July 2009)

11. *Elatostema calcareum* with bait pan. (Rt 15 South transect, site S03, 20 July 2009)

12. *Elatostema calcareum*. (Pagat Cave Trail, site P01, 22 July 2009)

Appendix B
Hypolimnas octocula marianensis Images

1. *Hypolimnas* sp. chrysalis on *Elatostema calcareum* . (Rt 15 North transect, site N01, 15 July 2009)

2. *Hypolimnas* sp. larvae on *Procris pedunculata* . (Rt 15 South transect, site S03, 16 July 2009)

3. *Hypolimnas* sp. larvae on *Procris pedunculata* . (Rt 15 South transect, site S03, 16 July 2009)

4. *Hypolimnas* sp. frass and larvae on *Procris pedunculata* . (Rt 15 South transect, site S03, 16 July 2009)

5. *Hypolimnas* sp. larvae on *Elatostema calcareum* . (Rt 15 South transect, site S03, 16 July 2009)

6. *Hypolimnas* sp. larvae on *Elatostema calcareum* . (Rt 15 South transect, site S03, 16 July 2009)

7. *Hypolimnas* sp. eggs on *Elatostema calcareum* . (Rt 15 South transect, site S03, 16 July 2009)

8. *Hypolimnas* sp. larvae on *Procris pedunculata* . (Rt 15 South transect, site S03, 17 July 2009)

9. *Hypolimnas* sp. larvae on *Elatostema calcareum*. (Rt 15 South transect, site S03, 17 July 2009)

Appendix B

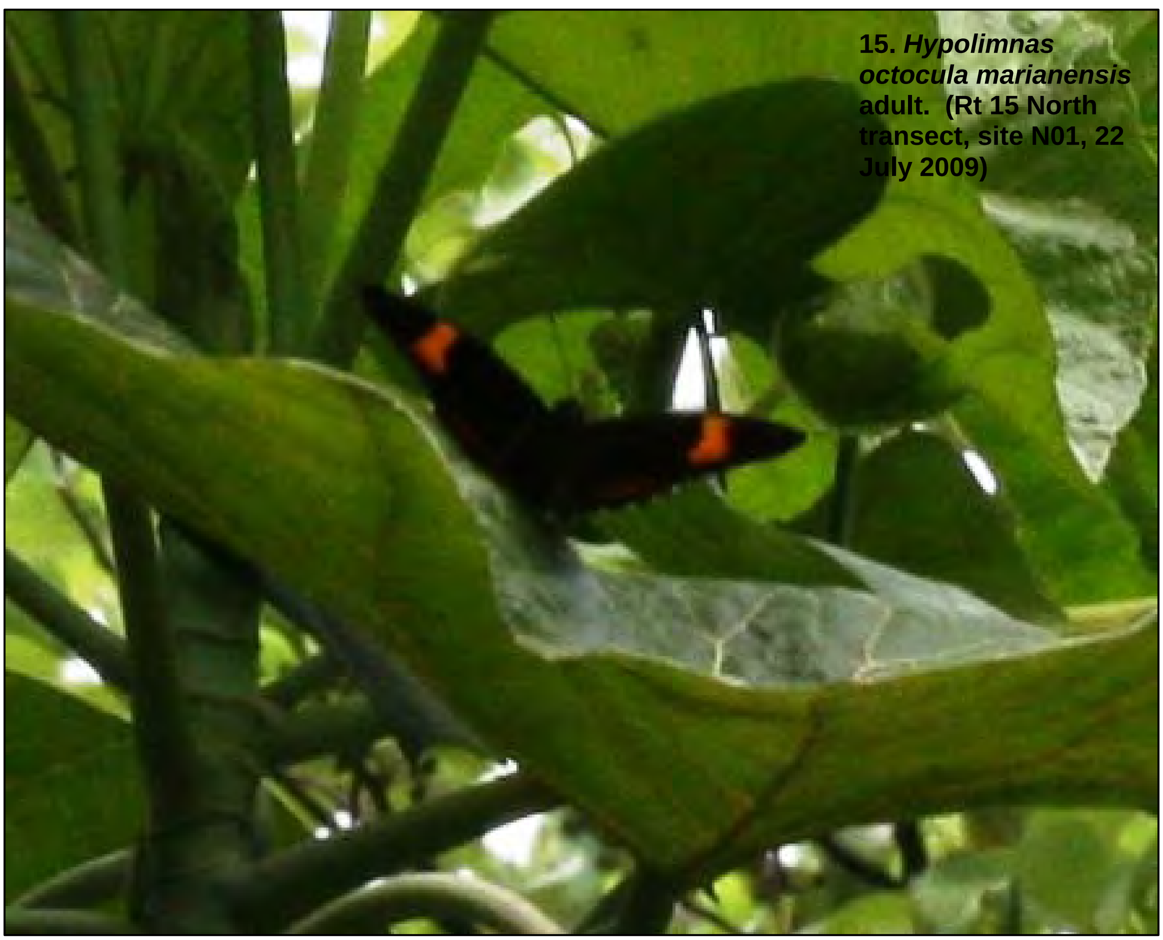
10. ***Hypolimnas* sp. egg on *Elatostema calcareum*. (Rt 15 North transect, site N01, 20 July 2009)**

11. ***Hypolimnas* sp. eggs on *Elatostema calcareum*. (Rt 15 North transect, site N01, 20 July 2009)**

12. *Hypolimnas* sp. eggs on *Elatostema calcareum*. (Rt 15 South transect, site S03, 21 July 2009)

13. *Hypolimnas* sp. eggs on *Elatostema calcareum*. (Rt 15 South transect, site S03, 21 July 2009)

14. *Hypolimnas* sp. chrysalis on *Procris pedunculata*. (Rt 15 South transect, site S03, 21 July 2009)



15. *Hypolimnas octocula marianensis* adult. (Rt 15 North transect, site N01, 22 July 2009)

Appendix B

16. ***Hypolimnas octocula marianensis*** **adult. (Rt 15 North transect, site N01, 22 July 2009)**

17. ***Hypolimnas octocula marianensis*** **adult. (Rt 15 North transect, site N01, 23 July 2009)**

APPENDIX F
Marine Biological Surveys

Marine Biological Survey of Inner Apra Harbor. Guam. Marine Laboratory, University of Guam, UOG Station, Mangilao; and

Marine Biological Survey of Oscar and Papa Wharves, Inner Apra Harbor, Guam. Marine Laboratory, Laboratory, University of Guam, UOG Station, Mangilao.

MARINE BIOLOGICAL SURVEY OF INNER APRA HARBOR, GUAM

by

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Table of Contents

LIST OF FIGURES

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ACKNOWLEDGMENTS

We are most grateful for the support and assistance provided by several organizations and individuals. We extend our thanks to Mr. James E. Ogburn, Director, Port Operations (NB31) Naval Base Guam, and his staff for providing access and coordinating our movements to and from the various study sites in Apra Harbor. We thank Mr. Roberto E. Cabreza, Environmental Protection Specialist, Naval Facilities Marianas, for assisting our personnel in obtaining base passes and for facilitating access to the inner harbor.

Marine Technicians Chris Bassler and Jason Miller piloted the boats and served as diving safety officials. They also maintained communications with Port Operations during our field work.

Finally, we are especially grateful for the guidance provided by Dr. Mark Moese of Earth Tech, Inc. for acting as our liaison and project coordinator. His guidance and patience made the project possible.

INTRODUCTION

Inner Apra Harbor is a natural embayment formed by tectonic activity along the Cabras Fault, separating the volcanic Tenjo Block in central Guam from the limestone Orote Block immediately to the west (see Tracey et al., 1964 for structural details). Rotation of the Orote Block resulted in subsidence of the eastern portion of the block adjacent to the Cabras Fault line. Accompanying rotation, the sea flooded into the slumped areas, forming Apra Harbor, a deep-water lagoon bounded on the north by Cabras Island and the long, curving Glass Breakwater. Two rivers—the Apalacha and Atantano—drain the volcanic mountain land to the east of Apra Harbor and empty into the inner harbor (Randall and Holloman, 1974).

Although naturally formed, Inner Apra Harbor has been extensively modified by dredging, construction, and landfills by the U.S. Navy since 1945 (Paulay et al., 2001a). The inner harbor was dredged, changing the southernmost part of the original lagoon from a reef-choked, silty embayment into a harbor with a nearly uniform depth and mud bottom. Fill projects created the Dry Dock Peninsula, Polaris Point, and manmade shorelines along the northeastern and southeastern boundaries of the harbor. These and other developments in the outer harbor (e.g., construction of Glass Breakwater) reduced water exchange between the harbor and the Philippine Sea, creating a gradient of increasing turbidity, abundance of plankton and benthic suspension feeders, and finer sediments from the entrance to the outer harbor to the inner harbor environment. The only portion of the inner harbor remaining unchanged is the mangrove area at the mouth of the Atantano River.

Randall and Holloman (1974) reported living *Pocillopora* and *Porites* corals on the wharf and dock structures in the inner harbor. Paulay et al. (2001a) found that artificial surfaces in the inner harbor supported diverse fouling communities, including both indigenous and introduced species. They noted the presence of *Porites convexa*, known in Guam from only a few locations. They also remarked about the abundance of the hammer oyster *Malleus decurtatus* on wharf faces in Inner Apra Harbor.

Relocation of elements of the Marine Expeditionary Force (MEF) from Okinawa to Guam by the Marine Corps will require renovation of existing port facilities to accommodate MEF embarkation, as well as construction of various new operations facilities in support of the MEF mission. Furthermore, new training areas and associated facilities are proposed for selected areas on Guam. These developments require extensive surveys that locate, identify, and assesses the natural resources of Guam.

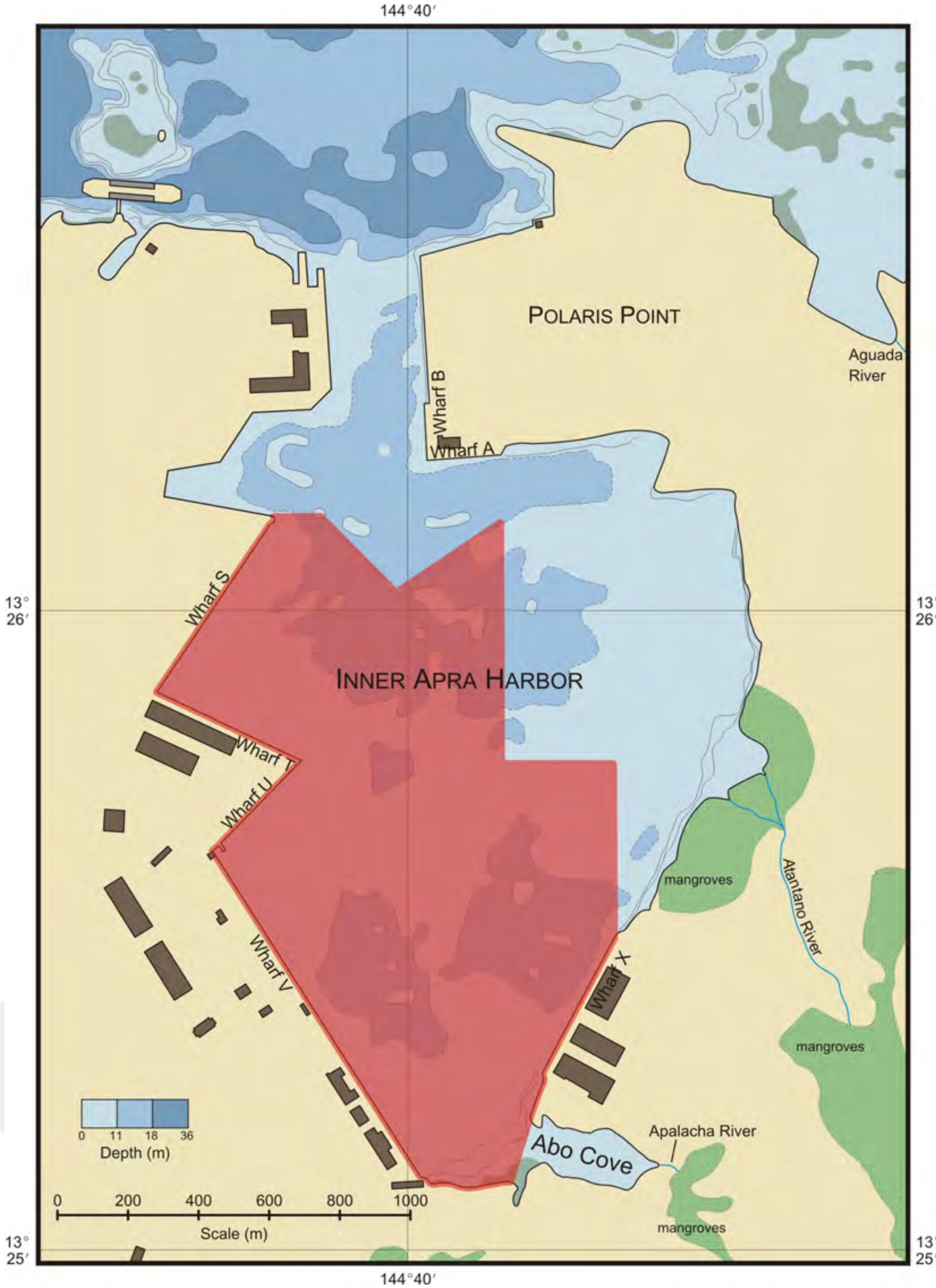

Figure 1. Map of Inner Apra Harbor showing geographic locations and the general survey area (shaded orange).

Scope of Work

The University of Guam Marine Laboratory was contracted to perform a study of marine communities in the southwestern half of Inner Apra Harbor (Figure 1) . The specific objectives of the study were:

- Quantitative assessments of corals
- Quantitative assessment of select macroinvertebrates
- Fish census
- Assessment of essential fish habitat
- Assessment of endangered species (both federally listed, proposed for listing, and candidate species and those similarly listed or otherwise recognized by Guam) to include abundance and preferred habitat, if any
- Survey areas will be subjectively evaluated using the four criteria for Habitat Areas of Particular Concern (HAPC): 1. the ecological function provided by the habitat is significant; 2. the habitat is sensitive to human-induced environmental degradation; 3. development activities are, or will be, stressing the habitat type; and 4. the habitat is rare

Data from the survey are expected to serve as a guide for decisions affecting land and coastal use for proposed construction and renovation of facilities and training sites on Department of Defense lands in Guam.

METHODS

Sampling Site Selection

The general ecological condition of an approximately 145 ha area (Figure 2) was assessed by a modified manta tow method. Two observers were towed behind a boat piloted along the 6,188-m boundary of the study area. Visibility was limited to less than 5 m because of high turbidity of the water. The locations and general surface coverage of corals were noted by the observers. Based upon these observations, three sites (Abo Cove, Transect 1, and Transect 2) were selected for benthic surveys, and five sites (Wharves S, T, U, V, and X) were selected for surveys of vertical wharf faces (Figure 2). A 100-m transect line was established along the 2-m isobath at Abo Cove. For Transects 1 and 2, in open areas of the harbor floor away from wharves or the shoreline, a GPS-tracking unit in a waterproof housing was towed by a diver swimming along the harbor floor. Lengths of the tracks were calculated with SigmaScan Pro 5.0 (SPSS, Inc., 1999). At Wharves S, V, and X, 100-m transects were established. At Wharves T and U, 50-m transects were established, because access to larger wharf areas was not granted. GPS coordinates were recorded for the ends of all transects.

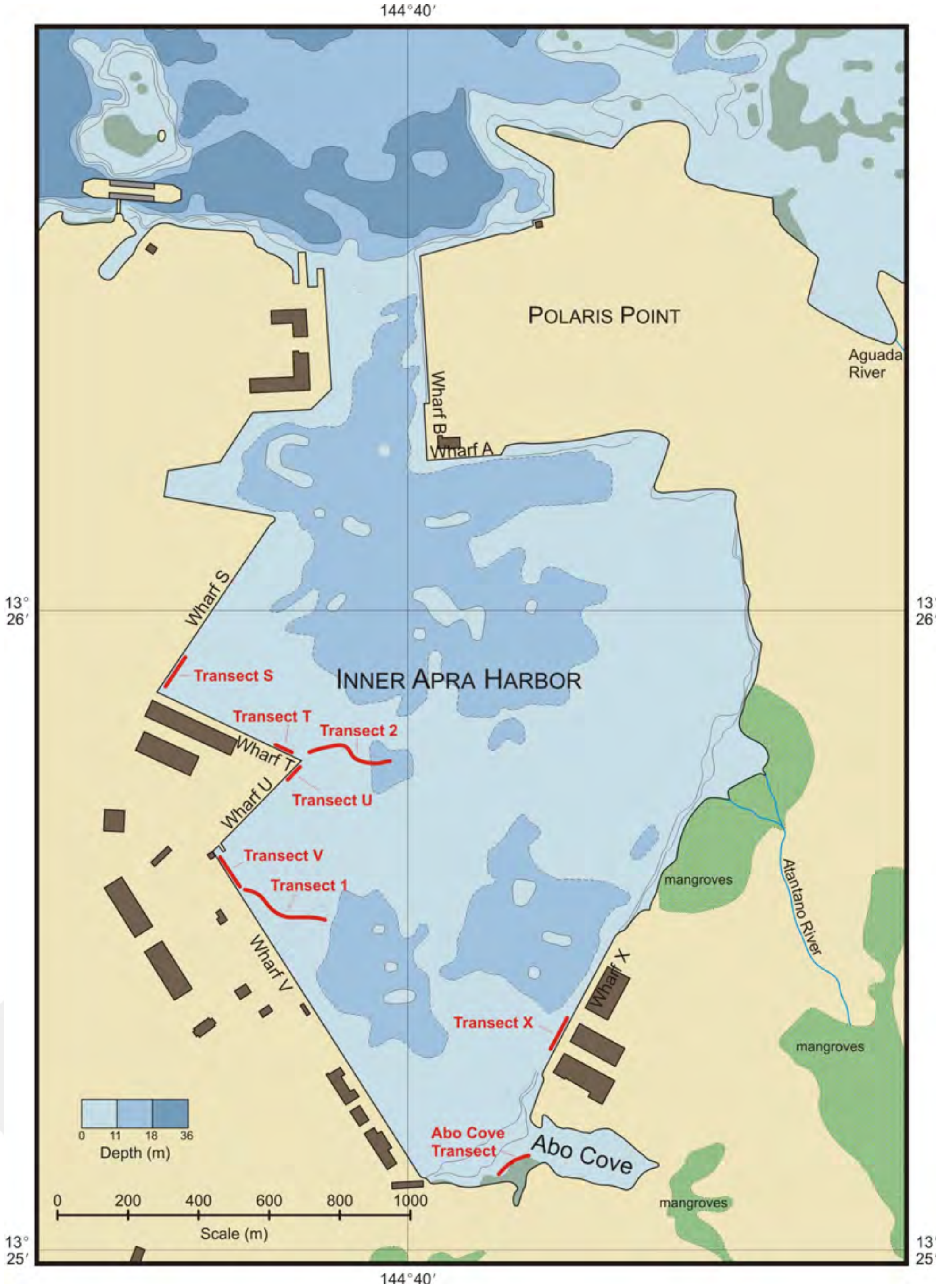

Figure 2. Map of Inner Apra Harbor showing locations of transects surveyed in this study.

Benthic Cover

Benthic quadrats were surveyed along transects established for coral, invertebrate, and fish surveys. Fifty-meter transects were installed at a fixed depth (3–5 m) at six sites throughout the inner harbor (Figure 2). Per transect, the percentage cover of algae, corals, and sponges in five 0.25-m^2 quadrats was quantified in situ, and the data were entered into a relational database (MS Access). The limited visibility in the inner harbor precluded documentation of benthic flora and fauna with photoquadrat records, but macro photographs of the representative species were taken. Voucher specimens of algae were collected to establish a reference collection of algae from Inner Apra Harbor. Explorative data analysis was performed through analysis of variance and non-metric multidimensional scaling. In situ cover estimates of turf algae were also troubled by poor visibility and, therefore, removed from the data set prior to analysis.

Corals

Coral communities were assessed quantitatively along the transects by an observer by the point-quarter method of Cottam et al. (1953). Points were assigned 3–10 m apart on each transect. Each point served as a focus of four equal-sized quadrants arrayed around the point. Within each quadrant, the coral closest to the central point was located. This coral's identity, distance from the point, length, and width were recorded. If no corals lay within 1 m of the point, that quadrant was recorded as having no corals. From the recorded data, community and species-specific population density of colonies, percent coverage, and frequency of occurrence were then computed with the following equations from Cottam et al. (1953):

Total Density Of All Colonies = Unit Area / (Average Point-To-Colony Distance)^2
Relative Density Of A Species = 100 * Number Of Colonies Of The Species / Number Of All Colonies
Absolute Density Of A Species = Percent Density * Total Density / 100
Total Percent Coverage Of All Species = Total Density * Average Coverage Of All Species
Relative Coverage Of A Species = Species Density * Average Coverage of the Species

Population data for each species were also calculated, including the number of colonies, average colony size, standard deviation of colony size, and minimum and maximum colony size. To record the less common species not recorded by the quantitative survey, a list of species was also assembled by swimming along the entire transects and recording all species seen within 2 m of the line. Species names followed Veron (2000).

Macroinvertebrates

All conspicuous solitary epibenthic macroinvertebrates occurring within 1 m of either side of the transect lines at Abo Cove and Wharves S, T, U, V, and X were identified and enumerated by an observer swimming along the transect line. For Transects 1 and 2, species of conspicuous epibenthic macroinvertebrates were recorded within 1 m of an imaginary line in front of an observer swimming over the harbor floor, as described above. For this study, conspicuous is defined as being larger than 50 mm in size and as being clearly visible to an observer without need of overturning rocks or digging into the substrate. Cryptic, microscopic, nocturnal, and highly motile species that avoid humans (e.g., crabs and shrimps) were not included within the scope of this study. Species diversity and abundance were recorded in 10-m intervals along the transect line. Therefore, for statistical purposes, each belt transect consisted of five to ten 20-m^2 replicate plots, except where noted.

Similarities in structure of macroinvertebrate assemblages for all transects were calculated by the Bray-Curtis similarity method, and the resulting matrix subjected to cluster analysis (group average method, fourth root-transformed data) and multidimensional scaling (MDS) analysis (fourth root-transformed data bootstrapped with n = 100 iterations) to investigate relationships between transects. Cluster and MDS analyses were performed with PRIMER v5 (Clarke and Gorley, 2001). Species of macroinvertebrates observed in the study area, but not encountered along the transect line, were also recorded but not included in the similarity analyses.

Fishes

Fishes were surveyed visually along transect lines. Observations were constrained by poor visibility and all species had to be counted on a single pass along the transect line. At Abo Cove, the line was deployed along the bottom as the diver observed and counted fishes. Along wharf faces, three transects were run (where possible), respective of depth, just below the surface (subsurface), at mid-depth (the principal transect line), and at the bottom of the wharf wall. All fishes observed 0.5m above or below the line, were counted on subsurface and mid-depth transects; at the bottom, all fishes observed 1 m to the seaward side (away from the wharf face) of the line were counted. At two stations located in open areas of the harbor away from wharves or the shoreline, GPS-tracking was used to census fishes. Here, one diver utilized a GPS unit set on timed-tracking mode and towed above him in a waterproof housing, recorded all benthic species observed within 1 m either side of an imaginary line directly in front of the diver (Colin and Donaldson, in review). Observations were recorded a during the course of the swim just above the bottom. Pelagic species could not be observed because of poor visibility. These methods provided estimates of density (no. individuals/m^2) for each species.

Fishes were identified to species. Identifications followed Myers (1999) and Myers and Donaldson (2003), except where more recent taxonomic studies were relevant. Reference photographs and video were taken with an underwater digital camera or underwater digital video camera, but image quality tended to be extremely poor because of turbid conditions.

For estimates of species diversity, standard measures of species richness, species diversity, and similarity were calculated and compared between stations with PRIMER vers. 5.2.2; DIVERSE PROCEDURE). Multidimensional scaling (PRIMER vers. 5.2.2; MDS procedure) was used to examine similarities between stations based upon Bray-Curtis coefficients calculated for each. This test indicates relative distances between samples based upon their similarities in assemblage structure. Points found close together represent samples that were very similar in species composition while those far away represented different assemblage structures (Clarke and Gorley, 2001). Analysis of Similarities (PRIMER, ver. 5.2.2;

ANOSIM procedure) was used to test the null hypothesis that there were no differences in assemblage structure between groups of samples at stations.

Essential Fish Habitat

Extremely poor visibility on transects at all stations limited the ability to collect data on essential fish habitat. Underwater photographs taken along the transect line to estimate benthic structure used by different species were essentially useless. Similarly, measures of rugosity (benthic structural complexity), limited to the edge of a shallow reef at Abo Cove, were made under near-zero visibility and were fraught with error. Therefore, it was possible only to make qualitative descriptions of habitats used by fishes.

Results and Discussion

GPS coordinates for the locations of transects are reported in Table 2 and illustrated in Figure 1. No GPS data were captured for the distal ends of transects at Victor and X-ray wharves.

Table 1. GPS coordinates of transects surveyed in Inner Apra Harbor for this study.

			Start		Finish	
Study Site	Date	Length (m) (M)	Latitude (°N)	Longitude (°E)	Latitude (°N)	Longitude (°E)
Abo Cove	2008/05/29	100	13.41927	144.66937	13.41865	144.6692
Sierra Wharf	2008/05/29	100	13.25922	144.39646	13.25881	144.39616
Tango Wharf	2008/05/23	50	13.42973	144.66336	nd[1]	nd
Victor Wharf	2008/05/29	100	13.62535	144.66269	13.42627	144.66206
Uniform Wharf	2008/05/22	50	13.25687	144.39766	13.25706	144.39783
X-ray Wharf	2008/05/21	100	13.42399	144.67168	nd	nd
Transect 1	2008/05/29	260	13.42617	144.66239	13.42531	144.66441
Transect 2	2008/05/29	250	13.42946	144.66391	13.42916	144.66638

[1]No data recorded.

Benthic Cover

Table 2 shows the sampling effort of benthic surveys. The number of surveyed transects is a function of site accessibility, which was often limited by port operations and the size of the wharfs. Continued efforts to increase the number of transects at Uniform and Tango wharves were prevented as the team was denied access to the inner harbor on several occasions.

Table 2. Dates and sampling effort of benthic surveys.

Site	Date	# Transects	# Quadrats
Abo Cove	5-May-08	3	14
Sierra Wharf	21-May-08	2	10
X-ray Wharf	21-May-08	2	10
Uniform Wharf	22-May-08	1	5
Tango Wharf	23-May-08	1	5
Victor Wharf	23-May-08	2	10

Table 3 lists the 70 benthic taxa that were recorded and quantified during this study. The total number of taxa recorded is low compared to benthic surveys in other parts of the harbor. The average species richness of the quadrats is also low compared to similar studies in other parts of Guam. Figures 3 and 4 show a large difference in the total number of species and species richness between quadrats from Abo Cove and the wharf transects. The most authentic "natural" site (Abo Cove) is significantly less taxon-rich than the wharf sites (Tables 4 and 5). Turbidity and sediment deposition are most likely the most important causal factors for this difference. *Caulerpa verticillata* is a green alga that copes well with increased levels of sedimentation and reduced salinities. Exceptionally large specimens of this alga were found in Abo Cove, probably a result of relatively low herbivore pressure. The distribution of the seagrass species *Halophila japonica* also seems to be restricted to Abo Cove in the inner harbor.

Table 3. Taxonomic list of biotic categories observed in the benthic surveys.

Higher classification	Taxon
Chlorophyta - Ulvophyceae - Bryopsidales - Caulerpaceae	*Caulerpa serrulata*
Chlorophyta - Ulvophyceae - Bryopsidales - Caulerpaceae	*Caulerpa verticillata*
Chlorophyta - Ulvophyceae - Bryopsidales - Udoteaceae	*Halimeda gracilis*
Chlorophyta - Ulvophyceae - Bryopsidales - Udoteaceae	*Halimeda opuntia*
Chlorophyta - Ulvophyceae - Bryopsidales - Udoteaceae	*Rhipilia sinuosa*
Chordata - Ascidiacea - Phlebobranchia - Ascidiidae	*Phallusia julinea*
Chordata - Ascidiacea - Phlebobranchia - Ascidiidae	*Phallusia nigra*
Chordata - Ascidiacea - Phlebobranchia - Diazonidae	*Rhopalaea circula*
Chordata - Ascidiacea - Phlebobranchia - Diazonidae	*Rhopalaea* sp. 2–gold spot
Cnidaria - Anthozoa - Corallimorpharia - Actinodiscidae	*Discosoma* sp.

Higher classification	Taxon
Cnidaria - Anthozoa - Scleractinia - Acroporidae	*Astreopora* sp.
Cnidaria - Anthozoa - Scleractinia - Agariciidae	*Leptoseris mycetoseroides*
Cnidaria - Anthozoa - Scleractinia - Astrocoeniidae	*Stylocoeniella armata*
Cnidaria - Anthozoa - Scleractinia - Dendrophylliidae	*Tubastrea* sp.
Cnidaria - Anthozoa - Scleractinia - Faviidae	*Goniastrea retiformis*
Cnidaria - Anthozoa - Scleractinia - Faviidae	*Leptastrea bottae*
Cnidaria - Anthozoa - Scleractinia - Faviidae	*Leptastrea purpurea*
Cnidaria - Anthozoa - Scleractinia - Oculinidae	*Galaxea fascicularis*
Cnidaria - Anthozoa - Scleractinia - Pocilloporidae	*Pocillopora damicornis*
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Alveopora* sp.
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Porites densa*
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Porites horizontalata*
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Porites lichen*
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Porites lobata*
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Porites lutea*
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Porites rus*
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Porites solida*
Cnidaria - Anthozoa - Scleractinia - Siderastreidae	*Psammocora superficialis*
Ectoprocta - Gymnolaemata - Cheilostomata - Bugulidae	*Celleporaria sibogae*
Ectoprocta - Gymnolaemata - Cyclostomata - Lichenoporidae	*Lichenopora* sp.
Magnoliophyta - Liliopsida - Alismatales - Hydrocharitaceae	*Halophila japonica*
Mollusca - Bivalvia - Pterioida - Malleidae	*Malleus decurtatus*
Mollusca - Bivalvia - Veneroida - Chamidae	*Chama lazarus*
Ochrophyta - Phaeophyceae - Dictyotales - Dictyotaceae	*Dictyota adnata*
Ochrophyta - Phaeophyceae - Dictyotales - Dictyotaceae	*Dictyota bartayresiana*
Ochrophyta - Phaeophyceae - Dictyotales - Dictyotaceae	*Dictyota friabilis*
Ochrophyta - Phaeophyceae - Dictyotales - Dictyotaceae	*Lobophora variegata*
Ochrophyta - Phaeophyceae - Dictyotales - Dictyotaceae	*Padina boryana*
Porifera - Demospongiae - Dendroceratida - Darwinellidae	*Aplysilla* sp.
Porifera - Demospongiae - Dendroceratida - Dysideidae	*Dysidea* cf. *avara*
Porifera - Demospongiae - Dictyoceratida - Spongiidae	*Aplysina* sp. (yellow)
Porifera - Demospongiae - Dictyoceratida - Thorectidae	*Hyrtios* sp.
Porifera - Demospongiae - Hadromerida - Spirastrellidae	*Spheciospongia vagabunda*
Porifera - Demospongiae - Halichondrida - Halichondriidae	*Halichondria* sp.
Porifera - Demospongiae - Poecilosclerida - Anchinoidae	*Phorbas* sp.
Porifera - Demospongiae - Poecilosclerida - Desmacellidae	*Biemna fistulosa*
Porifera - Demospongiae - Poecilosclerida - Desmacellidae	*Neofibularia hartmani*
Porifera - Demospongiae - Poecilosclerida - Desmacididae	*Iotrochota protea*
Porifera - Demospongiae - Poecilosclerida - Guitarridae	*Tetrapocillon* sp.
Porifera - Demospongiae - Poecilosclerida - Microcionidae	*Clathria eurypa*
Porifera - Demospongiae - Poecilosclerida - Microcionidae	*Clathria mima*
Porifera - Demospongiae - Poecilosclerida - Microcionidae	*Clathria* sp. 1
Porifera - Demospongiae - Poecilosclerida - Microcionidae	*Echinochalina* sp.
Porifera - Demospongiae - Poecilosclerida - Mycalidae	*Ulosa spongia*
Porifera - Demospongiae - Poecilosclerida - Phoriospongiidae	*Psammoclemma* sp.
Porifera - Demospongiae - Poecilosclerida - Raspailiidae	*Ceratopsion* sp. 1
Prokaryota - Bacteria - Negibacteria - Cyanobacteria	*Calothrix scopulorum*
Prokaryota - Bacteria - Negibacteria - Cyanobacteria	*Lyngbya penicilliformis*

Higher classification	Taxon
Prokaryota - Bacteria - Negibacteria - Cyanobacteria	*Phormidium* cf. *dimorphum*
Prokaryota - Bacteria - Negibacteria - Cyanobacteria	*Symploca hydnoides*
Rhodophyta - Florideophyceae - Ceramiales - Rhodomelaceae	*Lophocladia* sp.
Rhodophyta - Florideophyceae - Corallinales - Corallinaceae	*Hydrolithon onkodes*
Rhodophyta - Florideophyceae - Corallinales - Corallinaceae	*Lithophyllum kotschyanum*
Rhodophyta - Florideophyceae - Corallinales - Corallinaceae	*Lithophyllum pygmaeum*
Rhodophyta - Florideophyceae - Corallinales - Corallinaceae	*Mesophyllum funafutiense*
Rhodophyta - Florideophyceae - Corallinales - Corallinaceae	*Pneophyllum conicum*
Rhodophyta - Florideophyceae - Halymeniales - Peyssonneliaceae	*Peyssonnelia boergesenii*
Rhodophyta - Florideophyceae - Halymeniales - Peyssonneliaceae	*Peyssonnelia inamoena*
Rhodophyta - Florideophyceae - Halymeniales - Peyssonneliaceae	*Peyssonnelia rubra*
Turf algae	Turf algae

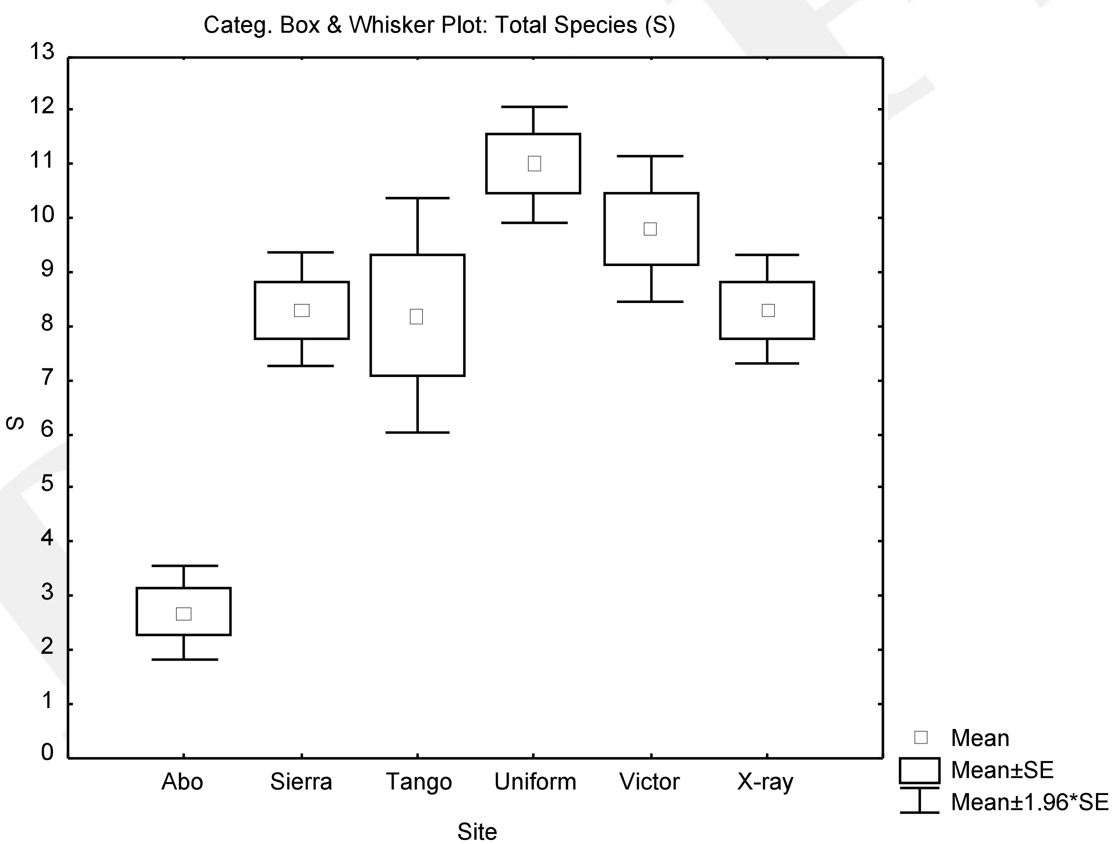

Figure 3. Total species (*S*) of quadrats per site. Abbreviations: Abo, Abo Cove; Sierra, Sierra Wharf; Tango, Tango Wharf; Uniform, Uniform Wharf; Victor, Victor Wharf; X-ray, X-ray Wharf.

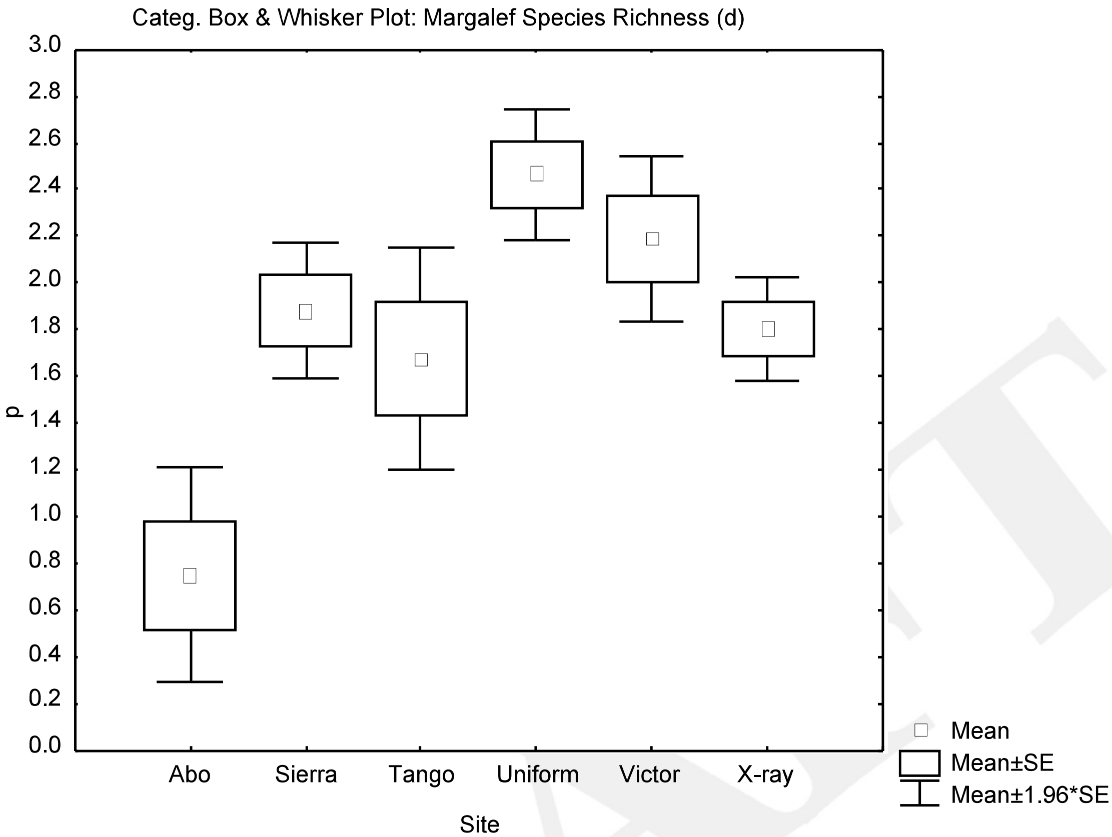

Figure 4. Margalef species richness (*d*) of quadrats per site. Abbreviations as in Figure 3.

Table 4. One-way Analysis of Variance (ANOVA) of *S* with Tukey HSD for unequal sample size as a post-hoc test. Differences significant at P < 0.05 are italicized. Abbreviations as in Figure 3.

	Abo	Sierra	Tango	Uniform	Victor	X-ray
Abo		*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Sierra	*0.00*		1.00	0.19	0.44	1.00
Tango	*0.00*	1.00		0.16	0.73	1.00
Uniform	*0.00*	0.19	0.16		0.90	0.19
Victor	*0.00*	0.44	0.73	0.90		0.44
X-ray	*0.00*	1.00	1.00	0.19	0.44	

Table 5. One-way ANOVA of *d* with Tukey HSD for unequal sample size as a post-hoc test. Differences significant at P < 0.05 are italicized. Abbreviations as in Figure 3.

	Abo	Sierra	Tango	Uniform	Victor	X-ray
Abo		*0.00*	0.13	*0.00*	*0.00*	*0.00*
Sierra	*0.00*		0.99	0.59	0.83	1.00
Tango	0.13	0.99		0.27	0.72	1.00
Uniform	*0.00*	0.59	0.27		0.97	0.46
Victor	*0.00*	0.83	0.72	0.97		0.66
X-ray	*0.00*	1.00	1.00	0.46	0.66	

Turbidity is high throughout the inner harbor, but the vertical orientation of hard substrates (and probably ship activity) at the wharves results in a lower amount of sediment deposition, favoring the growth of epilithic biota adapted to low light conditions. Although very different from Abo Cove, the benthic assemblages of the wharves contain interesting taxa as well. Some of the taxa recorded here do not appear in the most recent taxonomic treatises for Guam. For example, the very abundant *Celleporaria sibogae* and the rather uncommon *Lichenopora* sp. are most likely new bryozoan records for Guam, as this group has been virtually unstudied in the region (Paulay, 2003). Diversity measures mimic the differences in species richness between the inner harbor sites (Figure 5; Table 6). Sponges contribute most to the benthic diversity of the wharves. A number of these probably also constitute new records for Guam, and others are infrequently encountered elsewhere around the island as they are typically confined to deep water, caves, or other cryptic habitats.

Table 6. One-way ANOVA of *H′* with Tukey HSD for unequal sample size as a post-hoc test. Differences significant at P < 0.05 are italicized. Abbreviations as in Figure 3.

	Abo	Sierra	Tango	Uniform	Victor	X-ray
Abo		*0.01*	0.13	*0.00*	*0.00*	*0.00*
Sierra	*0.01*		1.00	0.64	0.14	0.73
Tango	0.13	1.00		0.69	0.53	0.94
Uniform	*0.00*	0.64	0.69		1.00	0.99
Victor	*0.00*	0.14	0.53	1.00		0.87
X-ray	*0.00*	0.73	0.94	0.99	0.87	

As found for taxonomic richness and diversity, the benthic assemblages of Abo Cove differ significantly from the wharf sites in having a low overall biotic cover (Figure 6; Table 7). As discussed before, this is a direct result of the Abo Cove site being a mostly horizontally oriented sedimentation flat. In contrast, the biotic assemblages of the wharfs are best developed on the shallow vertical surfaces. It is important to note, however, that corals are the main constituent of the biotic assemblages at Abo Cove, while the wharfs are predominantly covered by crustose algae and sponges (Figure 7).

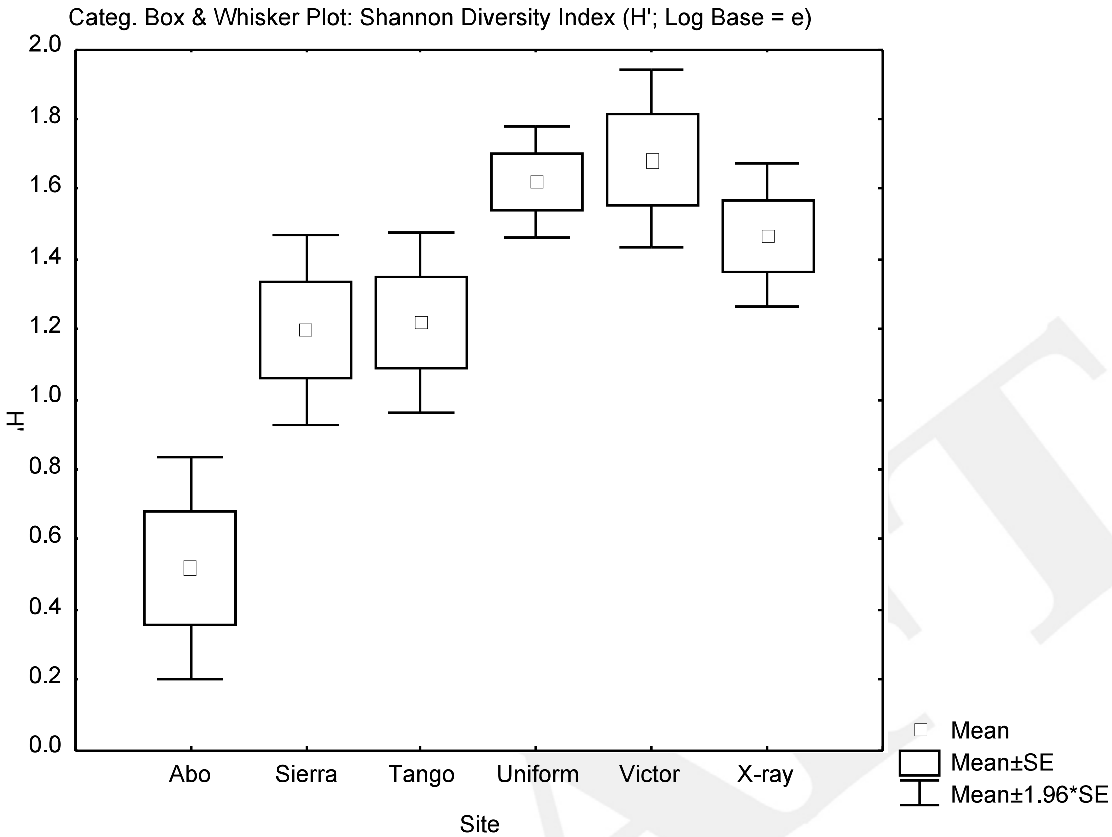

Figure 5. Shannon index (H') of quadrats per site. Abbreviations as in Figure 3.

Table 7. One-way ANOVA of biotic cover with Tukey HSD for unequal sample size as a post-hoc test. Differences significant at P < 0.05 are italicized. Abbreviations as in Figure 3.

	Abo	Sierra	Tango	Uniform	Victor	X-ray
Abo		*0.00*	*0.02*	0.21	*0.01*	*0.01*
Sierra	*0.00*		0.98	1.00	1.00	1.00
Tango	*0.02*	0.98		0.87	0.92	0.92
Uniform	0.21	1.00	0.87		1.00	1.00
Victor	*0.01*	1.00	0.92	1.00		1.00
X-ray	*0.01*	1.00	0.92	1.00	1.00	

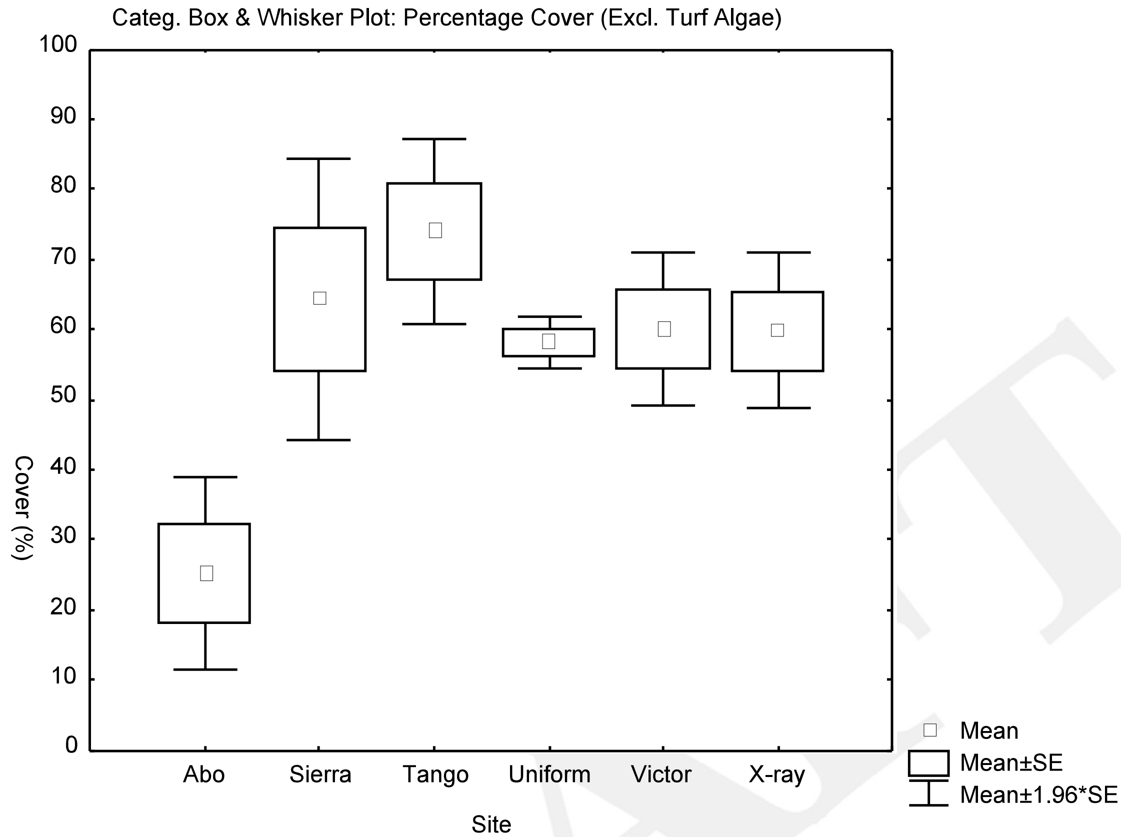

Figure 6. Biotic cover (excluding turf algae) of quadrats per site. Abbreviations as in Figure 3.

Non-metric multidimensional scaling (NMDS) was performed on the square root-transformed benthic data. The two-dimensional NMDS plot is an excellent representation of the biotic affinities between sites (low stress) and highlights the differences between Abo Cove and the Wharf sites in accordance with the above findings. Similarity is highest among the three southwestern wharves (Tango, Uniform, and Victor). Further multivariate analyses should reveal the main differences between the other sites and the most important indicator taxa in the data set.

Corals

Size-frequency distributions of the 13 species of scleractinian corals encountered on six transects in Inner Apra Harbor are presented in Table 8. An additional 13 species of scleractinian corals were observed on substrates adjacent to the transects (Table 3). Two species of non-scleractinian anthozoans were also recorded. Therefore, a cumulative total of 28 species of corals and related organisms, representing 11 families and 13 genera, was observed at the study site. This count represents a minimum, because several corals could be identified only to genus in the field and, therefore, may consist of more than one species.

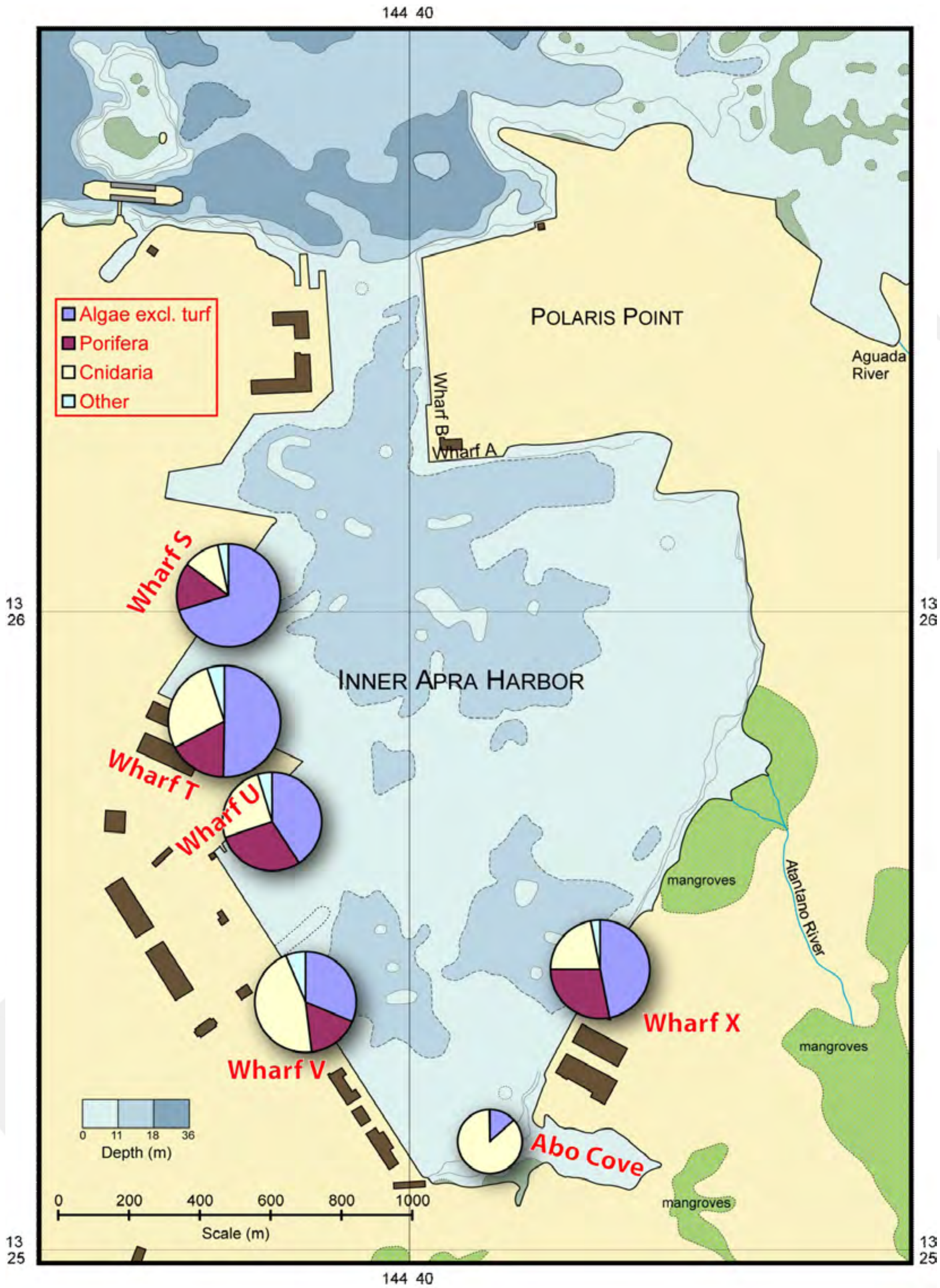

Figure 7. Pie charts displaying the percent cover of algae (Chlorophyta, Ochrophyta, Prokaryota, Rhodophyta), Porifera, Cnidaria, and other groups (Chordata, Magnoliophyta, Mollusca) for the different study sites. Size of the pie chart is proportional to the average total cover of benthic assemblages in the sampled quadrats. Biotic cover ranges from 25 % (Abo Cove) to 74 % (Tango Wharf).

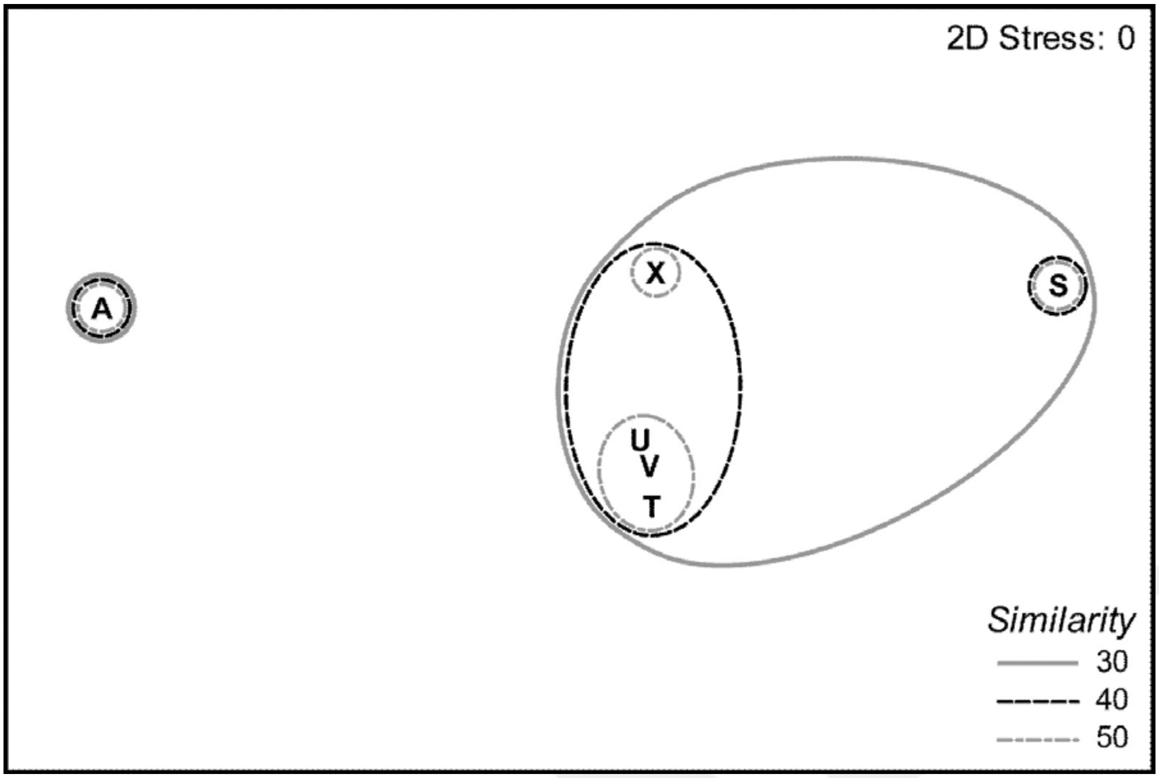

Figure 8. Non-metric multidimensional scaling (NMDS) plot of the six inner harbor sites. Bray-Curtis similarities obtained from a cluster analysis based on the benthic data (square root transformed) are overlaid. Abbreviations: A, Abo Cove; S, Sierra Wharf; T, Tango Wharf; U, Uniform Wharf; V, Victor Wharf; X, X-ray Wharf.

Species richness was highest at X-ray Wharf, where eight species occurred on the transect; only four species occurred on transects at Above Cove and Tango, Uniform, and Victor Wharves. *Porites lutea* and *Pocillopora damicornis* were the most common species, occurring on five of the six transects. Seven species occurred on only one transect, and three of these species were represented by single observations.

Quantitative analysis of the coral species encountered on transect is presented in Table 9. Poritid corals were predominant in coverage, averaging some 83% relative coverage on transects. Similarly, *Porites* spp. occurred at high frequencies on transects, although smaller species, such as *Pocillopora damicornis* and *Leptastrea purpurea*, exhibited high frequencies, as well.

The harbor floor consists of fine-grain sediments unsuitable for settlement by coral larvae. Consequently, few corals were encountered on Transects 1 and 2 on the harbor floor. Small colonies of *Porites lutea* were observed on scattered pieces of debris and old pilings that provided the only hard substrate available for settlement of larvae. With the exception of what

Table 8. Size-frequency distributions of coral species recorded on transects in Inner Apra Harbor. N = number of colonies. Mean, SD (standard deviation), and Range refer to colony coverage in cm^2.

Location	Habitat	Species	N	Mean	SD	Range
Abo Cove	Reef	*Porites* sp.	10	1291.9	1703.2	74.02–5013.98
		Goniastrea retiformis	4	12.7	15.0	3.93–34.99
		Porites lutea	7	1472.2	2624.4	45.95–7242.94
		Porites murrayensis	2	27.7	10.8	20.01–35.34
Wharf S	Wharf face	*Porites rus*	8	19.7	10.7	7.42–39.25
		Lobophyllia hataii	1	9.9	–	9.88
		Stylocoeniella armata	3	25.8	18.1	7.15–43.28
		Leptastrea purpurea	3	8.7	2.6	5.72–10.60
		Pocillopora damicornis	1	0.3	–	0.31
Wharf T	Wharf face	*Leptastrea purpurea*	5	11.7	11.3	0.55–29.10
		Porites lutea	10	99.3	191.2	2.64–631.43
		Pocillopora damicornis	3	25.0	29.1	1.65–57.59
		Porites sp.	2	4.1	0.0	4.10–4.10
Wharf U	Wharf face	*Porites lutea*	12	134.9	282.7	1.53–978.21
		Pocillopora damicornis	10	46.3	43.1	1.98–129.59
		Leptastrea purpurea	15	8.7	9.4	0.20–37.70
		Porites rus	2	1165.7	855.0	561.10–1770.29
Wharf V	Wharf face	*Leptastrea purpurea*	10	2.8	2.4	0.33–8.91
		Pocillopora damicornis	14	46.4	66.0	0.44–253.68
		Porites lutea	12	256.3	434.0	4.67–1555.09
		Stylocoeniella guntheri	3	236.2	406.9	0.55–706.07
Wharf X	Wharf face	*Porites lutea*	11	25.7	26.9	1.96–74.30
		Porites rus	7	640.3	866.3	3.77–2172.16
		Leptastrea purpurea	15	5.3	6.5	0.20–25.40
		Porites sp.	1	1.04	–	3.77
		Montipora sp.	2	12.9	5.1	9.30–16.49
		Porites australiensis	1	4.9	–	4.90
		Pocillopora damicornis	2	32.6	28.3	12.53–52.59
		Pavona explanulata	1	1.0	–	1.04

appeared to be the remains of an old pier extending perpendicular from Victor Wharf (Transect 1, Figure 1), the amount of debris was greater near the wharves. No corals were observed on the harbor floor at distances of 20 m or more.

The fourth root-transformed relative coral coverage data were analyzed by non-metric multidimensional scaling (NMDS). The two-dimensional NMDS plot (Figure 9) shows the biotic affinities between the sites (low stress) and reveals differences not only between Abo Cove and the wharf sites, but between Sierra Wharf and the four remaining wharves. Uniform and X-ray

Table 9. Population density, frequency, and coverage of coral species recorded on transects in Inner Apra Harbor.

Location	Habitat	Species	N	Relative Density	Absolute Density	Frequency	Coverage	Relative Coverage
Abo Cove	Reef	*Porites* sp.	10	0.43	0.06	0.60	80.98	81.58
		Goniastrea retiformis	4	0.17	0.03	0.20	0.32	0.32
		Porites lutea	7	0.30	0.04	0.30	17.62	17.75
		Porites murrayensis	2	0.09	0.01	0.10	0.35	0.35
Wharf S	Wharf face	*Porites rus*	8	0.50	0.04	0.60	1.01	61.78
		Lobophyllia hataii	1	0.06	0.01	0.20	0.05	3.33
		Stylocoeniella armata	3	0.19	0.02	0.40	0.42	26.02
		Leptastrea purpurea	3	0.19	0.02	0.40	0.14	8.77
		Pocillopora damicornis	1	0.06	0.01	0.20	0.00	0.10
Wharf T	Wharf face	*Leptastrea purpurea*	5	0.25	0.03	0.80	0.39	5.11
		Porites lutea	10	0.50	0.07	0.80	6.63	86.85
		Pocillopora damicornis	3	0.15	0.02	0.40	0.56	7.37
		Porites sp.	2	0.10	0.01	0.20	0.06	0.72
Wharf U	Wharf face	*Porites lutea*	12	0.31	0.30	0.800	39.80	35.63
		Pocillopora damicornis	10	0.26	0.25	0.600	11.39	10.20
		Leptastrea purpurea	15	0.38	0.37	1.000	3.20	02.87
		Porites rus	2	0.05	0.05	0.100	57.32	51.31
Wharf V	Wharf face	*Leptastrea purpurea*	10	0.26	0.10	0.50	0.29	00.62
		Pocillopora damicornis	14	0.36	0.15	0.80	6.78	14.55
		Porites lutea	12	0.31	0.13	0.50	32.13	68.93
		Stylocoeniella guntheri	3	0.08	0.03	0.10	7.40	15.88
Wharf X	Wharf face	*Porites lutea*	11	0.28	0.05	0.50	1.15	05.66
		Porites rus	7	0.18	0.03	0.50	18.34	89.92
		Leptastrea purpurea	15	0.38	0.06	0.70	0.49	02.40
		Porites sp.	1	0.03	0.00	0.10	0.02	0.08
		Montipora sp.	2	0.05	0.01	0.10	0.11	0.52
		Porites australiensis	1	0.03	0.00	0.10	0.02	0.10
		Pocillopora damicornis	2	0.05	0.01	0.20	0.27	1.31
		Pavona explanulata	1	0.03	0.00	0.10	0.00	0.02

Wharves cluster together, as do Tango and Victor Wharfs. Coral communities on the four southern wharves are more similar to each other than to either Sierra Wharf or Abo Cove.

Macroinvertebrates

The distribution and abundance of conspicuous solitary epibenthic macroinvertebrates occurring on 8 transects in Inner Apra Harbor are reported in Table 10

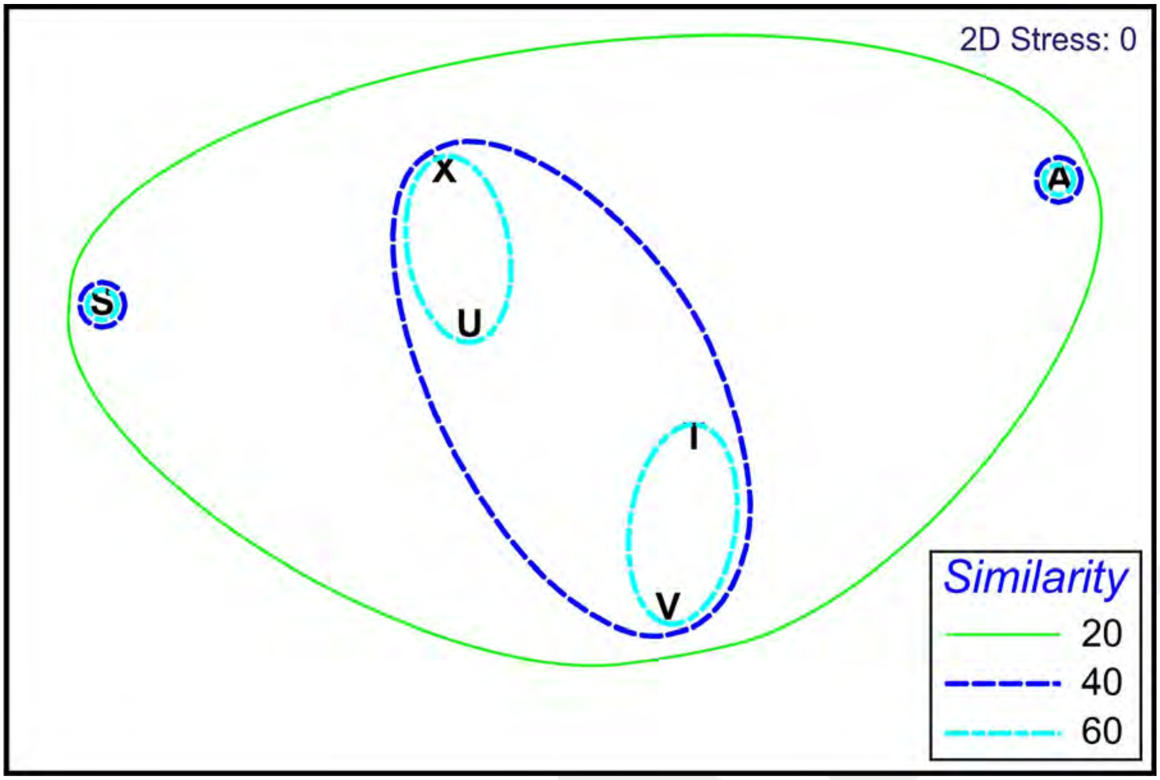

Figure 9. Non-metric multidimensional scaling (NMDS) plot of the six inner harbor transect sites. Bray-Curtis similarities obtained from a cluster analysis based on the coral data (fourth root-transformed) are overlaid. Abbreviations: A, Abo Cove; S, Sierra Wharf; T, Tango Wharf; U, Uniform Wharf; V, Victor Wharf; X, X-ray Wharf.

(colonial invertebrates are included in Table 3). Twenty species of solitary macroinvertebrates in four phyla were encountered on the transects, and 10 additional species were observed in areas adjacent to the transects (Table 11). Three of the species on transects occurred as single observations, and one species, *Phallusia nigra*, is reported as nonindigenous (Paulay et al., 2001a; Lambert, 2002, 2003). The greatest á diversity (i.e., 16 species, or 80% of the á diversity on transects) was found on the vertical face at Victor Wharf (Transect V), and the least (i.e., 8 species) on the coral reef at Abo Cove (Transect A). Bivalve molluscs and ascidians dominated the macroinvertebrate fauna in terms of both diversity and density. Remarkably, 100% of the macroinvertebrate species encountered on transects were suspension feeders. Of the total 30 species of solitary macroinvertebrates listed in Table 11, all but three are suspension feeders—the three being detritus feeders. The predominance of suspension feeders in lagoonal environments, such as the inner harbor, may be a result of nutrient enrichment by terrestrial run-off and the extended residence time of waters in the lagoon.

Table 10. Mean densities of conspicuous epibenthic invertebrates observed on transects in Inner Apra Harbor, Guam. Densities are reported as mean ± standard deviation in twenty 10-m^{-1} quadrats sampled along a 100-m transect, except at Wharf T and Wharf U, where ten 10-m^{-1} quadrats were sampled along a 50-m transect.

	Abo Cove	Wharf S	Wharf T	Wharf U	Wharf V	Wharf X
Cirripathes sp.					0.05 ± 0.22	
Spirobranchus giganteus	0.05 ± 0.22		0.90 ± 0.74	1.20 ± 1.69	0.35 ± 0.67	0.10 ± 0.31
Sabellastarte sanctijosephi	0.05 ± 0.22					
Arca ventricosa					0.05 ± 0.22	
Barbatia spp.	0.30 ± 0.47		0.40 ± 1.26			0.35 ± 0.93
Chama lazarus		7.25 ± 4.30	9.70 ± 2.54	7.90 ± 4.36	11.50 ± 11.37	6.20 ± 3.32
Chama spp.	0.05 ± 0.22	0.35 ± 0.67		0.50 ± 0.85		0.75 ± 1.25
Malleus decurtatus	3.15 ± 2.43	0.20 ± 0.52	4.10 ± 1.73	31.90 ± 27.65	93.40 ± 91.23	54.60 ± 39.55
Spondylus multimuricatus		1.65 ± 2.46	3.10 ± 2.08	2.30 ± 1.49	3.75 ± 3.01	3.05 ± 1.76
Spondylus squamosus		0.65 ± 0.93	0.40 ± 0.52	1.70 ± 1.25	2.15 ± 2.18	5.90 ± 4.76
Spondylus spp.			28.10 ± 9.10	19.90 ± 5.92	10.95 ± 10.65	20.00 ± 9.21
ostreid spp.		0.20 ± 0.70		0.30 ± 0.48	0.65 ± 0.99	0.50 ± 1.15
Septifer bilocularis			0.30 ± 0.95			0.25 ± 0.72
Ascidia ornata	0.20 ± 0.52			0.10 ± 0.32	0.15 ± 0.37	
Ascidia sp. 1[a,b]					0.40 ± 0.60	
Phallusia julinea		0.05± 0.22	0.40 ± 0.70	2.70 ± 2.45	5.45 ± 5.58	
Phallusia nigra				0.20 ± 0.42	0.50 ± 0.83	
Polycarpa spp.	0.55 ± 0.69	0.20 ± 0.52	1.10 ± 1.10	2.20 ± 1.87	1.40 ± 1.43	0.50 ± 0.76
Rhopalaea circula	0.05 ± 0.22	2.45 ± 1.99	63.30 ± 18.09	8.20 ± 5.69	11.60 ± 8.09	4.50 ± 4.51
Rhopalaea sp. 2–gold spot[a,c]			31.90 ± 11.44		1.35 ± 1.69	

[a]These identifications follow the morphospecies designated by Paulay et al. (2001b).
[b]*Ascidia* sp. A of Lambert (2003).
[c]*Rhopalaea* sp. A (n.sp.?) of Lambert (2003).

Table 11. Species of conspicuous epibenthic invertebrates observed on or adjacent to transects in Inner Apra Harbor, Guam. Observations of live specimens are denoted by filled circles (●), and records based on dead specimens are denoted by open circles (○).

	Harbor Floor 1	Harbor Floor 2	Abo Cove	Wharf S	Wharf T	Wharf U	Wharf V	Wharf X
Mastigias papua							●	●
Scyphozoa sp.–transparent				●		●	●	
Cirripathes sp.							●	
Zoanthus sp.							●	
Spirobranchus giganteus	●		●		●	●	●	●
Sabellastarte sanctijosephi			●					
Bittium sp.	●							
cf. *Styliola subula*				●	●	●	●	●
Arca ventricosa							●	
Barbatia spp.	●		●		●	●		●
Chama lazarus				●	●	●	●	●
Chama spp.			●	●				●
Malleus decurtatus	●		●	●	●	●	●	●
Spondylus multimuricatus				●	●	●	●	●
Spondylus squamosus	●			●	●	●	●	●
Spondylus varius						○		
Spondylus spp.	●				●	●		●
Hyotissa hyotis						○		
Saccostrea cf. *cucullata*	●	●						
ostreid spp.				●			●	●
Septifer bilocularis					●	●		●
Mespilia globulus						●		
Parasalenia gratiosa						●		
Ascidia ornata			●			●	●	
Ascidia sp. 1[a]							●	
Phallusia julinea				●	●	●	●	
Phallusia nigra						●	●	
Polycarpa spp.			●	●	●	●	●	●
Rhopalaea circula			●	●	●	●	●	●
Rhopalaea sp. 2–gold spot[a]					●	●	●	

[a]These identifications follow the morphospecies designated by Paulay et al. (2001b).

Densities of solitary macroinvertebrates ranged from less than 1 individual of a species to more than 90 individuals/10 m^2, with bivalve molluscs and ascidians being predominant. The hammer oyster *Malleus decurtatus* occurred in the greatest densities (up to 9.3 oysters/m^2 at Victor Wharf), with thorny oysters, *Spondylus* spp., and jewel box clams, *Chama* spp., also abundant. Among ascidians, *Rhopalaea circula* reached a density of 6.3 individuals/m^2 at Tango Wharf. The greatest total density was observed Victor Wharf (Transect V), where there were 143.7 macroinvertebrates/10 m^2; the lowest total density was 4.4 macroinvertebrates/10 m^2 at Abo Cove (Transect V). As noted above for benthic coverage, this pattern may be explained by the greater availability of hard substrate for post-larval settlement on the vertical faces of the wharves, as compared to the sediment-laden horizontal substrate on the reef at Abo Cove.

The harbor floor is largely depauperate of epibenthic macroinvertebrates. The substrate of the harbor consists predominately of a sticky, fine silt/mud sediment that is easily resuspended. As a result, the transect line sank from sight into the soft sediments. Further, any contact or near contact with the bottom by divers resuspended sediments and reduced visibility markedly. Therefore, we were not able to quantify macroinvertebrates on the harbor floor. However, seven epibenthic species were observed during two swimming transects (Transects 1 and 2). Observed species were associated with debris that provided hard substrate, with the exception of the detritivorous snail *Bittium* sp. Generally, the volume of debris, and therefore the number of macroinvertebrates, diminished with distance from the wharves. Although few epibenthic macroinvertebrates were observed on the harbor floor, large numbers of burrow openings were present, indicating an abundance infaunal organisms.

Comparison of macroinvertebrate community structure across transects by cluster analysis indicates considerable contrast for horizontal and vertical substrates (Figure 10). The macroinvertebrate community on vertical faces of the wharves form a single, large clade that is distinctly different than the community inhabiting the horizontal substrate at Abo Cove. As noted for benthic cover, similarity is high for Uniform and Victor Wharves. However, for solitary macroinvertebrates, X-ray Wharf is more similar to these communities than to the community at Tango Wharf.

Non-metric multidimensional scaling (NMDS) on the fourth root-transformed data further demonstrate the dissimilarity of macroinvertebrate assemblages on horizontal and vertical substrates (Figure 11). The Abo Cove macroinvertebrate community is distinctly different from the communities on the wharf faces, which clustered together. A stress level of 0.01 indicates a high level of significance in the relationships represented by this analysis.

Possibly the most abundant solitary invertebrates were neither epibenthic nor conspicuous. The pelagic thecosomate gastropod cf. *Styliola subula* was abundant in surface waters adjacent to all the wharves that we surveyed. Commonly known as sea butterflies, these free-swimming gastropods feed upon plankton, exhibiting diurnal migrations in pursuit of their prey. Although small (<1 cm) and transparent, the snails are important in marine food webs (Seibel and Diersson, 2003). Their sensitivity to temperature and acidity have led scientists to express concern over the possible effects of global climate change and ocean acidification upon the survival of these organisms and the consequent impacts on marine food webs (Seibel and Diersson, 2003; Orr et al., 2005).

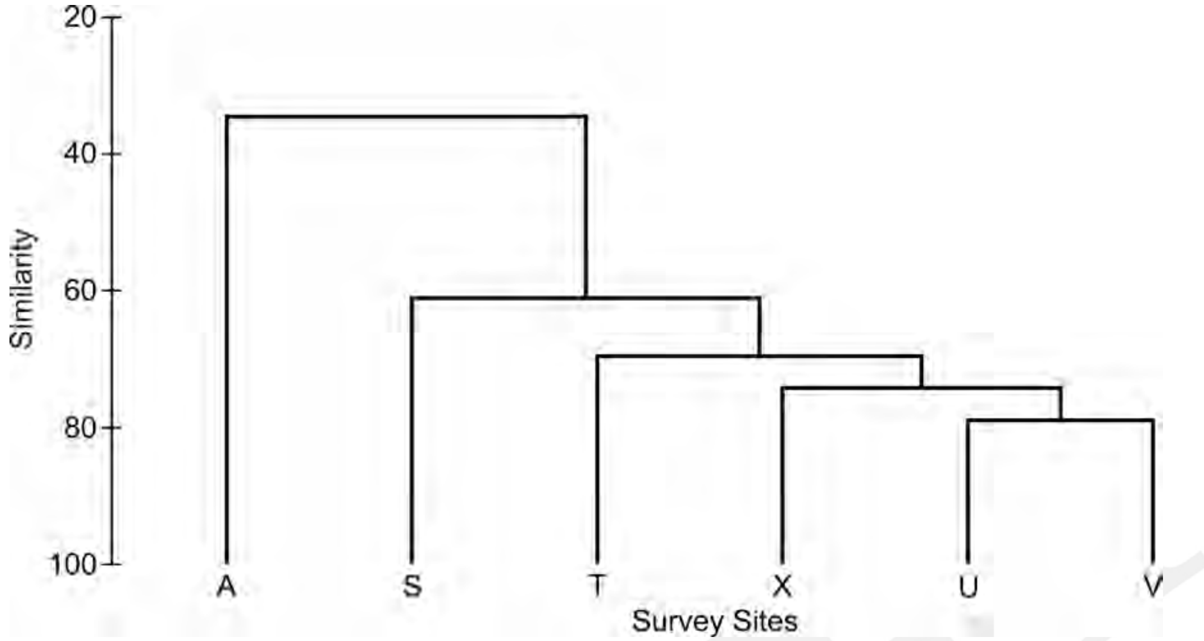

Figure 10. Cluster analysis (group averaging) of macroinvertebrate assemblage relationships between transects at Inner Apra Harbor study sites. Values of similarity (0 to 100%) were calculated in pair-wise comparisons with the Bray-Curtis similarity index and then assembled in a matrix prior to cluster analysis. Abbreviations: A, Abo Cove; S, Sierra Wharf; T, Tango Wharf; U, Uniform Wharf; V, Victor Wharf; X, X-ray Wharf.

We have no basis for statistical comparison of our data on macroinvertebrate populations in Inner Apra Harbor. The most recent survey (Paulay et al., 2001a) of the macroinvertebrate communities in the inner harbor focused primarily upon only three taxa (i.e., sponges, echinoderms, and ascidians), and their study was qualitative in structure.

Fishes

A checklist of species and their relative abundance (as percent) at each station is given in Table 12. Sixty-two species of fishes were observed on transects surveyed within the Apra Inner Harbor. While this number indicates an impoverished fish fauna (there are approximately 1,000 species of reef and nearshore fishes known from the Mariana Islands; Myers and Donaldson, 2003; unpublished data), the fauna seems representative of protected, turbid lagoons or bays of Guam (unpublished data). Further, at least three species appear to be invasive or new records for Guam and the Mariana Islands. One, *Neopomacentrus violescens* (Pomacentridae-damselfishes), has been reported previously (Myers, 1999; Myers and Donaldson, 2003). The other two, *Amblygliphididon ternatensis* (Pomacentridae) and *Rhamdia cypselurus* (Apogonidae-cardinalfishes) have not been reported previously from the Mariana Islands. Both occur elsewhere in the western Indo-Pacific region in natural habitats somewhat similar to those found in Inner Apra Harbor (Myers, 1999). Either both of these species have escaped detection

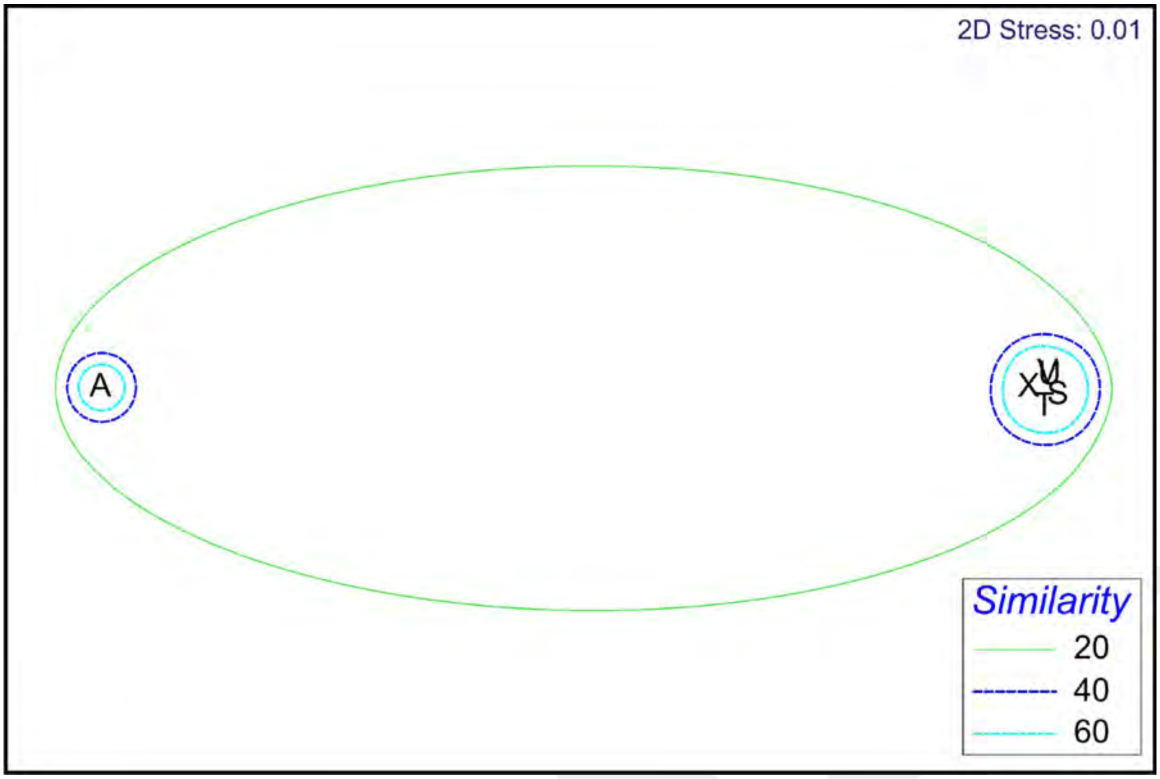

Figure 11. Non-metric multidimensional scaling (NMDS) plot of macroinvertebrate assemblages at the six inner harbor transect sites. Bray-Curtis similarities obtained from a cluster analysis based on the coral data (fourth root-transformed) are overlaid. Abbreviations: A, Abo Cove; S, Sierra Wharf; T, Tango Wharf; U, Uniform Wharf; V, Victor Wharf; X, X-ray Wharf.

previously, owing to the very turbid conditions found in the inner harbor, or they have been introduced, likely as larvae in bilge water of ships moored in the inner harbor, and have been seen for the first time during the present surveys,

Species richness (the number of species observed) between stations ranged from 2 (harbor floor, Transect 2) to 29 (UniformWharf–bottom, Transect U_B). Generally, species richness was greater on the bottom at stations, where debris provided shelter for various species. Some wharf walls (mid-depth transects), however, supported relatively high numbers of species, as well. Subsurface transects at all wharf stations tended to have the lowest number of species, with some exceptions, as did Abo Cove (Table F3). A measure of species diversity, Shannon's H' (Magurran, 1988), that adjusts species richness to consider also the influence of abundance, was highest along the mid-depth transect at Victor Wharf (Transect V_M), and then along the bottom transect at Uniform (Transect U_B). Species diversity was also relatively high on mid-depth transects at X-ray (Transect X_M) and Uniform (Transect U_M) Wharves, but also on subsurface transects at Tango (Transect T_S) and X-ray (Transect X_S) wharves. Corals, soft corals, and molluscs (mainly oysters) were present at these stations and appeared to be protected

Table 12. Relative abundance (%) of fishes observed on transects in Inner Apra Harbor. Survey sites are designated as follows: A = Abo Cove, S_M = Sierra Wharf mid-depth, S_S = Sierra Wharf subsurface, T_M = Tango Wharf mid-depth, T_S = Tango Wharf subsurface, T_B = Tango Wharf bottom, U_M = Uniform Wharf mid-depth, U_S = Uniform Wharf subsurface, U_B = Uniform Wharf bottom, V_M = Victor Wharf mid-depth, V_S = Victor Wharf subsurface, V_B = Victor Wharf bottom, X_M = X-Ray Wharf mid-depth, X_S = X-Ray Wharf subsurface, X_B = X-Ray Wharf bottom, O_1 = harbor floor 1, O_2 = harbor floor 2.

	Survey Sites																
Taxon	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	O_1	O_2
Family Clupeidae (herrings)																	
Spratelloides delicatulus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Mugilidae (mullets)																	
Moolgarda seheli	5.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Holocentridae (squirrelfishes)																	
Neoniphon opercularis	0	0	0	0	0.6	0	0	0	0.2	0	0	0	0	0	0	0	0
Sargocentron spiniferum	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Serranidae (groupers)																	
Epinephelus maculatus	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0
Family Apogonidae (cardinalfishes)																	
Apogon lateralis	0	97.5	64.4	28.2	0	5.8	0	0	44.6	0	0	75.4	58.9	0	89.2	0	0
Apogon leptacanthus	5.3	1	2.9	0	6	0	0	0	5	0	0	1	6	0	9	0	0
Archamia biguttata	0	0	0	0	1.2	0	0	0	2	0	0	0	0	0	0	0	0
Archamia fucata	0	0	0	0	0	5.8	0	0	0	0	0	14.1	0	0	0	0	0
Cheilodipterus quinquelineatus	68.2	0	0	0	1.2	0	0	3.1	0.2	5	0.6	3.6	0	0	0	0	0
Foa brachygramma?	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0
Rhabdamia cypselurus?	0	0	2.3	57.6	68.3	0	0	0	20	0	0	0	1.8	0	0	0	0
Sphaeramia orbicularis	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0
Family Carangidae (trevallys)																	
Caranx ignobilis	0	0	0	0.9	0	0	0	0	0	0	0	0.1	1.8	0	0	0	0
Caranx melampygus	0	0	0	0.3	0	0	0	0	0.2	0	0	0.1	0	0	0	0	0
Scomberoides lysan	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnathanodon speciosus	0	0	0	0	0	0	0	0	0	0	0.6	0.1	0	0	0	0	0
Family Lutjanidae (snappers)																	
Lutjanus ehrenbergi?	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0
Lutjanus fulvus	5.3	0.1	0	0	0	11.6	0	0	0	0	0	0.3	0	0	0	0	0

Table 12. Continued.

Taxon	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	O_1	O_2
	Survey Sites																
Family Lethrinidae (emperors)																	
Lethrinus harak	0	0	0	0	0	0	1.6	0	0	0	0	0.1	0	0	0	0	0
Family Haemulidae (sweetlips)																	
Plectorhinchus albovittatus	0	0	0	0	0	0	0	0	0.2	0	0	0.1	0	0	0	0	0
Family Chaetodontidae (butterflyfishes)																	
Chaetodon auriga	0	0	0	0	0	0	0	0	0.4	0	0	0.1	0.6	1	0	0	0
Chaetodon bennetti	0	0.1	0	0	0	0	1.6	0	0.6	6	7	0.1	0	0	0	0	0
Chaetodon ephippium	0	0	0	0.6	0	5.8	0	0	1.2	0	0	0.2	3	0	0	0	0
Chaetodon lunula	0	0	0	0	0.6	0	0	0	0	1	0.6	0	0.6	0	0	0	0
Chaetodon lunulatus	0	0	0	0	1.2	0	0	0	0	0	0	0	1.8	0	0	0	0
Chaetodon unimaculatus	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Chaetodon ulietensis	0	0	0	0.3	0.6	0	4.8	0	0.6	0	0	1	0	0	0	0	0
Heniochus chrysostomus	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0
Family Pomacentridae (damselfishes)																	
Amblyglyphididon ternatensis	0	0	16.9	0	2.4	0	29	81.7	0	18	78.6	0	0	0	0	0	0
Abudefduf sexfasciatus	0	0	0	0	0	0	0	0	0	0	1.2	0	2.4	0	0	0	0
Chromis viridis	0	0.2	11.7	0.3	0	0	0	0	0	19.4	0	0	0	0	0	0	0
Chrysiptera traceyi	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neopomacentrus violascens	0	0	0	0	4.8	0	0	6.1	10	0	0	0	0	1	0	0	0
Pomacentrus blue spot	0	0	0	0	0	0	0	9.1	0	0	0	0	10.1	0	0	0	0
Pomacentrus amboinensis	0	0	0	0.6	6.8	0	1.6	0	0.6	9.7	9.7	0	0	1	0	0	0
Pomacentrus pavo	0	0	0.3	0	11.1	0	3.2	0	0	7.2	5.7	0	1.2	1	0	0	0
Family Labridae (wrasses)																	
Cheilinus fasciatus	0	0	0	0	0	5.8	1.6	0	0	0	0	0	0	0	0	0	0
Cheilinus trilobatus	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0
Family Blenniidae (blennies)																	
Ecsenius bicolor	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meiacanthus atrodorsalis	0	0	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0
Petroscirtes mitratus	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0
Blue dorsal spot tube blenny	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0

Table 12. Continued.

Taxon	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	O_1	O_2
	Survey Sites																
Family Gobiidae (gobies)																	
Amblygobius nocturnus	0	0	0	0	0	11.6	0	0	2.4	0	0	5	0	0	0	0	0
Amblygobius phaelena	0	0	1.5	0.3	0.6	0	1.6	0	0.2	0	1.2	0.2	0.6	0	0	0	0
Asterropteryx semipunctatus	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0
Cryptocentrus strigilliceps	5.3	0	0	0	0	0	0	0	0	0	0	0	0	0	1.8	0	0
Cristatogobius sp. A	0	0	0	0	0	11.6	0	0	0.4	0	0	6	0	0	0	0	0
Ctenogobiops feroculus	5.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	62.5	90
Gnatholepis cauerensis	5.3	0	0	0	0	5.8	0	0	4.2	0	0	0	0	0	0	0	0
Oplopomus oplopomus	0	0	0	0	0	0	0	0	0.2	0	0	0.2	0	0	0	12.5	0
Oxyurichthys papuensis	0	0	0	0	0	0	0	0	2.6	0	0	0.2	0	0	0	25	10
Paragobiodon lacunicolus	0	0	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0
Priolepis cincta	0	0	0	0	0.6	0	0	0	0	3	0.6	0	0	0	0	0	0
Family Zanclidae (Moorish Idol)																	
Zanclus cornutus	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Family Siganidae (rabbitfishes)																	
Siganus argenteus	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0
Family Acanthuridae (surgeonfishes)																	
Acanthurus blochii	0	0	0	0.3	0	36.2	19.4	0	0	11.3	0	2.8	11.2	0	0	0	0
Acanthurus xanthopterus	0	0	0	2.5	0	0	32.4	0	0	15.4	0	0	0	1	0	0	0
Zebrasoma veliferum	0	0	0	0	0	0	0	0	0.6	0	0.6	0.1	1.8	0	0	0	0
Family Balistidae (triggerfishes)																	
Balistoides viridescens	0	0	0	0.3	0	0	0	0	0.6	0	0	0.1	0	0	0	0	0
Rhinecanthus aculeatus	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Tetraodontidae (pufferfishes)																	
Canthigaster solandri	0	0	0	0.3	0	0	0	0	0.2	0	0.6	0	1.2	0	0	0	0
Total individuals	**19**	**1025**	**343**	**346**	**162**	**17**	**62**	**33**	**528**	**97**	**157**	**632**	**179**	**17**	**56**	**16**	**10**

by ship fenders that effectively prevented ship hulls from damaging these microhabitats, thus making them available to fishes for shelter.

Densities of fish species (no. individuals/m^2) at each station are given in Table 13. Small, structure-associated cardinalfishes had the greatest density among stations. *Apogon lateralis* (Apogonidae) densities where high at Sierra Wharf (20/m^2 at mid-depth and 4.4/m^2 at subsurface depth), Victor Wharf (4.5/m^2 at the bottom), Uniform Wharf (2.5/m^2 at the bottom), and X-ray Wharf (2.06/m^2 at mid-depth). Another cardinalfish, the apparently invasive *Rhabdamia cypselerus*, had relatively high densities at Sierra Wharf (8/m^2 at subsurface depth) and Tango Wharf (4/m^2 at mid-depth and 2/m^2 at subsurface depth). Both species tended to occur in aggregations of several individuals. The invasive damselfish, *Amblyglyphididon ternatensis* (Pomacentridae), was relatively dense at Victor Wharf (2.24/m^2 at mid-depth) and Sierra Wharf (1.16 per m^2 subsurface depth). This species occurred in aggregations as well; many were juveniles. Densities of other species were low to very low and ranged from 0.0033/m^2 to1.0/m^2 (Table 13).

The similarity of species composition between stations and transect depths was examined with multiple dimension scaling analysis (Figure 12). The meager fish assemblages of the two harbor floor transects (Transect 1 and Transect 2) formed a distinct group. The fish assemblages on the Abo Cove and Tango Wharf-bottom transects formed a group, as well. The mid-depth and subsurface transects at Uniform and Victor wharves formed a distinct group, too, as did the subsurface transect at X-ray Wharf. Finally, the fish assemblages on the subsurface transects at Sierra and Tango wharves, the mid-depth transects at Sierra, Tango and X-ray wharves, and the bottom transects at Uniform, Victor, and X-ray wharves, all formed a distinct group. A stress level of 0.11 indicated a moderate confidence in the analysis results (Clarke and Gorley, 2001). Analysis of similarity (ANOSIM) between stations (locality and depth treated as a station) indicated that there were only weakly significant differences between them (Global R = 0.21). Thus, the fish faunas of each tended to share many of the same species typical of protected and turbid waters, while differences can be attributed to the presence of seemingly unusual species (i.e., butterflyfishes normally seen in clear or less-turbid reef systems) associated with structure on some transects or the simple absence of species, other than some burrowing gobies, on others (i.e., Transect 1 and Transect 2).

Essential Fish Habitat

Qualitative measures of habitat utilization by fishes were limited to observations of association between species and habitat and microhabitat types (Table 14). Major habitat types were reefs (Abo Cove), wharves (all stations except Abo Cove and the harbor floor transects), or harbor floor. Microhabitats included corals, debris (hanging and deposited on the bottom), rubble, rocks, soft corals, sand, shells, or the water column), and wharf faces and pilings. Corals, soft corals, and shells were usually found on the wharf faces, as well.

Overall, wharves provided considerable habitat for a diverse array of fishes compared to the reef at Abo Cove or the harbor floor offshore from the wharves (Table 14). Microhabitats associated with wharves included coral, debris, shell, and soft corals that were attached to a wharf, the wharf wall and associated structures (pilings, fenders, pipes, cables, etc.), debris, rubble, rock, and sand at the base of the wharf wall, and the water column directly adjacent to the wharf. Most species were associated with one or more of these microhabitats. Benthic

Table 13. Density of fishes (no./m^2) on transects in Inner Apra Harbor. Survey sites are designated as follows: A = Abo Cove, S_M = Sierra Wharf mid-depth, S_S = Sierra Wharf subsurface, T_M = Tango Wharf mid-depth, T_S = Tango Wharf subsurface, T_B = Tango Wharf bottom, U_M = Uniform Wharf mid-depth, U_S = Uniform Wharf subsurface, U_B = Uniform Wharf bottom, V_M = Victor Wharf mid-depth, V_S = Victor Wharf subsurface, V_B = Victor Wharf bottom, X_M = X-Ray Wharf mid-depth, X_S = X-Ray Wharf subsurface, X_B = X-Ray Wharf bottom, 1 = Transect 1 (harbor floor), 2 = Transect 2 (harbor floor).

	Survey Sites																
Taxon	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	1	2
Family Clupeidae (herrings)																	
Spratelloides delicatulus	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Mugilidae (mullets)																	
Moolgarda seheli	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Holocentridae (squirrelfishes)																	
Neoniphon opercularis	0	0	0	0	0.02	0	0	0	0.01	0	0	0	0	0	0	0	0
Sargocentron spiniferum	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Serranidae (groupers)																	
Epinephelus maculatus	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Family Apogonidae (cardinalfishes)																	
Apogon lateralis	0	20	4.4	2	0	0.01	0	0	2.5	0	0	4.5	2.06	0	0.5	0	0
Apogon leptacanthus	0.01	0.2	0.2	0	0.2	0	0	0	0.25	0	0	0.1	0.2	0	0.05	0	0
Archamia biguttata	0	0	0	0	0.04	0	0	0	0.1	0	0	0	0	0	0	0	0
Archamia fucata	0	0	0	0	0	1	0	0	0	0	0	0.89	0	0	0	0	0
Cheilodipterus quinquelineatus	0.13	0	0	0	0.04	0.01	0	0.02	0.01	0.1	0.02	0.23	0	0	0	0	0
Foa brachygramma?	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0
Rhabdamia cypselurus?	0	0	8	4	2	0	0	0	0.01	0	0	0	0.06	0	0	0	0
Sphaeramia orbicularis	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0
Family Carangidae (trevallys)																	
Caranx ignobilis	0	0	0	0.06	0	0	0	0	0	0	0	0.01	0.06	0	0	0	0
Caranx melampygus	0	0	0	0.02	0	0	0	0	0.05	0	0	0.01	0	0	0	0	0
Scomberoides lysan	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnathanodon speciosus	0	0	0	0	0	0	0	0	0	0	0.02	0.01	0	0	0	0	0
Family Lutjanidae (snappers)																	
Lutjanus ehrenbergi?	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0
Lutjanus fulvus	0.01	0.02	0	0	0	0.02	0	0	0	0	0	0.03	0	0	0	0	0
Family Lethrinidae (emperors)																	
Lethrinus harak	0	0	0	0	0	0	0.02	0	0	0	0	0.01	0	0	0	0	0
Family Haemulidae (sweetlips)																	
Plectorhinchus albovittatus	0	0	0	0	0	0	0	0	0.01	0	0	0.01	0	0	0	0	0
Family Chaetodontidae (butterflyfishes)																	
Chaetodon auriga	0	0	0	0	0	0	0	0	0.02	0	0	0.01	0.02	0.02	0	0	0
Chaetodon bennetti	0	0.02	0	0	0	0	0.02	0	0.03	0.12	0.22	0.01	0	0	0	0	0

Table 13.

Taxon	Survey Sites																
	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	1	2
Family Chaetodontidae (butterflyfishes)																	
Chaetodon ephippium	0	0	0	0.04	0	0.02	0	0	0.06	0	0	0.02	0.1	0	0	0	0
Chaetodon lunula	0	0	0	0	0.02	0	0	0	0	0.02	0.02	0	0.02	0	0	0	0
Chaetodon lunulatus	0	0	0	0	0.04	0	0	0	0	0	0	0	0.06	0	0	0	0
Chaetodon unimaculatus	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0
Chaetodon ulietensis	0	0	0	0.02	0.02	0	0.06	0	0.03	0	0	0.1	0	0	0	0	0
Heniochus chrysostomus	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0
Family Pomacentridae (damselfishes)																	
Amblyglyphididon ternatensis	0	0	1.16	0	0.08	0	0.36	0.54	0	0.36	2.24	0	0	0	0	0	0
Abudefduf sexfasciatus	0	0	0	0	0	0	0	0	0	0	0.04	0	0.08	0	0	0	0
Chromis viridis	0	0.04	0.8	0.02	0	0	0	0	0	0.4	0	0	0	0	0	0	0
Chrysiptera traceyi	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neopomacentrus violascens	0	0	0	0	0.16	0	0	0.04	0.5	0	0	0	0	0.02	0	0	0
Pomacentrus blue spot	0	0	0	0	0	0	0	0.06	0	0	0	0	0.36	0	0	0	0
Pomacentrus amboinensis	0	0	0	0.04	0.22	0	0.02	0	0.03	0.2	0.3	0	0	0.02	0	0	0
Pomacentrus pavo	0	0	0.02	0	0.36	0	0.04	0	0	0.14	0.18	0	0.04	0.02	0	0	0
Family Labridae (wrasses)																	
Cheilinus fasciatus	0	0	0	0	0	0.01	0.02	0	0	0	0	0	0	0	0	0	0
Cheilinus trilobatus	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0
Family Blenniidae (blennies)																	
Ecsenius bicolor	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meiacanthus atrodorsalis	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0
Petroscirtes mitratus	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0
Blue dorsal spot tube blenny	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0	0	0
Family Gobiidae (gobies)																	
Amblygobius nocturnus	0	0	0	0	0	0.02	0	0	0.12	0	0	0.05	0	0	0	0	0
Amblygobius phaelena	0	0	0.1	0.02	0.02	0	0.02	0	0.01	0	0.04	0.02	0.02	0	0	0	0
Asterropteryx semipunctatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0
Cryptocentrus strigilliceps	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0
Cristatogobius sp. A	0	0	0	0	0	0.02	0	0	0.02	0	0	0.06	0	0	0	0	0
Ctenogobiops feroculus	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0.03
Gnatholepis cauerensis	0.01	0	0	0	0	0.01	0	0	0.21	0	0	0	0	0	0	0	0
Oplopomus oplopomus	0	0	0	0	0	0	0	0	0.01	0	0	0.02	0	0	0	0.004	0
Oxyurichthys papuensis	0	0	0	0	0	0	0	0	0.13	0	0	0.02	0	0	0	0.008	0.0033
Paragobiodon lacunicolus	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0
Priolepis cincta	0	0	0	0	0.02	0	0	0	0	0.06	0.02	0	0	0	0	0	0

Table 13. Continued.

Taxon	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	1	2
	Survey Sites																
Family Zanclidae (Moorish Idol)																	
Zanclus cornutus	0	0	0	0	0	0	0	0	0.05	0	0	0	0	0	0	0	0
Family Siganidae (rabbitfishes)																	
Siganus argenteus	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0
Family Acanthuridae (surgeonfishes)																	
Acanthurus blochii	0	0	0	0.02	0	0.05	0.24	0	0	0.22	0	0.18	0.4	0	0	0	0
Acanthurus xanthopterus	0	0	0	0.38	0	0	0.4	0	0	0.3	0	0	0	0.02	0	0	0
Zebrasoma veliferum	0	0	0	0	0	0	0	0	0.03	0	0.02	0.01	0.06	0	0	0	0
Family Balistidae (triggerfishes)																	
Balistoides viridescens	0	0	0	0.02	0	0	0	0	0.03	0	0	0.01	0	0	0	0	0
Rhinecanthus aculeatus	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Tetraodontidae (pufferfishes)																	
Canthigaster solandri	0	0	0	0.02	0	0	0	0	0.01	0	0.02	0	0.04	0	0	0	0

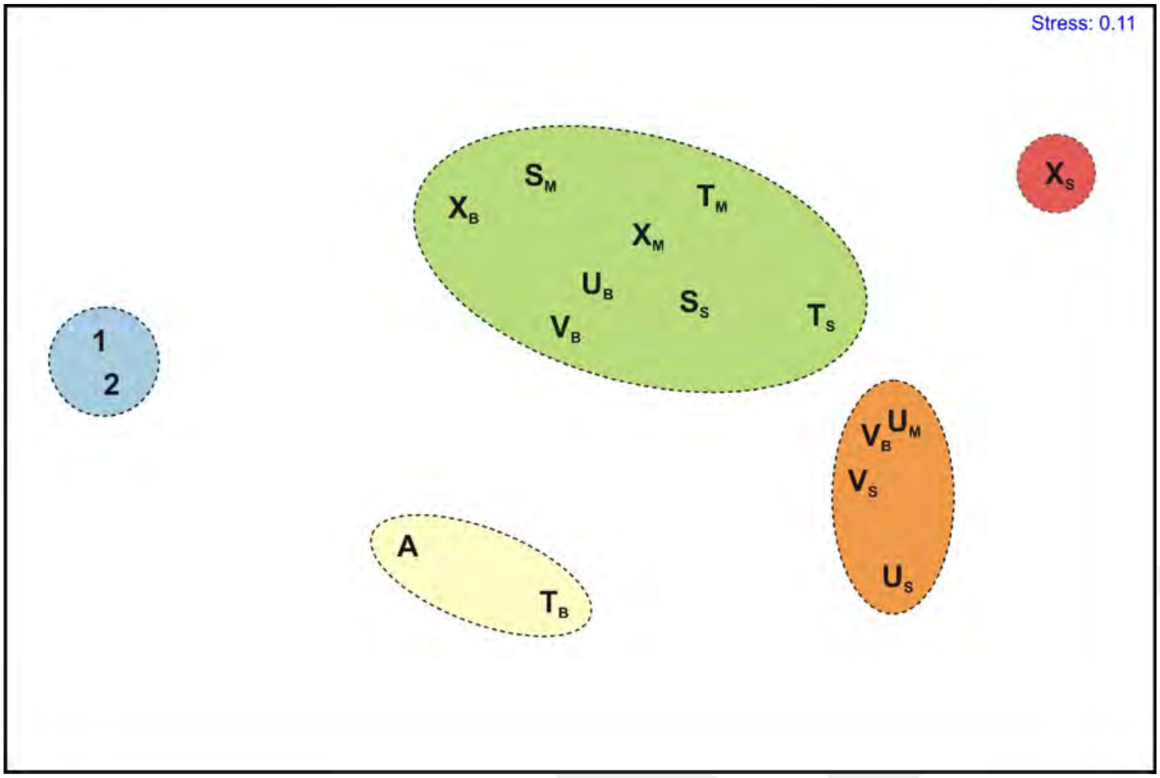

Figure 12. Multiple dimensional scaling (MDS) analysis of fish assemblages observed on transects in Inner Apra Harbor. Five distinct groups are recognized based upon similarities in fish faunal composition. Transect abbreviations are given in Table 12.

species such as cardinalfishes, damselfishes and gobies favored corals, debris, shells, sand, soft corals, and the wharf wall and pilings. Species that were active swimmers, such as butterflyfishes (Chaetodontidae), emperors (Lethrinidae), snappers (Lutjanidae), surgeonfishes (Acanthuridae), sweetlips (Haemulidae), trevallys and jacks (Carangidae), etc., were found in the water column directly adjacent to the wharves.

On the reef at Abo Cove, cardinalfishes were observed with corals or rock, gobies with sand, mullet (Mugilidae) with rubble or sand, and a snapper with sand (Table 14). Visibility was exceptionally poor at Abo Cove during the survey, and it is expected that other species listed for the wharf transects would be present as well, particularly at high tide. The harbor floor transects, also surveyed under conditions of poor visibility, had burrowing gobies associated with fine sand, only (Table 14).

Threatened and Endangered Species

High turbidity levels in Inner Apra Harbor limited visibility (<5 m)of highly motile species, especially vertebrate organisms. Despite this constraint, we observed a single green

Table 14. Habitat and microhabitat associations of fishes in the Inner Apra Harbor. Associations listed are based upon qualitative observations. Station codes are defined in Table F1. Habitat codes are: SB = soft bottom (harbor floor), R = coral reef, and W = wharf. Microhabitat codes are: C = coral, D = debris, Rb = rubble, Rk = rock, Sc = soft coral, Sd = sand, Sh = shell, Wc = water column, and Wp = wharf wall and pilings.

	Survey Sites																
Taxon	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	1	2
Family Clupeidae																	
Spratelloides delicatulus		W;Wc															
Family Mugilidae																	
Moolgarda seheli	R;Rb,Sd																
Family Holocentridae																	
Neoniphon opercularis					W;Wp				W;D								
Sargocentron spiniferum				W;Wp													
Family Serranidae																	
Epinephelus maculatus									W;D								
Family Apogonidae																	
Apogon lateralis		W;C,Wp	W;C,Wp	W;C,Wp		W;D			W;D			W;D	W;C		W;D		
Apogon leptacanthus	R;C,Rk	W;C,Sc	W;C,Wp		W;C,Wp				W;D			W;D	W;C		W;D		
Archamia biguttata					W;C,Wp				W;D								
Archamia fucata						W;D						W;D					
Cheilodipterus quinquelineatus	R;C,Rk				W;C,Wp			W;Wp	W;D	W;Wp	W;Wp	W;D					
Foa brachygramma?									W;D								
Rhabdamia cypselurus?			W;C,Wp	W;C,Wp	W;C,Wp				W;D				W;C				
Sphaeramia orbicularis														W;Wp			
Family Carangidae																	
Caranx ignobilis				W:Wc								W;Wc	W;Wc				
Caranx melampygus				W;Wc					W;Wc			W;Wc					
Scomberoides lysan				W;Wc													
Gnathanodon speciosus											W;Wc	W;Wc					
Family Lutjanidae																	
Lutjanus ehrenbergi?									W;Sd								
Lutjanus fulvus	R;Sd	W;Wc				W;Wc						W;Wc					
Family Lethrinidae																	
Lethrinus harak							W;Wc					W;Wc					
Family Haemulidae																	
Plectorhinchus albovittatus									W;D			W;Wc					
Family Chaetodontidae																	
Chaetodon auriga									W;D			W;Wc	W;Wp	W;Wp			
Chaetodon bennetti		W;Wc					W;Wc		W;D	W;Wc	W;Wc	W;Wc					
Chaetodon ephippium				W;Wc		W;Wc			W;D			W;Wc	W;Wp				
Chaetodon lunula					W;Wc					W;Wc	W;Wc		W;Wp				
Chaetodon lunulatus					W;Wc								W;Wp				
Chaetodon unimaculatus										W;Wc							
Chaetodon ulietensis				W;Wc	W;Wc		W;Wc		W;D			W;Wc					

Table 14. Continued.

Taxon	Survey Sites																
	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	1	2
Family Chaetodontidae																	
Heniochus chrysostomus									W;D								
Family Pomacentridae																	
Amblyglyphididon ternatensis			W;Wc		W;C,Sc		W;Wp	W;Wp		W;Wp	W;Wp						
Abudefduf sexfasciatus											W;Wp		W;Wp				
Chromis viridis		W;C,Wp	W;C,Wp	W;C,Wp						W;C,Wp							
Chrysiptera traceyi			W;Wp														
Neopomacentrus violascens					W;Wp			W;Wp	W;D					W;C,Wp			
Pomacentrus blue spot								W;Wp					W;Wp				
Pomacentrus amboinensis				W;Wp	W;Wp		W;Wp		W;D	W;Wp	W;Wp			W;Wp			
Pomacentrus pavo			W;D,Wp		W;C,Wp					W;Wp	W;Wp		W;Wp	W;Wp			
Family Labridae																	
Cheilinus fasciatus						W;Wc	W;Wc										
Cheilinus trilobatus												W;Wc					
Family Blenniidae																	
Ecsenius bicolor		W;Sh,Wp															
Meiacanthus atrodorsalis							W;Wp,Sh										
Petroscirtes mitratus				W;Sh,Wp													
Blue dorsal spot tube blenny														W;Wp			
Family Gobiidae																	
Amblygobius nocturnus						W;Wp			W;D,Sd			W;Sd					
Amblygobius phaelena			W;Wp	W;Wp	W;Wp		W;Wp		W;D,Sd		W;Wp	W;Sd	W;Wp				
Asterropteryx semipunctatus														W;Wp			
Cryptocentrus strigilliceps	R;Sd														W;Sd		
Cristatogobius sp. A						W;Sd			W;Sd			W;Sd					
Ctenogobiops feroculus	R;Sd															SB;Sd	SB;Sd
Gnatholepis cauerensis	R;Sd					W;Sd			W;Sd								
Oplopomus oplopomus									W;Sd			W;Sd				SB;Sd	
Oxyurichthys papuensis									W;Sd			W;Sd				SB;Sd	SB;Sd
Paragobiodon lacunicolus							W;C										
Priolepis cincta					W;Wp					W;Wp	W;Wp						
Family Zanclidae																	
Zanclus cornutus									W;Wc								
Family Siganidae																	
Siganus argenteus									W;Wc								
Family Acanthuridae																	
Acanthurus blochii				W;Wc		W;Wc	W;Wc			W;Wc		W;Wc	W;Wc				
Acanthurus xanthopterus				W'Wc			W;Wc			W;Wc				W;Wp			
Zebrasoma veliferum									W;Wc		W;Wc	W;Wc	W;Wc				

Table 14. Continued.

Taxon	Survey Sites																
	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	1	2
Family Balistidae																	
Balistoides viridescens				W;Wc					W;D,Wp			W;D,Wc					
Rhinecanthus aculeatus				W;Wp													
Family Tetraodontidae																	
Canthigaster solandri				W;Wp					W;D,Wp		W;D,Wc		W;Wp				

turtle from the boat in waters between Abo Cove and the southern end of Victor Wharf. *Chelonia mydas* is listed as a threatened species under the U.S. Endangered Species Act. The individual that we observed was small (0.5–1.0 m carapace length), and it dove immediately after a quick breath. Because of the fine-grained, muddy composition of the shoreline of Inner Apra Harbor, the beaches in the vicinity are not considered as potential nesting sites for endangered and threatened marine turtles known to occur in the seas around Guam. The nearest documented nesting beaches are near Gabgab Beach, in the outer harbor. Therefore, we presume the individual that we sighted was foraging.

Habitat Areas of Particular Concern (HAPC)

None of the three areas of Apra Harbor recognized by Paulay et al. (2001a) for their species richness and unique biota are encompassed by Inner Apra Harbor. These authors described the inner harbor as the most altered area with Apra Harbor, while remarking on the presence of uncommon species, such as *Porites convexa*, and the abundance of the hammer oyster *Malleus decurtatus* on wharf faces.

Inner Apra Harbor lies at the extreme end of the gradient of increasing turbidity, abundance of plankton and benthic suspension feeders, and finer sediments. The harbor continues to support thriving marine communities, despite the extensive dredging and filling operations that significantly altered the area after World War II. Data from this study indicate that Abo Cove is unique and deserves special attention in managing the natural resources of the inner harbor. As Paulay et al. (2001a) noted, Apra Harbor is unlike other major ports, where communities of marine organisms tend to be greatly degraded. Therefore, we advise decision-makers not to extrapolate data from the current study to other areas within Inner Apra Harbor that were not within the scope of this study, especially the inner Abo Cove embayment and the mangrove area at the mouth of the Atantano River.

SUMMARY

This study shows a clear difference between the most authentic inner harbor habitats at Abo Cove and the manmade wharfs. Because of its restricted spatial extent, the distinct benthic assemblages, and the relatively high coral cover, Abo Cove deserves special attention in managing the natural resources of the inner harbor. Ironically, the artificial and most anthropogenically impacted habitats of the wharfs might contribute most to the biotic richness and diversity of the inner harbor. The synoptic account of the benthic invertebrates is indicative of unique benthic fauna, especially so for the sponges. Hence, more extensive taxonomic surveys are warranted to assess the biological value of the inner harbor, as well as its potential as an area for potential establishment of invasive species.

The coral fauna of the study area consisted of 30 species, or about 10% of the coral fauna of Guam (see Randall, 2003). The predominant corals were massive *Porites* spp., one of which exceeded 1 m in diameter at Abo Cove. The coral assemblage in Inner Apra Harbor is characteristic of environments with high levels of sedimentation and turbidity, with the most common species, in order of tolerance to these conditions, being *Porites lutea*, *Pocillopora damicornis*, and *Leptastrea* *purpurea* (Amesbury et al., 1977). Coral species richness is highest on relatively sediment-free, hard substrates on vertical faces of wharves.

Macroinvertebrates communities in the inner harbor were only moderately diverse, with 30 species observed on or near transects. As for corals, availability of sediment-free hard substrate for sessile and sedentary macroinvertebrates is a limiting factor on horizontal surface. On the harbor floor, macroinvertebrates were limited to scattered debris that provided on the only hard substrate available. Macroinvertebrate assemblages in the inner harbor were dominated by suspension-feeding species, which comprised 100% of the species occurring on transects and 90% of all species observed. Except for a single species of marine snail, no macroinvertebrates were observed on the soft sediments of the harbor floor.

The species richness and diversity of the fish fauna within the Inner Harbor are relatively low compared to habitats elsewhere on Guam (Donaldson, unpublished data). However, the fauna is highly adapted and representative of protected and turbid habitats usually associated with mangroves, estuaries, and back reefs, with some exceptions. A considerable amount of habitat is provided by artificial shelter in the form of wharves, and the microhabitats found on or adjacent to those wharves was utilized by many species of fishes. Larval fishes of these species could have settled and recruited to these habitats and microhabitats, either through natural stochastic processes or by transport (i.e., bilge water), and became established at each of the stations. Many of the individuals of these species were juveniles or subadults. Alternatively, some species, particularly those that swim actively in the water column, may have colonized these habitats as adults after swimming to them from outside of the inner harbor.

Perhaps the only relatively unique species present at most or all stations are the bottom-dwelling, burrowing goby species that may be specific only to sand bottoms in back bay or estuarine areas. The extent of the distribution of these species is not well known, however, because of the generally poor visibility encountered in such areas (i.e., Inner Apra Harbor and Sasa Bay in western Guam, and the estuaries of the Pago, Ylig, and Talofofo Rivers in eastern Guam).

RECOMMENDATIONS

During the planning phase for construction and renovation of facilities and training sites surveyed in Inner Apra Harbor in this study, the following recommendations should be given consideration.

1. Abo Cove and its associated coral reefs deserve special attention in managing the natural resources of the inner harbor.
Despite its restricted spatial extent, Abo Cove is unique within the inner harbor because of the coral reefs that have developed there. The reef is characterized by relatively high coral cover and the largest coral colonies in the area studied. Further, Abo Cove supports distinct benthic assemblages of sponges, corals, and macroinvertebrates (see Figures 8, 9, and 11). Therefore, renovation and construction activities requiring dredging and filling in and adjacent to Abo Cove should have the lowest priority. A minimum buffer zone of 400 feet should be maintained between Abo Cove and all dredge and fill activities in the inner harbor.

If Abo Cove is selected for development, a compensatory mitigation plan should be developed for review by the appropriate agencies and authorities. To the extent possible and appropriate, any mitigation project should be “on-site” and “in-kind” (PBS&J, 2008), with consideration given to relocation of the corals to a similar environment, like that in the outer portion of Sasa Bay in the outer harbor. Biological monitoring should be required for any project that is proposed for construction in the vicinity of Abo Cove.

2. **Floating turbidity curtains, extending from the surface to the lagoon floor, should be placed completely around all dredge and fill sites, and turbidity curtains should be routinely monitored and maintained to contain silt produced by construction.**
Dredge and fill operations produce large quantities of fine silt particles suspended in the water column. Turbidity and sedimentation are significant problems for coral reefs surrounding high islands or in coastal areas of continents. Sediments may have an energetic cost to the coral that must cleanse its surface, resulting in slower growth rates and in less energy available for reproduction (Tomascik and Sander, 1987; Wolanski et al., 2003). Sediments can also interfere with larval recruitment on coral reefs by interfering with the chemosensory ability of coral larvae seeking the appropriate chemical signals from preferred settlement substrates, such as coralline algae (Richmond, 1997). Turbidity curtains can be effective in confining suspended sediments when properly deployed and maintained. Removal of the turbidity barriers and the related components is vital once the project activities are complete. Failure to do so can cause the barrier to come loose from its anchors and entangle benthic and other marine organisms (PBS&J, 2008).

3. **All dredge and fill operations should be suspended during the period of the annual coral spawning event in Guam waters.**
Some 85% of reef-building corals are spawners, i.e., reproduction occurs after the release of gametes into the water, where fertilization takes place (Richmond, 1997). Multispecies mass-spawning events occur during limited periods each year. To maximize reproductive success, most spawning species release their gametes over a 5–8-day period that is related to the lunar cycle. Studies in Guam revealed that peak spawning occurs 7–10 days after the full moon in July (Richmond and Hunter, 1990). Because suspended sediments may interfere with egg-sperm interactions in the fertilization process (Richmond, 1997; Wolanski et al., 2003), dredge and fill operations can affect coral reproduction on reefs far down current of the actual construction activities.

Construction windows are a management tool to map out the times of year during which coastal construction may be limited due to the presence of threatened or endangered species or other sensitive marine life (PBS&J, 2008). Construction windows may consider wildlife activity such as coral spawning and coral bleaching. U.S. Army Corps of Engineers permits for maintenance dredging of the Naval Base require that dredging operations cease during annual coral spawning periods in Guam (M.E. Guarin, P.E., Construction Management Engineer, NAVFAC OICC Marianas, personal communication, April 27, 2004).

4. **Marine biological communities should be monitored during and after dredge and fill operations in Inner Apra Harbor.**
Monitoring studies on small, tropical islands have shown that precautions for environmental protection can limit the effects of dredge and fill operations on nearby marine communities.

Amesbury et al. (1982) identified few measurable effects related to construction of the airport runway extension at Weno Island, Chuuk [= Moen Island, Truk]. However, these authors reported that fluctuations in species richness, percent cover, and population density of several taxa occurred during the construction period. Where siltation was heaviest, the decline in coral coverage was significant, and no evidence of new coral recruitment was found one year after the completion of runway construction. Marine plants, macroinvertebrates, and reef fishes also declined at those monitoring stations that were inundated with sediments.

Biological monitoring should be required for any project that is proposed for construction in Inner Apra harbor , especially in the vicinity of Abo Cove, so that any damage to coral communities caused by sedimentation can be identified promptly and so that the necessary measures can be taken to minimize any damage. Monitoring is necessary to determine any direct or indirect biological impacts to the ecosystem caused by physical and/or chemical changes to the environment as a result of the project.

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MARINE BIOLOGICAL SURVEY OF OSCAR AND PAPA WHARVES, INNER APRA HARBOR, GUAM

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INTRODUCTION

This report describes marine natural resources surveyed at Oscar and Papa Wharves, Inner Apra Harbor, Guam during March, 2010. This report compliments previous surveys conducted at other wharves, as well as patch reefs and the harbor bottom within the Inner Apra Harbor (Smith et al., 2008).

Inner Apra Harbor is a natural embayment formed by tectonic activity along the Cabras Fault, separating the volcanic Tenjo Block in central Guam from the limestone Orote Block immediately to the west (see Tracey et al., 1964 for structural details). Rotation of the Orote Block resulted in subsidence of the eastern portion of the block adjacent to the Cabras Fault line. Accompanying rotation, the sea flooded into the slumped areas, forming Apra Harbor, a deep-water lagoon bounded on the north by Cabras Island and the long, curving Glass Breakwater. Two rivers—the Apalacha and Atantano—drain the volcanic mountain land to the east of Apra Harbor and empty into the inner harbor (Randall and Holloman, 1974).

Although naturally formed, Inner Apra Harbor has been extensively modified by dredging, construction, and landfills by the U.S. Navy since 1945 (Paulay et al., 2001a). The inner harbor was dredged, changing the southernmost part of the original lagoon from a reef-choked, silty embayment into a harbor with a nearly uniform depth and mud bottom. Fill projects created the Dry Dock Peninsula, Polaris Point, and manmade shorelines along the northeastern and southeastern boundaries of the harbor. These and other developments in the outer harbor (e.g., construction of Glass Breakwater) reduced water exchange between the harbor and the Philippine Sea, creating a gradient of increasing turbidity, abundance of plankton and benthic suspension feeders, and finer sediments from the entrance to the outer harbor to the inner harbor environment. The only portion of the inner harbor remaining unchanged is the mangrove area at the mouth of the Atantano River.

Randall and Holloman (1974) reported living *Pocillopora* and *Porites* corals on the wharf and dock structures in the inner harbor. Paulay et al. (2001a) found that artificial surfaces in the inner harbor supported diverse fouling communities, including both indigenous and introduced species. They noted the presence of *Porites convexa*, known in Guam from only a few locations. In a more recent survey, Smith et al. (2008) found both *Pocillopora* and *Porites* corals to be relatively abundant on wharf faces, as well, with *Pocillopora damicornis* and *Porites lutea* being especially common among the 13 species observed on wharf face transects. With the inclusion of non-scleractinian anthozoans, they found 28 species of corals and related organisms from 11 families and 13 genera on or adjacent to transects (including patch reefs on the harbor bottom and on miscellaneous scrap found there

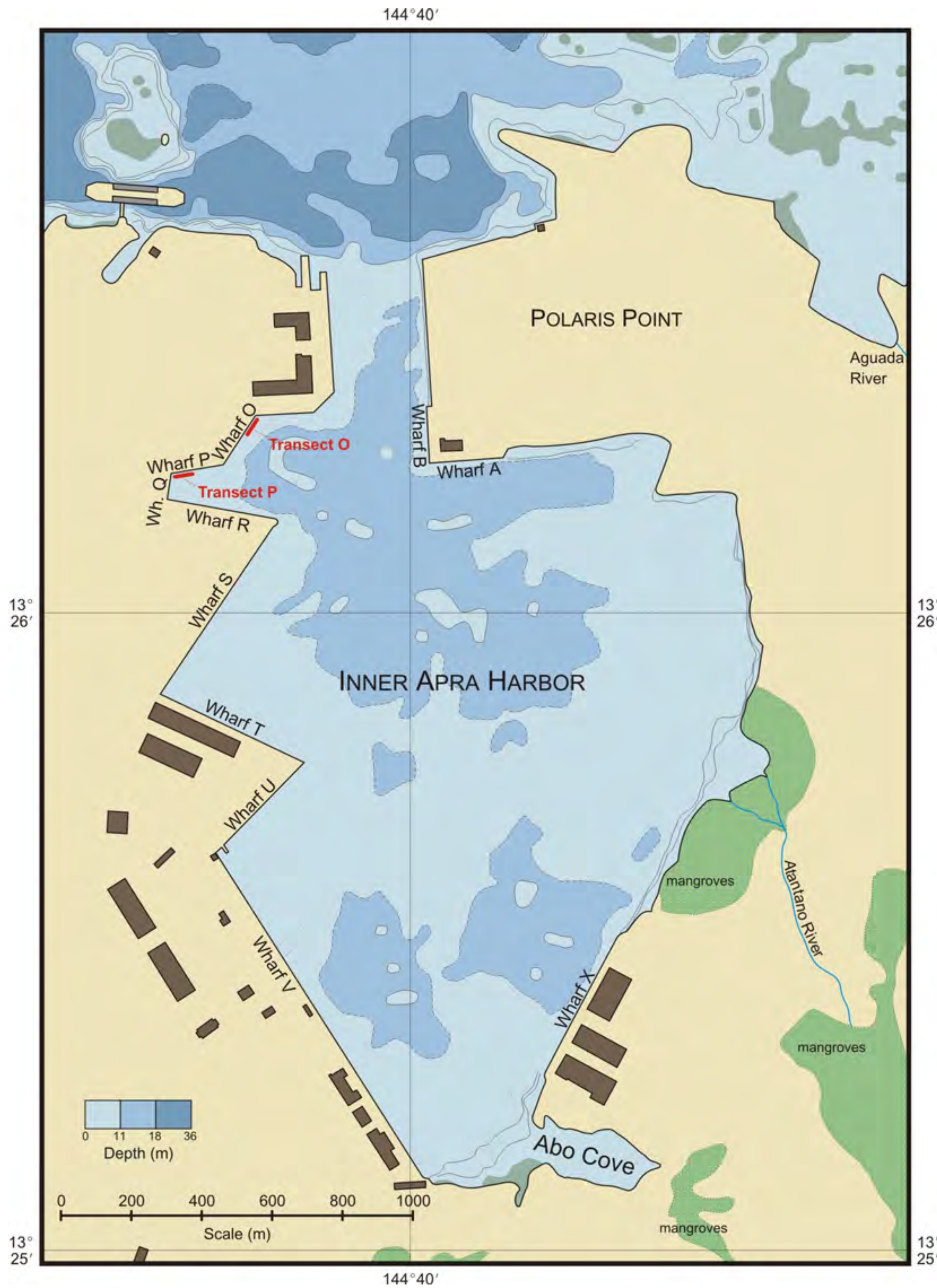

Figure 1. Map of Inner Apra Harbor showing geographic locations of transect sites at Oscar and Papa Wharves.

Randall and Holloman (1974) also remarked about the abundance of the hammer oyster *Malleus decurtatus* on wharf faces in Inner Apra Harbor. Smith et al. (2008) found this species to be very common, especially on Victor Wharf, as well.

Wharves and adjacent structures, including silt or fine sediment substrates at the base of wharves, support small assemblages of fishes (Smith et al., 2008). Juvenile fishes, especially damselfishes (Pomacentridae), such as *Chromis viridis* and *Pomacentrus pavo*, cardinalfishes (Apogonidae), and diminutive gobies (Gobiidae), seek shelter amongst corals, benthic algae, and man-made structures along wharf faces. Burrowing gobies may be common in the sediments at the base of these faces. Free-ranging fishes, such as the surgeonfish *Acanthurus blochii* (Acanthuridae), the snapper *Lutjanus fulvus* (Lutjanidae), and the trevallys *Caranx melampygus* and *C. sexfasciatus*, (Carangidae) were observed swimming near wharf faces and adjacent jetsam and debris. Three invasive fish species were found along some wharf faces, as well (Smith et al., 2008). These include two damselfishes, *Amblyglyphididon ternatensis* and *Neopomacentrus violescens*, and a cardinalfish, *Rhabdamia cypselerus*.

Relocation of elements of the Marine Expeditionary Force (MEF) from Okinawa to Guam by the Marine Corps will require renovation of existing port facilities to accommodate MEF embarkation, as well as construction of various new operations facilities in support of the MEF mission. Furthermore, new training areas and associated facilities are proposed for selected areas on Guam. These developments require extensive surveys that locate, identify, and assesses the natural resources of Guam, and also identify and assess invasive species that might expand their ranges within Guam's waters.

Data from these surveys are expected to serve as a guide for decisions affecting land and coastal use for proposed construction and renovation of facilities and training sites on Department of Defense and contractor-controlled lands in the Inner Apra Harbor of Guam.

Scope of Work

1. Conduct field surveys for fish, corals, macroinvertebrates, and macrophytes of harbor bottom and sheet piling wharf faces at Oscar and Papa Wharves in Inner Apra Harbor.

2. Prepare a technical report on fishes, corals, macroinvertebrates, macrophytes, essential fish habitat evaluation, and assessment of endangered species.

3. Attend project team meetings/conferences calls.

METHODS

Survey Site Selection

Both Oscar and Papa Wharves (Figure 1) are obstructed by large shipyard facilities that limited access to wharf faces. During the survey period, two large crane barges were moored at Oscar Wharf while a large dry dock occupies virtually all of Papa Wharf's main face. Therefore, transect lengths were limited to a 50-m stretch of wharf face at Oscar Wharf and a 50-m stretch of wharf face at the back of Papa Wharf where this wharf s with Romeo Wharf. GPS coordinates were recorded for transect locations at each wharf.

Benthic Cover

Benthic cover was surveyed along 50-m transects established at a depth of 6 m for coral, invertebrate, and fish surveys at Oscar and Papa Wharves. Marine plant communities and substrate types in each zone were quantified by a modified point-quadrat method (Tsuda, 1972). This method consists of identifying and recording substrate types and organisms under the points of intersection of strings stretched across a 0.25-m² (50 cm x 50 cm) quadrat. Four strings stretched from each side of the quadrat provide 16 points (intersections). The quadrat was placed randomly at 5-m intervals along the length of the transect. The quadrat was deployed a total of 10 times, providing 160 data points on a 50-m transect. Percent cover was calculated from these points. Limited visibility in the inner harbor precluded documentation of benthic flora and fauna with photoquadrat records. Species within the study area, but not encountered along the transect line, were also recorded.

Corals

Coral communities were quantified along the transects by an observer using the point-quarter method of Cottam et al. (1953). Points were assigned at 5-m intervals along each transect. Each point served as a focus of four equal-sized quadrants arrayed around the point. Within each quadrant, the coral closest to the central point was located. This coral's identity, distance from the point, length, and width were recorded. If no corals lay within 1 m of the point, that quadrant was recorded as having no corals. From the recorded data, community and species-specific population density of colonies, percent coverage, and frequency of occurrence were then computed with the following equations from Cottam et al. (1953):

Total Density Of All Colonies = Unit Area / (Average Point-To-Colony Distance)^2
Relative Density Of A Species = 100 * Number Of Colonies Of The Species / Number Of All Colonies
Absolute Density Of A Species = Percent Density * Total Density / 100
Total Percent Coverage Of All Species = Total Density * Average Coverage Of All Species
Relative Coverage Of A Species = Species Density * Average Coverage of the Species

Population data for each species were also calculated, including the number of colonies, average colony size, standard deviation of colony size, and minimum and maximum colony size. To record the less common species not recorded by the quantitative survey, a list of species was also assembled by swimming along the entire transects and recording all species seen within 2 m of the line.

Macroinvertebrates

All conspicuous solitary epibenthic macroinvertebrates occurring within 1 m of either side of the transect lines were identified and enumerated by an observer swimming along the transect line. For this study, conspicuous is defined as being larger than 50 mm in size and as being clearly visible to an observer without need of overturning rocks or digging into the substrate. Cryptic, microscopic, nocturnal, and highly motile species that avoid humans (e.g., crabs and shrimps) were not included within the scope of this study. Species diversity and abundance were recorded in 10-m intervals along the transect line. Therefore, for statistical purposes, each belt transect consisted of five 20-m^2 replicate plots, except where noted.

Similarities in structure of macroinvertebrate assemblages on the two transects were calculated by the Bray-Curtis similarity method with PRIMER ver. 6 (Clarke and Gorley, 2006). Species of macroinvertebrates observed in the study area, but not encountered along the transect line, were also recorded but not included in the similarity analyses.

Fishes

Fishes were surveyed visually along transect lines. Observations were constrained by poor visibility and all species had to be counted on a single pass along the transect line. Along both wharf faces, three transects were run (where possible), respective of depth, just below the surface(subsurface), at mid-depth (the principal transect line), and at the bottom of the wharf wall. All fishes observed 0.5m above or below the line, were counted on subsurface and mid-depth transects; at the bottom, all fishes observed 1 m to the seaward side (away from the wharf face) of the line were counted. These methods provided estimates of density (no. individuals/m_2) for each species. Fishes were identified to species. Identifications followed Myers (1999) and Myers and Donaldson (2003), except where more recent taxonomic studies were relevant. Reference photographs were taken with an underwater digital camera but image quality tended to be extremely poor because of turbid conditions. For estimates of species diversity, standard measures of species richness, species diversity, and similarity were calculated and compared between stations with PRIMER vers. 6; DIVERSE PROCEDURE; Clarke and Gorley, 2006). Multidimensional scaling (PRIMER vers. 6; MDS procedure) was used to examine similarities between stations based upon Bray-Curtis coefficients calculated for each. This test indicates relative distances between samples based upon their similarities in assemblage structure. Points found close together represent samples that were very similar in species composition while those far away represented different assemblage structures (Clarke and Gorley, 2006). Analysis of Similarities (PRIMER, ver. 6; ANOSIM procedure, square root transformed) was used to test the null hypothesis that there were no differences in assemblage structure between groups of observations (depth of transect) at the stations (wharves).

Essential Fish Habitat

Qualitative measures of habitat utilization by fishes were limited to observations of association between species and habitat and microhabitat types. Major habitat types were the vertical surfaces of both Oscar and Papa Wharves (= wharf) and the harbor floor (= soft bottom). Microhabitats included corals, mollusc shells (mainly *Malleus decurtatus* and *Spondylus squamosus*), debris (hanging and deposited on the bottom), silt, and the water column).

RESULTS AND DISCUSSION

Because of the length of the transects (50m) at each wharf, no attempt was made to determine the starting and ending coordinates of each transect. GPS coordinates describing the general location of each 50 m transect were N 13.43824, E 144.66241 for Oscar Wharf and N 13.43658, E 144.66032 for Papa Wharf.

Benthic Cover

Mean surface coverage of the vertical substrate along the transects at Oscar and Papa Wharves is presented in Figure 2. The harbor floor not sampled. Substrate coverage was divided into seven abiotic and biotic features at the sites. The mean biotic coverage in ten quadrat samples was 20.63 % at Oscar Wharf and 55.63 % at Papa Wharf. Sponges were the predominant biotic cover organisms at Oscar Wharf, ranging from 0–18.75 percent cover; macroalgae were predominant at Papa Wharf, ranging from 12.5–62.5 percent cover. Bray-Curtis similarity analysis (fourth root transform, cluster mode: group average) indicated 83.91% resemblance of the benthic cover data at the two wharves. A list of marine plants observed at the two sites is given in Table 1.

Corals

Size-frequency distributions of the six species of scleractinian corals encountered on transects at Oscar and Papa Wharves, Inner Apra Harbor are presented in Table 2. An additional 13 species of scleractinian corals were observed on wharf faces adjacent to the transects (Table 3). One species of non-scleractinian anthozoan and one species of hydrozoan were also recorded. Therefore, a cumulative total of 21 species of corals and related organisms, representing 13 families and 16 genera was observed at the study site.

Species richness was highest at Oscar Wharf, where six species occurred on the transect; only three species occurred on the transects at Papa Wharf. *Leptastrea purpurea*, *Pocillopora damicornis* and *Porites lobata* were the most frequently observed species. Three species, *Dendrophyllia* sp., *Psammocora haimeana, and Porites rus* occurred on the transect only at Oscar Wharf.

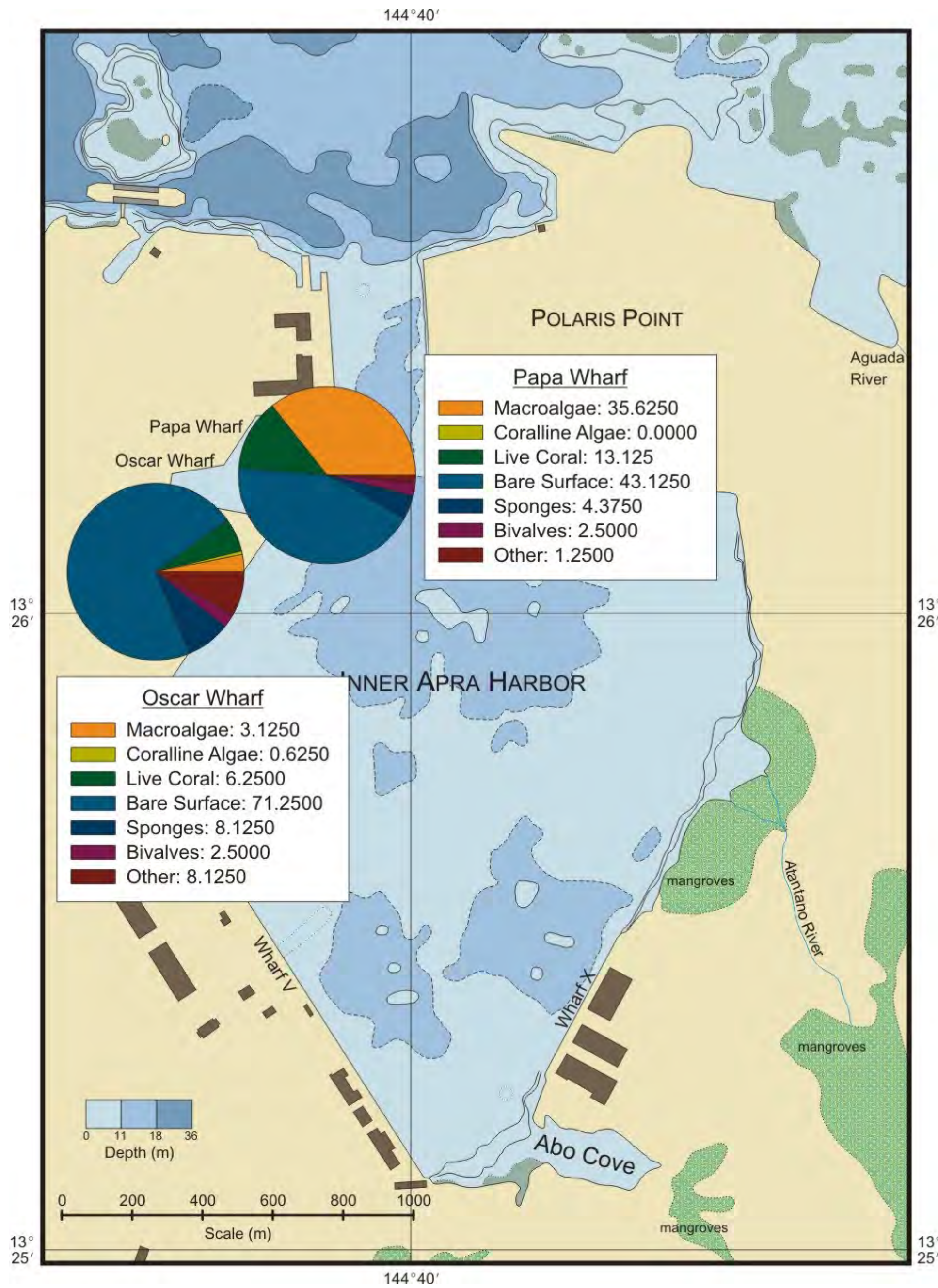

Figure 2. Mean surface coverage of the vertical substrate along the transects at Oscar and Papa Wharves

Table 1. Taxonomic list of marine plants observed at depths of 0–6 m on the faces of Oscar and Papa Wharves. Phylogenetic arrangement follows Lobban and Tsuda (2003).

	Oscar Wharf	Papa Wharf
Cyanophyta:Cyanophyceae		
cf. *Lyngbya aestuarii*	●	○
Rhodophyta:Rhodophyceae		
Galaxaura filamentosa	●	○
Peyssonnelia rubra		●
Heterokontophyta:Phaeophyceae		
Dictyota bartayersiana	●	●
Padina boryana	●	●
Chlorophyta:Chlorophyceae		
Enteromorpha clathrata	●	○
Bryopsis sp.	●	○

Table 2. Size-frequency distributions of coral species recorded on transects Oscar and Papa Wharves, Inner Apra Harbor. N_i = number of colonies. Mean, SD (standard deviation), and Range refer to colony size in cm^2.

Location	Species	N_i	Mean	SD	Range
Oscar Wharf	*Leptastrea purpurea*	15	7.36	9.355	1.18–29.45
	Pocillopora damicornis	7	24.15	20.627	4.71–65.97
	Porites lobata	7	4.82	5.038	0.79–14.14
	Tubastraea coccinea	2	3.63	1.805	2.36–4.91
	Porites rus	1	–	–	8.25
	Psammocora haimeana	1	–	–	1.18
Papa Wharf	*Pocillopora damicornis*	21	346.67	364.357	0.79–1,154.54
	Leptastrea purpurea	17	13.32	14.513	1.57–44.18
	Porites lobata	2	214.71	296.701	4.91–424.51

Table 3. Species of scleractinian and hydrozoan corals observed at Oscar and Papa Wharves. A filled circle (●) indicates presence of a species, and an open circle (○) indicates that the species was not recorded at that site. Phylogenetic arrangement follows Randall (2003).

	Oscar Wharf	Papa Wharf
Hydrozoa:Milleporidae		
Millepora tuberosa	●	○
Anthozoa:Pocilloporidae		
Pocillopora damicornis	●	●
Anthozoa:Acroporidae		
Astreopora myriophthalma	●	●
Astreopora randalli	○	●
Anthozoa:Agariciidaea		
Leptoseris mycetoseroides	●	○
Anthozoa:Siderastreidae		
Psammocora haimeana	●	●
Anthozoa:Fungiidae		
Herpolitha weberi	●	○
Anthozoa:Poritidae		
Porites compressa	○	●
Porites lichen	●	○
Porites lobata	●	●
Porites rus	●	●
Anthozoa:Faviidae		
Diploastrea heliopora	○	●
Leptastrea purpurea	●	●
Oulophyllia levis	○	●
Anthozoa:Rhizangiidae		
Culicia rubeola	●	○
Anthozoa:Mussidae		
Lobophyllia corymbosa	●	○
Lobophyllia hemprichii	○	●

Table 3, continued.

	Oscar Wharf	Papa Wharf
Anthozoa:Pectiniidae		
Pectinia paeonia	○	●
Anthozoa:Dendrophylliidae		
Dendrophyllia sp.	●	●
Turbinaria reniformis	○	●

Quantitative analysis of the coral species encountered on each transect is presented in Table 4. *Pocillopora damicornis* was predominant in coverage and averaged 71.5% relative coverage between the two transects. *Leptastrea purpurea* had the second highest relative coverage (18.2%) between the two transects. A Bray-Curtis Similarity Index value calculated from 4^{th}- root transformed relative coverage data indicated a similarity of 68.6% between coral assemblages at the two wharves. The data set was too small, however, to compare assemblage structures by non-metric multidimensional scaling (NMDS) analysis.

Macroinvertebrates

Mean densities of conspicuous, solitary invertebrates at Oscar and Papa Wharves are given in Table 5. Seventeen species of solitary macroinvertebrates were encountered on the transect at Papa Wharf, and 12 species were recorded on the transect at Oscar Wharf. As noted at other sites in Inner Apra Harbor (Smith et al., 2008), 100 percent of the macroinvertebrates encountered on the transects were suspension feeders. Bivalve molluscs (7 species) and solitary ascidians (8 species) dominated the macroinvertebrate fauna at both wharves, and mean densities were generally greater at Papa Wharf. The bivalves *Malleus decurtatus* and *Spondylus squamosus* were remarkably more abundant at Papa Wharf, as was the ascidian *Rhopalaea circula*. Mean densities ranged from <1.0 individual/20 m^2 (several species) to 55.0 individuals/20 m^2 (*Spondylus squamosus* at Papa Wharf). Spondylid bivalves occurred at the greatest density encountered at both sites, with a cumulative density of 70.0 ± 30.9 individuals/20 m^2. Mean density of all species at Oscar Wharf was 45.4 ± 43.71 solitary invertebrates/20 m^2, and 207.6 ± 199.47 solitary invertebrates/20 m^2 at Papa Wharf. Bray-Curtis similarity analysis (fourth root transform, cluster mode: group average) indicated 71.2% resemblance of the solitary invertebrate densities in the two communities.

α-level diversity of conspicuous epibenthic invertebrates, including both solitary and colonial forms, at Oscar and Papa Wharves is given in Table 6. A total of 36 species was observed during the survey, 28 species at Oscar Wharf and 33 species at Papa Wharf. The two wharves share 75% of the total recorded fauna. As noted above for invertebrate densities on transects, α-diversity was dominated by bivalve molluscs (12 species) and ascidians (10 species). Bray-Curtis similarity analysis (fourth root transform, cluster mode: group average) indicated 80.0% resemblance of the α-diversity in the two invertebrate communities.

Suspension-feeding invertebrates were predominant, making up some 86% of the fauna at the two sites. Grazing herbivorous gastropods were observed just above the water-line on the faces of both wharves, as was a browsing herbivorous grapsid crab. The deposit-feeding sea cucumber *Synapta maculata* was observed on the face of Papa Wharf. No predatory invertebrates were observed at either wharf.

Two noteworthy species of macroinvertebrates were observed at Oscar and Papa Wharves. The ahermatypic coral *Dendrophyllia* sp. was recorded on vertical wharf faces of both transects.

Table 4. Population density, frequency, and coverage of coral species recorded on transects at Oscar and Papa Wharves, Inner Apra Harbor, Guam.

Location	Species	N_i	Relative Density	Absolute Density	Frequency	Absolute Coverage	Relative Coverage
Oscar Wharf	*Leptastrea purpurea*	15	0.375	2.285	0.70	0.0021	0.3345
	Pocillopora damicornis	7	0.175	1.066	0.40	0.0033	0.5125
	Porites lobata	7	0.175	1.066	0.50	0.0007	0.1024
	No coral	7	0.175	1.066	0.40	0.0000	0.0000
	Dendrophylla sp.	2	0.050	0.305	0.20	0.0001	0.0220
	Psammocora haimeana	1	0.025	0.152	0.10	0.0000	0.0036
	Porites rus	1	0.025	0.152	0.10	0.0002	0.0250
Papa Wharf	*Pocillopora damicornis*	21	0.525	10.088	1.00	0.4453	0.9173
	Leptastrea purpurea	17	0.425	8.167	1.00	0.0139	0.0285
	Porites lobata	2	0.050	0.961	0.20	0.0263	0.0541

Table 5. Mean densities of conspicuous, solitary invertebrates at Oscar and Papa Wharves. Data given are means ± standard deviations of counts in five 10-m^2 quadrats. Phylogenetic arrangement follows Paulay (2003) for bivalves and Lambert (2003) for ascidians.

	Oscar Wharf	Papa Wharf
Cnidaria:Anthozoa		
Dendrophyllia sp.	1.40 ± 1.14	0.20 ± 0.45
Annelida:Polychaeta		
Sabellastarte spectabilis	0.20 ± 0.45	0.60 ± 0.89
Mollusca:Bivalvia		
Malleus decurtatus	2.00 ± 1.58	36.00 ± 23.69
Spondylus multimuricatus	4.00 ± 5.10	10.80 ± 2.77
Spondylus squamosus	13.00 ± 11.07	55.00 ± 23.98
Spondylus spp.	2.40 ± 2.61	11.20 ± 4.15
Ostreidae sp.	---	0.20 ± 0.45
Chama lazarus	6.20 ± 3.56	15.20 ± 7.05
Chama spp.	1.40 ± 1.34	1.20 ± 1.10
Chordata:Ascidiacea		
Ascidia ornata	---	0.40 ± 0.89
Phallusia julinea	0.20 ± 0.45	2.80 ± 1.30
Phallusia niger	---	1.20 ± 2.17
Rhopalaea circula	8.00 ± 8.57	50.60 ± 40.34
Rhopalaea crassa	---	1.00 ± 1.00
Rhopalaea sp. A	6.20 ± 7.29	10.80 ± 6.72
Polycarpa cryptocarpa	0.40 ± 0.55	7.40 ± 1.82
Polycarpa spp.	---	3.00 ± 0.71

Table 6. Species of conspicuous epibenthic invertebrates observed at Oscar and Papa Wharves. A filled circle (●) indicates presence of a species, and an open circle (○) indicates that the species was not recorded at that site. Phylogenetic arrangement follows Kelly et al. (2003) for sponges, Smith (2003) for gastropods, Paulay (2003) for bivalves, and Lambert (2003) for ascidians.

	Oscar Wharf	Papa Wharf
Porifera:Demospongiae		
Dysidea sp.	●	●
Hyrtios sp.	●	●
Haliclona sp.	●	●
Clathria sp. (orange)	●	○
Clathria sp. (pink)	●	●
Clathria sp. (red)	●	●
Cnidaria:Hydrozoa		
Leptolida spp.	●	●
Cnidaria:Anthozoa		
Dendrophyllia sp.	●	●
Carijoa sp.	○	●
Annelida:Polychaeta		
Sabellastarte spectabilis	●	●
Mollusca:Gastropoda		
Littoraria pintado	●	○
Littoraria scabra	●	●
Siphonaria guamensis	●	●
Mollusca:Bivalvia		
Brachidontes sp.	○	●
Pinctada sp.	○	●
Malleus decurtatus	●	●
Spondylus multimuricatus	●	●
Spondylus squamosus	●	●
Spondylus spp.	●	●
Chama lazarus	●	●
Chama spp.	●	●
Alectryonella plicatula	●	●
Saccostrea mordax	●	●
Saccostrea cucullata	○	●

Table 6, continued.

	Oscar Wharf	Papa Wharf
Mollusca:Bivalvia		
Ostreidae spp.	●	●
Arthropoda:Crustacea		
Metapograpsus latifrons	●	●
Echinodermata:Holothuroidea		
Synapta maculata	○	●
Chordata:Ascideacea		
Lissoclinum fragile	○	●
Ascidia ornata	○	●
Phallusia julinea	●	●
Phallusia niger	●	●
Rhopalaea circula	●	●
Rhopalaea crassa	○	●
Rhopalaea sp. A.	●	●
Polycarpa cryptocarpa	●	●
Polycarpa spp.	●	●

Ahermatypic corals tolerate dim light conditions like those of the turbid waters of the inner harbor, as well as caves and deeper waters. *Dendrophyllia* spp. are considered rare in shallow waters in Guam (Richard H. Randall, personal communication, 26 March 2010); however, they are more common in deeper, darker waters offshore.

The observation of the octocoral *Carijoa* sp. is just the third record of this species in Guam. Paulay et al. (2003) previously reported *Carijoa* sp. from mooring buoys in Outer Apra Harbor and from a submarine cave near the Shark's Pit at Orote Peninsula. Although there is no indication of proliferation of *Carijoa* sp. in Guam, the presence of the species is noteworthy because of the situation in Hawaii. *Carijoa riisei*, a native of the tropical Western Atlantic, has invaded mesophotic coral reefs in Hawaii and devastated black coral communities that have been sustainably harvested for the jewelry industry for more than 40 years (Grigg, 2003, 2004; Kahng and Grigg, 2005)

Fishes

A checklist of species and their relative abundance (as percent) at each station is given in Table 7. Thirty-five species of fishes were observed on transects surveyed at both wharves. As with other sites within the Inner Apra Harbor surveyed previously (Smith et al., 2008), this low level of species richness represents an impoverished fish fauna (there are ca. 1,000 species of reef and nearshore fishes reported from the Mariana Islands; Myers and Donaldson, 2003; unpublished data). Components of this fauna, however, are indicative of protected, turbid lagoons or bays of Guam, of which there are relatively few compared to clear water reefs (unpublished data), and thus constitute a relatively unique assemblage of fishes.

Two invasive species were observed at both wharves. One, *Neopomacentrus violescens* (Pomacentridae, damselfishes), has been reported previously (Myers, 1999; Myers and Donaldson, 2003). This species was found more recently on Tango, Uniform and X-ray Wharves (Smith et al., 2008). The second species, *Amblygliphididon ternatensis* (Pomacentridae) was reported from Sierra, Tango, Uniform and Victor Wharves, while a third, *Rhamdia cypselurus* (Apogonidae, cardinalfishes), was reported previously from Sierra, Tango, Uniform and X-ray Wharves (Smith et al., 2008). The latter species was not observed at Oscar or Papa Wharves. The two damselfishes occur elsewhere in the western Indo-Pacific region in natural habitats somewhat similar to those found in Inner Apra Harbor (Myers, 1999).

Data on species richness, diversity, and abundance for each transect are given in Table 8. Species richness (the number of species observed) ranged from 15 (n = 57 individuals) at Oscar Wharf to 29 (n = 1347 individuals) at Papa Wharf. Generally, species richness was greater on or adjacent to mid-wall and top-wall transects at both wharves, where corals, hanging debris, and oyster shells provided shelter for various species, but especially damselfishes, cardinalfishes and juvenile butterflyfishes. Bottom-transects at both wharves had the lowest number of species and individuals. These included burrowing gobies (mainly *Oplopomus oplopomus*) or transient snappers (*Lutjanus fulvus*).

Table 7. Fishes observed on transects at Oscar and Papa Wharves, Inner Apra Harbor. M = mid-transect, B = bottom transect, T = top transect, IS = invasive species.

	Oscar Wharf					Papa Wharf				
Species	IS	M	B	T	Total	M	B	T	Total	Grand total
Family Apogonidae										
Apogon lateralis		0	0	10	10	0	0	3	3	13
Apogon leptacanthus		0	0	0	0	0	0	1	1	1
Archamia fucata		0	0	0	0	1	0	6	7	7
Cheilodipterus quinquelineatus		1	1	0	2	0	0	9	9	11
Sphaeramia orbicularis		0	0	1	1	0	0	0	0	1
Family Carangidae										
Caranx melampygus		0	0	0	0	2	0	0	2	2
Caranx sexfasciatus		0	0	0	0	13	0	0	13	13
Family Lutjanidae										
Lutjanus fulvus		0	1	0	1	2	8	0	10	11
Family Mullidae										
Parupeneus ciliatus		0	0	0	0	1	0	0	1	1
Family Chaetodontidae										
Chaetondon bennetti		0	0	0	0	0	0	10	10	10
Chaetodon ephippium		2	0	0	2	2	0	0	2	4
Chaetodon ulietensis		0	2	0	2	0	0	0	0	2
Chaetodon unimaculatus		0	0	0	0	0	0	1	1	1
Chaetodon vagabundus		1	0	0	1	0	0	0	0	1
Family Pomacentridae										
Abudefduf sexfasciatus		0	0	2	2	0	0	0	0	2
Amblyglyphididon curacao		1	0	0	1	0	0	0	0	1
Amblyglyphididon ternatensis	1	1	0	0	1	50	0	47	97	98
Chromis viridis		0	0	12	12	98	0	1015	1113	1125
Dascyllus aruanus		0	0	0	0	0	0	14	14	14
Neoglyphididon violescens	1	0	0	0	0	0	0	1	1	1
Pomacentrus amboinensis		3	0	10	13	2	2	4	8	21
Pomacentrus pavo		2	0	4	6	0	1	6	7	13
Family Labridae										
Halichoeres trimaculatus		0	0	0	0	0	0	3	3	3
Family Labridae: Scarinae										
Chlorurus sordidus juv		0	0	0	0	0	0	4	4	4
Leptoscarus vaigiensis juv		0	0	0	0	0	0	6	6	6
Family Callionymidae										
Dactylopus dactylopus		0	0	0	0	0	1	0	1	1
Family Gobiidae										
Amblygobius phaelena		0	0	0	0	0	0	0	0	0
Asterropteryx semipunctatus		0	0	0	0	0	0	1	1	1

Table 7. Continued.

Species	Oscar Wharf					Papa Wharf				
	IS	M	B	T	Total	M	B	T	Total	Grand total
Eviota punctulata		0	0	0	0	2	0	0	2	2
Eviota sp.		0	0	0	0	3	0	8	11	11
Exyrias bellissmus		0	0	0	0	0	1	0	1	1
Oplopomus oplopomus		0	0	0	0	0	6	0	6	6
Family Acanthuridae										
Acanthurus blochii		0	0	3	3	0	2	7	9	12
Zebrasoma veliferum		0	0	0	0	0	0	1	1	1
Family Tetraodontidae										
Canthigaster solandri		0	0	0	0	0	1	2	3	3
Total individuals		11	4	42	57	176	22	1149	1347	1404

Table 8. Species richness (S), diversity (H’), and abundance (N) of fishes at Oscar (O) and Papa (P) Wharves, Inner Apra Harbor. M = mid-transect, B = bottom-transect, and T = top-transect.

Transect	S	H’	N
OM	7	1.85	11
OB	3	1.04	4
OT	7	1.69	42
PM	11	1.26	176
PB	8	1.72	22
PT	20	0.63	1149

Shannon's H', a measure of species diversity that adjusts species richness to consider also the influence of abundance (Magurran, 1988), was highest on the mid-transect at Oscar Wharf. Here, low abundance of fishes (n = 11) but relatively high species richness (7 species) accounted for high diversity. The top-transect at Papa Wharf, on the other hand, had high abundance (n = 1149) and also the greatest overall species richness (S = 20), but the most individuals were of a single species, *Chromis viridis* (Table 7). At both wharves, corals, soft corals, and molluscs (mainly oysters) were present and appeared to be protected from ship or barge damage by fenders, thus making them available to fishes for shelter.

At Oscar Wharf, relative abundance, the percentage of a single individual out of the total number of individuals observed (Table 9), was greatest for the juvenile butterflyfish, *Chaetodon ulietensis* (50% on the top-transect), followed by the damselfish *Pomacentrus amboinensis* (27.3 % on the mid-transect) and the cardinalfish *Cheilodipterus quinquelineatus* (25% on the bottom transect). At Papa Wharf, relative abundance was greatest for the damselfish *Chromis viridis* (88.4 % on the top-transect), followed by the snapper *Lutjanus fulvus* (37% on the bottom-transect) and the invasive damselfish *Amblyglyphididon ternatensis* (28.4% on the mid-transect).

Densities of fish species (number of individuals/m^2) at each wharf are given in Table (10). The damselfish *Pomacentrus amboinensis* had the greatest density at Oscar Wharf, followed by another damselfish, *Chromis viridis* and a cardinalfish, *Apogon lateralis*. Most of the damselfishes, particularly *C. viridis*, were juveniles or sub-adults. At Papa Wharf, *C. viridis* had, by far, the greatest density, followed by two water-column dwelling species, the trevally *Caranx sexfasciatus* and the snapper *Lutjanus fulvus*. A previous survey of other wharves within the Inner Apra Harbor (Smith et al., 2008) found that the small, structure-associated cardinalfish *Apogon lateralis* had the highest densities, followed by another cardinalfish, the apparently invasive *Rhabdamia cypselerus,* and the invasive damselfish, *Amblyglyphididon ternatensis*.

The similarity of species composition between stations and transect depths was examined with group cluster analysis (Figure 3) and multiple dimension scaling analysis (Figure 4). The fish assemblages revealed the following pattern: Oscar bottom-transect had a similarity of 20% with all other transects; Papa bottom and Oscar mid- and top transects had a 30% similarity with one another; Papa mid- and top transects had a similarity of 35%; Oscar top and Papa bottom transects were the most similar (40%) because of the presence of the surgeonfish *Acanthurus blochii* on both transects (Table 7). A stress level of 0.00 indicated a high degree of confidence in the MDA results (Clarke and Gorley, 2001).

Analysis of similarity (ANOSIM) between fish assemblage structure of both wharves in relation to depth of transect indicated that there were only minor differences between them (Global R = 0.167) and these were not significant. Thus, the fish faunas of each tended to share many of the same species typical of protected and turbid waters, while differences can be

Table 9. Relative abundance (RA, %) of fishes on transects at Oscar and Papa Wharves, Inner Apra Harbor, Guam. M = mid-transect, B = bottom transect, and T = top transect.

	Oscar Wharf Transect			Papa Wharf Transect		
Family and Species	M	B	T	M	B	T
Family Apogonidae						
Apogon lateralis	0.0	0.0	23.8	0.0	0.0	0.3
Apogon leptacanthus	0.0	0.0	0.0	0.0	0.0	0.1
Archamia fucata	0.0	0.0	0.0	0.5	0.0	0.5
Cheilodipterus quinquelineatus	9.1	25.0	0.0	0.0	0.0	0.8
Sphaeramia orbicularis	0.0	0.0	2.4	0.0	0.0	0.0
Family Carangidae						
Caranx melampygus	0.0	0.0	0.0	1.1	0.0	0.0
Caranx sexfasciatus	0.0	0.0	0.0	7.1	0.0	0.0
Family Lutjanidae						
Lutjanus fulvus	0.0	25.0	0.0	1.1	53.3	0.0
Family Mullidae						
Parupeneus ciliatus	0.0	0.0	0.0	0.5	0.0	0.0
Family Chaetodontidae						
Chaetondon bennetti	0.0	0.0	0.0	0.0	0.0	0.9
Chaetodon ephippium	18.2	0.0	0.0	1.1	0.0	0.0
Chaetodon ulietensis	0.0	50.0	0.0	0.0	0.0	0.0
Chaetodon unimaculatus	0.0	0.0	0.0	0.0	0.0	0.1
Chaetodon vagabundus	9.1	0.0	0.0	0.0	0.0	0.0
Family Pomacentridae						
Abudefduf sexfasciatus	0.0	0.0	4.8	0.0	0.0	0.0
Amblyglyphididon curacao	9.1	0.0	0.0	0.0	0.0	0.0
Amblyglyphididon ternatensis	9.1	0.0	0.0	27.3	0.0	4.1
Chromis viridis	0.0	0.0	28.6	53.6	0.0	88.3
Dascyllus aruanus	0.0	0.0	0.0	0.0	0.0	1.2
Neoglyphididon violescens	0.0	0.0	0.0	0.0	0.0	0.1
Pomacentrus amboinensis	27.3	0.0	23.8	1.1	13.3	0.3
Pomacentrus pavo	18.2	0.0	9.5	0.0	6.7	0.5
Family Labridae						
Halichoeres trimaculatus	0.0	0.0	0.0	0.0	0.0	0.3
Family Labridae: Scarinae						
Chlorurus sordidus juv	0.0	0.0	0.0	0.0	0.0	0.3
Leptoscarus vaigiensis juv	0.0	0.0	0.0	0.0	0.0	0.5
Family Callionymidae						
Dactylopus dactylopus	0.0	0.0	0.0	0.0	6.7	0.0
Family Gobiidae						
Amblygobius phaelena	0.0	0.0	0.0	0.0	0.0	0.0
Asterropteryx semipunctatus	0.0	0.0	0.0	0.0	0.0	0.1
Eviota punctulata	0.0	0.0	0.0	1.1	0.0	0.0
Eviota sp.	0.0	0.0	0.0	1.6	0.0	0.7
Exyrias bellissmus	0.0	0.0	0.0	0.5	0.0	0.0
Oplopomus oplopomus	0.0	0.0	0.0	3.3	0.0	0.0

Table 9. Continued.

Family and Species	Oscar Wharf Transect			Papa Wharf Transect		
	M	B	T	M	B	T
Family Acanthuridae						
Acanthurus blochii	0.0	0.0	7.1	0.0	13.3	0.6
Zebrasoma veliferum	0.0	0.0	0.0	0.0	0.0	0.1
Family Tetraodontidae						
Canthigaster solandri	0.0	0.0	0.0	0.0	6.7	0.2
Total number of individuals	11	4	42	183	15	1149

Table 10. Density (no. /sq m) of fishes observed on transects at Oscar and Papa Wharves, Inner Apra Harbor, Guam. IS = invasive species, M = mid-transect, B = bottom transect, T = top transect.

	Oscar Wharf Transect				Papa Wharf Transect			
Family and Species	M	B	T		M	B	T	
Family Apogonidae								
Apogon lateralis	0	0	0.1	0.1	0	0	0.03	0.03
Apogon leptacanthus	0	0	0	0	0	0	0.01	0.01
Archamia fucata	0	0	0	0	0.01	0	0.06	0.07
Cheilodipterus quinquelineatus	0.01	0.01	0	0.02	0	0	0.09	0.09
Sphaeramia orbicularis	0	0	0.01	0.01	0	0	0	0
Family Carangidae								
Caranx melampygus	0	0	0	0	0.02	0	0	0.02
Caranx sexfasciatus	0	0	0	0	0.13	0	0	0.13
Family Lutjanidae								
Lutjanus fulvus	0	0.01	0	0.01	0.02	0.08	0	0.1
Family Mullidae								
Parupeneus ciliatus	0	0	0	0	0.01	0	0	0.01
Family Chaetodontidae								
Chaetondon bennetti	0	0	0	0	0	0	0.1	0.1
Chaetodon ephippium	0.02	0	0	0.02	0.02	0	0	0.02
Chaetodon ulietensis	0	0.02	0	0.02	0	0	0	0
Chaetodon unimaculatus	0	0	0	0	0	0	0.01	0.01
Chaetodon vagabundus	0.01	0	0	0.01	0	0	0	0
Family Pomacentridae								
Abudefduf sexfasciatus	0	0	0.02	0.02	0	0	0	0
Amblyglyphididon curacao	0.01	0	0	0.01	0	0	0	0
Amblyglyphididon ternatensis	0.01	0	0	0.01	0.5	0	0.47	0.97
Chromis viridis	0	0	0.12	0.12	0.98	0	10.15	11.13
Dascyllus aruanus	0	0	0	0	0	0	0.14	0.14
Neoglyphididon violescens	0	0	0	0	0	0	0.01	0.01
Pomacentrus amboinensis	0.03	0	0.1	0.13	0.02	0.02	0.04	0.08
Pomacentrus pavo	0.02	0	0.04	0.06	0	0.01	0.06	0.07
Family Labridae								
Halichoeres trimaculatus	0	0	0	0	0	0	0.03	0.03
Family Labridae: Scarinae								
Chlorurus sordidus juv	0	0	0	0	0	0	0.04	0.04
Leptoscarus vaigiensis juv	0	0	0	0	0	0	0.06	0.06
Family Callionymidae								
Dactylopus dactylopus	0	0	0	0	0	0.01	0	0.01
Family Gobiidae								
Amblygobius phaelena	0	0	0	0	0	0	0	0
Asterropteryx semipunctatus	0	0	0	0	0	0	0.01	0.01
Eviota punctulata	0	0	0	0	0.02	0	0	0.02
Eviota sp.	0	0	0	0	0.03	0	0.08	0.11
Exyrias bellissmus	0	0	0	0	0.01	0	0	0.01
Oplopomus oplopomus	0	0	0	0	0.06	0	0	0.06

Table 10. Continued.

Family and Species	Oscar Wharf Transect M	B	T		Papa Wharf Transect M	B	T	
Family Acanthuridae								
Acanthurus blochii	0	0	0.03	0.03	0	0.02	0.07	0.09
Zebrasoma veliferum	0	0	0	0	0	0	0.01	0.01
Family Tetraodontidae								
Canthigaster solandri	0	0	0	0	0	0.01	0.02	0.03
Total density of all fishes	0.11	0.04	0.42	0.57	1.83	0.15	11.49	13.47

attributed to the presence of seemingly unusual species (i.e., butterflyfishes normally seen in clear or less-turbid reef systems) associated with structure on some transects or the simple absence of most species, other than some burrowing gobies, on others (i.e., bottom transects).

Essential Fish Habitat

Overall, both wharf faces provided some considerable habitat for most species of fishes observed compared to the harbor floor offshore from the wharves (Table 11). Microhabitats associated with wharves included coral, debris, and shells that were attached to a wharf, the wharf wall and associated structures (pilings, fenders, pipes, zinc electrodes, etc.), debris, and silt at the base of the wharf wall, and the water column directly adjacent to the wharf. Most species were associated with one or more of these microhabitats. Benthic species such as cardinalfishes (Apogonidae), damselfishes (Pomacentridae), and gobies (Gobiidae) favored corals, debris, shells, soft corals, and the wharf wall and pilings. Species that were active swimmers, such as butterflyfishes (Chaetodontidae), a snapper (Lutjanidae), a surgeonfish (Acanthuridae), trevallys and jacks (Carangidae), etc., were found in the water column directly adjacent to the wharves. Burrowing gobies and a dragonet (Callionymidae) were found on the silt bottom.

Threatened and Endangered Species

High turbidity levels at Oscar and Papa Wharves, as with elsewhere within Inner Apra Harbor (Smith et al., 2008), limited visibility (<5 m) prevented the detection of highly motile species, especially vertebrate organisms. No threatened or endangered species were observed at either of these survey sites.

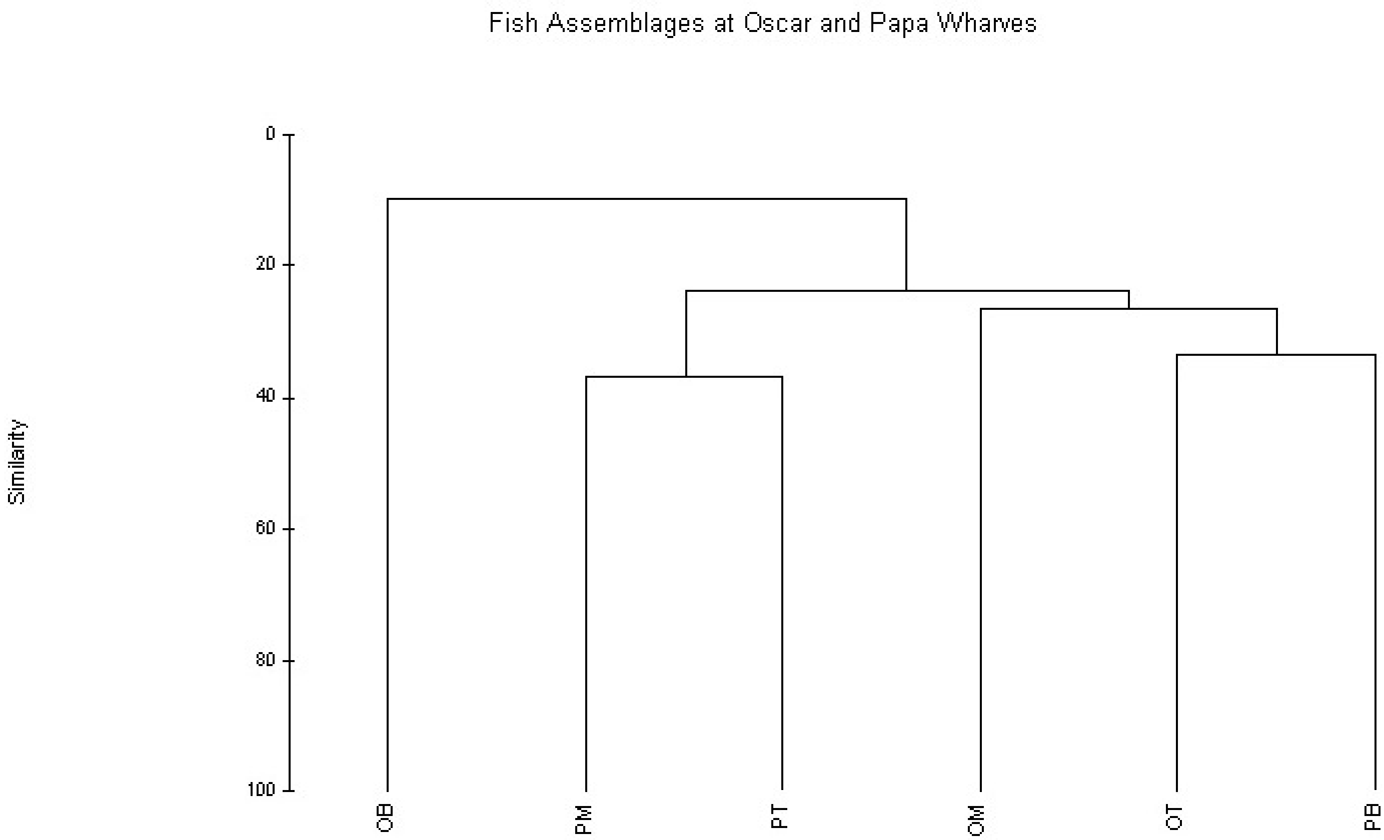

Figure 3. Cluster analysis of similarity between fish assemblages on transects at Oscar and Papa Wharves. See Table 7 for station definitions.

Fish Assemblages at Oscar and Papa Wharves

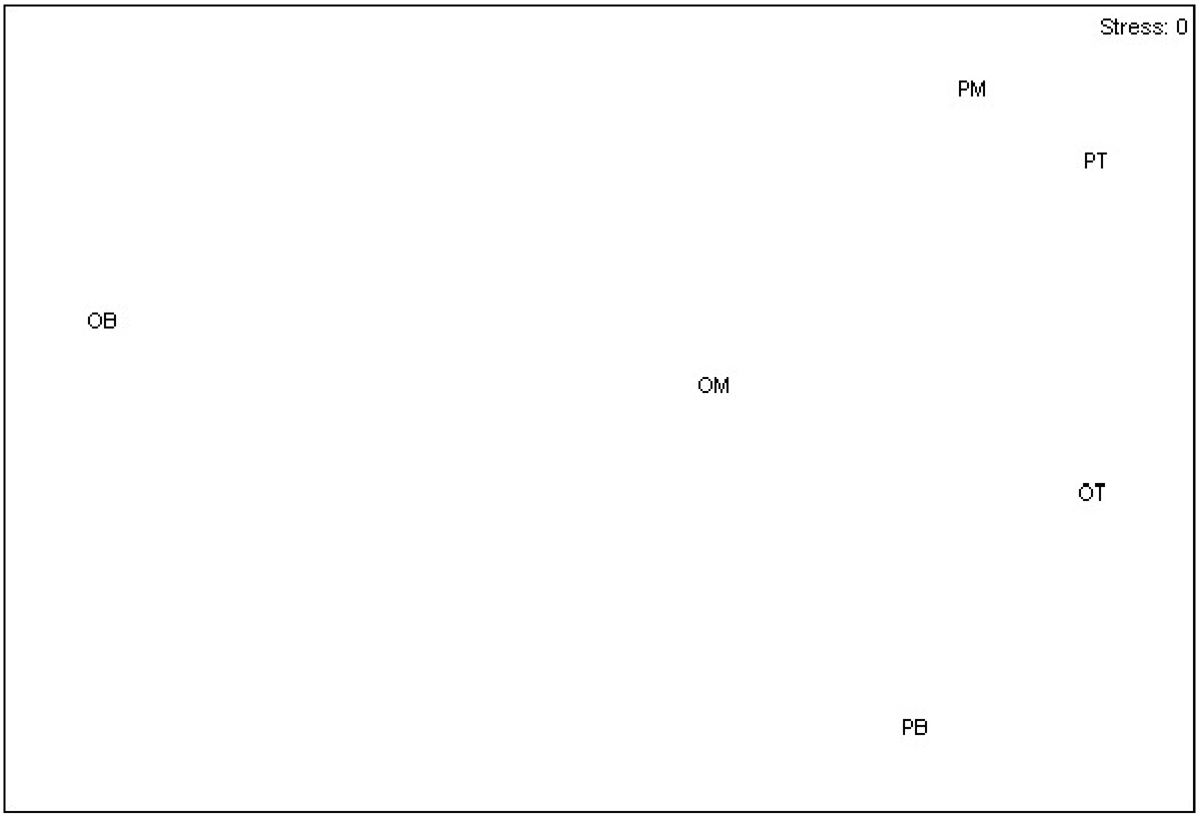

Figure 4. Multiple dimensional scaling (MDS) analysis of fish assemblages observed on transects at Oscar and Papa Wharves. See Table 7 for station definitions.

Table 11. Habitat and microhabitat associations of fishes observed at Oscar and Papa Wharves, Inner, Apra Harbor, Guam. Station codes are defined in Table . Habitat codes are W = wharf, B = soft , bottom. Microhabitat codes are c = coral, sh = shell, d = debris, st = silt, and wc = water column.

	Oscar Wharf Transect			Papa Wharf Transect			
Family and Species	M	B	T	M	B	T	
Family Apogonidae							
Apogon lateralis	0	0	Wc	0	0	Wc	
Apogon leptacanthus	0	0	0	0	0	Wc	
Archamia fucata	0	0	0	Wc	0	Wc	
Cheilodipterus quinquelineatus	1	1	0	0	0	Wc	d
Sphaeramia orbicularis	0	0	1	0	0	0	
Family Carangidae							
Caranx melampygus	0	0	0	Wwc	0	0	
Caranx sexfasciatus	0	0	0	Wwc	0	0	
Family Lutjanidae							
Lutjanus fulvus	0	1	0	Wwc	Wwc	0	
Family Mullidae							
Parupeneus ciliatus	0	0	0	Wc	0	0	
Family Chaetodontidae							
Chaetondon bennetti	0	0	0	0	0	Wc	
Chaetodon ephippium	Wwc	0	0	Wwc	0	0	
Chaetodon ulietensis	0	Wwc	0	0	0	0	
Chaetodon unimaculatus	0	0	0	0	0	Wwc	
Chaetodon vagabundus	Wwc	0	0	0	0	0	
Family Pomacentridae							
Abudefduf sexfasciatus	0	0	Wc	0	0	0	
Amblyglyphididon curacao	Wc	0	0	0	0	0	
Amblyglyphididon ternatensis	Wc	0	0	Wc	0	Wc	d
Chromis viridis	0	0	Wc	d	98	0	Wcd
Dascyllus aruanus	0	0	0	0	0	Wc	sh
Neoglyphididon violescens	0	0	0	0	0	Wsh	
Pomacentrus amboinensis	Wc	sh	0	Wc	2	Wd	Wsh
Pomacentrus pavo	Wc	0	Wc	0	Wd	Wc	
Family Labridae							
Halichoeres trimaculatus	0	0	0	0	0	Wd	
Family Labridae: Scarinae							
Chlorurus sordidus juv	0	0	0	0	0	Wd	
Leptoscarus vaigiensis juv	0	0	0	0	0	Wd	
Family Callionymidae							
Dactylopus dactylopus	0	0	0	0	Bst	0	
Family Gobiidae							
Amblygobius phaelena	0	0	0	0	0	0	
Asterropteryx semipunctatus	0	0	0	0	0	Wc	
Eviota punctulata	0	0	0	Wc	0	0	
Eviota sp.	0	0	0	Wc	sh	0	Wc
Exyrias bellissmus	0	0	0	0	Bst	0	
Oplopomus oplopomus	0	0	0	0	Bst	0	

Table 11. Continued.

Family and Species	Oscar Wharf Transect M	B	T	Papa Wharf Transect M	B	T
Family Acanthuridae						
Acanthurus blochii	0	0	Wwc	0	Wwc	Wwc
Zebrasoma veliferum	0	0	0	0	0	Wwc
Family Tetraodontidae						
Canthigaster solandri	0	0	0	0	Wc	Wc

Habitat Areas of Particular Concern (HAPC)

None of the three areas of Apra Harbor recognized by Paulay et al. (2001a) for their species richness and unique biota are encompassed by Oscar or Papa Wharves within the Inner Apra Harbor. These authors described the inner harbor as the most altered area with Apra Harbor, while remarking on the presence of uncommon species, such as *Porites convexa*, and the abundance of the hammer oyster *Malleus decurtatus* on wharf faces. Inner Apra Harbor lies at the extreme end of the gradient of increasing turbidity, abundance of plankton and benthic suspension feeders, and finer sediments. The harbor continues to support thriving marine communities, despite the extensive dredging and filling operations that significantly altered the area after World War II.

SUMMARY

As shown in a previous study (Smith et al., 2008), the artificial and most anthropogenically-impacted habitats, wharves, might contribute most to the biotic richness and diversity of the inner harbor. The synoptic account of the benthic invertebrates is indicative of unique benthic fauna, especially so for the sponges. Hence, more extensive taxonomic surveys are warranted to assess the biological value of the inner harbor, as well as its potential as an area for potential establishment of invasive species.

The coral fauna of the study area consisted of 19 species of scleractinian corals, and an additional two taxa including a stony hydrozoan, and an octocoral. The predominant corals were *Pocillopora damicornis*, *Porites lobata,* and *Leptastrea purpurea.* The coral assemblage in Inner Apra Harbor is characteristic of environments with high levels of sedimentation and turbidity, with the most common species, in order of tolerance to these conditions, being *Porites lutea*, *Pocillopora damicornis*, and *Leptastrea purpurea* (Amesbury et al., 1977). Coral species richness is highest on relatively sediment-free, hard substrates on vertical faces of wharves (Smith et al., 2008; this report).

Macroinvertebrates communities on the vertical surfaces of Oscar and Papa Wharves were only moderately diverse, with species observed on or near transects. This pattern is consistent with that reported for similar localities within the inner harbor (Smith et al., 2008). For corals, availability of sediment-free hard substrate for sessile and sedentary macroinvertebrates is a limiting factor on horizontal surfaces. Macroinvertebrate assemblages on both wharves were dominated by suspension feeding species, which comprised 100% of the species occurring on transects and 90% of all species observed.

The species richness and diversity of the fish faunas of Oscar and Papa Wharves, like elsewhere in the inner harbor (Smith et al., 2008), are relatively low compared to habitats elsewhere on Guam (Donaldson, unpublished data). These faunas are highly adapted and representative of protected and turbid habitats usually associated with mangroves, estuaries, and back reefs, with some exceptions. A considerable amount of habitat is provided by artificial shelter in the form of wharves and jetsam and debris (pilings, frames, storage units, etc.), and the microhabitats found on or adjacent to these were utilized by many species of fishes. Larval fishes of these species could have settled and recruited to these habitats and microhabitats, either through natural stochastic processes or by transport (i.e., bilge water), and became established at each of the wharves. Many of the individuals of these species were juveniles or subadults. Alternatively, some species, particularly those that swim actively in the water column, may have colonized these habitats as adults after swimming to them from outside of the inner harbor.

RECOMMENDATIONS

During the planning phase for construction and renovation of facilities at Oscar and Papa Wharves, the following recommendations should be given consideration.

1. Floating turbidity curtains, extending from the surface to the lagoon floor, should be placed completely around all dredge and fill sites, and turbidity curtains should be routinely monitored and maintained to contain silt produced by construction.

Dredge and fill operations produce large quantities of fine silt particles suspended in the water column. Turbidity and sedimentation are significant problems for coral reefs surrounding high islands or in coastal areas of continents. Sediments may have an energetic cost to the coral that must cleanse its surface, resulting in slower growth rates and in less energy available for reproduction (Tomascik and Sander, 1987; Wolanski et al., 2003). Sediments can also interfere with larval recruitment on coral reefs by interfering with the chemosensory ability of coral larvae seeking the appropriate chemical signals from preferred settlement substrates, such as coralline algae (Richmond, 1997). Turbidity curtains can be effective in confining suspended sediments when properly deployed and maintained. Removal of the turbidity barriers and the related components is vital once the project activities are complete. Failure to do so can cause the barrier to come loose from its anchors and entangle benthic and other marine organisms (PBS&J, 2008).

2. All dredge and fill operations should be suspended during the period of the annual coral spawning event in Guam waters.

Some 85% of reef-building corals are spawners, i.e., reproduction occurs after the release of gametes into the water, where fertilization takes place (Richmond, 1997). Multispecies mass-spawning events occur during limited periods each year. To maximize reproductive success, most spawning species release their gametes over a 5–8-day period that is related to the lunar cycle. Studies in Guam revealed that peak spawning occurs 7–10 days after the full moon in July (Richmond and Hunter, 1990). Because suspended sediments may interfere with egg-sperm interactions in the fertilization process (Richmond, 1997; Wolanski et al., 2003), dredge and fill operations can affect coral reproduction on reefs far down current of the actual construction activities.

Construction windows are a management tool to map out the times of year during which coastal construction may be limited due to the presence of threatened or endangered species or other sensitive marine life (PBS&J, 2008). Construction windows may consider wildlife activity such as coral spawning and coral bleaching. U.S. Army Corps of Engineers permits for maintenance dredging of the Naval Base require that dredging operations cease during annual coral spawning periods in Guam (M.E. Guarin, P.E., Construction Management Engineer, NAVFAC OICC Marianas, personal communication, April 27, 2004).

3. Marine biological communities should be monitored during and after dredge and fill operations at Oscar and Papa Wharves.

Monitoring studies on small, tropical islands have shown that precautions for environmental protection can limit the effects of dredge and fill operations on nearby marine communities. Amesbury et al. (1982) identified few measurable effects related to construction of the airport runway extension at Weno Island, Chuuk [= Moen Island, Truk]. However, these authors reported that fluctuations in species richness, percent cover, and population density of several taxa occurred during the construction period. Where siltation was heaviest, the decline in coral coverage was significant, and no evidence of new coral recruitment was found one year after the completion of runway construction. Marine plants, macroinvertebrates, and reef fishes also declined at those monitoring stations that were inundated with sediments.

Biological monitoring should be required for any project that is proposed for construction in Oscar and Papa Wharves, so that any damage to coral communities along vertical surfaces caused by sedimentation can be identified promptly and so that necessary measures can be taken to minimize any damage. Monitoring is necessary to determine any direct or indirect biological impacts to the ecosystem caused by physical and/or chemical changes to the environment as a result of the project.

4. Invasive species should be monitored.

Because invasive species have been detected on both wharves, and on others surveyed previously (Smith et al., 2008), monitoring studies should emphasize early detection and eradication/management of invasive species and the possible expansion of their ranges locally.

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MARINE BIOLOGICAL SURVEYS OF SELECTED SITES ADJACENT TO NAVAL LANDS IN GUAM, MARIANA ISLANDS

by

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April 2010

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Finally, we are especially grateful for the guidance provided by Dr. Mark Moese of Earth Tech, Inc. for acting as our liaison and project coordinator. His guidance and patience made the project possible.

INTRODUCTION

The planned relocation of elements of the Marine Expeditionary Force (MEF) from Okinawa to Guam by the U.S. Marine Corps will require renovation of existing port facilities to accommodate MEF embarkation, as well as construction of various new operations facilities in support of the MEF mission. Furthermore, new training areas and associated facilities are proposed for selected areas on Guam. These developments require extensive surveys that locate, identify, and assesses the natural resources of Guam at four sites: Tipalao and Dadi reefs, south of Orote Peninsula; the shallow channel adjacent to Pol Causeway in Piti, and the landward corner of Polaris Point in Inner Apra Harbor.

Scope of Work

The University of Guam Marine Laboratory was contracted to perform a study of marine communities at selected sites adjacent to Navy lands in Guam (Figure 1) .

The specific objectives of the study were:

- Quantitative assessments of corals
- Quantitative assessment of select macroinvertebrates
- Fish census
- Assessment of endangered species (both federally listed, proposed for listing, and candidate species and those similarly listed or otherwise recognized by Guam) to include abundance and preferred habitat, if any
- Survey areas will be subjectively evaluated using the four criteria for Habitat Areas of Particular Concern (HAPC):
    1. the ecological function provided by the habitat is significant;
    2. the habitat is sensitive to human-induced environmental degradation;
    3. development activities are, or will be, stressing the habitat type; and
    4. the habitat is rare

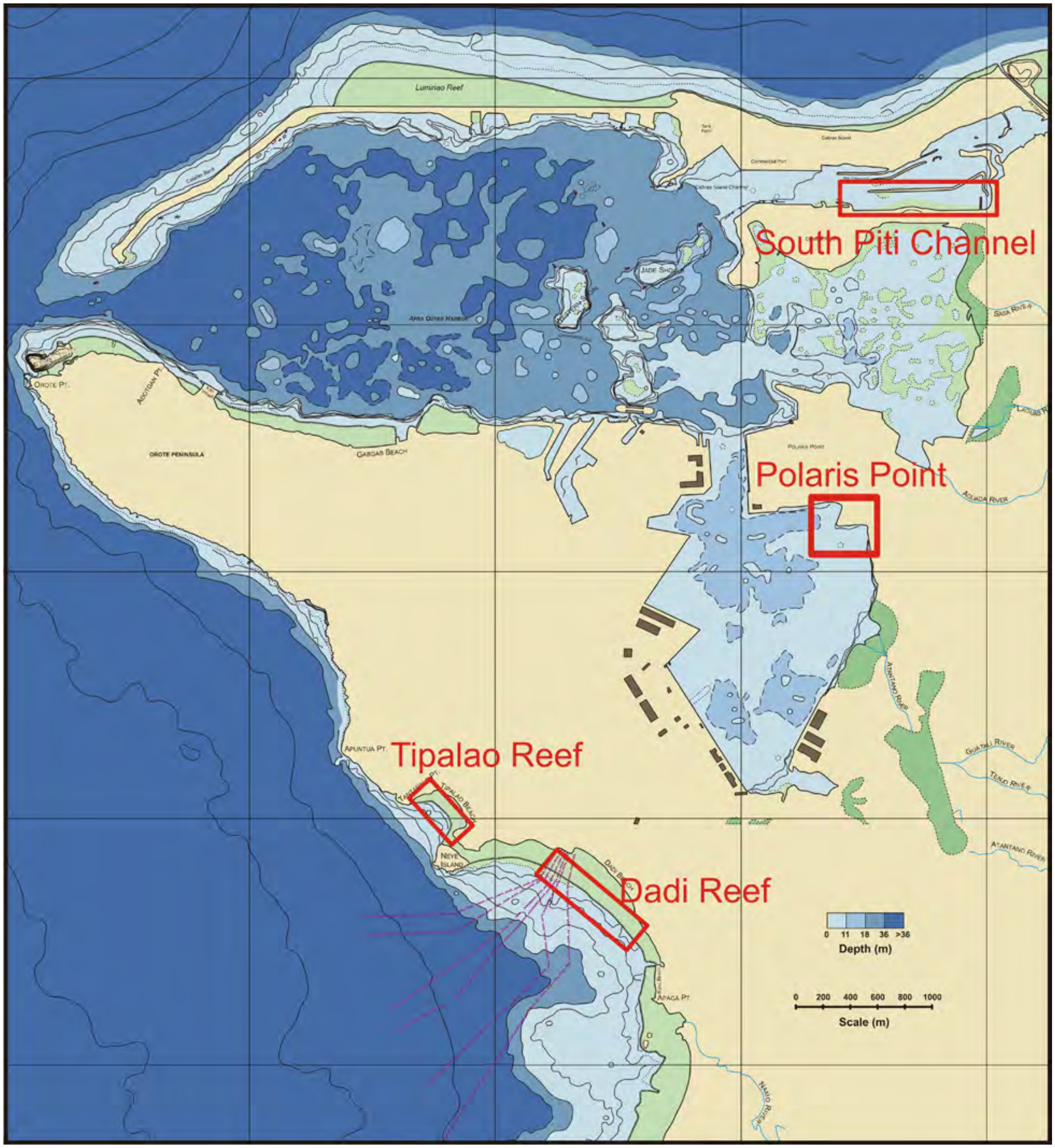

Figure 1. Map of Apra Harbor and environs showing locations of reefs and marine areas surveyed in the present report. Map is adapted from NOAA Nautical Chart #81054 (2003).

- Prepare a technical report on fishes, corals, macroinvertebrates, macrophytes, essential fish habitat evaluation, and assessment of endangered species.
- Attend project team meetings/conferences calls.

Data from the survey are expected to serve as a guide for decisions affecting land and coastal use for proposed construction and renovation of facilities and training sites on Department of Defense and contractor-controlled lands in Guam.

Site Descriptions

Tipalao Reef

Tipalao Reef is a narrow fringing reef at the southern margin of Orote Peninsula (Figure 2). The reef flat is some 375 m in length and averages some 100 m in width, covering about 48,300 m^2 in area. Tipalao Beach is bordered on the north by a steep-sloped limestone cliff and a small limestone peninsula and a rocky islet, Neye Island, on the south side. Neye Island and the north side of Tipalao Bay are both about 18 m high. Unconsolidated beach deposits and beach rock border the shoreline at Tipalao Beach.

This reef suffered heavy damage during a population irruption of the crown-of-thorns starfish *Acanthaster planci* that persisted from 1970 to 1974 (Tsuda, 1970; Randall and Holloman, 1974). The density of starfishes ranged from 1.0/m^2 to 1.0/100 m^2 during this period.

Dadi Reef

In general, the reef-flat platform is wider along the low coastal plain at Dadi Beach (Figure 3). The reef flat stretches some 963 m in length, and it narrows from more than 250 m in width at the north end to about 100 m at the south end, averaging some 165 m in width. The total area covered by the reef flat is about 166,380 m^2.

Beach deposits dominate the shoreline at Dadi Beach. Emery (1962) reported that beach samples along this part of the coast have a non-bioclastic fraction ranging from 2–39 %. The submarine terrace consists of extensive sand-floored areas with intermittent, irregular rocky zones (see Burdick, 2005). Several small patch reefs extend to the low-tide surface opposite the reef margin at Dadi Beach. The reef margin and reef front zones near these patch reefs consist of rich coral growth (Randall and Holloman, 1974). The submarine buttress-and-channel development along the reef front zone contains a margin of coral pinnacles, knobs, and bosses.

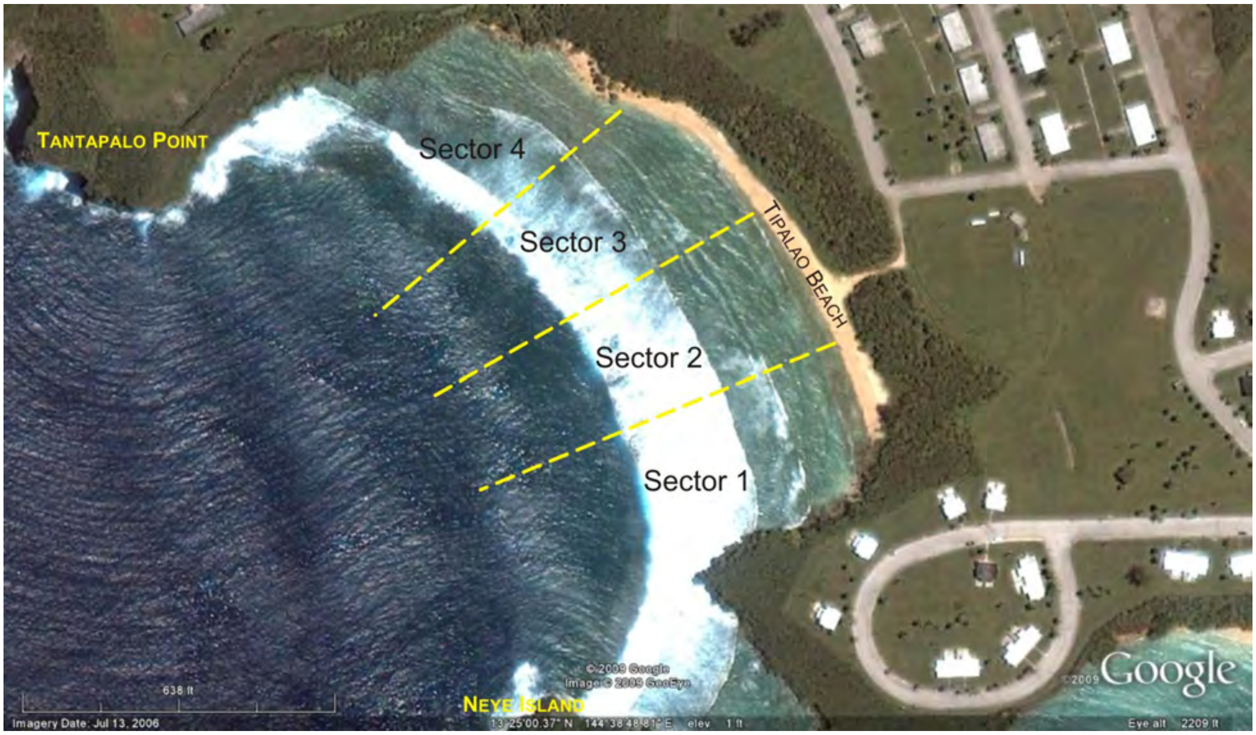

Figure 2. Satellite image of Tipalao Reef showing division of the reef into four sectors for purposes of this survey. Image source: Google Earth.

Figure 3. Satellite image of Dadi Reef showing division of the reef into four sectors for purposes of this survey. Image source: Google Earth.

Figure 4. Satellite image of the south Piti Channel showing division of the channel into four sectors plus a fifth sector at the mouth of the channel. Image source: Google Earth.

Of particular note are large colonies of the blue coral *Heliopora coerulea*, and many rounded, pink-colored clumps of ramose coralline algae up to some 1.0 m in diameter.

South Piti Channel

South Piti Channel (Figure 4) is a narrow, shallow-water area partially enclosed by a series of causeways and small elongated islets on the north and by the Pol Causeway (often called Dry Dock Peninsula) on the south. This channel is some 750 m length, with its eastern one-third averaging 94 m in width and its western end averaging 129 m in width. The channel floor covers an area of about 211,000 m^2.

The shoreline in this area was extensively modified by construction and land-filling activities on a shallow reef-flat platform after World War II (Randall and Holloman, 1974; Paulay et al., 2001). Pol Causeway is developed extensively at its western end, but much of the shoreline along the remainder of the landfill has been colonized by mangroves and scrub vegetation on the north side and by mangroves on the south side.

Polaris Point

The area for the proposed AAVR at Polaris Point (Figure 5) is characterized by a shallow, narrow shelf with little to no intertidal reef flat development. The shelf is generally <5 m in width and extends some 200 m in length. The depth increases abruptly from <2 m at the outer edge of the shelf to some 12 m on the harbor floor.

Like Pol Causeway, Polaris Point was constructed by land-filling activities on shallow fringing reefs of Apra lagoon following World War II (Randall and Holloman, 1974; Paulay et al., 2001). The western end of Polaris Point is extensively developed by the U. S. Navy, but eastern end is presently unused. The largest expanse of mangrove community in Guam is found along the landward side of inner Apra Harbor (Randall and Holloman, 1974). Examination of this community shows that it is in a stage of accretional development in many areas that were previously disturbed, especially along the land-filled regions of Polaris Point. Randall and Holloman (1974) reported that the subtidal parts of Apra Harbor support a rich and varied biocoenosis of marine life although there has been considerable alteration of the shoreline and lagoon floor.

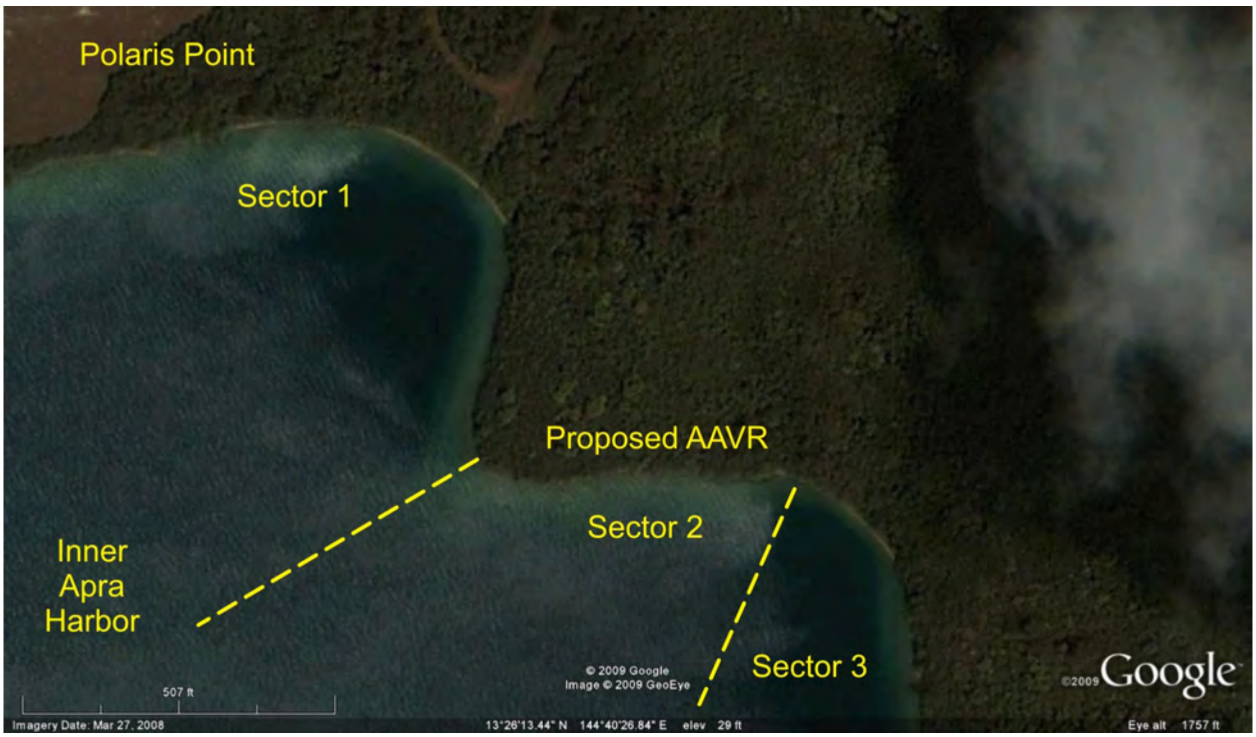

Figure 5. Satellite image of the southeastern coast of Polaris Point showing division of the reef into three sectors for purposes of this survey. Image source: Google Earth.

METHODS

Each of the four study sites was subdivided into sectors that were sampled along 50-m belt transects established parallel to the shore. Tipalao and Dadi reefs (Figures 2 and 3) were subdivided into four sectors each, and each sector was further subdivided into middle reef flat (MRF), outer reef flat (ORF), shallow reef front (6-m depth), and deeper reef front (12-m depth). South Piti Channel (Figure 4) was subdivided into four sectors plus an additional sector at the mouth of the channel; replicate 50-m transects were established in each sector. Three sectors were sampled along 50-m belt transects at Polaris Point (Figure 5). The areas immediately north and south of the AAVR were designated as Sectors 1 and 3, respectively, and the area adjacent to the proposed amphibious assault vessel ramp (AAVR) was designated Sector 2. Within each sector, 50-m belt transects were established at depths of 2 m and 4 m.

Benthic Cover

Benthic marine communities and substrate types in each zone were quantified by a modified point-quadrat method (Tsuda, 1972). This method consists of tallying organisms or substrate type under the points of intersection of strings stretched across a 0.25-m^2 (50 cm x 50 cm) quadrat. Four strings stretched from each side of the quadrat provide 16 points of intersection. The quadrat was tossed randomly at 5-m intervals along the length of the transect. Substrate coverage was divided into seven abiotic and biotic features at the sites; organisms or substrate type under the points of intersection were tallied. Thus, the quadrat was tossed a total of 10 times, providing 160 data points on each 50-m transect. Percent cover was calculated from these points. Species within the study area, but not encountered along the transect line, were also recorded.

Corals

Coral communities were assessed quantitatively along the transects by an observer using the point-quarter method of Cottam et al. (1953). Points were assigned at 5-m intervals on each transect. Each point served as a focus of four equal-sized quadrants arrayed around the point. Within each quadrant, the coral closest to the central point was located. This coral's identity, distance from the point, length, and width were recorded. If no coral lay within 1 m of the point, that quadrant was recorded as having no corals. From the recorded data, community and species-specific population density of colonies, percent coverage, and frequency of occurrence were then computed with the following equations from Cottam et al. (1953):

$$\text{Total Density Of All Colonies} = \text{Unit Area} / (\text{Average Point-To-Colony Distance})^2$$

Relative Density Of A Species = 100 * Number Of Colonies Of The Species / Number Of All Colonies
Absolute Density Of A Species = Percent Density * Total Density / 100
Total Percent Coverage Of All Species = Total Density * Average Coverage Of All Species
Relative Coverage Of A Species = Species Density * Average Coverage of the Species

Population data for each species were also calculated, including the number of colonies, average colony size, standard deviation of colony size, and minimum and maximum colony size. To record the less common species not recorded by the quantitative survey, a list of species was also compiled by swimming along the entire transects and recording all species seen within 2 m of the line.

Macroinvertebrates

All conspicuous solitary epibenthic macroinvertebrates occurring within 1 m of either side of the transect lines were identified and enumerated by an observer swimming along the transect line. For harbor floor transects at the proposed AAVR site, species of conspicuous epibenthic macroinvertebrates were recorded within 1 m of an imaginary line in front of an observer swimming over the harbor floor, as described above. For this study, conspicuous is defined as being larger than 50 mm in size and as being clearly visible to an observer without need of overturning rocks or digging into the substrate. Cryptic, microscopic, nocturnal, and highly motile species that avoid humans (e.g., crabs and shrimps) were not included within the scope of this study. Species diversity and abundance were recorded in 10-m intervals along the transect line. Therefore, for statistical purposes, each belt transect consisted of five to ten 20-m^2 replicate plots, except where noted.

Cluster and multidimensional scaling (MDS) analyses of macroinvertebrate data were performed with PRIMER v.6 (PRIMER-E, Ltd., Plymouth, United Kingdom). Similarities in structure of macroinvertebrate assemblages for all transects were calculated by the Bray-Curtis similarity method. The resulting matrix was subjected to cluster analysis (group average method, fourth root-transformed data) and MDS analysis (fourth root-transformed data bootstrapped with n = 100 iterations to investigate relationships between transects (Clarke and Gorley, 2006). Species of macroinvertebrates observed in the study area, but not encountered along the transect line, were also recorded but not included in the similarity analyses.

Fishes

Visual surveys of fishes were conducted by scuba diving or snorkeling, depending upon the location and depth of the transect. Data were recorded on underwater paper by the same diver. Fishes were identified to species and identifications followed Myers (1999) and Myers and Donaldson (2003), except where more recent taxonomic studies were relevant. Reference photographs and video were taken of some fishes with an underwater digital camera or underwater digital video camera, respectively.

Fishes were surveyed along belt transects at predetermined sites after the methods of English et al. (1997). Fishes were surveyed visually along 50-m transects deployed successively in each zone. During the first pass along the transect line, the diver counted larger-sized (ca. > 15 cm TL) species at a fixed distance (ca. 5 m) either side of the transect line. During the second pass, conducted on the return leg, the diver counted territorial benthic (i.e., damselfishes, Pomacentridae) and small-sized (ca. < 15 cm TL) species observed within 1 m of either side of the transect line. At Polaris Point, divers counted fishes observed within 1 m either side of the 50-m transect line during both passes down the line. Because of visibility limits, not all cryptic or diminutive (ca. < 1.5 cm) could be counted.

Analyses

A presence-absence checklist was assembled and calculations of density (number of fish per square meter) of each species were made. Diversity data were analyzed with a multivariate statistics program (PRIMER v.6, PRIMER-E, Ltd., Plymouth, United Kingdom). Comparisons of fish diversity and assemblage structure were made between transects and depths at a given site. PRIMER was used to calculate species richness (the number of species observed per transect), Shannon's H' index of diversity, and assemblage similarity (Bray-Curtis similarity index using fourth root-transformed data). Similarity data were analyzed further with multi-dimensional scaling (MDS) analysis and cluster analysis (group linkage) in order to elucidate relationships between transects. Plots of species richness per transect, the number of fishes observed per transect, Shannon's H' for each transect, and the relationship between species richness and the number of fishes observed were made with SigmaPlot 9.0 (Systat Software, Inc., San Jose, CA 95110).

The collected data provide a baseline that will be useful for subsequent long-term monitoring studies of fish assemblages at these sites.

RESULTS AND DISCUSSION

Field work at these sites was conducted from 24 November 2008 to 7 May 2009. Tipalao Reef was surveyed during the period of November 2008 to February 2009; Polaris Point was surveyed from March to May 2009. South Piti Channel was surveyed in February 2009, and Dadi Reef was surveyed in April 2009.

Tipalao Reef

Benthic Cover

Percent surface coverage of the substrate by seven abiotic and biotic features along 16 transects at Tipalao Reef is presented in Figure 2, and mean coverage in the four physiographic zones is given in Table 1. Limestone pavement and macroalgae were the prominent cover at Tipalao Reef, accounting for more than 65% of the total cover in all zones. Mean live coral cover ranged from about 2% on the middle reef flat to more than 13% on the reef slope at 6 m. Abiotic cover exceeded biotic cover, except on the reef slope at 12 m.

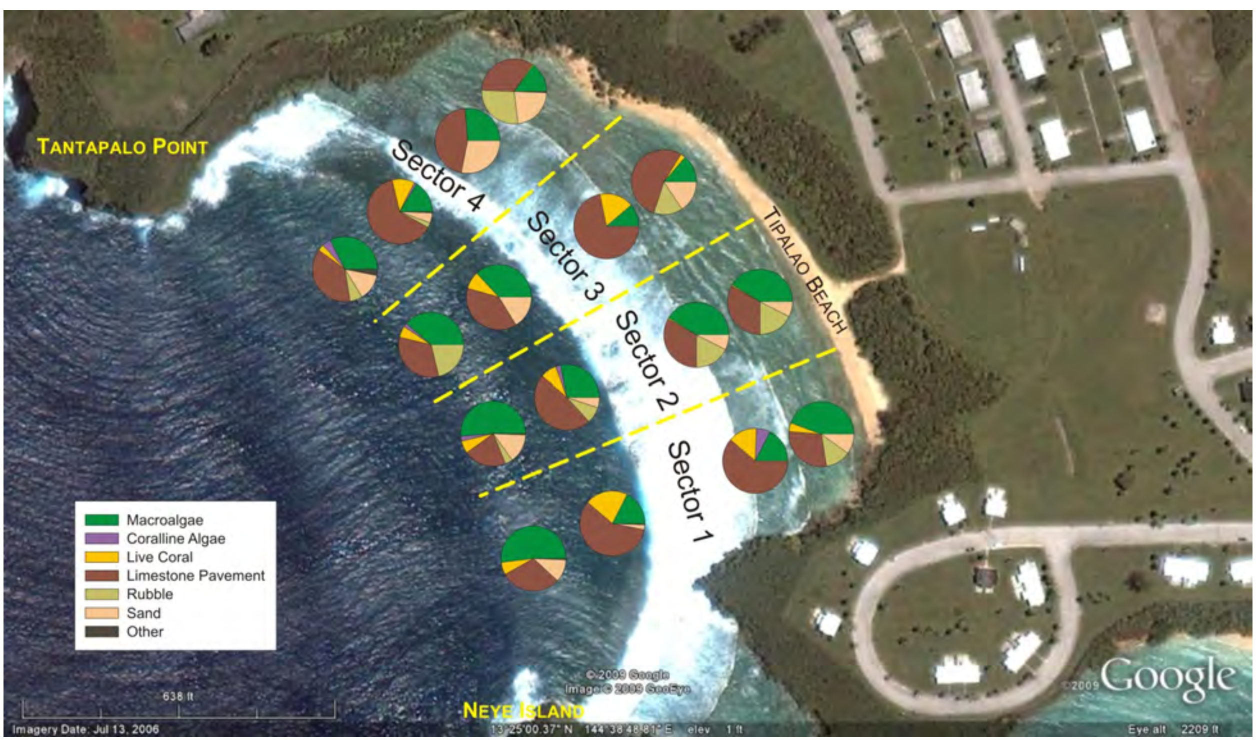

Figure 6. Percent surface coverage of the substrate along transects in four sectors and four reef zones at Tipalao Reef.

Table 1. Mean substrate coverage by physiographic zone at Tipalao Reef. MRF = middle reef flat, and ORF = outer reef flat.

	MRF	ORF	6 m	12 m
Macroalgae	28.59 ± 16.48	20.78 ± 7.86	24.84 ± 10.04	43.59 ± 9.55
Coralline Algae	0.00 ± 0.00	2.34 ± 3.24	0.47 ± 0.60	2.19 ± 1.80
Live Coral	2.03 ± 1.80	9.84 ± 7.52	13.75 ± 5.40	5.31 ± 1.49
Limestone Pavement	37.34 ± 11.16	56.72 ± 12.21	49.53 ± 12.97	30.31 ± 6.80
Rubble	17.97 ± 6.68	9.06 ± 13.27	0.63 ± 1.25	2.50 ± 3.06
Sand	13.91 ± 6.66	1.25 ± 2.50	10.47 ± 7.86	15.00 ± 4.36
Other	0.16 ± 0.31	0.00 ± 0.00	0.31 ± 0.36	1.09 ± 1.39

Bray-Curtis similarity analysis (fourth root-transform, cluster mode: group average) indicated more than 60% resemblance of the benthic cover data across all physiographic zones (Figure 7). Coverage data for the reef flat transects cluster according to the middle reef flat and outer reef flat zones, with the exception of the outer reef flat in Sector 2, which is more similar to the reef front transects. Multidimensional scaling and ordination of the coverage data reveal three clusters with 80% similarity and show considerable overlap of coverage patterns across the physiographic zones (Figure 8). A list of marine plants observed at Tipalao Reef is given in Table 2.

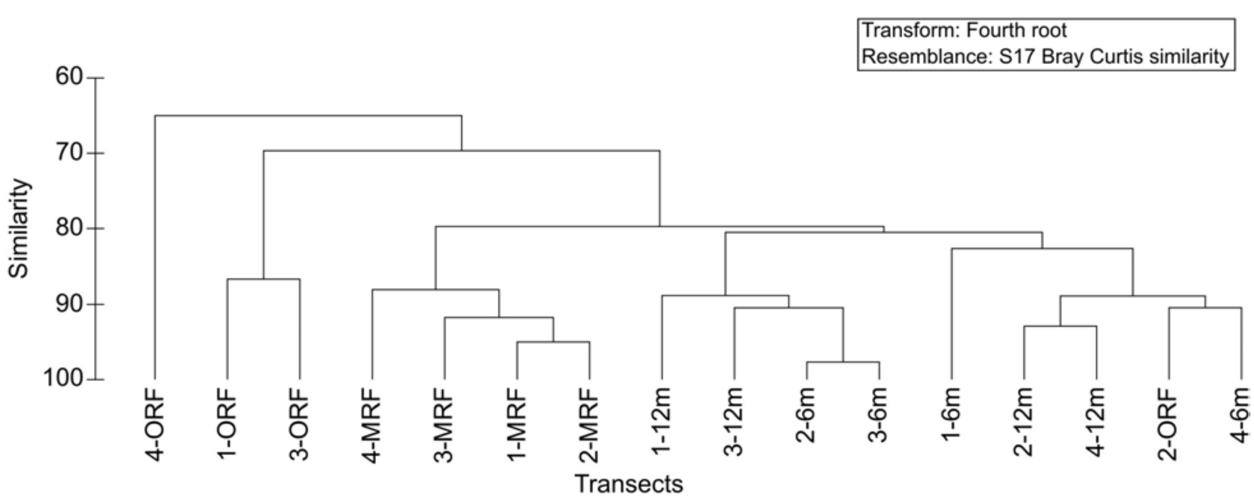

Figure 7. Cluster analysis (group averaging) of benthic cover patterns on transects at Tipalao Reef. Transects are designated by the sector number followed by the physiographic zone.

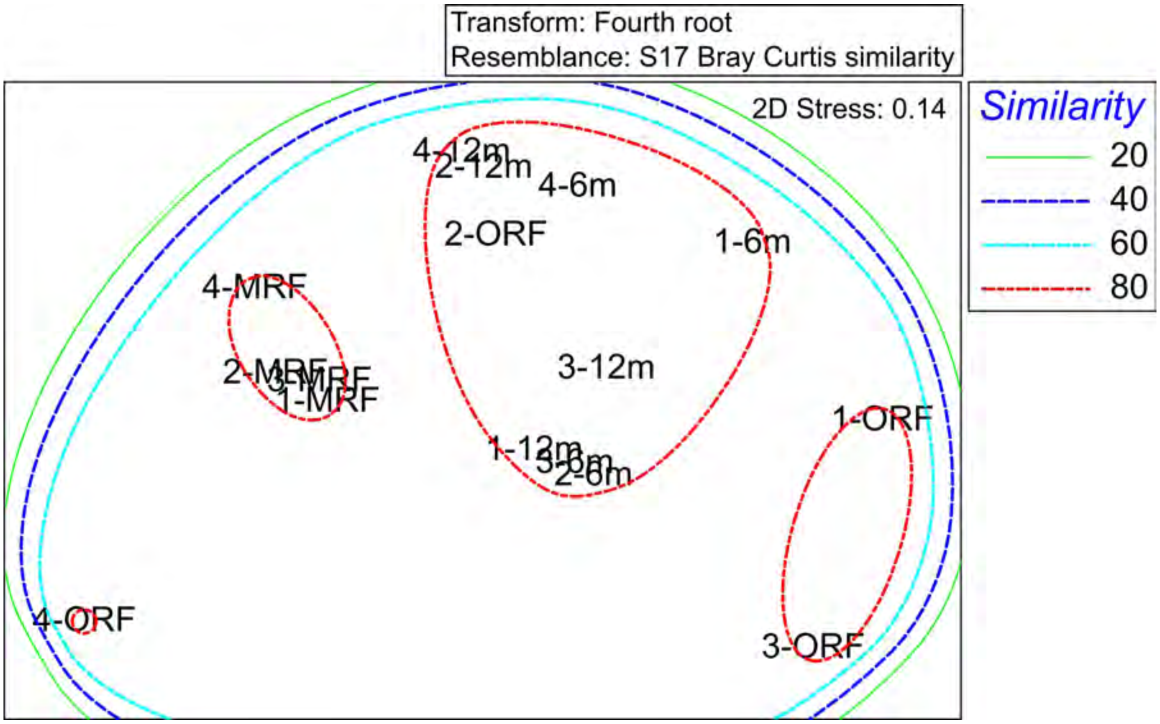

Figure 8.

Figure 8. Multi-dimensional scaling (MDS) analysis of benthic cover at Tipalao Reef. Values indicate the level of similarity between transects. See Figure 7 for transect definitions.

Table 2. Benthic marine plants observed on Tipalao Reef. Checklist of species observed. Phylogenetic arrangement follows Lobban and Tsuda (2003).

	Sector 1				Sector 2				Sector 3				Sector 4			
	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m
Cyanophyta																
Lyngbya majuscula			●				●					●			●	●
Microcoleus sp.									●			●				
Schizothrix calcicola		●					●			●	●	●				
Schizothrix mexicana	●			●				●							●	
Rhodophyta																
Galaxaura round	●	●			●	●			●	●			●	●	●	
Galaxaura flat	●	●			●	●				●	●					●
Gracilaria salicornia	●				●	●			●					●		
Amphiroa spp.	●	●			●	●			●	●	●				●	
Jania spp.	●	●	●		●	●					●	●	●	●		
Lithophyllum spp.	●	●														
Phaeophyta																
Padina boryana		●				●		●	●			●				●
Turbinaria ornata	●	●				●			●	●				●		
Chrysocystis fragilis									●		●				●	●
Chlorophyta																
Boodlea composita									●				●			
Ventricaria ventricosa								●	●		●	●			●	
Bryopsis pennata									●	●						
Caulerpa racemosa	●	●			●	●			●		●					
Caulerpa serrulata	●															
Halimeda discoidea																
Halimeda lichenoides	●	●	●	●	●	●	●	●	●							●
Halimeda opuntia	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●

Table 2, continued.

	Sector 1				Sector 2				Sector 3				Sector 4			
	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m
Halimeda velasquezii			●	●					●		●					●
Halimeda sp.	●	●			●		●									
Chlorodesmis fastigiata	●	●			●	●								●		
Tydemania expeditionis											●					
Neomeris annulata	●			●	●	●	●		●	●	●	●	●			

Corals

Size-frequency distributions of the scleractinian corals encountered on transects at Tipalao Reef are presented in Table 3. The surveyed area included 45 species of scleractinian corals, representing 8 families and 17 genera on the transect lines. This count represents a minimum, because several corals could be identified only to genus in the field and, therefore, may consist of more than one species. Smith et al. (2009) reported 14 species of corals from this site.

Species richness was generally greater on the reef front transects (i.e., 6-m and 12-m depths) than on the reef flat platform, where low tides and wave assault may limit corals. *Leptastrea purpurea* was the most common species, occurring on all transects in all four sectors and zones. *Pocillopora damicornis* and *Porites lutea* were also very common, occurring on 10 of the 16 transects on Tipalao Reef. Sixteen species occurred on only one transect, and 14 of these species were represented by single observations.

Quantitative analysis of the coral species encountered on transects is presented in Table 4. . In Sector 1, *Leptastrea purpurea* had the greatest absolute density on all four transects. The same was true for all four transects in Sector 2. In Sector 3, *Leptastrea purpurea* had the greatest absolute density on the MRF transect; at ORF, *Pocillopora meandrina*; at 6m and 12, *L. purpurea*. In Sector 4, *Leptastrea purpurea* had the greatest absolute density at MRF, ORF and 6m transects; at 12m, *Astreopora myriophthalma* had the greatest absolute density.

Relationships between all sectors and all transects determined by group cluster analysis of Bray-Curtis similarity data are depicted in a dendrogram given in Figure 9. In most cases, reef flat transects clustered separately from reef slope transects. These relationships are further illustrated in the results of the MDS analysis of these similarity (percent) data given in Figure 10. This analysis indicated 15 groups with 60% similarity, with 14 of these being single transects and one with two MRF transects.

Table 3. Size-frequency distributions of coral species recorded on transects at Tipalao Reef. N_i = number of colonies. Mean, SD (standard deviation), and Range refer to colony size in cm^2.

Location	Habitat	Species	N_i	Mean	SD	Range
<u>Sector 1</u>	MRF	*Leptastrea purpurea*	21	8.01	7.69	0.79–28.27
		Pocillopora damicornis	8	258.99	169.87	10.60–518.36
		Porites cylindrica	3	9.62	2.38	8.25–12.37
		Pocillopora verrucosa	3	122.91	160.40	21.99–307.88
		Pavona varians	2	19.05	11.94	10.60–27.49
		Pocillopora meandrina	1	–	–	71.47
		Favia matthaii	1	–	–	100.53
		Porites lutea	1	–	–	11.00
	ORF	*Leptastrea purpurea*	10	11.27	5.50	1.57–18.85
		Pocillopora verrucosa	6	71.86	78.83	14.14–226.98
		Pocillopora meandrina	4	224.28	123.25	42.41–302.38
		Porites lutea	3	248.97	206.79	127.23–487.73
		Galaxea fascicularis	3	72.13	56.91	39.27–137.84
		Porites lobata	2	79.33	92.75	13.74–144.91
		Pocillopora damicornis	2	286.67	404.30	0.79–572.56
		Montastrea curta	2	21.21	0.00	–
		Porites rus	2	142.94	0.00	–
		Pavona varians	2	89.54	0.00	–
		Acropora spp.	2	16.49	0.00	–
		Leptoria phrygia	1	–	–	9.42
		Acropora monticulosa	1	–	–	168.47
	6 m	*Leptastrea purpurea*	14	17.73	19.68	4.71–78.25
		Montipora elschneri	7	41.09	54.56	6.87–157.08
		Montipora tuberculosa	3	20.20	10.26	9.33–29.72
		Porites spp.	3	225.57	205.21	41.73–446.97
		Montipora hoffmeisteri	3	28.67	25.00	8.25–56.55
		Porites lutea	2	44.18	0.00	–
		Pavona varians	1	–	–	23.12
		Pocillopora damicornis	1	–	–	82.69
		Acanthastrea echinata	1	–	–	6.15
		Astreopora myriophthalma	1	–	–	55.61
		Favites abdita	1	–	–	16.49
		Acropora granulosa	1	–	–	45.95
		Porites lobata	1	–	–	188.50
		Montipora grisea	1	–	–	42.41
	12 m	*Leptastrea purpurea*	11	15.32	12.32	5.92–44.06
		Astreopora myriophthalma	9	10.62	8.57	1.96–28.08
		Porites spp.	4	22.29	16.20	4.08–38.41
		Astreopora randalli	3	48.97	7.86	43.42–57.96
		Montipora grisea	2	105.54	121.49	19.63–191.44
		Pavona varians	2	59.81	15.38	48.94–70.69
		Leptastrea transversa	1	–	–	28.42
		Diploastrea heliopora	1	–	–	39.58
		Favia pallida	1	–	–	11.22

Table 3, continued.

Location	Habitat	Species	N_i	Mean	SD	Range
		Montipora foveolata	1	–	–	65.60
		Montipora verrilli	1	–	–	28.48
		Porites lobata	1	–	–	13.74
		Pocillopora verrucosa	1	–	–	146.87
		Favia matthaii	1	–	–	17.28
		Astreopora listeri	1	–	–	4.71
Sector 2	MRF	*Leptastrea purpurea*	14	3.86	3.11	0.59–12.57
		Pocillopora damicornis	13	113.66	151.02	7.07–395.84
		Pocillopora verrucosa	5	52.07	27.46	25.53–88.36
		Pocillopora meandrina	2	142.94	0.00	–
	ORF	*Leptastrea purpurea*	15	4.96	3.68	1.18–11.78
		Goniastrea retiformis	9	602.23	180.42	345.58–829.38
		Favia matthaii	4	61.46	46.82	7.07–100.53
		Pocillopora verrucosa	3	96.87	40.36	50.27–120.17
		Pocillopora damicornis	3	25.39	26.09	1.18–53.01
		Pocillopora meandrina	2	219.91	0.00	–
		Stylocoeniella armata	1	–	–	7.85
		Leptoria phrygia	1	–	–	2.36
		Porites lutea	1	–	–	420.58
	6 m	*Leptastrea purpurea*	20	18.66	18.27	1.96–81.04
		Montipora hoffmeisteri	5	9.03	5.99	3.93–15.71
		Montipora grisea	4	19.59	8.96	14.51–32.99
		Goniastrea pectinata	1	–	–	27.36
		Montipora danae	1	–	–	37.36
		Pocillopora damicornis	1	–	–	34.75
		Goniastrea edwardsi	1	–	–	80.11
		Porites spp.	1	–	–	9.42
		Montipora tuberculosa	1	–	–	83.08
		Favites abdita	1	–	–	22.38
		Stylocoeniella armata	1	–	–	18.85
		Montipora elschneri	1	–	–	37.31
		Favia favus	1	–	–	2.36
		Cyphastrea agassizi	1	–	–	23.56
	12 m	*Leptastrea purpurea*	16	14.28	10.05	1.96–37.70
		Astreopora randalli	4	44.95	33.41	8.77–93.93
		Porites spp.	3	21.54	12.68	10.41–35.44
		Montipora hoffmeisteri	3	13.79	13.23	2.36–28.27
		Montipora verrucosa	2	43.76	44.39	12.37–75.15
		Montipora grisea	2	12.66	11.25	4.71–20.62
		Astreopora myriophthalma	2	34.56	17.77	21.99–47.12
		Montipora tuberculosa	1	–	–	23.63
		Astreopora listeri	1	–	–	14.14
		Pavona varians	1	–	–	10.72
		Favia pallida	1	–	–	13.57

Table 3, continued.

Location	Habitat	Species	N_i	Mean	SD	Range
		Favia matthaii	1	–	–	10.74
		Porites cylindrica	1	–	–	4.71
		Favites abdita	1	–	–	5.50
		Porites lutea	1	–	–	12.57
Sector 3	MRF	*Leptastrea purpurea*	18	7.34	6.14	1.96–27.49
		Pocillopora damicornis	12	29.19	47.37	0.79–168.47
		Pocillopora verrucosa	7	40.45	25.04	10.60–67.15
		Pocillopora meandrina	1	–	–	293.74
	ORF	*Pocillopora meandrina*	15	172.54	128.46	11.78–452.39
		Leptastrea purpurea	9	7.66	7.28	2.36–24.74
		Pocillopora verrucosa	6	72.94	53.07	15.12–131.95
		Porites lutea	3	197.13	303.24	3.93–546.64
		Acropora granulosa	1	–	–	51.05
		Pavona varians	1	–	–	88.36
		Montastrea curta	1	–	–	8.84
		Galaxea fascicularis	1	–	–	13.74
		Stylocoeniella armata	1	–	–	3.93
		Porites lobata	1	–	–	5.89
		Pocillopora damicornis	1	–	–	5.50
	6 m	*Leptastrea purpurea*	22	9.38	9.43	0.79–41.23
		Porites lutea	4	11.49	6.69	7.07–21.21
		Montipora ehrenbergii	4	16.00	2.15	14.14–17.87
		Montipora hoffmeisteri	3	5.76	0.45	5.50–6.28
		Pocillopora verrucosa	2	20.03	10.55	12.57–27.49
		Acropora spp.	1	–	–	7.85
		Favia stelligera	1	–	–	1.96
		Favites russelli	1	–	–	10.60
		Favia matthaii	1	–	–	6.87
	12 m	*Leptastrea purpurea*	17	7.15	5.32	1.57–20.03
		Astreopora myriophthalma	9	32.20	31.25	7.07–104.46
		Porites lutea	3	79.06	127.44	3.14–226.19
		Montipora tuberculosa	2	35.34	0.00	–
		Astreopora gracilis	2	21.01	10.27	13.74–28.27
		Favia pallida	2	21.01	20.83	6.28–35.74
		Montipora verrucosa	1	–	–	14.14
		Favites abdita	1	–	–	37.70
		Montipora grisea	1	–	–	206.17
		Pocillopora verrucosa	1	–	–	27.49
		Astreopora listeri	1	–	–	32.99
Sector 4	MRF	*Leptastrea purpurea*	30	8.84	7.60	1.57–28.27
		Porites lutea	2	2,721.40	0.00	–
		Goniastrea retiformis	1	–	–	11.78

Table 3, continued.

Location	Habitat	Species	N_i	Mean	SD	Range
	ORF	*Leptastrea purpurea*	17	7.73	8.10	2.36–32.99
		Pocillopora damicornis	8	37.85	63.13	2.36–162.58
		Pocillopora verrucosa	3	34.69	39.08	3.53–78.54
		Porites lutea	2	89.93	41.65	60.48–119.38
		Porites compressa	1	–	–	23.56
	6 m	*Leptastrea purpurea*	22	12.05	10.78	0.79–36.13
		Astreopora myriophthalma	4	29.35	9.95	21.60–42.41
		Montipora hoffmeisteri	3	62.05	96.25	5.89–173.18
		Montipora verrucosa	2	129.59	0.00	–
		Goniastrea retiformis	1	–	–	7.07
		Astreopora listeri	1	–	–	5.50
		Porites solida	1	–	–	47.12
		Pocillopora damicornis	1	–	–	40.06
		Montipora grisea	1	–	–	77.75
		Montipora elschneri	1	–	–	9.42
		Stylocoeniella armata	1	–	–	3.93
		Montipora ehrenbergii	1	–	–	19.63
	12 m	*Astreopora myriophthalma*	13	25.26	16.50	393–53.60
		Leptastrea purpurea	7	10.27	7.65	2.75–25.53
		Favia pallida	5	3.46	2.90	0.79–8.25
		Porites solida	4	167.44	312.53	4.91–669.75
		Montipora grisea	3	23.69	16.36	8.25–40.84
		Montipora hoffmeisteri	2	24.15	15.83	12.96–35.34
		Astreopora listeri	2	24.15	14.72	13.73–34.56
		Montipora verrucosa	2	18.85	0.00	–
		Astreopora randalli	1	–	–	9.62

Table 4. Population density, frequency, and coverage of coral species recorded on transects at Tipalao Reef.

Location	Habitat	Species	N_i	Relative Density	Absolute Density	Frequency	Coverage	Relative Coverage
Sector 1	MRF	*Leptastrea purpurea*	21	0.525	6.168	0.80	0.0063	0.059
		Pocillopora damicornis	8	0.200	2.350	0.40	0.0775	0.725
		Pocillopora verrucosa	3	0.075	0.881	0.20	0.0138	0.129
		Porites cylindrica	3	0.075	0.881	0.10	0.0011	0.010
		Pavona varians	2	0.050	0.587	0.20	0.0014	0.013
		Pocillopora meandrina	1	0.025	0.294	0.10	0.0027	0.025
		Favia matthaii	1	0.025	0.294	0.10	0.0038	0.035
		Porites lutea	1	0.025	0.294	0.10	0.0004	0.004
	ORF	*Leptastrea purpurea*	10	0.250	4.747	0.20	0.0068	0.029
		Pocillopora verrucosa	6	0.150	2.848	0.40	0.0261	0.112
		Pocillopora meandrina	4	0.100	1.899	0.30	0.0542	0.233
		Porites lutea	3	0.075	1.424	0.10	0.0451	0.194
		Galaxea fascicularis	3	0.075	1.424	0.20	0.0131	0.056
		Porites lobata	2	0.050	0.949	0.70	0.0096	0.041
		Pocillopora damicornis	2	0.050	0.949	0.20	0.0346	0.149
		Montastrea curta	2	0.050	0.949	0.10	0.0026	0.011
		Acropora sp.	2	0.050	0.949	0.10	0.0020	0.009
		Porites rus	2	0.050	0.949	0.10	0.0173	0.074
		Pavona varians	2	0.050	0.949	0.10	0.0108	0.046
		Leptoria phrygia	1	0.025	0.475	0.10	0.0006	0.002
		Acropora monticulosa	1	0.025	0.475	0.10	0.0102	0.044
	6 m	*Leptastrea purpurea*	14	0.350	12.637	0.70	0.0285	0.130
		Montipora elschneri	7	0.175	6.318	0.30	0.0331	0.151
		Porites sp.	3	0.075	2.708	0.20	0.0778	0.355
		Montipora tuberculosa	3	0.075	2.708	0.20	0.0070	0.032
		Montipora hoffmeisteri	3	0.075	2.708	0.20	0.0099	0.045
		Porites lutea	2	0.050	1.805	0.10	0.0102	0.046
		Pavona varians	1	0.025	0.903	0.10	0.0027	0.012
		Pocillopora damicornis	1	0.025	0.903	0.10	0.0095	0.043
		Acanthastrea echinata	1	0.025	0.903	0.10	0.0007	0.003
		Astreopora myriophthalma	1	0.025	0.903	0.10	0.0064	0.029
		Favites abdita	1	0.025	0.903	0.10	0.0019	0.009
		Acropora granulosa	1	0.025	0.903	0.10	0.0053	0.024
		Porites lobata	1	0.025	0.903	0.10	0.0217	0.099
		Montipora grisea	1	0.025	0.903	0.10	0.0049	0.022
	12 m	*Leptastrea purpurea*	11	0.275	9.196	0.70	0.0179	0.142
		Astreopora myriophthalma	9	0.225	7.524	0.40	0.0102	0.081
		Porites sp.	4	0.100	3.344	0.40	0.0095	0.075
		Astreopora randalli	3	0.075	2.508	0.30	0.0156	0.124
		Montipora grisea	2	0.050	1.672	0.20	0.0225	0.178
		Pavona varians	2	0.050	1.672	0.20	0.0127	0.109
		Leptastrea transversa	1	0.025	0.836	0.10	0.0030	0.024
		Diploastrea heliopora	1	0.025	0.836	0.10	0.0042	0.033
		Favia pallida	1	0.025	0.836	0.10	0.0012	0.010
		Montipora foveolata	1	0.025	0.836	0.10	0.0070	0.055

Table 4, continued.

Location	Habitat	Species	N_i	Relative Density	Absolute Density	Frequency	Coverage	Relative Coverage
		Montipora verrilli	1	0.025	0.836	0.10	0.0030	0.024
		Porites lobata	1	0.025	0.836	0.10	0.0015	0.012
		Montipora verrucosa	1	0.025	0.836	0.10	0.0156	0.124
		Favia matthaii	1	0.025	0.836	0.10	0.0018	0.015
		Astreopora listeri	1	0.025	0.836	0.10	0.0005	0.004
Sector 2	MRF	*Leptastrea purpurea*	14	0.350	1.364	0.60	0.0007	0.026
		Pocillopora damicornis	13	0.325	1.266	0.70	0.0183	0.711
		Pocillopora verrucosa	5	0.125	0.487	0.50	0.0032	0.125
		Pocillopora meandrina	2	0.050	0.195	0.10	0.0035	0.138
	ORF	*Leptastrea purpurea*	15	0.375	3.738	0.70	0.0024	0.013
		Goniastrea retiformis	9	0.225	2.243	0.40	0.1351	0.732
		Favia matthaii	4	0.100	0.997	0.30	0.0078	0.042
		Pocillopora damicornis	3	0.075	0.748	0.30	0.0024	0.013
		Pocillopora verrucosa	3	0.075	0.748	0.20	0.0092	0.050
		Pocillopora meandrina	2	0.050	0.498	0.10	0.0140	0.076
		Stylocoeniella armata	1	0.025	0.249	0.10	0.0002	0.001
		Leptoria phrygia	1	0.025	0.249	0.10	0.0001	0.000
		Porites lutea	1	0.025	0.249	0.10	0.0133	0.072
	6 m	*Leptastrea purpurea*	20	0.500	16.639	0.80	0.0395	0.427
		Montipora hoffmeisteri	5	0.125	4.160	0.20	0.0048	0.052
		Montipora grisea	4	0.100	3.328	0.20	0.0083	0.090
		Goniastrea pectinata	1	0.025	0.832	0.10	0.0029	0.031
		Montipora danae	1	0.025	0.832	0.10	0.0040	0.043
		Pocillopora damicornis	1	0.025	0.832	0.10	0.0037	0.040
		Goniastrea edwardsi	1	0.025	0.832	0.10	0.0085	0.092
		Porites sp.	1	0.025	0.832	0.10	0.0010	0.019
		Montipora tuberculosa	1	0.025	0.832	0.10	0.0088	0.095
		Favites abdita	1	0.025	0.832	0.10	0.0024	0.026
		Stylocoeniella armata	1	0.025	0.832	0.10	0.0020	0.022
		Montipora elschneri	1	0.025	0.832	0.10	0.0040	0.043
		Favia favus	1	0.025	0.832	0.10	0.0002	0.003
		Cyphastrea agassizi	1	0.025	0.832	0.10	0.0025	0.027
	12 m	*Leptastrea purpurea*	16	0.400	8.682	1.00	0.0158	0.289
		Astreopora randalli	4	0.100	2.170	0.30	0.0124	0.227
		Porites sp.	3	0.075	1.628	0.30	0.0045	0.082
		Montipora hoffmeisteri	3	0.075	1.628	0.30	0.0029	0.052
		Montipora verrucosa	2	0.050	1.085	0.20	0.0060	0.111
		Montipora grisea	2	0.050	1.085	0.20	0.0017	0.032
		Astreopora myriophthalma	2	0.050	1.085	0.20	0.0048	0.087
		Montipora tuberculosa	1	0.025	0.543	0.10	0.0016	0.030
		Astreopora listeri	1	0.025	0.543	0.10	0.0010	0.018
		Pavona varians	1	0.025	0.543	0.10	0.0007	0.014
		Favia pallida	1	0.025	0.543	0.10	0.0009	0.017
		Favia matthaii	1	0.025	0.543	0.10	0.0007	0.014
		Porites cylindrica	1	0.025	0.543	0.10	0.0003	0.006

Table 4, continued.

Location	Habitat	Species	N_i	Relative Density	Absolute Density	Frequency	Coverage	Relative Coverage
		Favites abdita	1	0.025	0.543	0.10	0.0004	0.007
		Porites lutea	1	0.025	0.543	0.10	0.0009	0.016
Sector 3	MRF	*Leptastrea purpurea*	18	0.450	2.574	1.00	0.0024	0.125
		Pocillopora damicornis	12	0.300	1.716	0.80	0.0064	0.331
		Pocillopora verrucosa	7	0.175	1.001	0.50	0.0052	0.267
		Pocillopora meandrina	1	0.025	0.143	0.10	0.0053	0.277
	ORF	*Pocillopora meandrina*	15	0.375	7.490	0.80	0.1646	0.670
		Leptastrea purpurea	9	0.225	4.494	0.70	0.0044	0.018
		Pocillopora verrucosa	6	0.150	2.996	0.30	0.0278	0.113
		Porites lutea	3	0.075	1.498	0.20	0.0376	0.153
		Acropora granulosa	1	0.025	0.499	0.10	0.0032	0.013
		Pavona varians	1	0.025	0.499	0.10	0.0056	0.023
		Montastrea curta	1	0.025	0.499	0.10	0.0006	0.002
		Galaxea fascicularis	1	0.025	0.499	0.10	0.0009	0.004
		Stylocoeniella armata	1	0.025	0.499	0.10	0.0002	0.001
		Porites lobata	1	0.025	0.499	0.10	0.0004	0.002
		Pocillopora damicornis	1	0.025	0.499	0.10	0.0003	0.001
	6 m	*Leptastrea purpurea*	22	0.550	38.921	0.80	0.0465	0.515
		Porites lutea	4	0.100	7.077	0.20	0.0104	0.115
		Montipora ehrenbergii	4	0.100	7.077	0.10	0.0144	0.160
		Montipora hoffmeisteri	3	0.075	5.307	0.30	0.0039	0.043
		Pocillopora verrucosa	2	0.050	3.538	0.20	0.0090	0.100
		Acropora sp.	1	0.025	1.769	0.10	0.0018	0.020
		Favia stelligera	1	0.025	1.769	0.10	0.0004	0.005
		Favites russelli	1	0.025	1.769	0.10	0.0024	0.026
		Favia matthaii	1	0.025	1.769	0.10	0.0015	0.017
	12 m	*Leptastrea purpurea*	17	0.425	7.280	0.80	0.0066	0.108
		Porites lutea	3	0.075	1.285	0.30	0.0129	0.211
		Montipora tuberculosa	2	0.050	0.856	0.10	0.0039	0.063
		Favia pallida	2	0.050	0.856	0.20	0.0023	0.038
		Astreopora gracilis	2	0.050	0.856	0.20	0.0023	0.038
		Montipora verrucosa	1	0.025	0.428	0.10	0.0008	0.013
		Favites abdita	1	0.025	0.428	0.10	0.0021	0.034
		Astreopora myriophthalma	9	0.225	3.854	0.60	0.0158	0.258
		Montipora grisea	1	0.025	0.428	0.10	0.0112	0.184
		Pocillopora verrucosa	1	0.025	0.428	0.10	0.0015	0.025
		Astreopora listeri	1	0.025	0.428	0.10	0.0018	0.029
Sector 4	MRF	*Leptastrea purpurea*	30	0.750	2.203	1.00	0.0025	0.046
		Porites lutea	2	0.050	0.147	0.10	0.0509	0.952
		Goniastrea retiformis	1	0.025	0.073	0.10	0.0001	0.002

Table 4, continued.

Location	Habitat	Species	N_i	Relative Density	Absolute Density	Frequency	Coverage	Relative Coverage
	ORF	*Leptastrea purpurea*	17	0.425	1.251	0.80	0.0012	0.177
		Pocillopora damicornis	8	0.200	0.589	0.60	0.0028	0.408
		Pocillopora verrucosa	3	0.075	0.221	0.30	0.0010	0.140
		Porites lutea	2	0.050	0.147	0.20	0.0017	0.243
		Porites compressa	1	0.025	0.074	0.10	0.0002	0.032
	6 m	*Leptastrea purpurea*	22	0.550	22.207	0.80	0.0341	0.255
		Astreopora myriophthalma	4	0.100	4.038	0.20	0.0151	0.113
		Montipora hoffmeisteri	3	0.075	3.028	0.30	0.0239	0.179
		Montipora verrucosa	2	0.050	2.019	0.10	0.0333	0.250
		Goniastrea retiformis	1	0.025	1.009	0.10	0.0009	0.007
		Astreopora listeri	1	0.025	1.009	0.10	0.0007	0.005
		Porites solida	1	0.025	1.009	0.10	0.0061	0.045
		Pocillopora damicornis	1	0.025	1.009	0.10	0.0051	0.039
		Montipora grisea	1	0.025	1.009	0.10	0.0100	0.075
		Montipora elschneri	1	0.025	1.009	0.10	0.0012	0.009
		Stylocoeniella armata	1	0.025	1.009	0.10	0.0005	0.004
		Montipora ehrenbergii	1	0.025	1.009	0.10	0.0025	0.019
	12 m	*Astreopora myriophthalma*	13	0.325	12.937	0.70	0.0421	0.175
		Leptastrea purpurea	7	0.175	6.966	0.50	0.0849	0.352
		Favia pallida	5	0.125	4.976	0.40	0.0022	0.009
		Porites solida	4	0.100	3.981	0.30	0.0849	0.352
		Montipora grisea	3	0.075	2.985	0.30	0.0090	0.037
		Montipora hoffmeisteri	2	0.050	1.990	0.20	0.0061	0.025
		Astreopora listeri	2	0.050	1.990	0.10	0.0061	0.025
		Montipora verrucosa	2	0.050	1.990	0.10	0.0048	0.020
		Astreopora randalli	1	0.025	0.995	0.10	0.0012	0.005

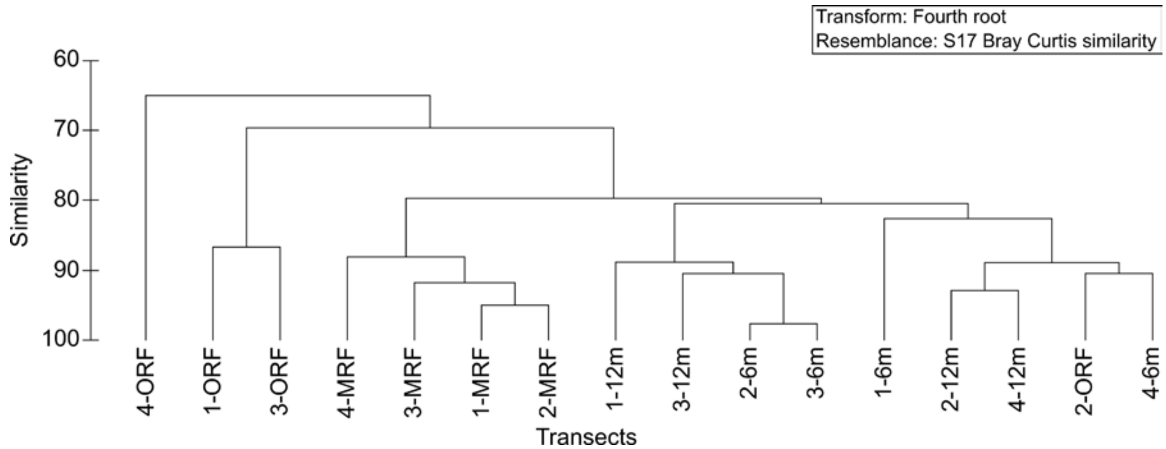

Figure 9. Dendrogram depicting similarities (per cent) in coral species assemblages of transects at Tipalao Reef as determined by cluster analysis (group linkage). See Figure 7 for transect definitions.

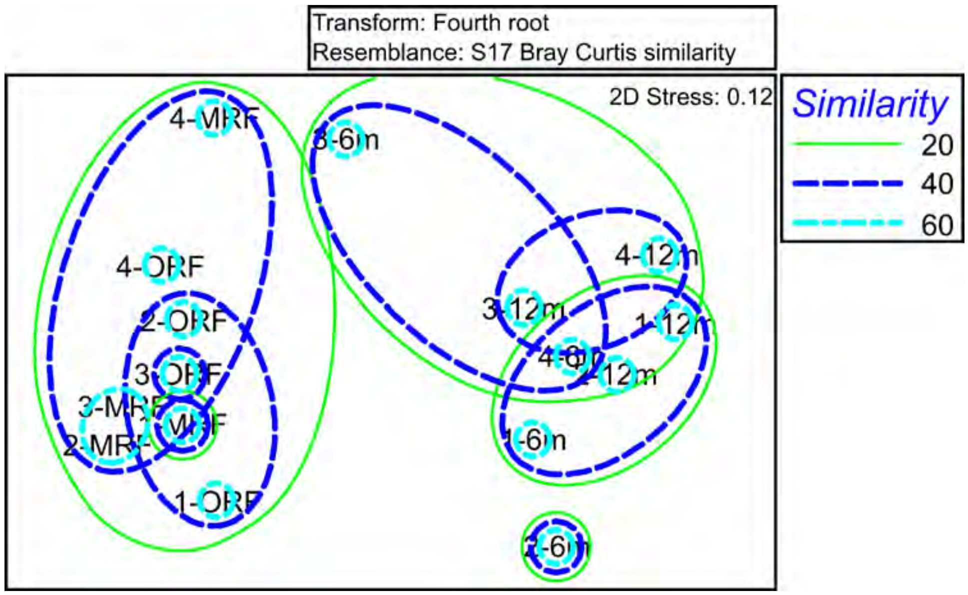

Figure 10. Multi-dimensional scaling (MDS) analysis of similarity in coral species assemblages at Tipalao Reef. Similarity values indicate the percentage of similarity between transects. See Figure 7 for transect definitions.

<u>Macroinvertebrates</u>

The distribution and abundance of conspicuous epibenthic macroinvertebrates observed on 16 transects in Sectors 1-4 are given in Table 5. A total of 114 species from 7 phyla were found. There were 9 species of sponges (Porifera: Demospongiae), 3 species of anthrozoans (Cnidaria), 4 species of polychaete worms (Annelida), one species of Polyplacophora (Mollusca), 47 species of gastropods (Mollusca), 13 species of bivalves (Mollusca), 10 species of shrimps and crabs (Anthropoda: Crustacea), 3 species of starfishes (Echinodermata: Asteroidea), one species of brittlestar (Echinodermata: Ophiouroidea), 7 species of sea urchins (Echinodermata:Echinoidea), 7 species of sea cucumbers (Echinodermata: Holothuroidea), and 8 species of sea squirts (Chordata:Ascidiacea). Sponges were most commonly observed in Sectors 1-3 and were absent from all transects in Sector 4 except that at 12m. Anthozoans were uncommon and seen mainly on the ORF, 6m and 12m transects across all four sectors. Polychaete worms were also uncommon and found variously on all four transects across the four sectors but mainly on transects at 12 and 6m. The single species of Polyplacophora , *Acanthopleura gemmata*, was found only on the ORF transect in Sector 4. Among gastropod molluscs, *Dendropoma maxima* was most common and found on nearly all transects in all sectors. Similarly, the giant clam *Tridacna maxima* (Bivalvia) was found on nearly all transects across all four sectors. The sea urchin *Echinometra mathaei* was found on most transects in all sectors, too. Sea squirts were found variously in all four sectors but mainly on 6 and 12m transects.

Comparisons of macroinvertebrate distributions across transects and sectors by cluster analysis of Bray-Curtis similarity data (Figure 11) indicated a clear separation between reef flat and reef slope transects for all sectors. MDS analysis of these data (Figure 12) group reef slope transects separately from reef flat transects as well, but with the former segregating into five subgroups of at least 40% similarity and the latter into three subgroups at that level.

Densities of macroinvertebrate species are given in Table 6. Densities of each species tended to be low, with the exception of some sea cucumbers (Holothuroidea).

Table 5. Species of conspicuous epibenthic invertebrates observed on or adjacent to transects at Tipalao Reef. Observations of live specimens are denoted by filled circles (●), and records based on dead specimens are denoted by open circles (○).

	Sector 1				Sector 2				Sector 3				Sector 4			
	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m
Porifera:Demospongiae																
Cinachyra cf. *australiensis*									●							
Axinyssa sp. 1				●								●				●
Dysidea granulosa				●			●					●				
Dysidea herbacea							●				●					
Iochotrocha baculifera		●				●										
Ircinia sp. 1				●							●					●
Stylissa massa			●	●		●	●	●			●	●				
Spheciospongia vagabunda																●
Haliclona sp. (blue)			●				●									●
Cnidaria:Anthozoa																
Lobophytum pauciflorum																●
Sinularia spp.										●	●					
Heteractis crispa			●			●										
Annelida:Polychaeta																
Loimia cf. *medusa*				●												
Sabellastarte spectabilis														●		
Protula sp.				●												
Spirobranchus corniculatus									●		●	●				

Table 5, continued.

	Sector 1				Sector 2				Sector 3				Sector 4			
	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m
Mollusca:Polyplacophora																
Acanthopleura gemmata														●		
Mollusca:Gastropoda																
Trochus niloticus		●							●							
Trochus ochroleucus										●						
Tectus pyramis		●				●										
Turbo argyrostomus										○						
Cerithium dialeucum																
Cerithium echinatum												○				
Cerithium nodulosum					●	●										
Cerithium punctatum													○			
Clypeomorus bifasciata										○						
Dendropoma maxima	●	●	●		●		●	●	●	●	●	●	●	●	●	
Serpulorbis sp.			●				●	●			●	●		●		
Strombus microurceus												○				
Strombus mutabilis			○	○	○											
Cypraea caputserpentis	○					●			○					●		
Cypraea carneola		○														
Cypraea erosa							○									
Cypraea helvola		○														
Cypraea isabella		○														
Cypraea lynx		○				○										
Cypraea moneta	●	●			●	●				○	○			●		
Cymatium echinatum																

Table 5, continued.

	Sector 1				Sector 2				Sector 3				Sector 4			
	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m
Cymatium rubeculum							●									
Bursa bufonia		●				●			○							
Bursa granularis			●													
Chicoreus brunneus	●				●					●						
Thais armigera														●		
Thais tuberosa	●					●				●						
Drupa grossularia			○			●										
Drupa morum										●				●		
Morula granulata					●					●						
Morula uva										●						
Coralliophila violacea							●	●			●	●			●	
Quoyula madreporarum							●			●	●				●	
Vasum turbinellus	●	●	●						●	●			●	●		
Euplica turturina									●							
Latirus polygonus	●															
Conus catus														○		
Conus chaldaeus	●								●							
Conus distans																●
Conus ebraeus	●				●				○	●				●		
Conus flavidus			●		●				●							
Conus imperialis																●
Conus lividus									●							
Conus miles						●										
Conus miliaris											●					
Conus rattus						●			●					●		
Conus sponsalis						●			●					●		
Plakobranchus ocellatus									●							

Table 5, continued.

	Sector 1				Sector 2				Sector 3				Sector 4			
	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m
Mollusca:Bivalvia																
Arca avellana													○			
Barbatia amygdalumtostum			○					○								
Barbatia sp. 1											○					
Chama pacifica		●											●			
groove oyster			●							●						
Isognomon perna														○		
Modiolus auriculatus	○								○					○		
Septifer excisus						○							○			
Pedum spondyloideum												●				
Tridacna maxima	●		●	●	●	●	●		●	●	●		●	●	●	
Tridacna squamosa				●												
Periglypta reticulata		○							○					○		
Gafrarium pectinatum													○			
Arthropoda:Crustacea																
Alpheus frontalis			●				●					●			●	●
Calcinus areolatus										●						
Calcinus laevimanus														●		
Calcinus minuta													●	●		
Paguritta kroppi							●									
Neaxius sp.								●	●				●			
Stenopus hispidus				●												
Carpilius maculatus															○	
Lissocarcinus orbicularis													●			
Thalamita sp.													○			

Table 5, continued.

	Sector 1				Sector 2				Sector 3				Sector 4			
	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m
Echinodermata:Asteroidea																
Acanthaster planci			●													
Linckia laevigata	●					●				●						
Linckia multifora						●	●		●	●	●			●		
Echinodermata:Ophiouroidea																
Ophiocoma										●						
Echinodermata:Echinoidea																
Heterocentrotus mammillatus										●						
Echinostrephus aciculatus			●	●	●		●	●		●	●	●	●		●	●
Echinometra mathaei	●	●	●		●	●	●		●	●	●			●	●	
Echinometra sp. A		●			●	●			●		●					
Echinothrix diadema	●	●			●				●	●				●		
Diadema savignyi	●				●											
Tripneustes gratilla															●	
Echinodermata:Holothuroidea																
Actinopyga echinites	●				●				●				●			
Actinopyga mauritiana	●	●	●			●			●	●						
Bohadschia argus						●										
Holothuria atra	●	●		●	●	●			●				●			
Holothuria edulis																●
Stichopus chloronotus	●		●		●	●			●							
Synapta maculata					●	●										

Table 5, continued.

	Sector 1				Sector 2				Sector 3				Sector 4			
	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m
Chordata:Ascidiacea																
Didemnum molle				●								●				●
Phallusia julinea				●								●				●
Polycarpa argentata			●					●				●			●	
Polycarpa cryptocarpa							●				●					
Ascidia sp. A							●				●	●				
Rhopalaea sp. A								●								
lemon ascidian								●								
coral-pink ascidian		●														

Table 6. Mean densities of conspicuous invertebrates observed on transects at Tipalao Reef. Densities are reported as mean ± standard deviation in five 20-m^2 quadrats sampled along a 50-m transect.

	SECTOR 1				SECTOR 2				SECTOR 3				SECTOR 4			
	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m
Porifera:Demospongia																
Cinachyra cf. *australiensis*										0.6 ± 0.9						
Cnidaria:Anthozoa																
Heteractis crispa						0.2 ± 0.4										
Sinularia sp.											0.2 ± 0.4					
Mollusca:Polyplacophora																
Acanthopleura gemmata														0.4 ± 0.9		
Mollusca:Gastropoda																
Tectus pyramis		0.2 ± 0.4														
Trochus niloticus									0.2 ± 0.4							
Trochus ochroleucus										0.2 ± 0.4						
Cerithium nodulosum					0.4 ± 0.5	0.2 ± 0.4										
Cymatium rubeculum							0.2 ± 0.4									
Morula granulata										0.2 ± 0.4						
Thais tuberosa	0.2 ± 0.4					0.2 ± 0.4				0.2 ± 0.4						
Vasum turbinellus	0.2 ± 0.4								0.4 ± 0.5	0.2 ± 0.4			0.2 ± 0.4	0.4 ± 0.5		
Mollusca:Bivalvia																
Tridacna maxima	0.2 ± 0.4			0.2 ± 0.4	0.4 ± 0.9	0.6 ± 1.3	0.8 ± 0.8		0.2 ± 0.4	0.2 ± 0.4	0.4 ± 0.5		0.4 ± 0.5	0.2 ± 0.4		
Echinodermata:Ophiouroidea																
Ophiocoma sp.										0.2 ± 0.4						

Table 6, continued.

	SECTOR 1				SECTOR 2				SECTOR 3				SECTOR 4			
	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m
Echinodermata:Asteroidea																
Linckia laevigata										0.2 ± 0.4						
Linckia multifora							0.2 ± 0.4			0.8 ± 1.3				0.2 ± 0.4		
Echinodermata:Echinoidea																
Diadema savignyi	0.6 ± 0.5															
Echinothrix diadema	1.6 ± 1.5	3.8 ± 3.2			1.4 ± 1.1	3.2 ± 1.5			1.4 ± 0.5	3.0 ± 1.2						
Echinometra mathaei	1.8 ± 1.1	20.8 ± 4.5	1.6 ± 1.1		0.4 ± 0.5	5.4 ± 3.4	2.8 ± 3.1		0.6 ± 0.9	10.6 ± 7.0	0.4 ± 0.9			0.2 ± 0.4	0.4 ± 0.5	
Echinometra sp. A		0.2 ± 0.4			0.2 ± 0.4						0.2 ± 0.4					
Echinostrephus aciculatus	3.0 ± 4.1				0.6 ± 0.5	0.4 ± 0.5		1.8 ± 2.5	0.8 ± 1.1	0.2 ± 0.4		0.2 ± 0.4	0.8 ± 1.3			0.6 ± 0.9
Heterocentrotous mammillatus											0.2 ± 0.4					
Echinodermata:Holothuroidea																
Stichopus chloronotus			0.2 ± 0.4			0.2 ± 0.4										
Actinopyga echinites	4.2 ± 1.6				3.4 ± 3.4				1.2 ± 0.4				0.2 ± 0.4			
Actinopyga mauritiana	0.4 ± 0.5	2.0 ± 2.1	0.4 ± 0.9			2.8 ± 2.9				0.4 ± 0.5						
Bohadschia argus						0.2 ± 0.4										
Holothuria atra	4.8 ± 1.9	1.2 ± 1.6		0.2 ± 0.4	1.6 ± 0.9	0.8 ± 1.3			0.6 ± 0.9				0.4 ± 0.5			
Synapta maculata					0.2 ± 0.4											
Chordata:Ascidiacea																
Ascidia ornata							0.2 ± 0.4									
Phallusia julinea												0.2 ± 0.4				

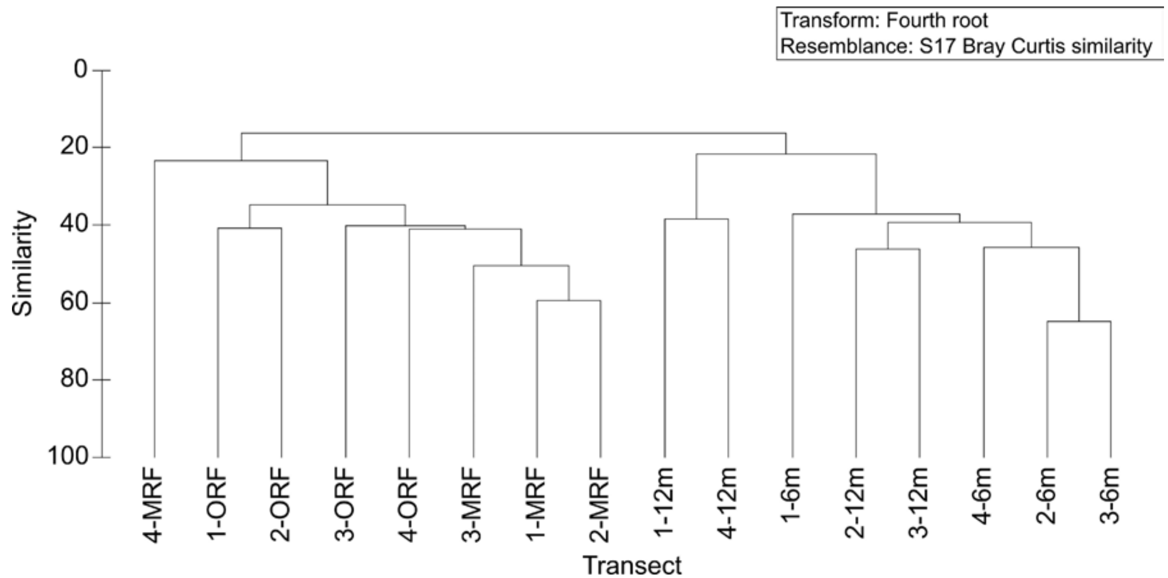

Figure 11. Dendrogram depicting similarities (per cent) in macroinvertebrate species assemblages of transects at Tipalao Reef as determined by cluster analysis (group linkage). See Figure 7 for transect definitions.

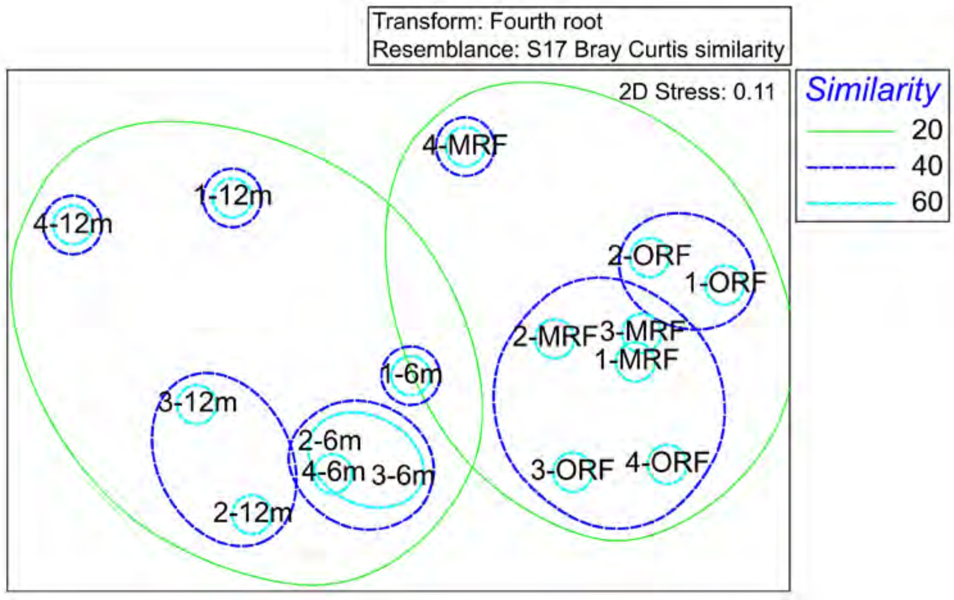

Figure 12. Multi-dimensional scaling (MDS) analysis of similarity in macroinvertebrate species assemblages at Tipalao Reef. Similarity values indicate the percentage of similarity between transects. See Figure 7 for transect definitions.

Fishes

A checklist of reef fishes with their observed patterns of distribution on transects is given in Appendix 1. A total of 140 species were observed at the Tipalao Beach site. Species richness ranged from 11 on transect 1-MFR to 57 on transect 2-6m (Figure 13). Mean (± SE) species richness was 33.4 (± 3.7) for all transects combined. The number of fishes per transect ranged from 71for transect 4-MFR to 245 for transect 2-6m (Figure 14). The mean (± SE) number of fishes per transects was 84.4 (± 13.9) for all transects combined. Shannon's H' index of diversity ranged from 1.948 on transect 1-MFR to 3.458 on transect 2-6m (Figure 15). The mean (± SE) value of H' was 2.7843 (± 0.1402) for all transects combined. The relationship between species richness and the number of fishes was generally positive (Figure 16) and significant ($r^2 = 0.685$, $p < 0.011$, $n = 16$). Overall, species richness, abundance and species diversity were highest on shallow spur and groove (6m) transects and, like fish assemblages at Dadi Beach (see below), lowest on mid-reef flat (MFR) transects. The reef fish assemblages observed at this site were typical of semi-protected reef areas (in contrast to the neighboring Orote Peninsula cliffline), and were similar to those reported previously Smith et al. (2009) and Paulay et. al (2001).

The density (number per m^2) of each reef fish species observed on transects is given in Appendix 2. Densities ranged from 0.002 to 1.07 fish per m^2. Densities for most species were less than 0.01 fish per m^2, however. Species with the greatest densities were all benthic damselfishes (Pomacentridae), and included *Chrysiptera brownriggii amabilis* outer reef flat transects (3-OFR = 1.07 per m^2; 1-OFR = 0.63 m^2), *Stegastes albifasciatus* on a mid-reef flat transect (3-MFR = 0.49 m^2), *Chrysiptera traceyi* on a shallow (spur and groove) transect (1-6m = 0.45 m^2), and *Pomacentrus vaiuli* on also on transect 1-6m (0.31 m^2). Many *Chrysiptera traceyi* and *Pomacentrus vaiuli* individuals were juveniles, however, and usually were found with adults of the same species.

The relationships between transects with respect to fish assemblage structure are illustrated in a cluster analysis of transect assemblage structures (Figure 17) that support the results of a multi-dimensional space (MDS) plot (Figure 18) and indicate two major clusters. The first consists of shallow reef and deep reef transects, while the second consists of mid- and outer reef flat transects. Shallow reef transects, found in the spur and groove zone, are, with one exception (transect 1-6m), distinct from the deep reef transects found on the reef terrace. The reef flat transects were less easily discriminated, with only two outer reef flat transects, 2-OFR and 3-OFR, showing comparable levels of similarity (ca. 60%) in assemblage structure. In the MDS plot, the reef flat transects are clearly distinct from those in the spur and groove zone (6m) and reef terrace (12m), but the reef flat transects are more variable compared to the shallow and deep transects.

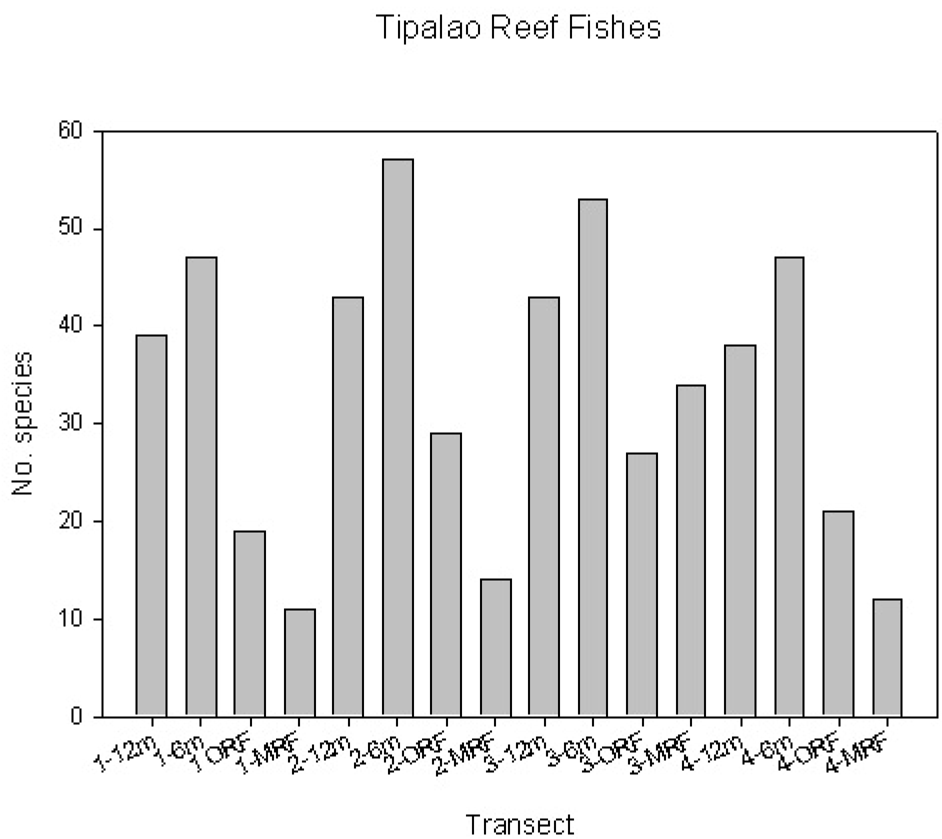

Figure 13. Species richness of fishes on transects at Tipalao Reef. See Figure 7 for transect definitions.

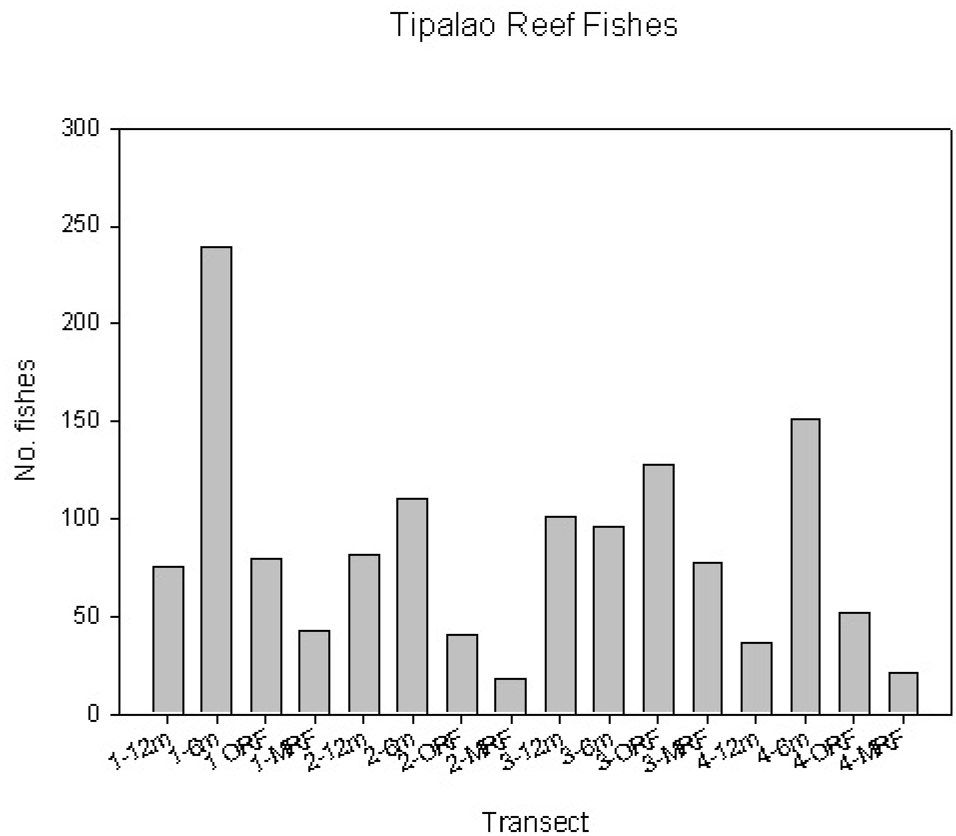

Figure 14. Abundance (number of fishes) of reef fishes on transects at Tipalao Reef. See Figure 7 for transect definitions.

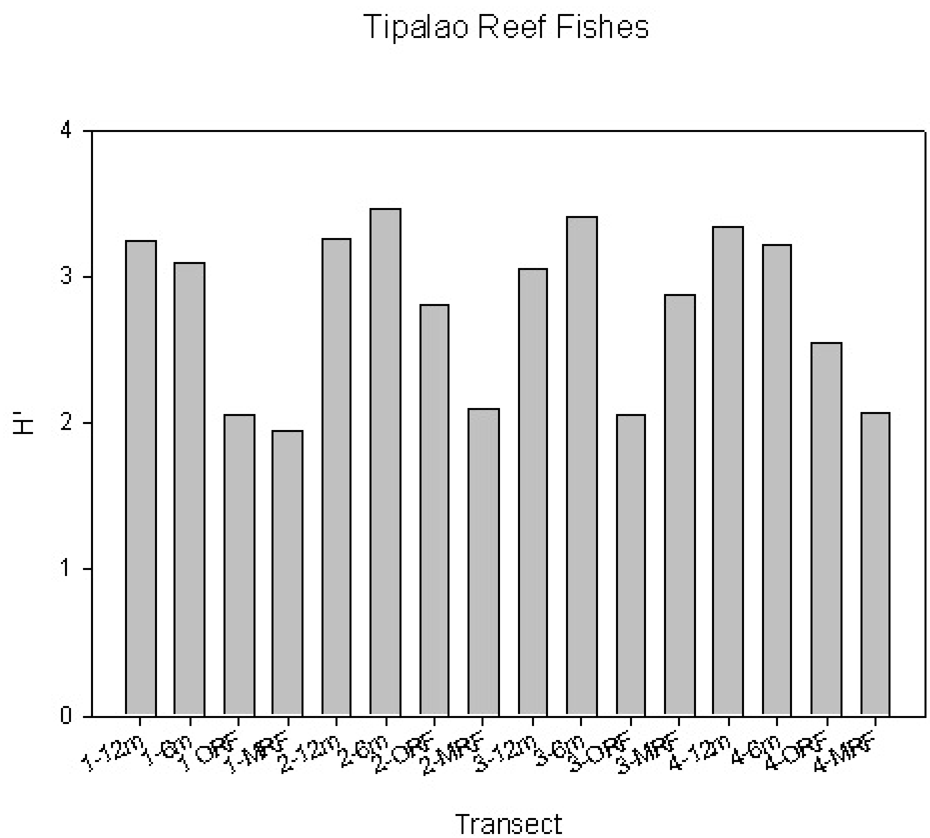

Figure 15. Species diversity (Shannon's H') of reef fishes on transects at Tipalao Reef . See Figure 7 for transect definitions.

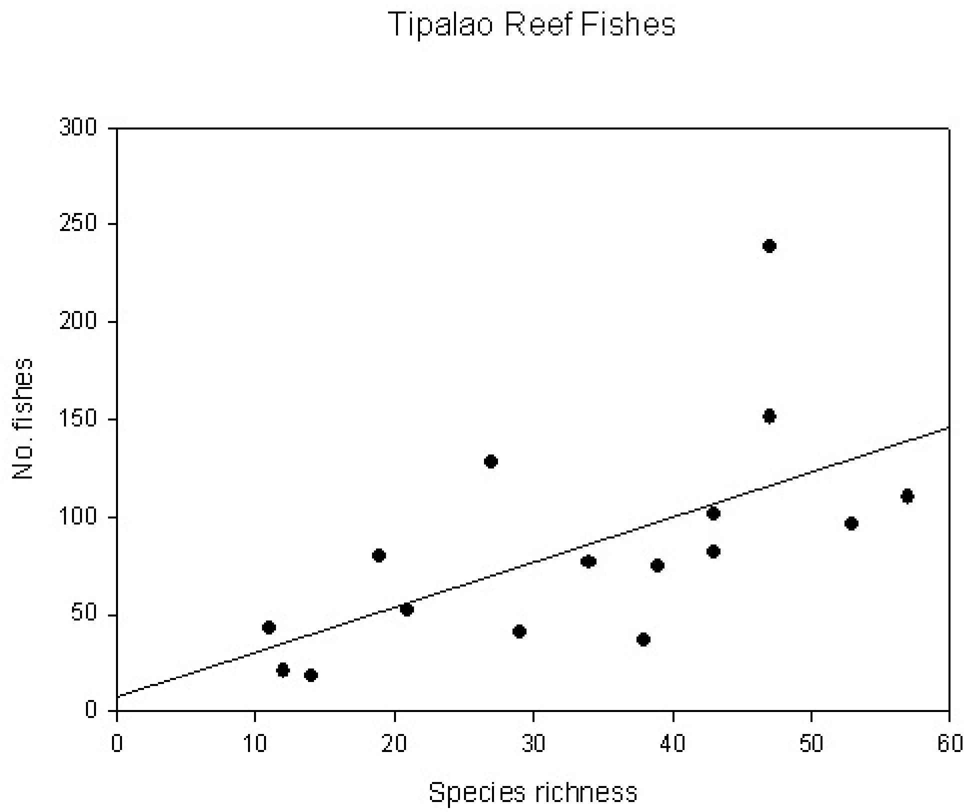

Figure 16. Relationship between species richness and abundance (number of fishes) on transects at Tipalao Reef.

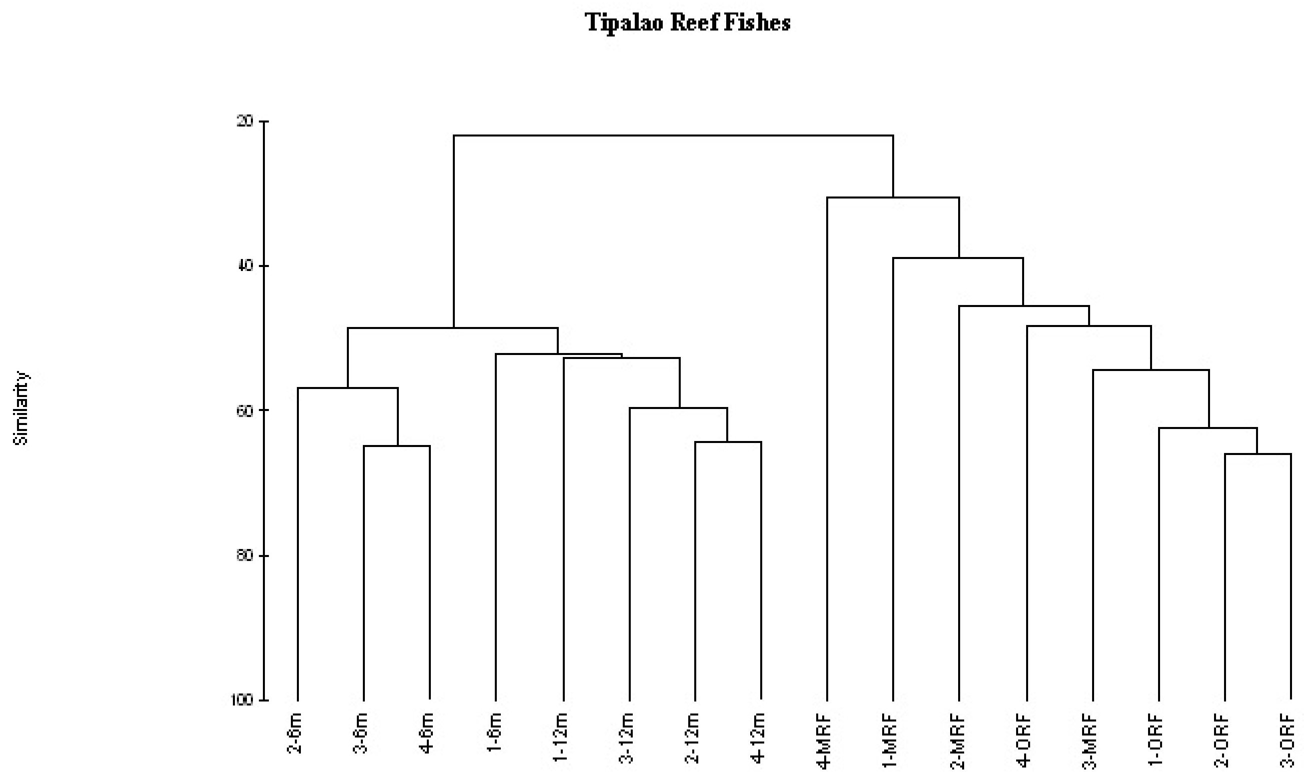

Figure 17. Dendrogram generated from group-linkage cluster analysis of reef fish assemblages on transects at Tipalao Reef. Similarity values range between 0.0 (no similarity) and 1.0 (complete similarity). See Figure 7 for transect definitions.

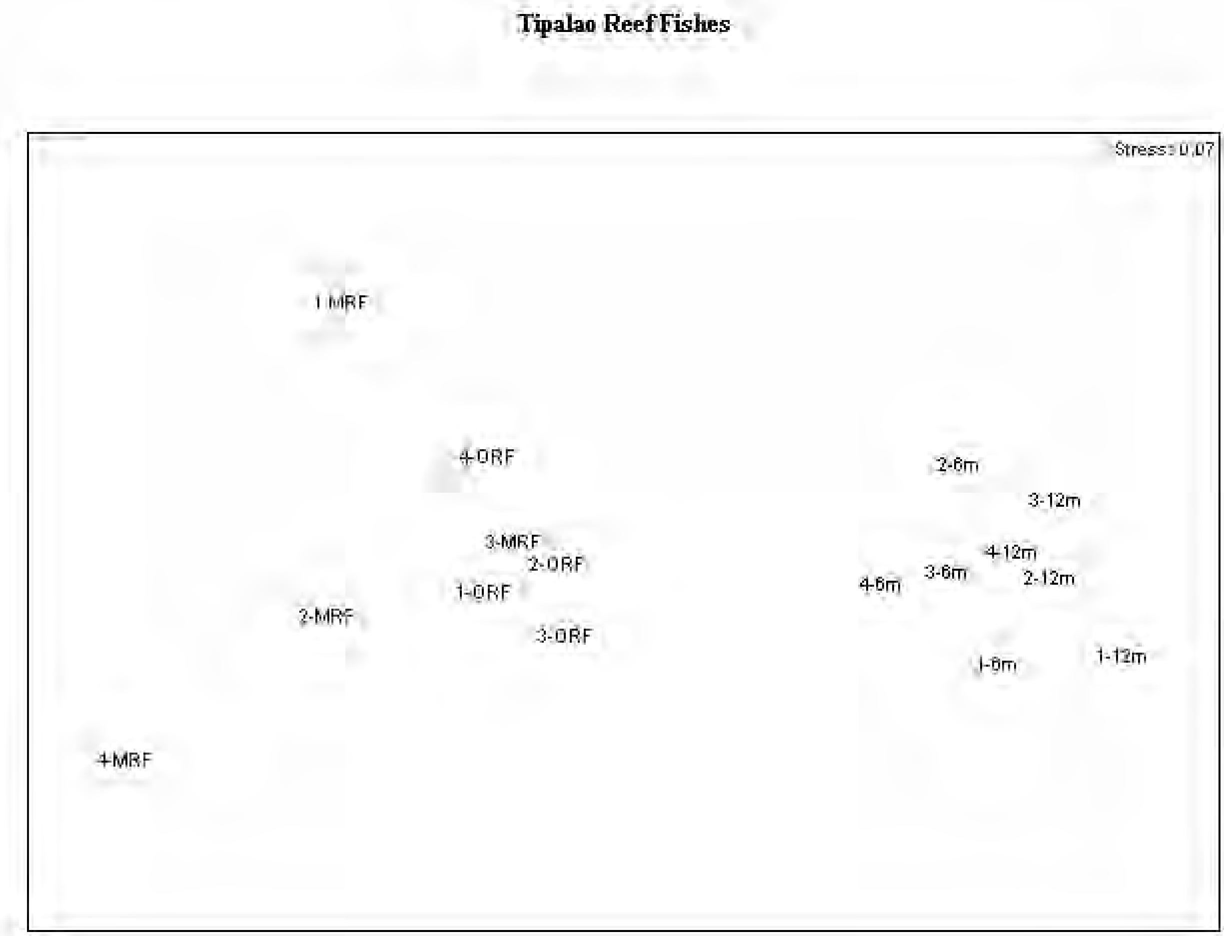

Figure 18. Multidimensional Scaling (MDS) analysis of reef fish assemblages on transects at Tipalao Reef. The stress value is an indicator of reliability that ranges between 0.00 (very high reliability) and 1.00 (no reliability). See Figure 7 for transect definitions.

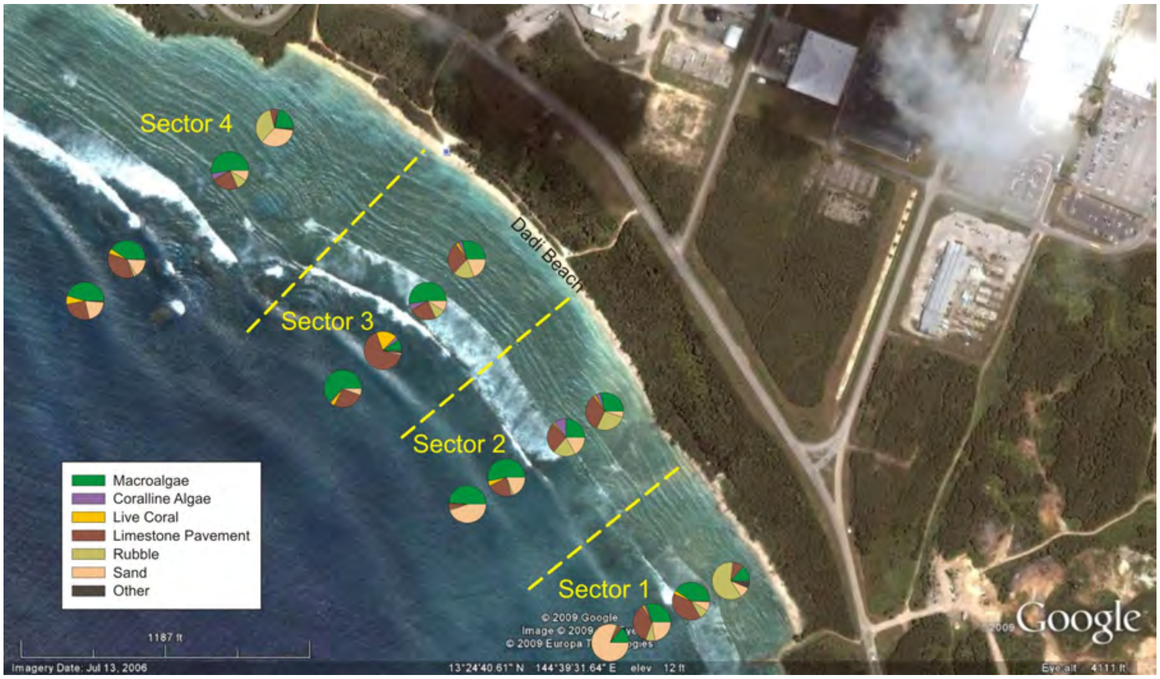

Figure 19. Percent surface coverage of the substrate along transects in four sectors and four reef zones at Dadi Reef.

Dadi Beach

Benthic Cover

Percent surface coverage of the substrate by seven abiotic and biotic features along 16 transects at Dadi Reef is presented in Figure 19, and mean coverage in the four physiographic zones is given in Table 7. Macroalgae and limestone pavement were the prominent cover at Dadi Reef, accounting for more than 65% of the total cover in all zones. Mean live coral cover ranged from about 1.3% on the middle reef flat to more than 7% on the reef slope at 6 m. biotic cover exceeded abiotic cover on all transects. Coverage data for the reef flat transects (Figure 20) show that some middle reef flat transects cluster with reef slope transects (mainly 12m) while outer reef flat transects tended to cluster with some middle reef flat and slope transects (mainly 6m). Multidimensional scaling and ordination of the coverage data reveal four clusters with 80% similarity. Two 12m slope transects formed one cluster, one 6m slope another, two middle reef flat transects a third, and a fourth consisted of outer reef flat, and the remaining middle reef flat, and slope transects (Figure 21).

A list of marine plants observed at Dadi Reef is given in Table 8.

Table 7. Mean substrate coverage by physiographic zone at Dadi Reef. MRF = middle reef flat, and ORF = outer reef flat.

	MRF	ORF	6 m	12 m
Macroalgae	23.28 ± 6.36	43.91± 12.52	33.28 ± 16.05	42.81 ± 17.60
Coralline Algae	2.19 ± 1.68	5.94 ± 3.87	1.25 ± 1.33	0.47 ± 0.52
Live Coral	1.25 ± 0.99	2.03 ± 1.12	7.19 ± 6.40	2.81 ± 3.11
Limestone Pavement	19.06 ± 11.77	27.81 ± 6.92	39.84 ± 15.96	15.31 ± 10.96
Rubble	35.16 ± 16.13	10.47 ± 5.38	3.13 ± 3.03	0.63 ± 0.63
Sand	17.03 ± 11.50	9.69 ± 4.39	14.69 ± 7.79	37.66 ± 28.41
Other	2.03 ± 2.55	0.16 ± 0.27	0.63 ± 0.77	0.31 ± 0.54

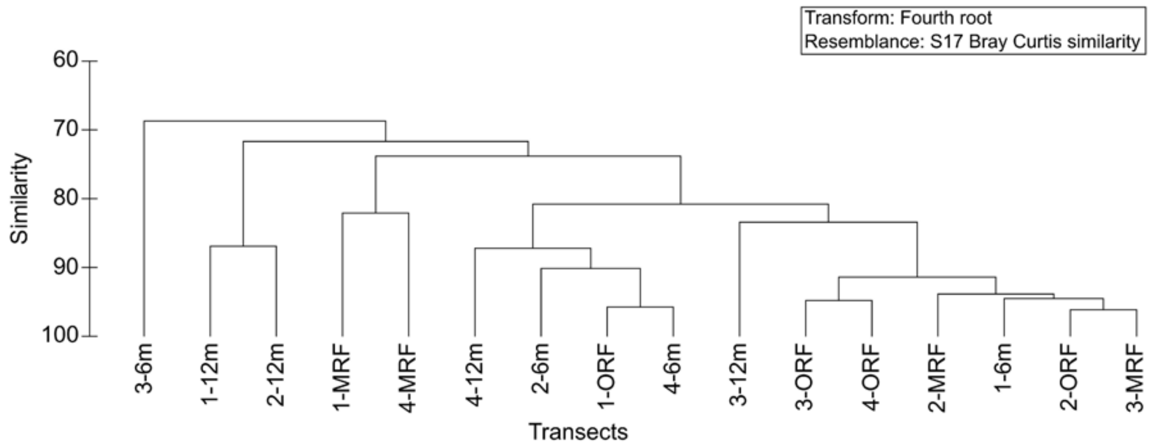

Figure 20. Cluster analysis (group averaging) of benthic coverage patterns on transects at Dadi Reef. Transects are designated by the sector number followed by the physiographic zone.

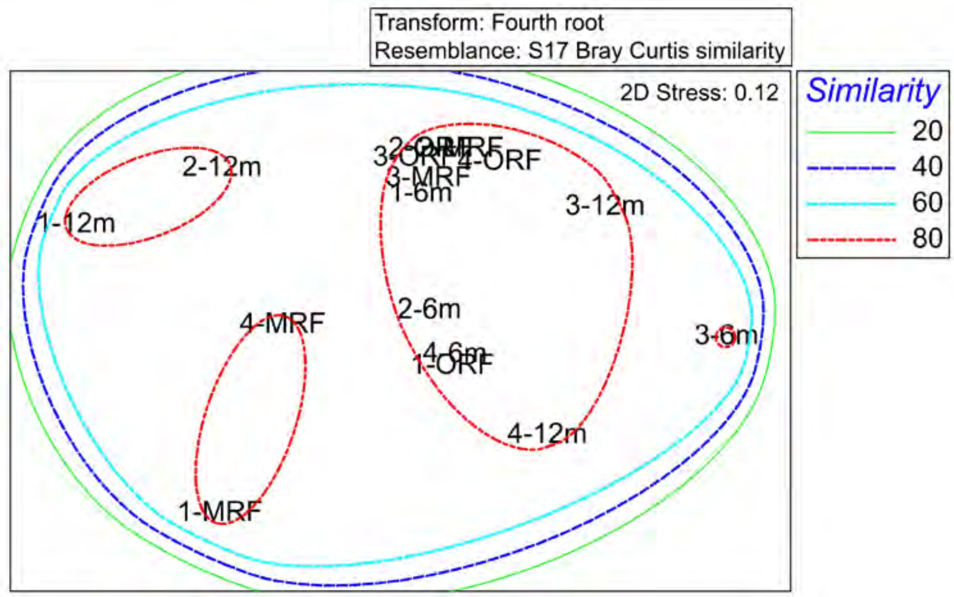

Figure 21. Multi-dimensional scaling (MDS) analysis of similarity of benthic cover on transects at Dadi Reef. Similarity values indicate the percentage of similarity between transects. See Figure 20 for transect definitions.

Table 8. Benthic marine plants observed on Dadi Reef. Checklist of species observed. Phylogenetic arrangement follows Lobban and Tsuda (2003).

	Sector 1				Sector 2				Sector 3				Sector 4			
	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m
Cyanophyta																
Lyngbya majuscula			●				●					●			●	●
Microcoleus sp.									●			●				
Schizothrix calcicola		●					●			●	●	●				
Schizothrix mexicana	●			●				●							●	
Rhodophyta																
Galaxaura round	●	●			●	●			●	●			●	●	●	
Galaxaura flat	●	●			●	●				●	●					●
Gracilaria salicornia	●				●	●			●					●		
Amphiroa spp.	●	●			●	●			●	●	●				●	
Jania spp.	●	●	●		●	●					●	●	●	●		
Lithophyllum spp.	●	●														
Phaeophyta																
Padina boryana		●				●		●	●			●				●
Turbinaria ornata	●	●				●			●	●				●		
Chrysocystis fragilis									●		●				●	●
Chlorophyta																
Boodlea composita									●				●			
Ventricaria ventricosa								●	●		●	●			●	

Table 8, continued.

	Sector 1				Sector 2				Sector 3				Sector 4			
	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m
Bryopsis pennata									●	●						
Caulerpa racemosa	●	●			●	●			●		●					
Caulerpa serrulata	●															
Halimeda discoidea																
Halimeda lichenoides	●	●	●	●	●	●	●	●	●							●
Halimeda opuntia	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●
Halimeda velasquezii			●	●					●		●					●
Halimeda sp.	●	●			●		●									
Chlorodesmis fastigiata	●	●			●	●								●		
Tydemania expeditionis											●					
Neomeris annulata	●			●	●	●	●		●	●	●	●	●			

Corals

Size-frequency distributions of the scleractinian corals encountered on transects at Dadi Reef are presented in Table 9. The surveyed area included 31 species of scleractinian corals, representing 8 families and 17 genera on the transect lines. This count represents a minimum also, because several corals could be identified only to genus in the field and, therefore, may consist of more than one species. Smith et al. (2009) reported a range of 13-23 species from this site.

Species richness was generally greater also on the reef front transects (i.e., 6-m and especially 12-m depths) than on the reef flat platform, where low tides and wave assault may limit corals. Corals were absent from Sector 1 MRF and Sector 2 6m transects. *Leptastrea purpurea* was the most common species, occurring on 12 of 14 transects in all four sectors and zones. *Pocillopora damicornis* (7 of 14 transects), *Porites lobata* (8 of 14), *and Porites lutea* (6 of 14) were also common on Dadi Reef. Thirteen species occurred on only one transect, and 8 of these species were represented by single observations.

Quantitative analysis of the coral species encountered on transects is presented in Table 10. In Sector 1, greatest absolute densities of coral species were as follows: MRF had no corals; ORF and 6m, *Leptastrea purpurea*; at 12m, four species including . In Sector 2, *Pocillopora damicornis* had the greatest absolute densities in both MRF and ORF; no corals were present on the 6m transect; at 12m , *Porites lutea* had the greatest absolute density. In Sector 3, *Pocillopora damicornis* had the greatest absolute densities in MRF; at ORF, *L. purpurea*; at 6m, *Favites russelli*; at 12m , *L. purpurea*. In Sector 4, *Pocillopora damicornis* had the greatest absolute densities in MRF; at ORF, *L. purpurea*; at 6m, *Porites rus*; at 12m , *Astreopora myriophthalma*.

Relationships between all sectors and all transects determined by group cluster analysis of Bray-Curtis similarity data are depicted in a dendrogram given in Figure 22. These relationships are further illustrated in the results of the MDS analysis of these similarity (percent) data given in Figure 23.

Table 9. Size-frequency distributions of coral species recorded on transects at Dadi Reef. N_i = number of colonies. Mean, SD (standard deviation), and Range refer to colony size in cm^2.

Location	Habitat	Species	N_i	Mean	SD	Range
Sector 1	MRF	No Corals				
	ORF	*Leptastrea purpurea*	15	3.48	3.66	1.18–11.78
		Porites lobata	7	636.17	1,056.97	12.57–2,183.41
		Pocillopora verrucosa	4	26.31	9.71	15.71–34.56
		Leptoria phrygia	3	188.50	108.83	125.66–314.16
		Pocillopora damicornis	2	43.20	58.87	1.57–84.82
		Favia matthaii	1	–	–	12.57
		Acropora humilis	1	–	–	78.54
	6 m	*Leptastrea purpurea*	11	5.89	4.86	0.79–15.90
		Porites lutea	8	6.80	8.60	0.79–27.49
		Porites lobata	4	26.62	30.49	3.93–70.10
		Cyphastrea agassizi	3	7.13	1.67	5.50–8.84
		Astreopora randalli	2	8.05	0.28	7.85–8.25
		Favia pallida	2	7.07	6.66	2.36–11.78
		Favia favus	1	–	–	9.42
		Goniastrea retiformis	1	–	–	3.93
		Favia matthaii	1	–	–	4.71
	12 m	*Cyphastrea agassizi*	1	–	–	5.50
		Astreopora randalli	1	–	–	11.78
		Leptastrea purpurea	1	–	–	3.93
		Porites lutea	1	–	–	1.57
Sector 2	MRF	*Pocillopora damicornis*	7	229.42	362.98	4.71–1,026.12
		Leptastrea purpurea	6	5.24	3.37	0.79–9.42
		Porites lobata	4	468.49	420.52	38.48–829.38
	ORF	*Pocillopora damicornis*	11	142.66	92.35	21.21–251.33
		Leptastrea purpurea	7	3.73	3.14	1.18–9.42
		Porites lobata	5	322.01	330.61	54.98–706.86

Table 9, continued.

Location	Habitat	Species	N_i	Mean	SD	Range
<u>Sector 2</u>	ORF	*Pocillopora verrucosa*	3	2,625.85	2,212.84	70.69–3,903.43
		Porites cylindrica	3	1,612.16	1,389.37	7.85–2,413.41
		Goniastrea retiformis	2	94.25	0.00	–
		Porites rus	1	–	–	70.69
	6 m	No corals				
	12 m	*Porites lutea*	6	8.61	5.04	2.36–15.71
		Leptastrea purpurea	5	9.11	14.31	1.18–34.56
		Astreopora myriophthalma	2	21.21	0.00	–
		Favia matthaii	2	11.78	11.11	3.93–19.63
		Cyphastrea agassizi	2	36.13	42.21	6.28–65.97
		Montastrea foveolata	2	8.25	6.11	3.93–12.57
		Favia pallida	2	13.94	15.27	3.14–24.74
		Astreopora randalli	1	–	–	15.71
<u>Sector 3</u>	MRF	*Pocillopora damicornis*	21	393.23	235.67	19.63–971.93
		Leptastrea purpurea	12	2.52	2.32	0.59–8.25
		Porites lobata	2	5,977.67	0.00	–
		Porites compressa	1	–	–	78.54
		Pavona cactus	1	–	–	12.57
	ORF	*Leptastrea purpurea*	23	21.84	80.46	1.18–390.34
		Favia matthaii	4	29.06	18.56	15.71–56.55
		Psammacora contigua	3	136.92	219.50	6.28–390.34
		Goniastrea retiformis	2	45.16	19.44	31.42–58.90
		Pocillopora damicornis	2	14.53	2.78	12.57–16.49
		Pocillopora verrucosa	1	–	–	12.57
	6 m	*Porites rus*	17	4,1441.11	40,138.84	76.77–115,374.99
		Porites lobata	9	69.40	108.16	0.59–254.47
		Porites lichen	4	37.70	45.18	2.95–103.67

Table 9, continued.

Location	Habitat	Species	N_i	Mean	SD	Range
Sector 3	6 m	*Montipora hoffmeisteri*	3	2.62	1.98	0.79–4.71
		Goniastrea pectinata	2	9.82	3.89	7.07–12.57
		Favites russelli	1	–	–	0.39
		Porites compressa	1	–	–	3279.82
		Leptastrea purpurea	1	–	–	1.57
		Astreopora myriophthalma	1	–	–	3.93
	12 m	*Leptastrea purpurea*	9	7.40	5.80	0.39–21.21
		Porites lobata	6	53.01	50.89	2.36–112.31
		Gardineroseris planulata	5	9.35	5.14	3.53–16.49
		Porites rus	3	13.61	9.07	3.14–18.85
		Cyphastrea agassizi	3	11.13	7.35	2.75–16.49
		Favia pallida	2	34.56	0.00	–
		Favia rotumana	2	21.21	0.00	–
		Montipora hoffmeisteri	2	4.12	2.50	2.36–5.89
		Favites russelli	2	10.60	6.66	5.89–15.32
		Porites compressa	2	5,103.52	0.00	–
		Porites lutea	1	–	–	2.36
		Astreopora myriophthalma	1	–	–	7.07
		Porites lichen	1	–	–	3.14
		Pavona varians	1	–	–	25.13
Sector 4	MRF	*Leptastrea purpurea*	10	2.75	2.29	0.39–7.07
		Pocillopora damicornis	7	638.19	594.23	3.14–1385.44
		Porites compressa	7	173.83	265.58	9.62–755.55
	ORF	*Leptastrea purpurea*	21	3.32	2.56	0.39–11.00
		Pocillopora damicornis	13	418.44	307.20	1.18–988.03
		Heliopora coerulea	2	909.49	619.78	471.24–1,347.74
		Porites compressa	1	–	–	12.57
		Pavona varians	1	–	–	565.49
		Porites densa	1	–	–	17.67

Table 9, continued.

Location	Habitat	Species	N_i	Mean	SD	Range
<u>Sector 4</u>	ORF	*Galaxea fascicularis*	1	–	–	21.99
	6 m	*Porites rus*	11	1,728.05	2676.64	14.14–8,563.98
		Leptastrea purpurea	9	3.71	2.82	1.18–9.42
		Porites lichen	9	147.70	128.84	2.75–341.65
		Porites compressa	4	1,999,43	2,121.47	471.24–5,140.43
		Porites lutea	3	72.58	34.18	33.18–94.25
		Montipora verrucosa	2	21.99	0.00	–
		Favia pallida	1	–	–	1.57
		Astreopora listeri	1	–	–	3.14
	12 m	*Astreopora myriophthalma*	9	23.67	19.51	4.12–56.55
		Porites lutea	7	686.77	790.56	8.64–1,531.53
		Leptastrea purpurea	5	4.41	3.70	1.57–10.60
		Favia pallida	4	4.61	6.38	0.79–14.14
		Porites lobata	4	353.43	0.00	–
		Favites russelli	2	5.42	4.33	2.36–8.48
		Porites lichen	2	36.13	11.11	28.27–43.98
		Astreopora randalli	2	2.55	0.28	2.36–2.75
		Cyphastrea agassizi	2	14.92	1.11	14.14–15.71
		Goniastrea pectinata	1	–	–	9.82
		Porites rus	1	–	–	40.06
		Gardineroseris planulata	1	–	–	1.18

Table 10. Population density, frequency, and coverage of coral species recorded on transects at Dadi Reef.

Location	Habitat	Species	N_i	Relative Density	Absolute Density	Frequency	Coverage	Relative Coverage
Sector 1	MRF	No corals						
	ORF	*Leptastrea purpurea*	15	0.375	1.275	1.00	0.0006	0.010
		Porites lobata	7	0.175	0.595	0.50	0.0482	0.832
		Pocillopora verrucosa	4	0.100	0.340	0.30	0.0011	0.020
		Leptoria phrygia	3	0.075	0.255	0.20	0.0061	0.106
		Pocillopora damicornis	2	0.050	0.170	0.20	0.0009	0.016
		Acropora humilis	1	0.025	0.085	0.10	0.0009	0.015
		Favia matthaii	1	0.025	0.085	0.10	0.0001	0.002
	6 m	*Leptastrea purpurea*	11	0.275	0.833	0.70	0.0006	0.225
		Porites lutea	8	0.200	0.606	0.40	0.0005	0.189
		Porites lobata	4	0.100	0.303	0.20	0.0010	0.370
		Cyphastrea agassizi	3	0.075	0.227	0.30	0.0001	0.050
		Astreopora randalli	2	0.050	0.151	0.20	0.0002	0.056
		Favia pallida	2	0.050	0.151	0.20	0.0001	0.049
		Favia matthaii	1	0.025	0.076	0.10	0.0000	0.016
		Favia favus	1	0.025	0.076	0.10	0.0001	0.033
		Goniastrea retiformis	1	0.025	0.076	0.10	0.0000	0.012
	12 m	*Cyphastrea agassizi*	1	0.025	0.029	0.10	0.0000	0.241
		Astreopora randalli	1	0.025	0.029	0.10	0.0000	0.517
		Leptastrea purpurea	1	0.025	0.029	0.10	0.0000	0.173
		Porites lutea	1	0.025	0.029	0.10	0.0000	0.069
Sector 2	MRF	*Pocillopora damicornis*	7	0.175	0.261	0.60	0.0076	0.457
		Leptastrea purpurea	6	0.150	0.224	0.40	0.0001	0.009
		Porites lobata	4	0.100	0.149	0.20	0.0089	0.534
	ORF	*Pocillopora damicornis*	11	0.275	0.805	0.60	0.0000	0.000
		Leptastrea purpurea	7	0.175	0.512	0.50	0.0002	0.002
		Porites lobata	5	0.125	0.366	0.30	0.0150	0.110
		Pocillopora verrucosa	3	0.075	0.220	0.20	0.0734	0.539
		Porites cylindrica	3	0.075	0.220	0.10	0.0451	0.331
		Goniastrea retiformis	2	0.050	0.146	0.10	0.0018	0.013
		Porites rus	1	0.025	0.073	0.10	0.0007	0.005

Table 10, continued.

Location	Habitat	Species	N_i	Relative Density	Absolute Density	Frequency	Coverage	Relative Coverage
Sector 2	6 m	No corals						
	12 m	*Porites lutea*	6	0.150	0.280	0.50	0.0003	0.1748
		Leptastrea purpurea	5	0.125	0.233	0.50	0.0003	0.1541
		Astreopora myriophthalma	2	0.050	0.093	0.10	0.0003	0.1435
		Favia matthaii	2	0.050	0.093	0.20	0.0001	0.0797
		Cyphastrea agassizi	2	0.050	0.093	0.20	0.0004	0.2445
		Montastrea foveolata	2	0.050	0.093	0.20	0.0001	0.0558
		Favia pallida	2	0.050	0.093	0.20	0.0002	0.0943
		Astreopora randalli	1	0.025	0.047	0.10	0.0001	0.0532
Sector 3	MRF	*Pocillopora damicornis*	21	0.525	1.558	0.90	0.0780	0.406
		Leptastrea purpurea	12	0.300	0.890	0.70	0.0003	0.002
		Porites lobata	2	0.050	0.148	0.10	0.1129	0.588
		Porites compressa	1	0.025	0.074	0.10	0.0007	0.004
		Pavona cactus	1	0.025	0.074	0.10	0.0001	0.001
	ORF	*Leptastrea purpurea*	23	0.575	2.642	0.80	0.0073	0.433
		Favia matthaii	4	0.100	0.460	0.10	0.0017	0.100
		Psammacora contigua	3	0.075	0.345	0.30	0.0060	0.358
		Goniastrea retiformis	2	0.050	0.230	0.20	0.0013	0.078
		Pocillopora damicornis	2	0.050	0.230	0.20	0.0004	0.025
		Pocillopora verrucosa	1	0.025	0.115	0.10	0.0002	0.011
	6 m	*Porites rus*	17	0.425	1.549	0.50	8.1749	0.994
		Porites lobata	9	0.225	0.820	0.50	0.0072	0.001
		Porites lichen	4	0.100	0.365	0.40	0.0017	0.000
		Montipora hoffmeisteri	3	0.075	0.273	0.30	0.0001	0.000
		Goniastrea pectinata	2	0.050	0.182	0.20	0.0002	0.000
		Favites russelli	1	0.025	0.091	0.10	0.0000	0.000
		Porites compressa	1	0.025	0.091	0.10	0.0381	0.005
		Leptastrea purpurea	1	0.025	0.091	0.10	0.0000	0.000
		Astreopora myriophthalma	1	0.025	0.091	0.10	0.0000	0.000
	12 m	*Leptastrea purpurea*	9	0.225	6.426	0.50	0.0061	0.006
		Porites lobata	6	0.150	4.284	0.40	0.0289	0.029
		Gardineroseris planulata	5	0.125	3.570	0.30	0.0042	0.004
		Porites rus	3	0.075	2.142	0.20	0.0037	0.004

Table 10, continued.

Location	Habitat	Species	N_i	Relative Density	Absolute Density	Frequency	Coverage	Relative Coverage
Sector 3	12m	*Cyphastrea agassizi*	3	0.075	2.142	0.20	0.0002	0.000
		Favia pallida	2	0.050	1.428	0.10	0.0063	0.006
		Favia rotumana	2	0.050	1.428	0.10	0.0039	0.004
		Montipora hoffmeisteri	2	0.050	1.428	0.20	0.0007	0.001
		Favites russelli	2	0.050	1.428	0.20	0.0019	0.002
		Porites compressa	2	0.050	1.428	0.10	0.9279	0.940
		Porites lutea	1	0.025	0.714	0.10	0.0002	0.000
		Astreopora myriophthalma	1	0.025	0.714	0.10	0.0006	0.001
		Porites lichen	1	0.025	0.714	0.10	0.0003	0.000
		Pavona varians	1	0.025	0.714	0.10	0.0023	0.002
Sector 4	MRF	*Pocillopora damicornis*	7	0.175	0.415	0.50	0.0338	0.782
		Porites compressa	7	0.175	0.415	0.30	0.0092	0.213
		Leptastrea purpurea	10	0.250	0.594	0.50	0.0002	0.005
	ORF	*Leptastrea purpurea*	21	0.525	2.924	0.90	0.0012	0.009
		Pocillopora damicornis	13	0.325	1.810	0.80	0.0964	0.685
		Heliopora coerulea	2	0.050	0.278	0.20	0.0322	0.229
		Porites compressa	1	0.025	0.139	0.10	0.0002	0.002
		Pavona varians	1	0.025	0.139	0.10	0.0100	0.071
		Porites densa	1	0.025	0.139	0.10	0.0003	0.002
		Galaxea fascicularis	1	0.025	0.139	0.10	0.0004	0.003
	6 m	*Porites rus*	11	0.275	5.071	0.50	1.1157	0.664
		Leptastrea purpurea	9	0.225	4.149	0.40	0.0020	0.001
		Porites lichen	9	0.225	4.149	0.40	0.0780	0.046
		Porites compressa	4	0.100	1.844	0.20	0.4694	0.279
		Porites lutea	3	0.075	1.383	0.20	0.0128	0.007
		Montipora verrucosa	2	0.050	0.922	0.10	0.0026	0.002
		Favia pallida	1	0.025	0.461	0.10	0.0001	0.000
		Astreopora listeri	1	0.025	0.461	0.10	0.0002	0.000
	12 m	*Astreopora myriophthalma*	9	0.225	9.691	0.40	0.0292	0.032
		Porites lutea	7	0.175	7.537	0.40	0.6591	0.724
		Leptastrea purpurea	5	0.125	5.384	0.30	0.0030	0.003
		Favia pallida	4	0.100	4.307	0.10	0.0025	0.003
		Porites lobata	4	0.100	4.307	0.10	0.1938	0.213
		Favites russelli	2	0.050	2.153	0.20	0.0015	0.002
		Porites lichen	2	0.050	2.153	0.10	0.0099	0.011

Table 10, continued.

Location	Habitat	Species	N_i	Relative Density	Absolute Density	Frequency	Coverage	Relative Coverage
Sector 4	12m	*Astreopora randalli*	2	0.050	2.153	0.20	0.0007	0.001
		Cyphastrea agassizi	2	0.050	2.153	0.20	0.0041	0.004
		Goniastrea pectinata	1	0.025	1.077	0.10	0.0013	0.002
		Porites rus	1	0.025	1.077	0.10	0.0055	0.006
		Gardineroseris planulata	1	0.025	1.077	0.10	0.0002	0.000

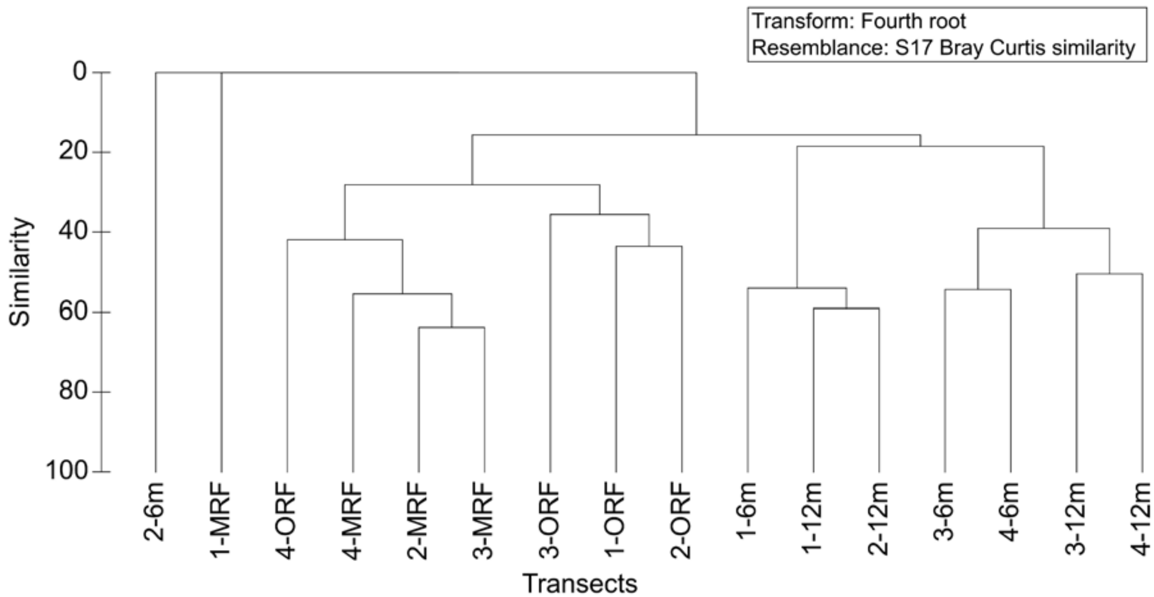

Figure 22. Cluster analysis (group averaging) of coral assemblages on transects at Dadi Reef. See Figure 20 for transect and zone definitions.

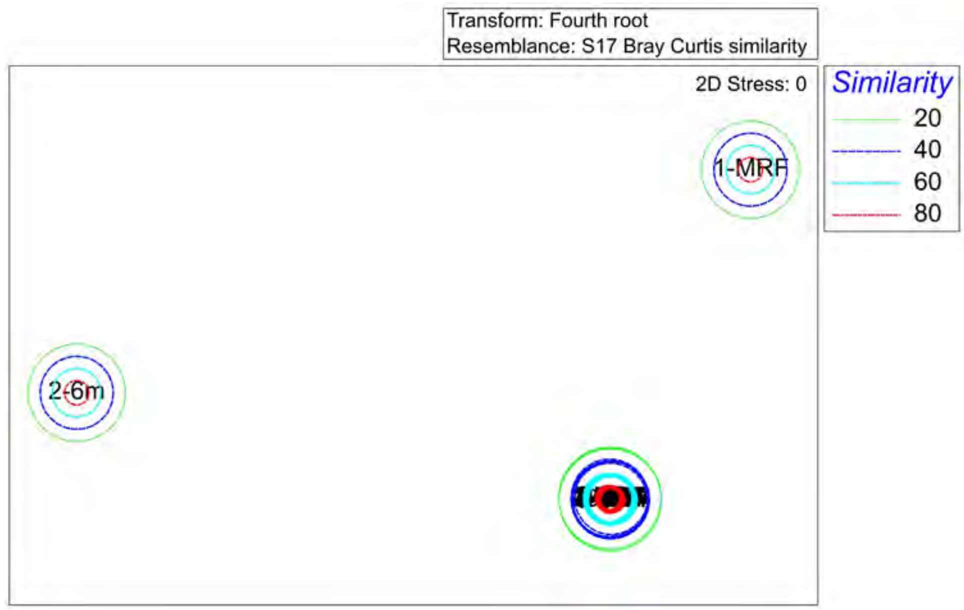

Figure 23. Multi-dimensional scaling (MDS) analysis of similarity in coral species assemblages at Dadi Reef. Similarity values indicate the percentage of similarity between transects. See Figure 20 for transect and zone definitions.

Macroinvertebrates

The distribution and abundance of conspicuous epibenthic macroinvertebrates observed on 16 transects in Sectors 1-4 are given in Table 11. A total of 118 species from 7 phyla were found. There were 13 species of sponges (Porifera: Demospongiae), 3 species of anthrozoans (Cnidaria), 3 species of polychaete worms (Annelida), 43 species of gastropods (Mollusca), 13 species of bivalves (Mollusca), 14 species of shrimps and crabs (Anthropoda: Crustacea), 5 species of starfishes (Echinodermata: Asteroidea), one species of brittlestar (Echinodermata: Ophiouroidea), 5 species of sea urchins (Echinodermata:Echinoidea), 9 species of sea cucumbers (Echinodermata: Holothuroidea), and 9 species of sea squirts (Chordata:Ascidiacea).

Sponges were most commonly observed in reef slope transects but a single species, *Dysidea herbacea*, was found also on the middle and outer reef flat in Sector 3. Anthozoans were uncommon and seen only on the ORF of Sector 4 (one species) and on the 12m transects of sectors 3-4. Polychaete worms were also uncommon and found on 6m transects of sectors 2 and 4 and the 12m transects of sectors 3 and 4. No single gastropod species was common on all transects in all sectors. *Dendropoma maxima* tended to be distributed on reef flats and some reef slopes. *Trochus niloticus* was observed on both reef flats and on 6m reef slope transects. Similarly, the giant clam *Tridacna maxima* (Bivalvia) was found on reef flats and slopes but was absent from Sector 2. The sea urchins *Echinostrephus aciculeatus* and *Echinometrix diadema* were found mainly on reef flats or 6m slopes in sectors 1-3, as were the sea cucumbers *Holothuria atra*, *H. edelus*, and *Bohadschia argus*. Sea squirts were found variously in all four sectors but mainly on 6 and 12m transects. Two species, *Didemnum molle* and *D. recurivatum*, were found also on reef flats.

Comparisons of macroinvertebrate distributions across transects and sectors by cluster analysis of Bray-Curtis similarity data (Figure 22) indicated a clear separation between reef flat and reef slope transects for all sectors, with the exception of Sector 1 where a middle reef flat transect was more similar to that at 6m. MDS analysis of these data (Figure 23) group reef slope transects separately from reef flat transects as well, except that in Sector 4 both reef flat transects are distinct, and in Sector 1 the middle reef flat transect and the 6m transect are more similar.

Densities of macroinvertebrate species are given in Table 12 and their corresponding relationships between sectors in Figures 24 and 25. Densities of each species tended to be low, with the exception of some sea urchins (Echinoidea) and sea cucumbers (Holothuroidea). Clustering patterns were similar to those seen for distribution data (Figure 22) while the MDS analysis indicated two quite separate groups of 60% similarity; transect 1-12 formed one distinct group while the remaining transects from all sectors formed the other.

Table 11. Species of conspicuous epibenthic invertebrates observed on or adjacent to transects at Dadi Reef. Observations of live specimens are denoted by filled circles (●), and records based on dead specimens are denoted by open circles (○).

	Sector 1				Sector 2				Sector 3				Sector 4			
	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m
Porifera:Demospongiae																
Dysidea granulosa								●			●	●			●	●
Dysidea herbacea			●	●			●	●	●	●	●	●			●	●
Ircinia sp. 1								●								
Coscinoderma matthewsi				●				●				●				
Spheciospongia vagabunda																●
Acanthella cavernosa			●													
Stylissa massa			●				●	●			●	●			●	●
Liosina cf. *granularis*				●				●				●				●
Axinyssa sp. 1								●								
Haliclona sp. 2 (blue)												●				
Aka sp. 2								●								
Red sponge															●	
Brown sponge															●	
Cnidaria:Anthozoa																
Sinularia gibberosa												●				
Sinularia polydactyla														●		
Sinularia spp.																●
Annelida:Polychaeta																
Loimia medusa												●				
Protula sp.							●									●
Spirobranchus corniculatus							●					●			●	●
Mollusca:Gastropoda																
Patella flexuosa	●															
Trochus histrio		○			○						○					
Trochus niloticus		●	●			●				○	●				●	

Table 11, continued.

	Sector 1				Sector 2				Sector 3				Sector 4			
	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m
Astraea rhodostoma														●		
Turbo argyrostomus															○	
Cerithium columna									○			○				
Cerithium echinatum																○
Cerithium munitum			○				●									
Cerithium nodulosum		○				○			●	●						
Cerithium punctatum						○										
Rhinoclavis fasciata							○	●								
Turritella sp.				○												
Dendropoma maxima		●			●	●			●	●						●
Serpulorbis sp.						●	●		●	●	●				●	
Lambis lambis		●							●	●						
Lambis chiragra							○			○						
Lambis truncata												○				
Strombus mutabilis	○															
Cypraea carneola								○								○
Cypraea erosa											○	○				
Cypraea isabella											○					
Cypraea lynx										○						
Cypraea moneta									○							
Cypraea talpa								○								
Bursa bufonia										●						
Cantharus undosus	○															
Prodotia iostoma																○
Chicoreus brunneus		●				●			○							
Vitularia miliaris											○					
Drupa morum		●														

Table 11, continued.

	Sector 1				Sector 2				Sector 3				Sector 4			
	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m
____*Coralliophila violacea*							●				●	●			●	
Vasum turbinellus		●														
____*Nassarius granifer*			●					●								
Latirus polygonus		○													○	
Imbricaria olivaeformis				●												
Conus chaldaeus		●														
Conus coronatus										●						
Conus ebraeus														○		
Conus flavidus		●														
Conus miles				○												
Conus rattus						●									○	
Conus vexillum											○					
Phyllidiella pustulosa												●				●
Mollusca:Bivalvia																
Barbatia amygdalumtostum															○	
Spondylus sp.	○		○													
Limaria fragilis			○	○												
Ctena bella					○											
Pinna muricata										●						
Modiolus auriculatus		○			○	○										
Gastrochaena sp.																●
Vasticardium elongatum															○	
Tridacna maxima		●								●	○	●			●	
Lioconcha ornata				○				○								
Periglypta reticulata			○			○				○						
Scutarcopagia scobinata					○		○		○	○			○			

Table 11, continued.

	Sector 1				Sector 2				Sector 3				Sector 4			
	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m
Gafrarium pectinatum	○		○													
Arthropoda:Crustacea																
Alpheus djiboutiensis			●					●								
Alpheus frontalis						●									●	●
Calcinus gaimardi		●				●										
Calcinus guamensis			●													
Calcinus latens						●	●		●					●		●
Calcinus minuta											●					
Dardanus lagopodes							●		●						●	●
Paguritta kroppi											●				●	
Periclimenes soror								●								
Neaxius sp.	●	●			●	●			●	●						
Stenopus hispidus				●												
Etisus dentatus										○						
Etisus splendidus										○						
Thalamita spp.	○		○													
Echinodermata:Asteroidea																
Choriaster granulata																●
Culcita novaeguineae															●	
Linckia guildingi													●			
Linckia laevigata					●			●	●	●					●	
Linckia multifora															●	
Echinodermata:Ophiouroidea																
Ophiocoma		●														
Echinodermata:Echinoidea																
Echinostrephus aciculatus		●				●	●		●	●					●	●
Echinometra mathaei		●			●	●				●						

Table 11, continued

	Sector 1				Sector 2				Sector 3				Sector 4			
	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m
Echinometra sp. A															●	
Echinothrix diadema		●	●		●	●	●		●	●						
Diadema savignyi		●							●			●				
Echinodermata:Holothuroidea																
Actinopyga echinites	●	●			●											
Actinopyga mauritiana		●														
Bohadschia argus		●								●	●	●			●	●
Holothuria atra	●	●			●	●			●	●					●	
Holothuria edulis			●				●				●	●			●	●
Holothuria leucospilota	●															
Holothuria whitmaei							●	●								
Stichopus chloronotus						●				●					●	●
Synapta maculata									●	●		●				
Chordata:Ascidiacea																
Clavellina moluccensis				●				●				●			●	●
Didemnum molle	●															
Didemnum moseleyi												●			●	
Didemnum recurvatum		●				●										
Didemnum sp. 5												●				
Phallusia julinea								●								
Polycarpa argentata			●													
Polycarpa cryptocarpa											●				●	
Rhopalaea sp. A								●								

Table 12. Mean densities of conspicuous invertebrates observed on transects at Dadi Reef. Densities are reported as mean ± standard deviation in five 20-m^2 quadrats sampled along a 50-m transect.

	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m
Mollusca:Gastropoda																
Trochus niloticus		0.6 ± 0.9				0.4 ± 0.5						0.4 ± 0.5				
Cerithium nodulosum									1.0 ± 1.0							
Drupa morum		0.2 ± 0.4														
Vasum turbinellus		0.4 ± 0.5														
Conus flavidus		0.2 ± 0.4														
Conus miles			0.2 ± 0.4													
Conus rattus						0.2 ± 0.4										
Mollusca:Bivalvia																
Tridacna maxima		0.2 ± 0.4									0.2 ± 0.4				0.2 ± 0.4	
Echinodermata:Ophiouroidea																
Ophiocoma sp.		0.4 ± 0.5														
Echinodermata:Asteroidea																
Linckia guildingi																0.2 ± 0.4
Linckia laevigata			0.2 ± 0.4		0.2 ± 0.4				0.2 ± 0.4					0.2 ± 0.4		
Echinodermata:Echinoidea																
Diadema savignyi		0.4 ± 0.9							0.2 ± 0.4							
Echinothrix diadema		2.8 ± 3.6			0.2 ± 0.4	2.6 ± 1.3			0.2 ± 0.4	4.2 ± 2.4				0.4 ± 0.9		
Echinometra mathaei		18.8 ± 14.4			1.6 ± 2.2	11.4 ± 6.0				0.4 ± 0.5						
Echinometra sp. A						1.2 ± 1.3										
Echinostrephus aciculatus			1.0 ± 1.0								0.2 ± 0.4					0.8 ± 1.3

Table 12, continued.

	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m	MRF	ORF	6 m	12 m
Echinodermata:Holothuroidea																
Stichopus chloronotus						0.2 ± 0.4	0.2 ± 0.4			1.0 ± 0.7			0.2 ± 0.4	0.2 ± 0.4	0.4 ± 0.5	
Actinopyga echinites	1.6 ± 0.5	0.2 ± 0.4			0.2 ± 0.4											
Actinopyga mauritiana		0.2 ± 0.4														
Bohadschia argus										0.2 ± 0.4	0.2 ± 0.4	0.2 ± 0.4				
Holothuria atra	0.4 ± 0.9	0.2 ± 0.4			0.4 ± 0.5	0.4 ± 0.5	0.2 ± 0.4		0.2 ± 0.4	1.0 ± 1.0			1.4 ± 0.5	1.0 ± 1.0		
Holothuria edulis								0.6 ± 0.9			0.6 ± 0.5	0.4 ± 0.5			0.6 ± 0.5	0.6 ± 0.5
Synapta maculata									0.2 ± 0.4	0.4 ± 0.5	0.2 ± 0.4					

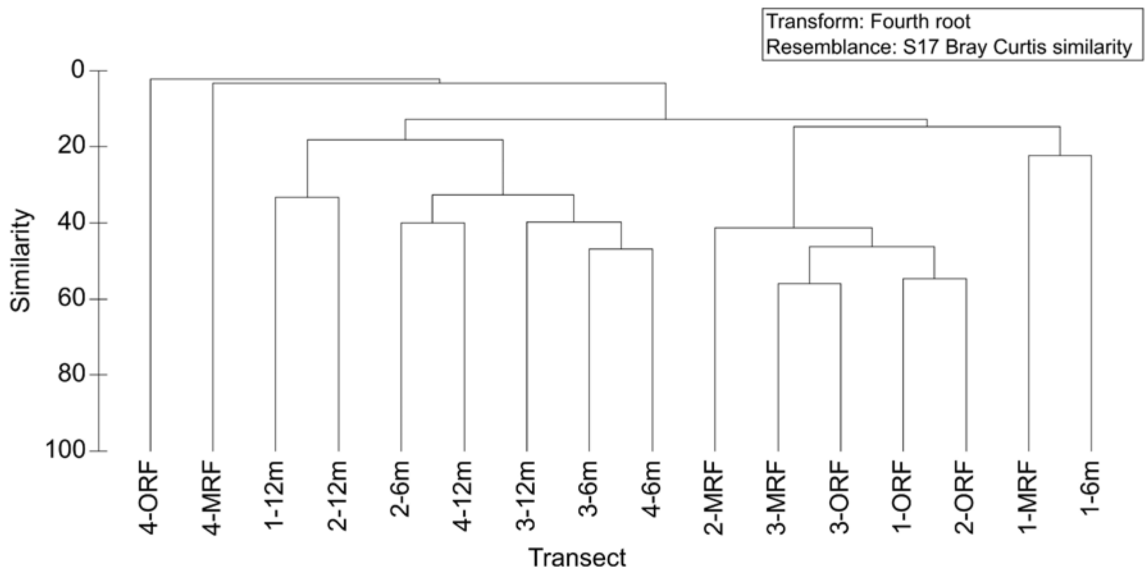

Figure 24. Dendrogram depicting similarities (per cent) in macroinvertebrate species assemblages of transects at Dadi Reef as determined by cluster analysis (group linkage). See Figure 20 for transect and zone definitions.

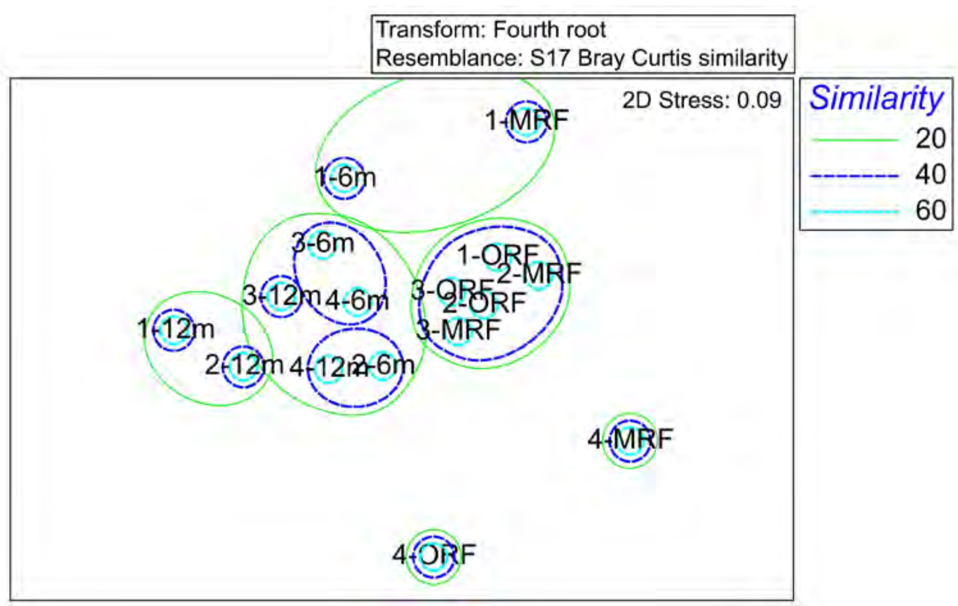

Figure 25. Multi-dimensional scaling (MDS) analysis of similarity in macroinvertebrate species assemblages at Dadi Reef. Similarity values indicate the percentage of similarity between transects. See Figure 20 for transect and zone definitions.

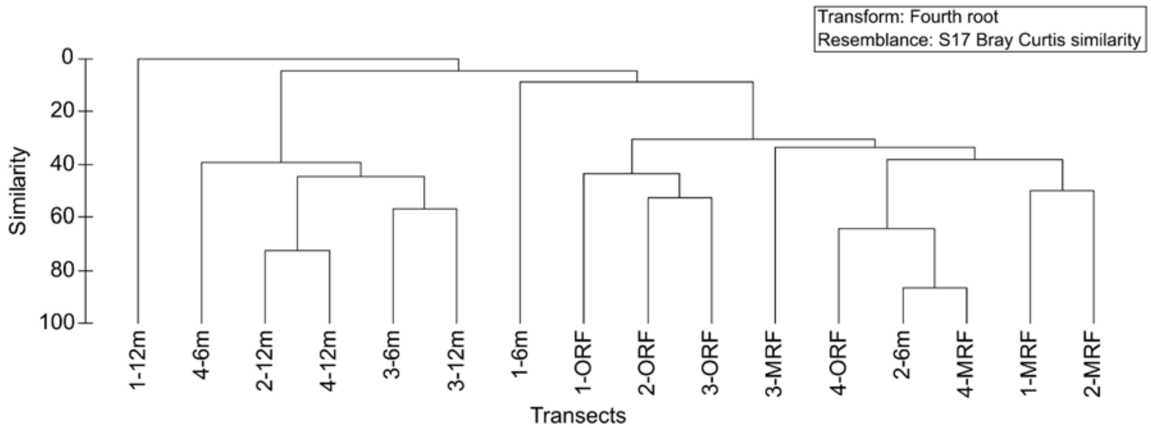

Figure 26. Dendrogram depicting similarities (per cent) in macroinvertebrate species densities on transects at Dadi Reef as determined by cluster analysis (group linkage). See Figure 20 for transect and zone definitions.

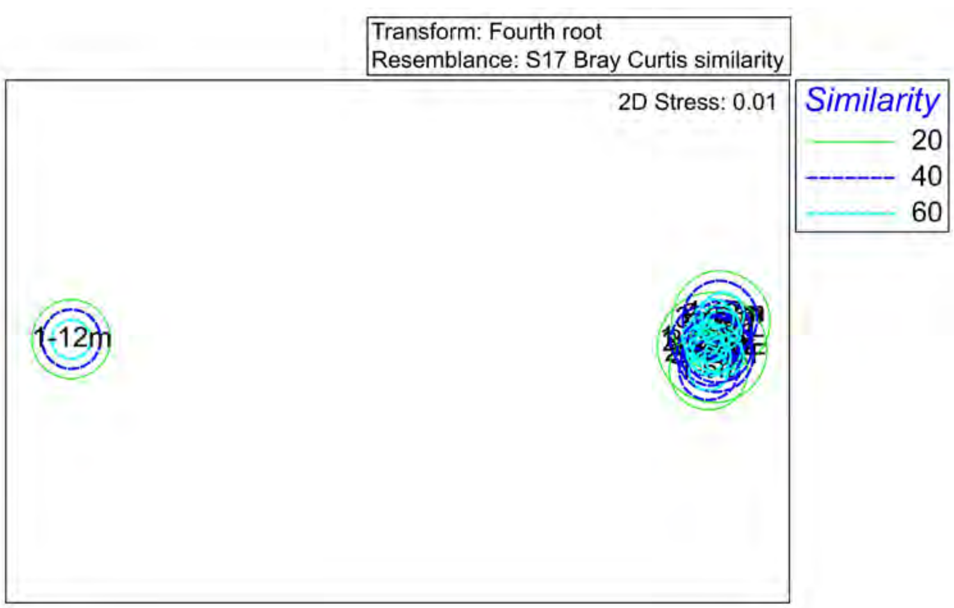

Figure 27. Multi-dimensional scaling (MDS) analysis of similarity in densities of macroinvertebrate species assemblages at Dadi Reef. Similarity values indicate the percentage of similarity between transects. See Figure 20 for transect and zone definitions.

Fishes

A checklist of reef fishes with their observed patterns of distribution on transects is given in Appendix 3. A total of 174 species were observed at the Dadi Beach site. Species richness ranged from 19 on transect 1-MRF to 62 on transect 2-MRF (Figure 28). Mean (± SE) species richness was 37.4 (± 3.9) for all transects combined. The number of fishes per transect ranged from 85 for transect 3-MRF to 631 for transect 3-6m (Figure 29). The mean (± SE) number of fishes per transects was 328.4 (± 47.2) for all transects combined. Shannon's H' index of diversity ranged from 1.257 on transect 4-MRF to 2.853 on transect 4-ORF (Figure 30). The mean (± SE) value of H' was 2.168 (± 0.110) for all transects combined. The relationship between species richness and the number of fishes was positive (Figure 31) and significant (r^2 = 0.66, $p < 0.001$, $n = 16$). Overall, shallow spur and groove (6m) and outer reef flat (ORF) transects accounted in most cases for greatest species richness, high abundance, and high species diversity compared to the other reef zones sampled. Conversely, mid-reef flat (MRF) transects had the lowest species richness, abundance, and diversity compared to other reef zones sampled.

The reef fish assemblages observed at this site were also similar to those from reported previously Smith et al. (2009) and Paulay et. al (2001). This site was more diverse compared to Tipalao Reef, probably because of the greater habitat complexity at Dadi Reef (T.J. Donaldson, personal observation).

The density (number per square meter) of each reef fish species observed on transects is given in Appendix 4. Densities ranged from 0.002 to 3.8 per m^2. Most species, however, had densities of less than 0.01 per m^2. The damselfish *Chrysiptera traceyi* (Pomacentridae), a diminutive species (usually less than 4cm in total length) had relatively high densities (1.4 to 3.8 per m^2) on most shallow and some deep transects. Most of the individuals contributing to these density levels were juvenile fish that had recruited recently, and these fish tended to be found in clusters of individuals rather than dispersed widely on the bottom. Another damselfish species, *Abudefduf sexfasciatus*, had densities of 2.01 per m^2 on two transects, 2-MRF (a mid-reef flat transect) and 3-6m (a shallow spur and groove transect at 6m depth) on rich coral where a tourist diver-snorkeler feeding station was found.

The relationships between transects with respect to fish assemblage structure are illustrated with respect to similarity in a group-linkage cluster analysis dendrogram (Figure 32). Two largely distinct clusters (reef flats, and shallow and deep transects), were found. Again, one mid-reef flat transect, 2MRF, shared over 80% similarity in assemblage structure with one shallow transect, 3-6m. The relationships are illustrated further in a multi-dimensional space (MDS) plot (Figure 33). Reef flat (MRF and ORF) transects, with one exception (transect 2-MRF), had similar fish assemblages distinct from 12m and 6m depth transects located on the upper terrace and spur and groove zone, respectively. This was not unexpected, as each reef zone has a compliment of species with distribution patterns limited to specific depths or habitat types.

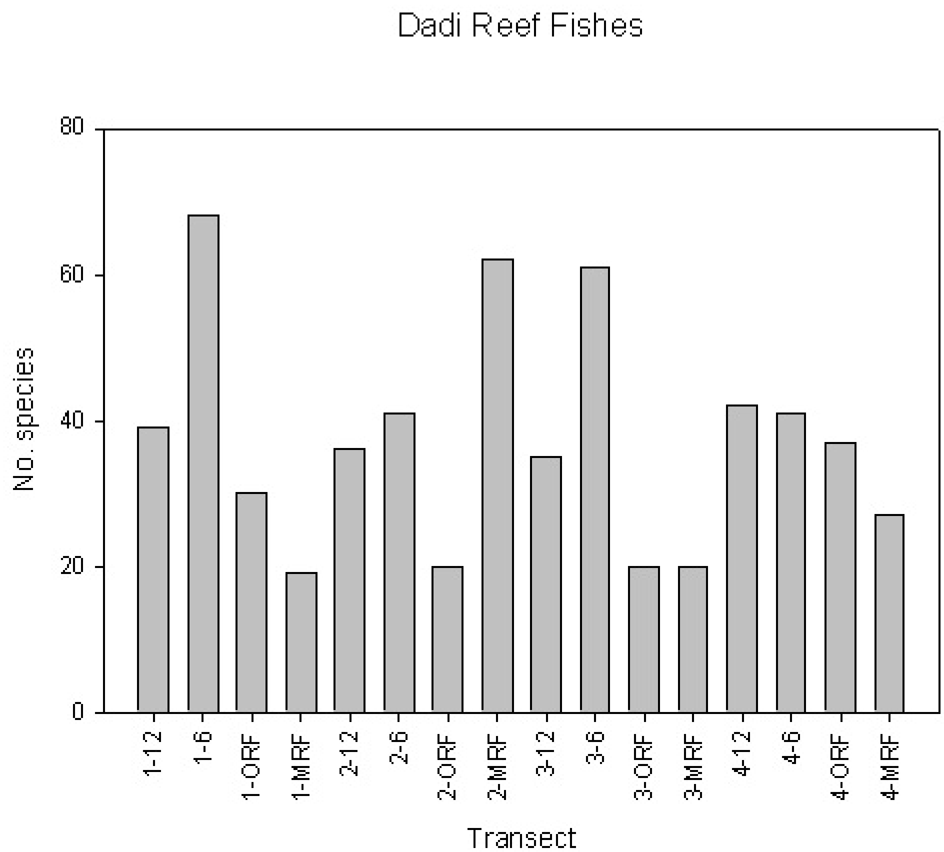

Figure 28. Species richness of fishes at Dadi Reef transects. 12 = deep slope, 6 = shallow slope, ORF = outer reef flat and MRF = middle reef flat. Numbers (1-4) refer to zones.

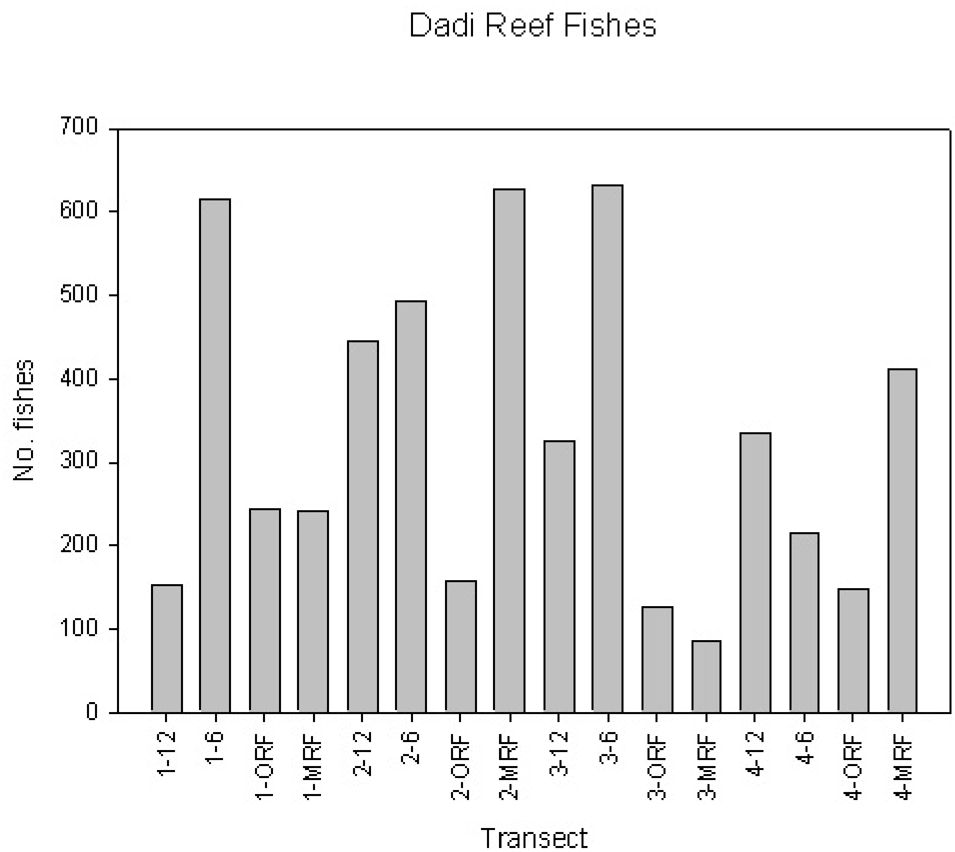

Figure 29. Abundance (number of fishes) of reef fishes observed on transects at Dadi Reef. See Figure 28 for transect definitions.

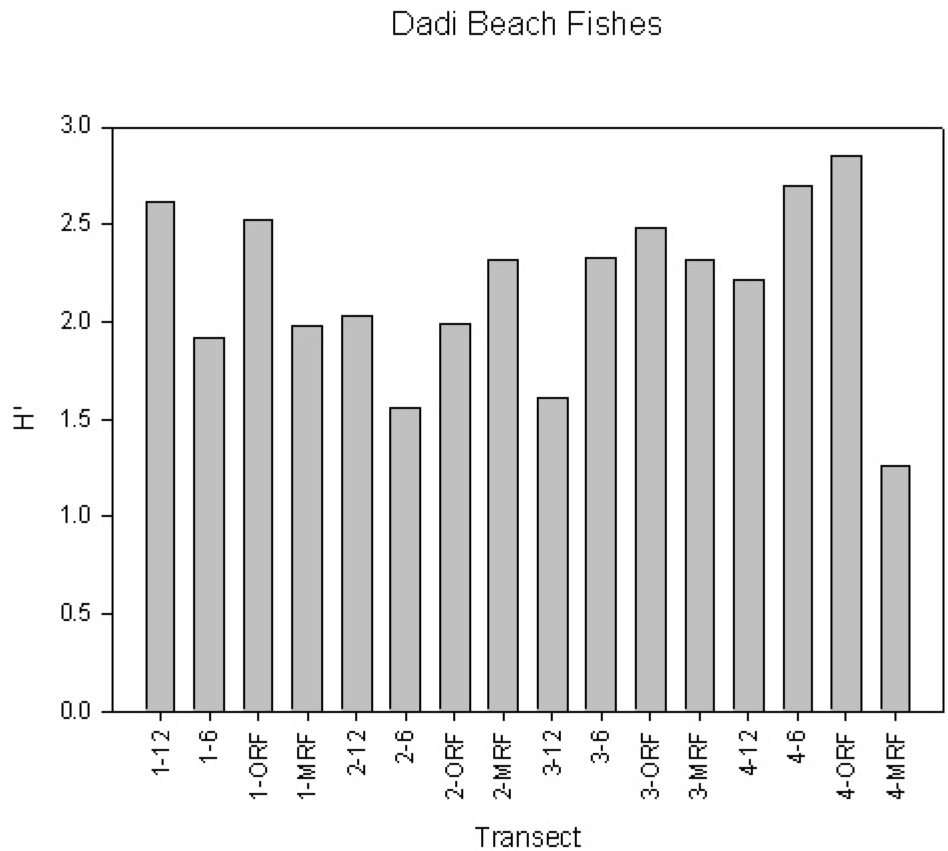

Figure 30. Species diversity (Shannon's H') of reef fishes on transects at Dadi Reef. See Figure 28 for transect definitions.

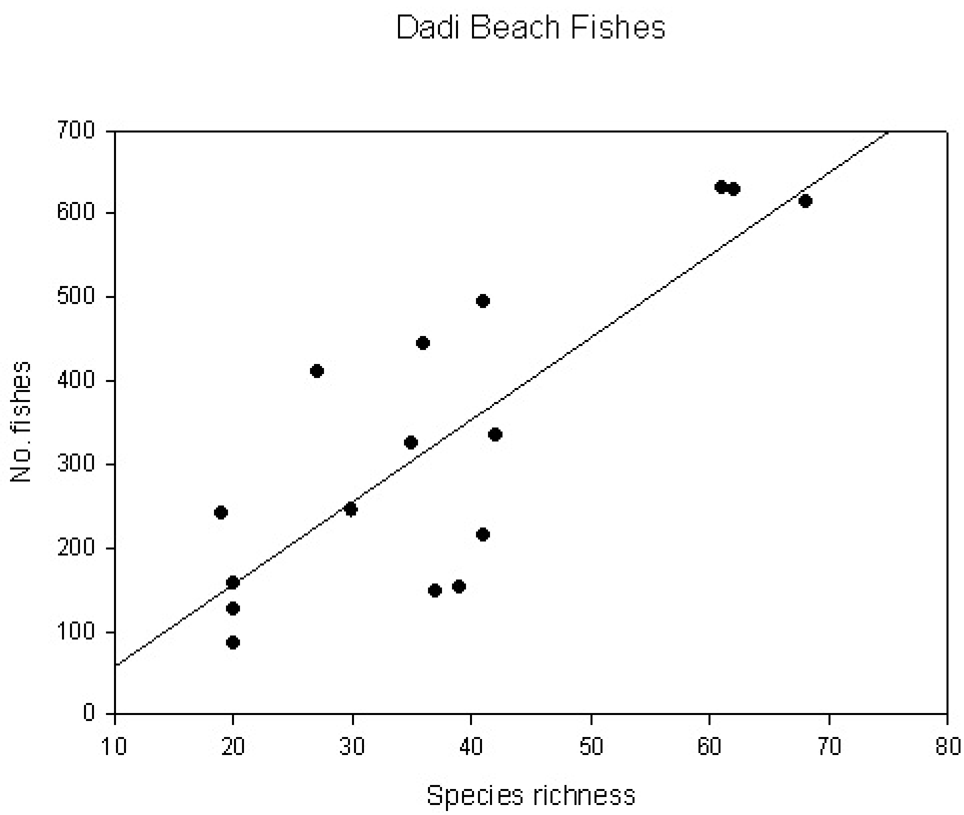

Figure 31. Relationship between species richness and abundance (number of fishes) on transects at Dadi Reef.

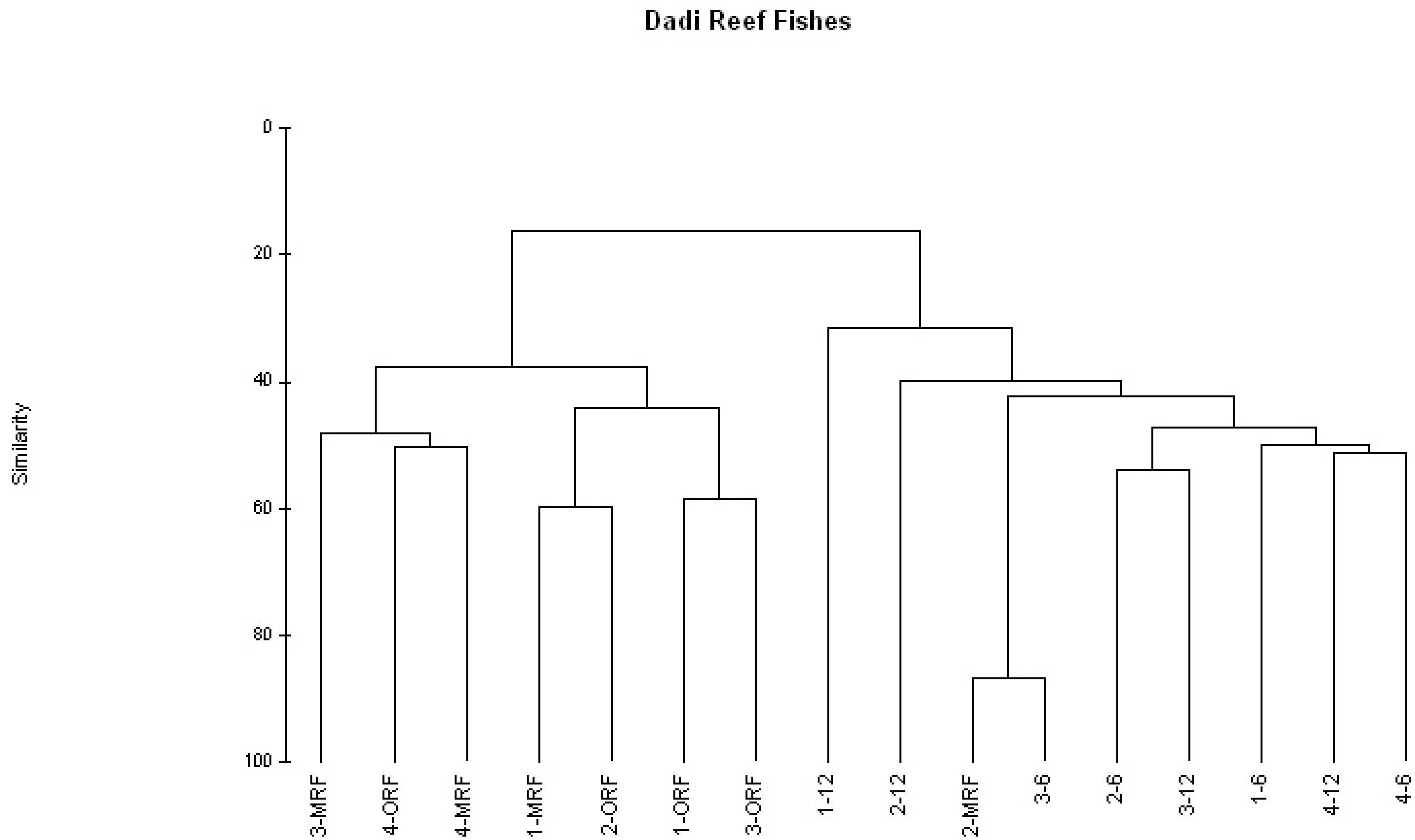

Figure 32. Dendrogram generated from group-linkage cluster analysis of reef fish assemblages on transects at Dadi Reef. Similarity values range between 0.0 (no similarity) and 1.0 (complete similarity). See Figure 28 for transect definitions.

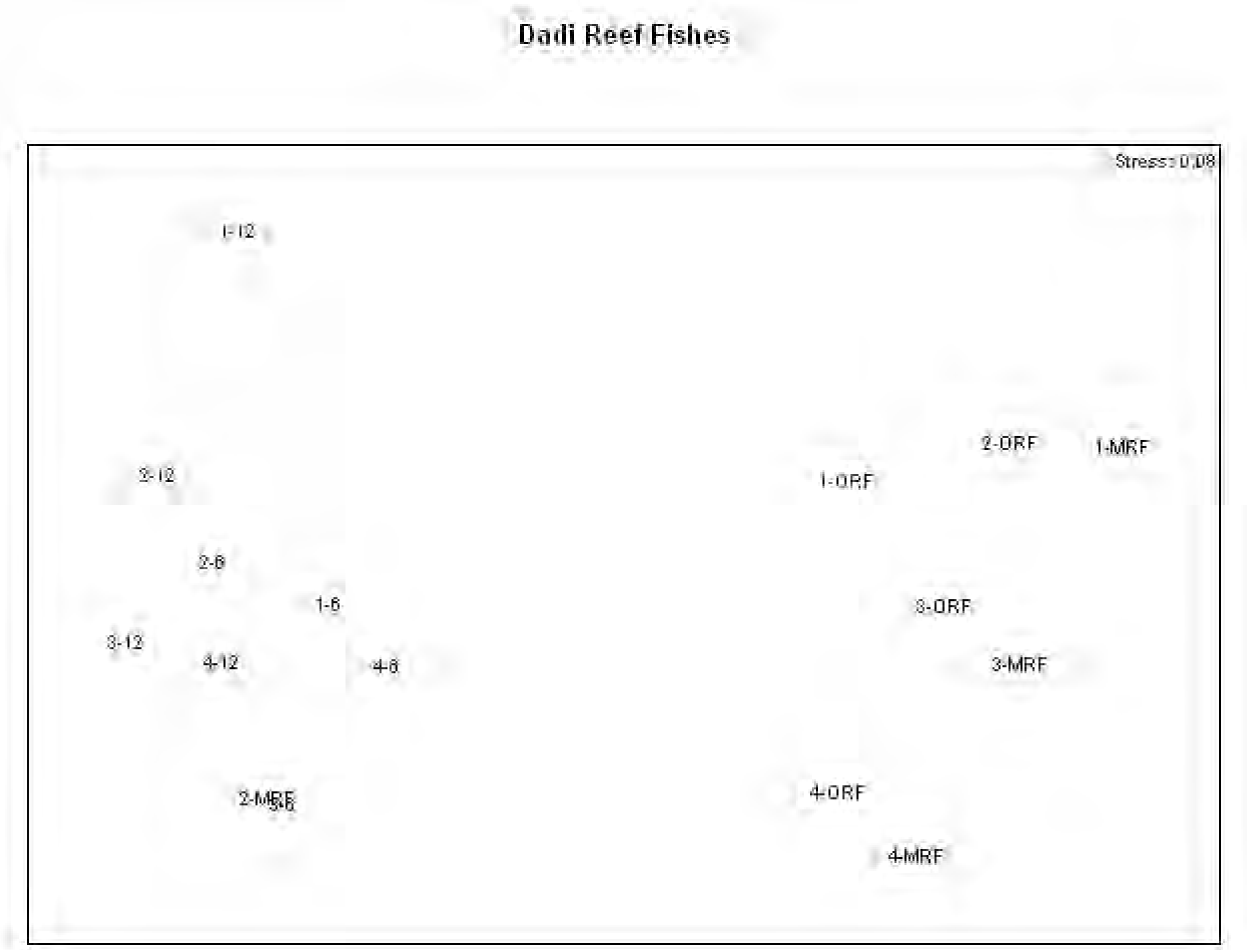

Figure 33. Multidimensional Scaling (MDS) analysis of reef fish assemblages on transects at Dadi Reef. The stress value is an indicator of reliability that ranges between 0.00 (very high reliability) and 1.00 (no reliability). See Figure 28 for transect definitions.

South Piti Channel

Benthic Cover

Mean coverage of benthic cover is given in Table 13. Sand is the most significant component of benthic cover at south Piti Channel, accounting for more than 65% of the total cover in all zones. And as much as 96% in Sector 4. Abiotic cover exceeded biotic cover in all sectors. The algae *Padina boryana* and *Gracilaria salicornia* accounted for most biotic cover. There were no live corals at this site.

Coverage data for transects cluster (Figure 34) according to sector except that 2A was more similar to transects 1A and 1B, transect 2A was more similar to transects 4A and 4B, and transects 2B and 3B were more similar. Multidimensional scaling and ordination of the coverage data reveal seven clusters with 80% similarity but five of these are just a single transect, one has two transects, and a third has three transects (Figure 36).

A list of marine plants observed at south Piti Channel is given in Table 14.

Table 13. Mean substrate coverage in east-west sectors of south Piti Channel. See Figure 4 for location of sectors in the study area.

	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5
Acanthophora spicifera	0.00 ± 0.00	1.25 ± 1.25	0.00 ± 0.00	0.00 ± 0.00	4.69 ± 4.06
Gracilaria salicornia	13.75 ± 0.25	2.81 ± 2.19	10.00 ± 10.00	4.38 ± 3.75	0.00 ± 0.00
Hypnea "esperi"[a]	2.50 ± 1.25	5.63 ± 1.25	0.94 ± 0.94	0.00 ± 0.00	0.00 ± 0.00
Halimeda opuntia	3.13 ± 3.13	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	8.13 ± 1.88
Padina boryana	14.06 ± 12.81	2.19 ± 2.19	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Halophila minor	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2.19 ± 2.19
Sand	64.69 ± 4.06	87.50 ± 6.25	89.06 ± .06	95.63 ± 3.75	85.00 ± 0.75
Bare rock	1.88 ± 1.88	0.63 ± 0.63	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

[a]See Lobban and Tsuda (2003) for discussion of this species.

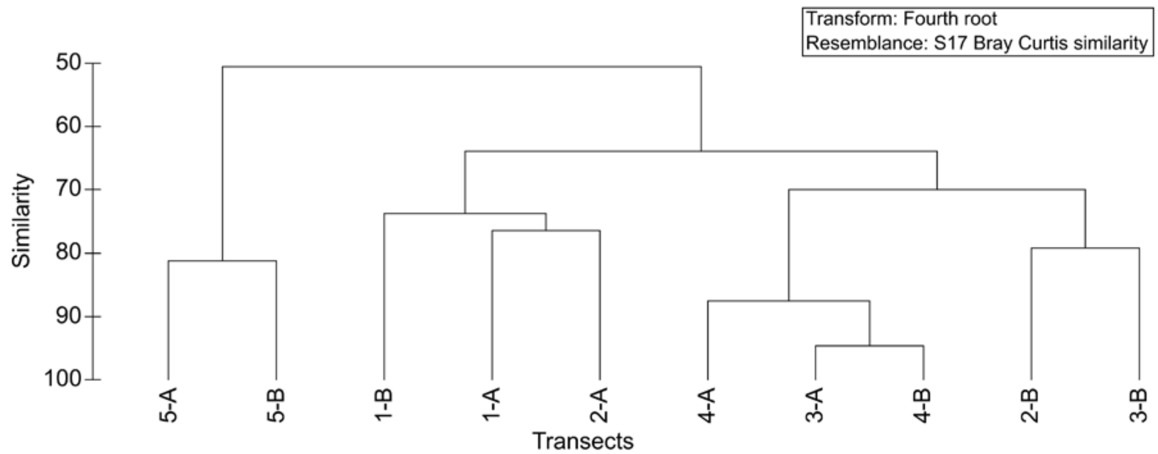

Figure 34. Cluster analysis (group averaging) of benthic coverage patterns on transects at south Piti Channel. Transects are designated by the sector number followed by the physiographic zone.

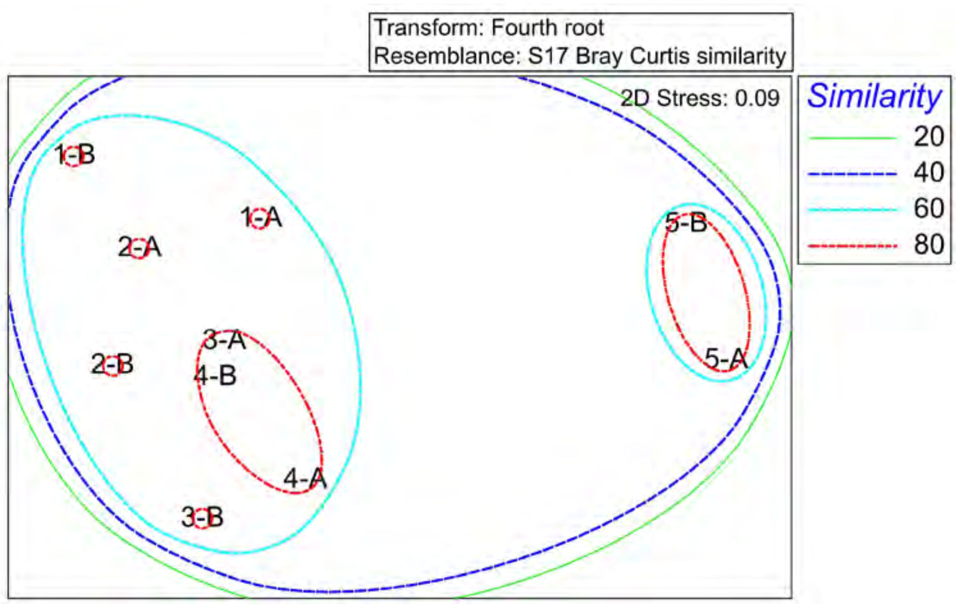

Figure 35. Multi-dimensional scaling (MDS) analysis of benthic cover at south Piti Channel. Values indicate the level of similarity between transects. See Figure 35 for transect definitions.

Table 14. Benthic marine plants observed on south Piti Channel. Checklist of species observed. Phylogenetic arrangement follows Lobban and Tsuda (2003).

	Sector 1		Sector 2		Sector 3		Sector 4		Sector 5	
	A	B	A	B	A	B	A	B	A	B
Rhodophyta										
Acanthophora spicifera		●	●	●				●		
Gracilaria salicornia	●	●	●	●	●	●	●	●	●	●
Hypnea "*esperi*"[a]	●	●	●	●	●	●		●		
Phaeophyta										
Padina boryana	●	●	●		●	●	●		●	●
Chlorophyta										
Halimeda macroloba										●
Halimeda opuntia	●								●	
Avrainvillea cf. *lacerata*							●			
Magnoliophyta										
Enhalus acoroides							●			
Halophila minor										●

[a]See Lobban and Tsuda (2003) for discussion of this species.

Corals

No corals were found on transects at the South Piti Channel site.

Macroinvertebrates

The distribution and abundance of conspicuous epibenthic macroinvertebrates observed on 10 transects in Sectors 1-5 are given in Table 11. A total of 54 species from 3 phyla were found. There were 4 species of sponges (Porifera: Demospongiae) (including two that were not identified to species) 18 species of gastropods (Mollusca), 22 species of bivalves (Mollusca), 8 species of shrimps and crabs (Anthropoda: Crustacea) (including 2 unidentified species and 3 identified only to genus), and 2 species of sea cucumbers (Echinodermata: Holothuroidea). The bivalve *Gafrarium pectinatum* was the most commonly seen macroinvertebrate across transects, although all specimens observed were dead shells. The gastropod *Cerithium corallium* was the most commonly seen live macroinvertebrate across transects.

Comparisons of macroinvertebrate distributions across transects and sectors by cluster analysis of Bray-Curtis similarity data (Figure 36) indicated five major clusters, of which Sector 5 being distinct from the other sectors, and Sector 3 being distinct from the rest within this grouping. MDS analysis of these data (Figure 37) show six groups of at least 80% similarity but three of these are for single transects alone.

Densities of macroinvertebrate species are given in Table 12. Densities of each species tended to be quite low, although bivalves tended to have the greatest densities across sectors. Comparisons of macroinvertebrate densities across transects and sectors by cluster analysis of Bray-Curtis similarity data (Figure 38) indicated two major clusters, with the second consisting of two separate clusters of transects. MDS analysis of these data (Figure 39) shows six groups of at least 80% similarity but these are arranged, as seen also in the cluster analysis dendrogram, into three distinct groups consisting of 3A alone, 2B and 5B, and the remaining transects.

Table 11. Species of conspicuous epibenthic invertebrates observed on or adjacent to transects in south Piti Channel, Guam. Observations of live specimens are denoted by filled circles (●), and records based on dead specimens are denoted by open circles (○).

	Sector 1		Sector 2		Sector 3		Sector 4		Sector 5	
	A	B	A	B	A	B	A	B	A	B
Porifera:Demospongiae										
Dysidea sp.	●	●	●							
Haliclona sp.	●	●								
orange sponge									●	●
tendril sponge	●	●	●	●						
Mollusca:Gastropoda										
Cerithium corallium	●	●	●	●	●	●		●		
Cerithium dialeucum	○				○					
Cerithium punctatum								○		
Cerithium rostratum							○			
Cerithium zebrum										●
Clypeomorus bifasciata	○									●
Rhinoclavis aspera							●			
Planaxis sulcata									●	●
Littorina scabra										●
Strombus gibberulus		○			○					
Strombus mutabilis	○			○	○			○		
Natica gualtieriana		○								

Table 11, continued.

	Sector 1		Sector 2		Sector 3		Sector 4		Sector 5	
	A	B	A	B	A	B	A	B	A	B
Polinices mammillata		○					●	○		
Cymatium muricinum						●		○		
Cymatium nicobaricum				○						
Mitra mitra								○		
Pyramidella sulcata	●									
Atys naucum					○					
Mollusca:Bivalvia										
Modiolus auriculatus			○							
Septifer bilocularis	●	●		○						
Anadara antiquata								○		○
Barbatia sp.				○						
Pinctada maculata									●	
Malleus decurtatus	●	●						●		
Spondylus squamosus									●	
Saccostrea cucullata	●			●					●	●
Saccostrea mordax	●							●		
Anodontia ovum					○	○	○			
Ctena bella	○		○	●	○		○			
Chama lazarus		●							●	

Table 11, continued.

	Sector 1		Sector 2		Sector 3		Sector 4		Sector 5	
	A	B	A	B	A	B	A	B	A	B
Fragum fragum		○	○	○	○		○	○		
Fragum loochooanum	○			●						
Quidnipagus palatum		○		○	○		○	○		
Scutarcopagia scobinata								○		
Tellina robusta	○	○	○	○		○	○		○	
Tellina staurella				○						
Gafrarium pectinatum	○	○	○	○	○	○	○	○	○	
Gafrarium tumidum	○	●	○	○	○	○		○		
Periglypta puerpera	○	○	○		○					
Pitar prora	○	○	○	○	○			○		
Arthropoda:Crustacea										
Alpheus djiboutiensis	●			●	●		●		●	
callianassid sp.				●			●	●	●	●
Calcinus spp.	●									
Clibanarius spp.		●								
Calappa calappa				○						
Calappa hepatica							○			
grapsid sp.										●
Thalamita spp.				○			○			

Table 11, continued.

	Sector 1		Sector 2		Sector 3		Sector 4		Sector 5	
	A	B	A	B	A	B	A	B	A	B
Echinodermata:Holothuroidea										
Holothuria atra									●	
Synapta maculata										●

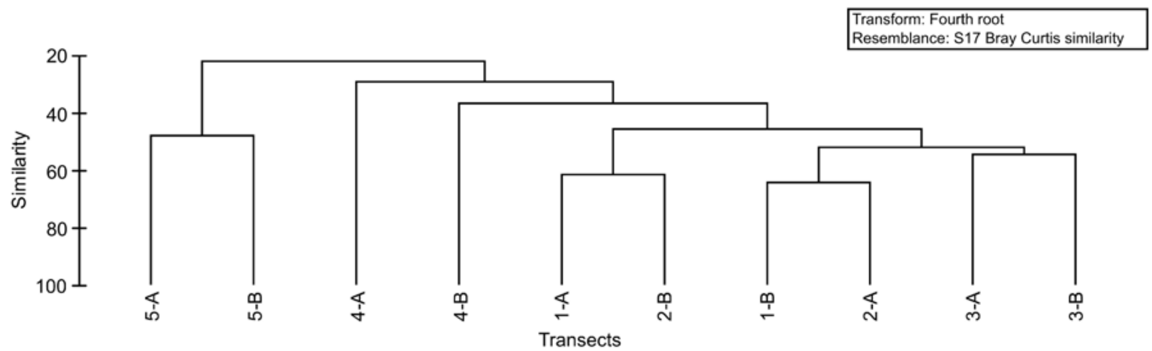

Figure 36. Dendrogram depicting similarities (per cent) in macroinvertebrate species assemblages of transects at south Piti Channel as determined by cluster analysis (group linkage). See Figure 35 for transect definitions.

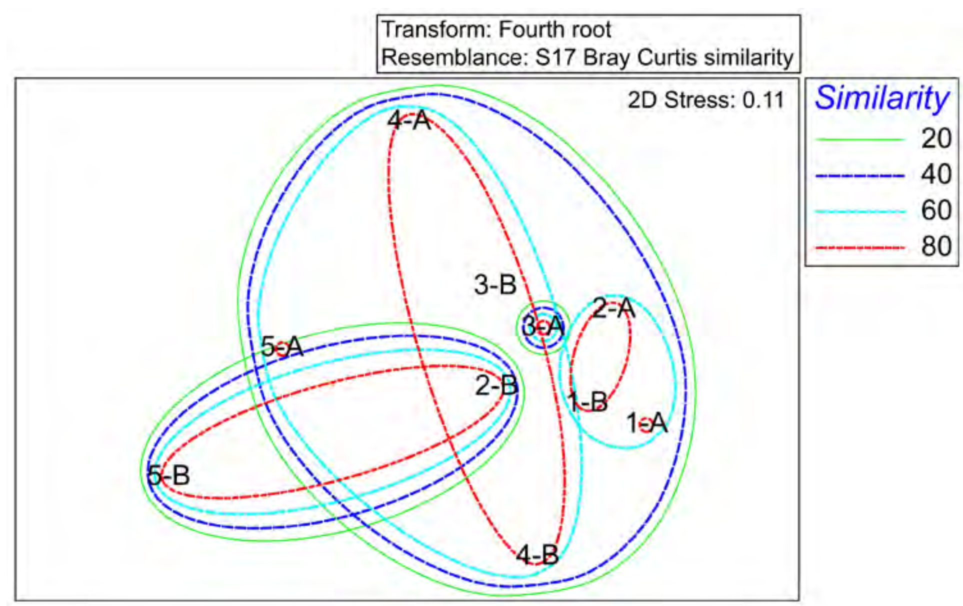

Figure 37. Multi-dimensional scaling (MDS) analysis of similarity in densities of macroinvertebrate species assemblages at south Piti Channel. Similarity values indicate the percentage of similarity between transects. See Figure 35 for transect definitions.

Table 12. Mean densities of conspicuous epibenthic invertebrates observed on transects in south Piti Channel.

	Sector 1		Sector 2		Sector 3		Sector 4		Sector 5	
	A	B	A	B	A	B	A	B	A	B
Mollusca:Gastropoda										
Cymatium muricinum						0.2 ± 0.4				
Mollusca:Bivalvia										
Septifer bilocularis	0.2 ± 0.4	0.2 ± 0.4	0.2 ± 0.4							
Malleus decurtata	0.2 ± 0.4	0.2 ± 0.4	0.2 ± 0.4							
Spondylus squamosus									0.2 ± 0.4	
Saccostrea cucullata	0.2 ± 0.4			0.2 ± 0.4						0.2 ± 0.4
Chama lazarus		0.2 ± 0.4	0.6 ± 0.9						0.2 ± 0.4	

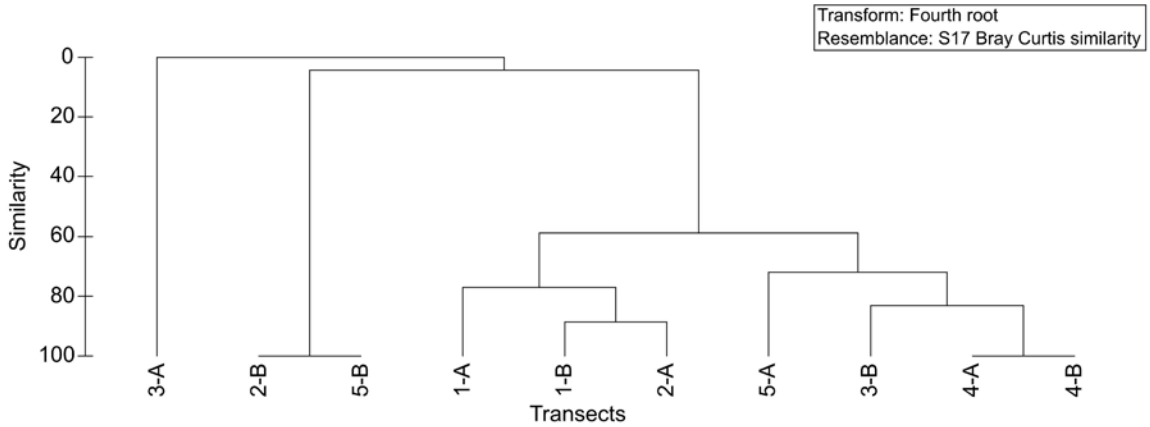

Figure 38. Dendrogram depicting similarities (per cent) in macroinvertebrate species densities on transects at south Piti Channel as determined by cluster analysis (group linkage). See Figure 35 for transect definitions.

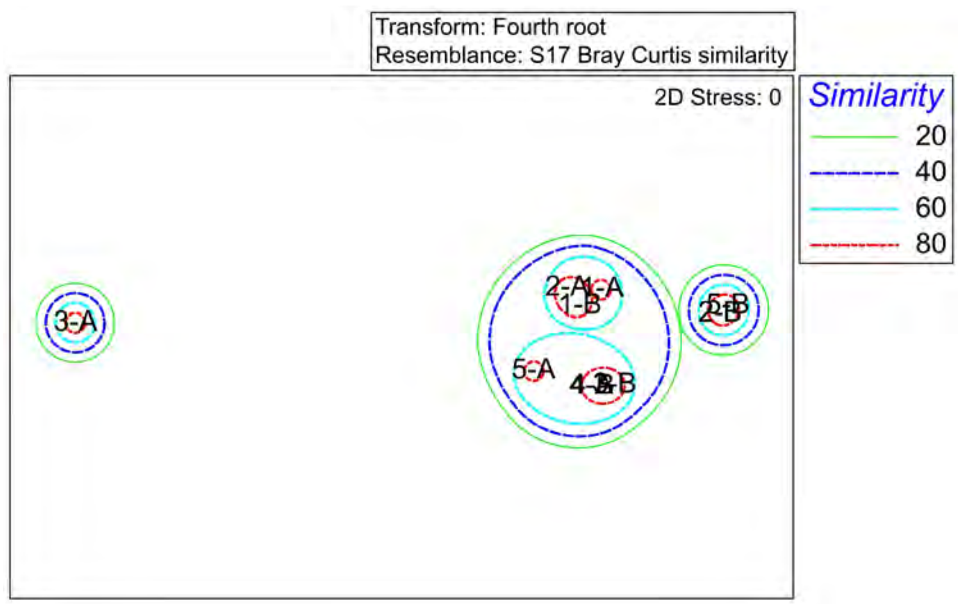

Figure 39. Multi-dimensional scaling (MDS) analysis of similarity in densities of macroinvertebrate species assemblages at south Piti Channel. Similarity values indicate the percentage of similarity between transects. See Figure 35 for transect definitions.

Fishes

A checklist of reef fishes with their observed patterns of distribution on transects is given in Appendix 5. A total of 24 species were observed at the south Piti Channel site. Species richness ranged from 6 on transects 4-A and 5-A to 12 on transect 3-A (Figure 40). Mean (± SE) species richness was 8.6 (± 0.592) for all transects combined. The number of fishes per transect ranged from 25 on transect 1-A to 497 on transect 4-B (Figure 41). The mean (± SE) number of fishes per transects was 117.7 (± 41.9) for all transects combined. Shannon's H' index of diversity ranged from 0.409 on transect 4-B to 1.893 on transect 1-A (Figure 42). The mean (± SE) value of H' was 1.289 (± 0.168) for all transects combined. The relationship between species richness and the number of fishes observed was somewhat positive (Figure 43) but was not significant ($r^2 = 0.06$, $p = 0.522$, $n = 11$). Transects with only a moderate number of species present often had between 100-491 individual fishes present, and when numerous these were mainly the cardinalfish *Apogon lateralis* (Apogonidae) or the shrimp goby *Cryptocentrus strigilliceps* (Gobiidae).

The density (number per square meter) of each reef fish species observed on transects is given in Appendix 6. Densities ranged from 0.005 to 4.6 per meter. Highest densities (range = .08 to 4.6 per square meter) were recorded for the cardinalfish *Apogon lateralis* (Apogonidae) that lived in groups within structure (mangroves, algal mats, etc.). At low tide, this species would migrate completely across the flat to its deepest part, adjacent to the spit that separated the study area from the adjacent flat and boat channel, where they sheltered in pools. As high tide approached, these fish would migrate back across the flat to the mangrove area or to suitable microhabitats that became submerged on flat proper (personal observations).

While burrowing gobies, including shrimp associated species such as *Cryptocentrus strigilliceps* (Gobiidae), were abundant, their densities were relatively low, with densities ranging from 0.01 to 0.48 per meter squared. Densities of *C. strigilliceps* ranged between 0.09 to 0.48 per meter squared.

The relationships are further illustrated with respect to similarity in a group-linkage cluster analysis dendrogram (Figure 44) and there are some differences compared to the results found in the MDS analysis. Four major clusters are indicated in the dendrogram. Transects 1A and 4A were distinct; all Sector 5 transects comprised a separate cluster; transect 2A linked with transects 3A and 3B; transect 1B linked with transects 2B and 4B. The relationships between transects with respect to fish assemblage structure are illustrated also in a multi-dimensional space (MDS) plot (Figure 45). The was considerable variation in assemblage structure at the site as a whole, but assemblages found on the north side of the flat (B transects) were distinct from those found on the south (A transects) of the flat and off of Port Authority Beach at the mouth of the channel (Sector 5 transects).

Overall, the fish faunas on all transects seem to be dominated by two types of fishes: cardinalfishes (*Apogon lateralis*) that live in groups associated with structure (mainly mangroves but also algal mats), and benthic-dwelling gobies, including many shrimp-associated gobies (i.e. *Cryptocentrus strigilliceps)*, that are particularly abundant.

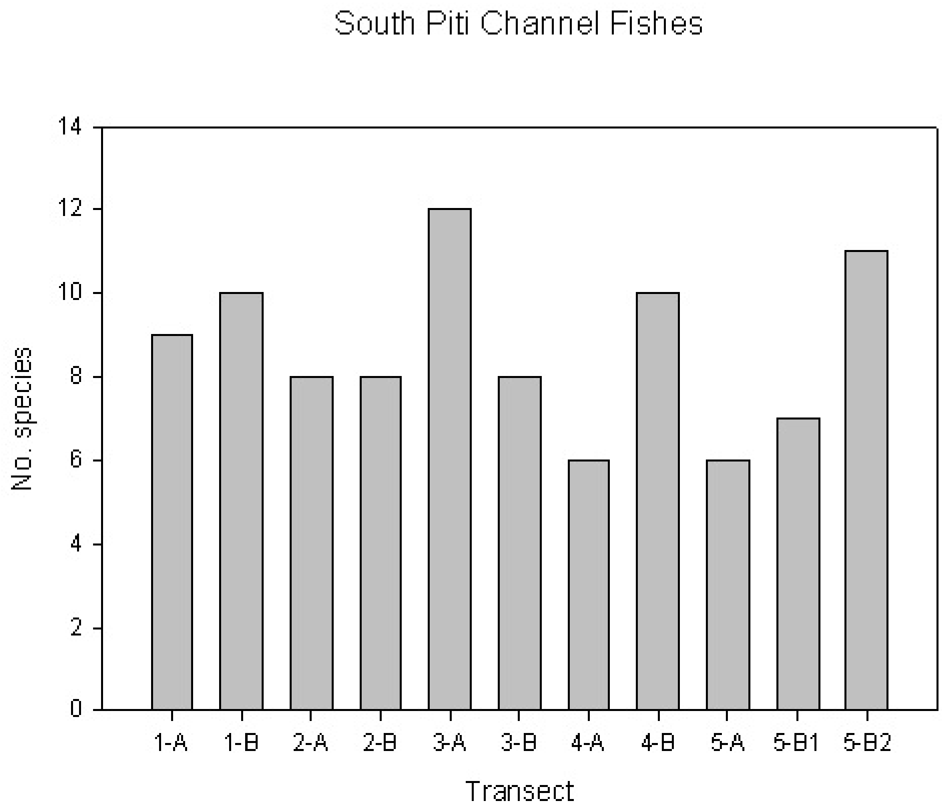

Figure 40 . Species richness of fishes on south Piti Channel transects. 1-5 = sector number; A or B = transect (there were two 5B transects, 1 and 2).

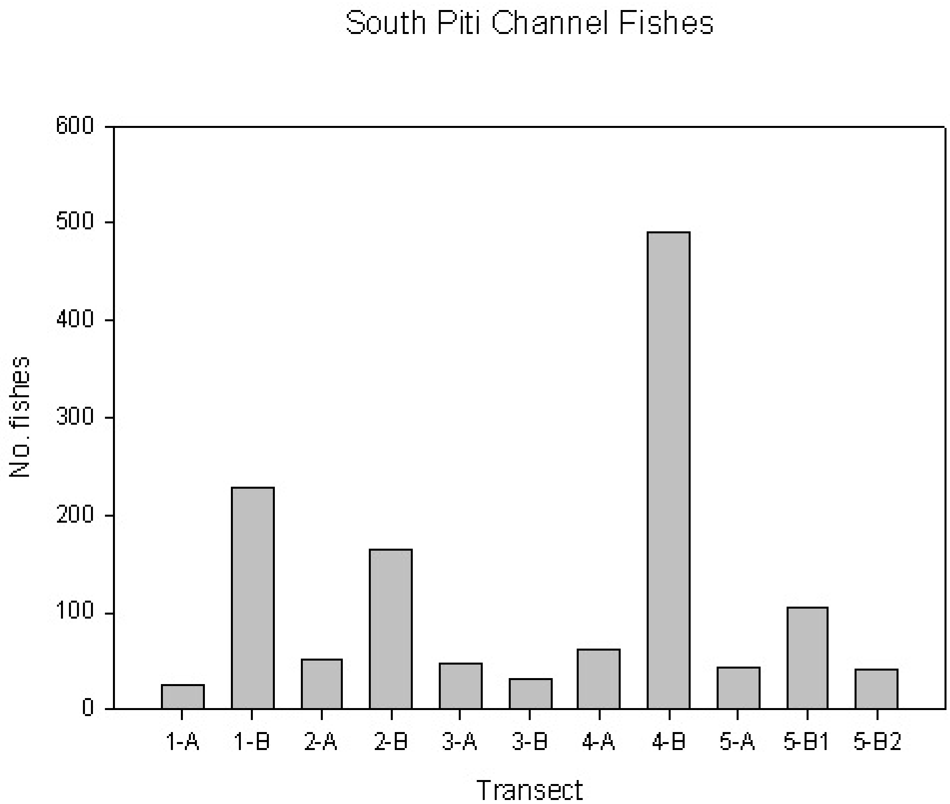

Figure 41. Abundance of fishes on south Piti Channel transects. See Figure 40 for transect definitions.

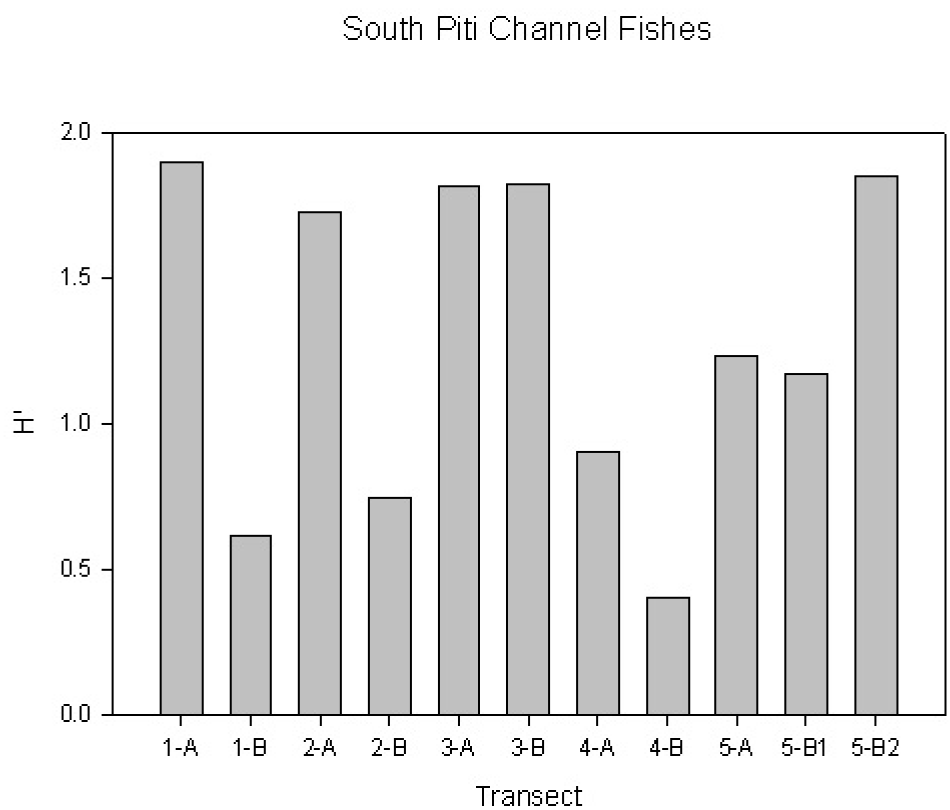

Figure 42. Species diversity (Shannon's H') of fishes on south Piti Channel transects. See Figure 40 for transect definitions.

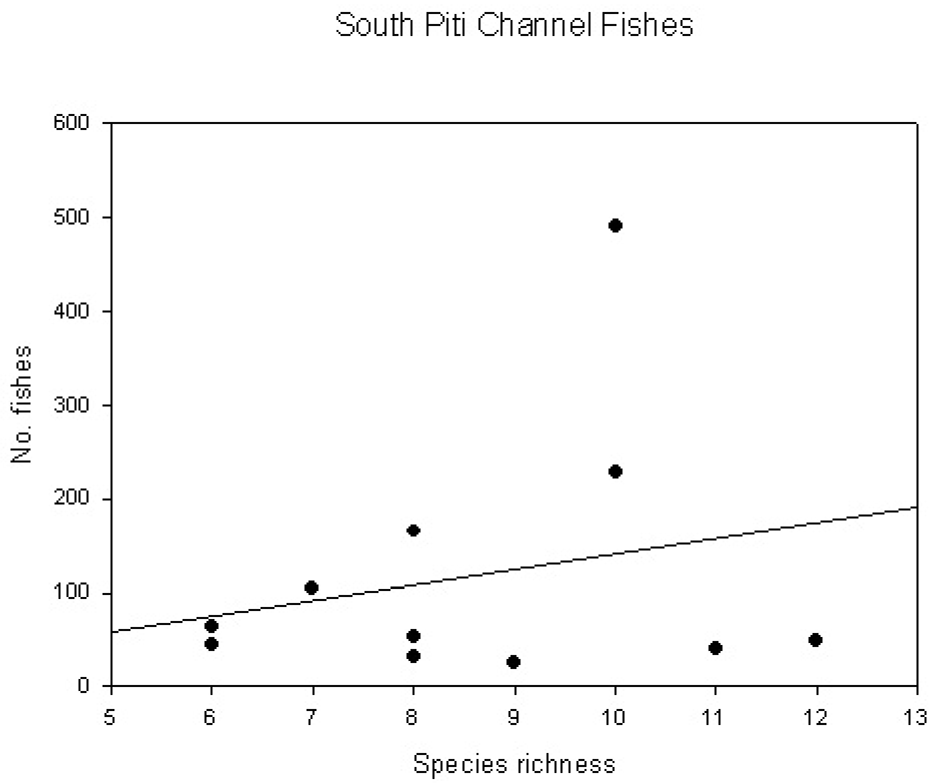

Figure 43. Relationship between species richness and abundance (number of fishes) on south Piti Channel transects.

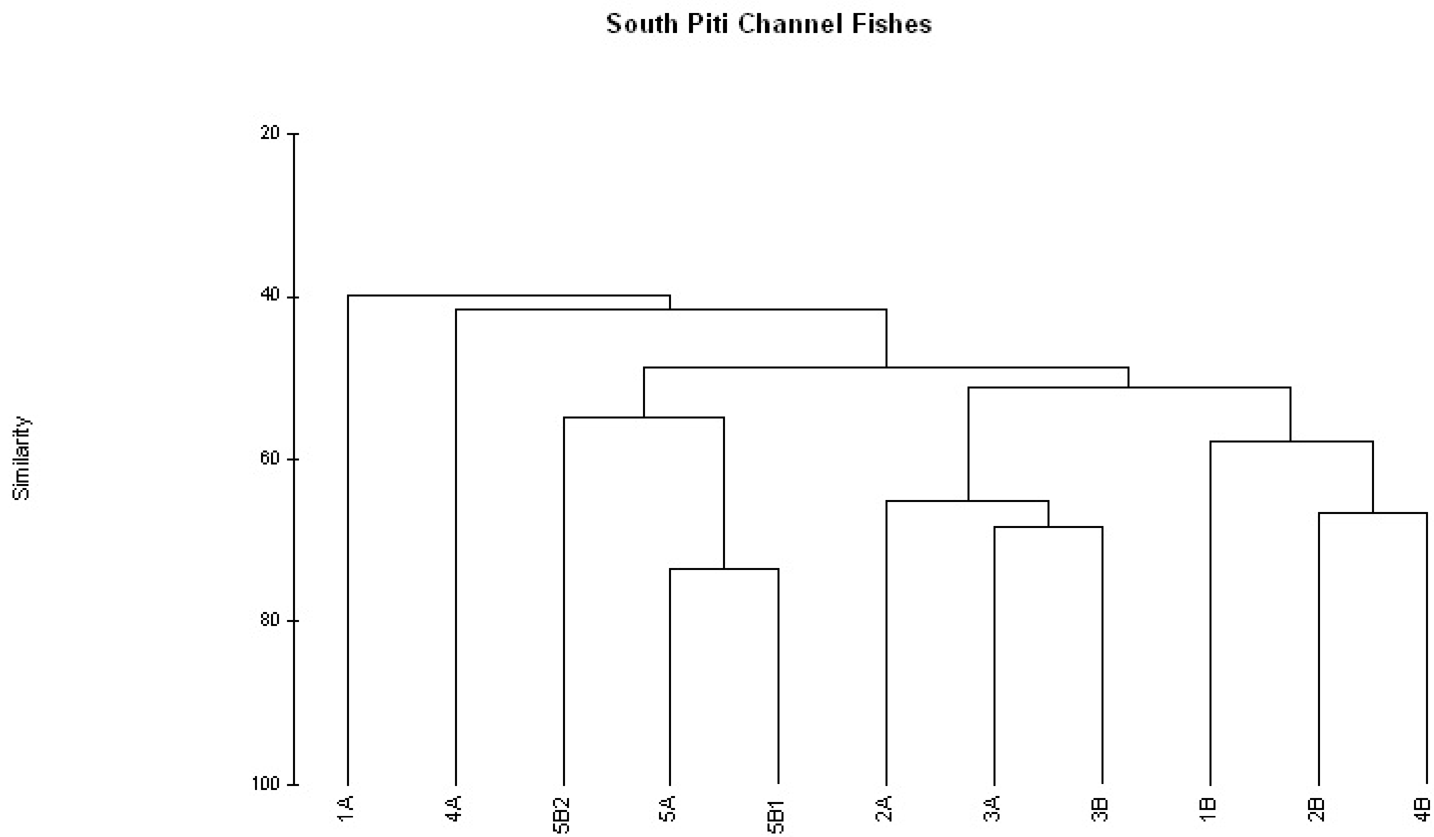

Figure 44. Dendrogram generated from group-linkage cluster analysis of reef fish assemblages on transects at South Piti Channel. Similarity values range between 0.0 (no similarity) and 1.0 (complete similarity). See Figure 40 for transect definitions.

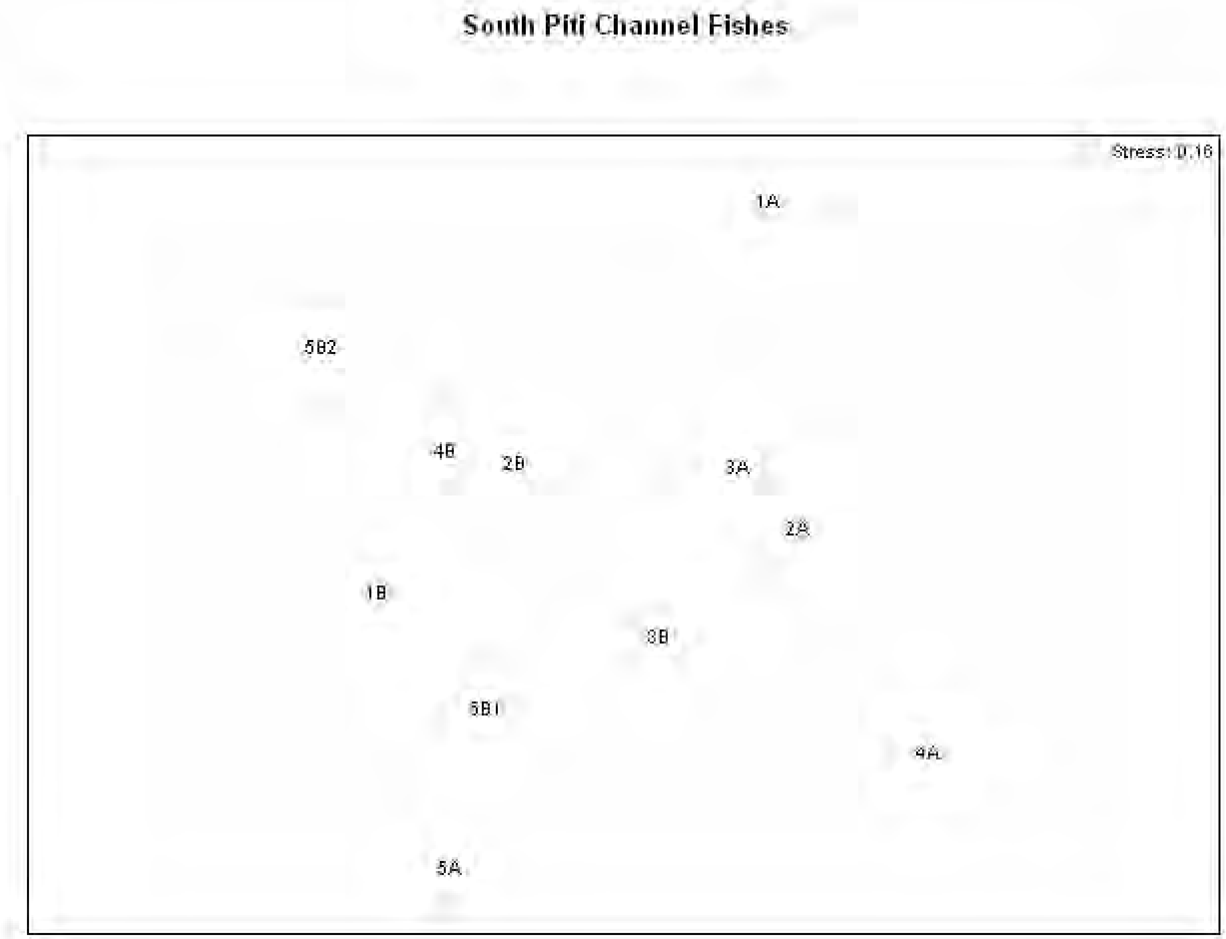

Figure 45. Multidimensional Scaling (MDS) analysis of reef fish assemblages on transects at South Piti Channel. The stress value is an indicator of reliability that ranges between 0.00 (very high reliability) and 1.00 (no reliability). See Figure 40 for transect definitions.

Polaris Point

Benthic Cover

Mean coverage of benthic cover for Polaris Point is given in Figure 46 for all sectors and in Table 13 by depth. Sand and mud are the most significant components of benthic cover at Polaris Point, accounting for more than 42-48% of the total cover by depth in all zones. Abiotic cover exceeded biotic cover in all sectors. Macroalgae comprised a very minor proportion of benthic cover in all sections and depths. *Padina boryana, Dictyota bartayersiana* and *Halimeda opuntia* accounted for most of the macroalgae observed at this site. A list of marine plants observed at Polaris Point is given in Table 14.

Coverage data for transects cluster (Figure 47) according to sector except that 1-2 and 3-4 were more similar to each other compared to the other transects while 1-4 and 3-2 were more similar to one another and to the Sector 2 transects. Multidimensional scaling and ordination of the coverage data indicated two clusters of 80% similarity according to this arrangement (Figure 48).

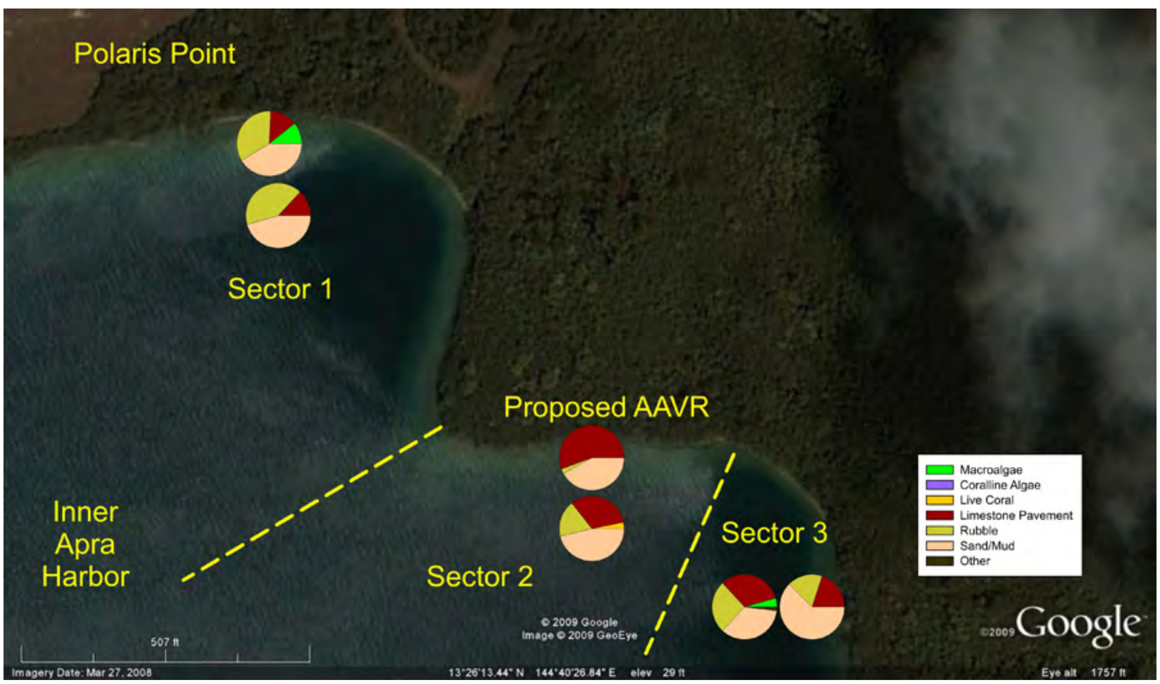

Figure 46. Percent surface coverage of the substrate along transects in three sectors and two reef zones at Polaris Point.

Table 13. Mean substrate coverage by physiographic zone at Polaris Point AAV Ramp site.

	2 m	4 m
Macroalgae	3.54 ± 5.01	1.46 ± 2.06
Coralline Algae	0.00 ± 0.00	0.00 ± 0.00
Live Coral	0.00 ± 0.00	1.04 ± 1.47
Limestone Pavement	29.79 ± 18.44	26.04 ± 9.13
Rubble	18.13 ± 13.02	28.54 ± 9.58
Sand/Mud	48.54 ± 9.87	42.29 ± 5.16
Other	0.00 ± 0.00	0.63 ± 0.88

Table 14. Benthic marine plants observed at Polaris Point. Checklist of species observed. Phylogenetic arrangement follows Lobban and Tsuda (2003).

	Sector 1		Sector 2		Sector 3	
	2 m	4 m	2 m	4 m	2 m	4 m
Cyanophyta:						
Microcoleus sp.					●	
Phaeophyta:						
Padina boryana	●	●			●	●
Dictyota bartayersiana	●					
Udotea sp.		●				
Chlorophyta:						
Halimeda opuntia	●				●	●
Avrainvillea sp.					●	
Caulerpa sp.					●	

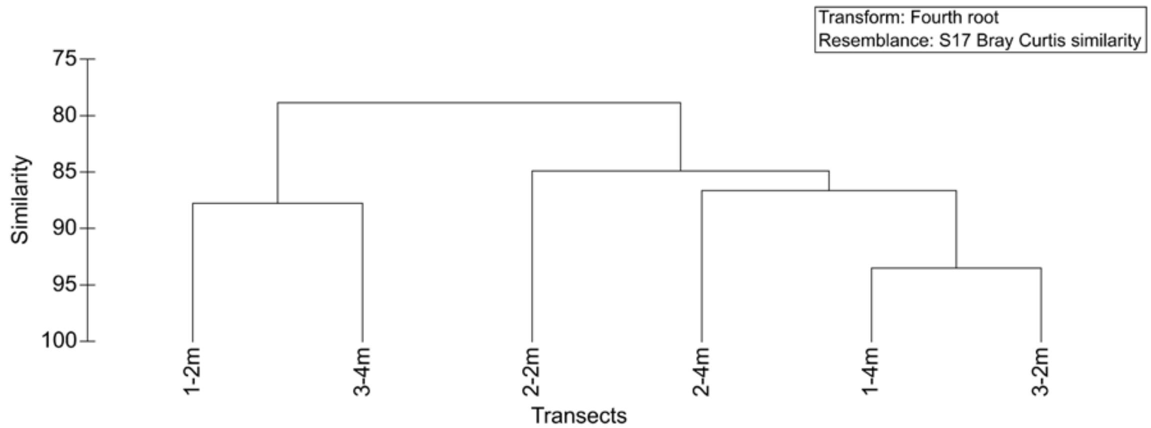

Figure 47. Cluster analysis (group averaging) of benthic coverage patterns on transects at south Polaris Point. Transects are designated by the sector number followed by the physiographic zone.

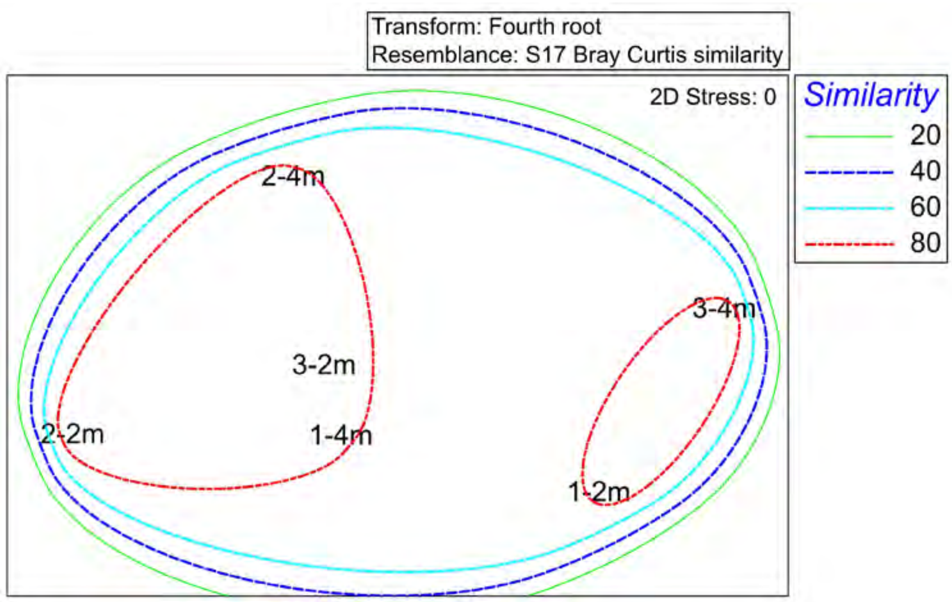

Figure 48. Multi-dimensional scaling (MDS) analysis of benthic cover at Polaris Point. Values indicate the level of similarity between transects. See Figure 47 for transect definitions.

Corals

Size-frequency distributions of the scleractinian corals encountered on transects at Polaris Point are presented in Table 15. The surveyed area included 9 species of scleractinian corals, representing 3 families and 3 genera on the transect lines.

Species richness was generally greater on the deeper transects, except in Sector 3 where the number of species observed was equivalent for both depths. *Leptastrea purpurea* was the most common species, occurring on 12 all transects and in the largest numbers. *Porites lutea* (5 transects) and *Porites rus* (4 transects) were also common but the latter species was more abundant. Two species, Porites compressa and P. densa, were seen on one transect (1-4), only.

Quantitative analysis of the coral species encountered on transects is presented in Table 16. In Sector 1, *Leptastrea purpurea* had the greatest density on the shallow (2m) transect while Porites lobata had the greatest on the deep (4m) transect. In Sector 2, *Leptastrea purpurea* had the greatest density on the shallow transect but on the deep transect both *Porites rus* and *P. lobata* had much higher densities. In Sector 3, *Porites lutea* had the greatest density on the shallow transect while *P. rus* had the greatest density on the deep transect.

Relationships between all sectors and all transects determined by group cluster analysis of Bray-Curtis similarity data are depicted in a dendrogram given in Figure 49. Two major clusters were found, the first consisting of two shallow transects (1-2 and 2-2) while the second was represented by both Sector 3 transects in one group and both deep transects from sectors 1 and 2 in the second group. These relationships are further illustrated in the results of the MDS analysis of these similarity (percent) data given in Figure 50. Sector 3 transects formed a single group with 60% similarity, while single transects from sectors 1 and 2 each formed separate groups with this level of similarity.

Table 15. Size-frequency distributions of coral species recorded on transects at the Polaris Point AAVR site. N_i = number of colonies. Mean, SD (standard deviation), and Range refer to colony size in cm^2.

Location	Habitat	Species	N_i	Mean	SD	Range
Sector 1	2 m	*Leptastrea purpurea*	3	57.73	50.08	8.25–108.38
		Porites lutea	1	–	–	87.96
	4 m	*Leptastrea purpurea*	8	15.86	8.62	4.71–31.42
		Porites lobata	5	275.83	202.04	86.39–518.36
		Porites lutea	3	66.17	63.19	4.71–130.97
		Porites compressa	1	–	–	15.71
		Porites rus	1	–	–	284.71
		Porites densa	1	–	–	69.12
Sector 2	2 m	*Leptastrea purpurea*	23	11.41	10.97	2.36–43.98
		Pocillopora damicornis	3	206.82	104.29	86.39–267.04
	4 m	*Porites rus*	13	3,263.21	4,004.01	14.14–10,383.75
		Pocillopora damicornis	10	606.62	541.41	38.48–1,553.12
		Porites lobata	4	2,094.07	2,291.07	54.98–4,078.18
		Porites lutea	4	456.07	518.13	3.93–904.78
		Leptastrea purpurea	3	10.60	7.73	2.36–17.67
Sector 3	2 m	*Porites lutea*	6	288.70	502.77	5.50–1,300.62
		Leptastrea purpurea	5	8.64	8.65	1.96–23.56
		Porites lichen	3	101.71	139.33	5.89–261.54
		Porites rus	1	–	–	100.53
		Pocillopora damicornis	1	–	–	1,485.97
	4 m	*Porites rus*	6	946.47	731.31	84.82–1,698.03
		Porites lutea	5	144.28	114.99	45.95–340.47
		Leptastrea purpurea	4	18.36	19.59	5.89–47.52
		Porites lichen	2	226.59	219.37	71.47–381.70
		Porites cylindrica	1	–	–	306.31

Table 16. Population density, frequency, and coverage of coral species recorded on transects at the proposed Polaris Point AAVR site.

Location	Habitat	Species	N_i	Relative Density	Absolute Density	Frequency	Coverage	Relative Coverage
Sector 1	2 m	*Leptastrea purpurea*	3	0.075	0.076	0.20	0.0006	0.663
		Porites lutea	1	0.025	0.025	0.10	0.0003	0.337
	4 m	*Leptastrea purpurea*	8	0.200	0.297	0.50	0.0006	0.061
		Porites lobata	5	0.125	0.186	0.30	0.0065	0.665
		Porites lutea	3	0.075	0.111	0.20	0.0009	0.096
		Porites compressa	1	0.025	0.037	0.10	0.0001	0.008
		Porites rus	1	0.025	0.037	0.10	0.0013	0.137
		Porites densa	1	0.025	0.037	0.10	0.0003	0.033
Sector 2	2 m	*Leptastrea purpurea*	23	0.575	1.00	0.90	0.0015	0.297
		Pocillopora damicornis	3	0.075	0.130	0.20	0.0034	0.703
	4 m	*Porites rus*	13	0.325	0.911	0.80	0.3784	0.722
		Pocillopora damicornis	10	0.250	0.701	0.70	0.0541	0.103
		Porites lobata	4	0.100	0.280	0.30	0.0747	0.143
		Porites lutea	4	0.100	0.280	0.20	0.0163	0.031
		Leptastrea purpurea	3	0.075	0.210	0.20	0.0003	0.001
Sector 3	2 m	*Porites lutea*	6	0.150	0.245	0.60	0.0015	0.130
		Leptastrea purpurea	5	0.125	0.205	0.40	0.0002	0.019
		Porites lichen	3	0.075	0.123	0.20	0.0016	0.137
		Porites rus	1	0.025	0.041	0.10	0.0005	0.045
		Pocillopora damicornis	1	0.025	0.041	0.10	0.0077	0.668
	4 m	*Porites rus*	6	0.150	0.266	0.30	0.0321	0.785
		Porites lutea	5	0.125	0.222	0.30	0.0041	0.100
		Leptastrea purpurea	4	0.100	0.177	0.30	0.0004	0.010
		Porites lichen	2	0.050	0.089	0.20	0.0026	0.063
		Porites cylindrica	1	0.025	0.044	0.30	0.0017	.0423

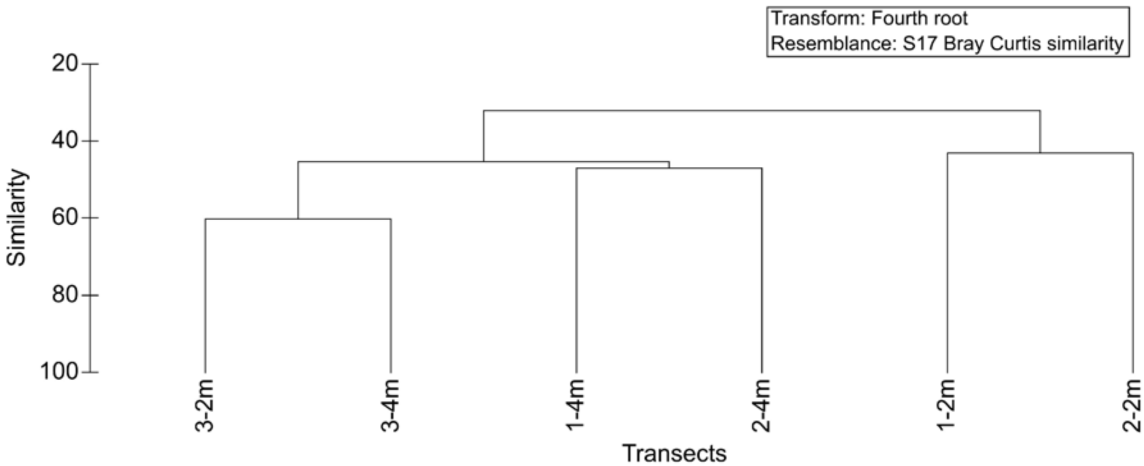

Figure 49. Cluster analysis (group averaging) of coral assemblages on transects at Polaris Point. See Figure 47 for transect definitions.

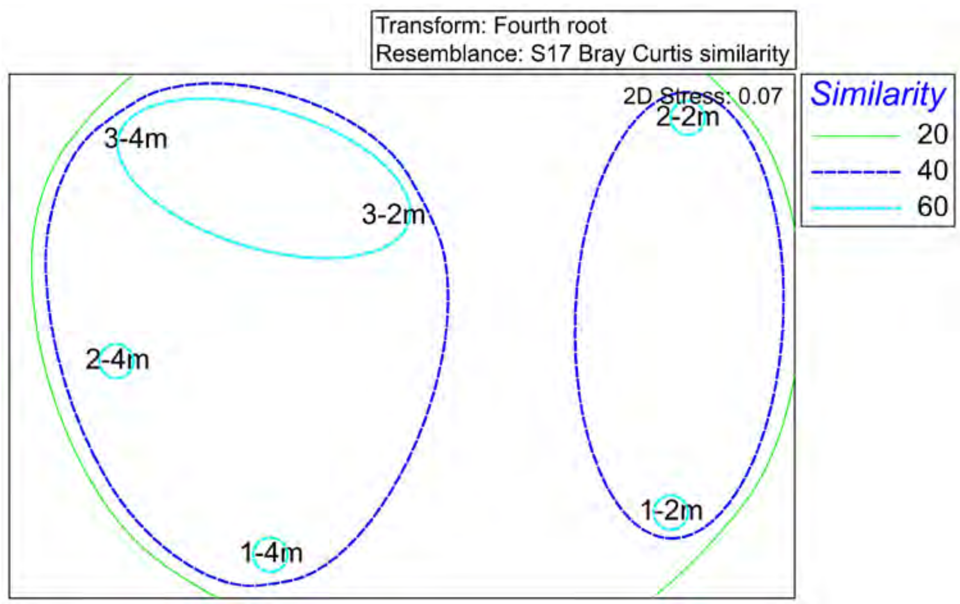

Figure 50. Multi-dimensional scaling (MDS) analysis of similarity in coral species assemblages at Polaris Point. Similarity values indicate the percentage of similarity between transects. See Figure 47 for transect definitions.

Macroinvertebrates

The distribution and abundance of conspicuous epibenthic macroinvertebrates observed on 9 transects in Sectors 1-3 are given in Table 17. A total of 41 species from 5 phyla were found. There were 9 species of sponges (Porifera: Demospongiae), 3 species of polychaete worms (Annelida), 6 species of gastropods (Mollusca), 15 species of bivalves (Mollusca), species of shrimps and crabs (Crustacea), and species of sea squirts (Ascidea). *Haliclona* sp. (blue) was the most common species of sponge and was observed on 8 of 9 transects in all three sectors. The polychaete annelid *Sabellastarte spectabilis* was found on 7 transects and three sectors. Among gastropod molluscs in the three sectors the most commonly observed species was *Cerithium munitum*, the dead shells of which were seen on 4 transects. Bivalve molluscs tended to be more common in all three sectors, with *Malleus decurtatus* and *Saccostrea cucullata* both observed on 7 transects, while *Lithophaga* sp. was seen on 6 and *Spondylus squamosus* on 5, respectively. *Alpheus djiboutiensis* was the most commonly seen shrimp but was observed only on 2 transects, one each in sectors 1 and 2; similarly, the crab *Calcinus* spp. was observed on 2 transects in these sectors, as well. As for sea squirts, the most common species was *Rhopalaea circula*, which was observed on 6 transects and all three sectors.

Comparisons of macroinvertebrate distributions across transects and sectors by cluster analysis of Bray-Curtis similarity data (Figure 51) indicated two major clusters. Transect 3-9 formed a single cluster distinct from the rest of the transects. In the second major cluster, transects 1-4, and 1-2, were separate from transects 2-2 and 2-4, with the latter being more similar to one another, while transects 3-2 and 3-4, and 1-9 and 2-9, formed separate clusters with greater similarity between them, respectively. MDS analysis of these data (Figure 52) show five groups of at least 60% similarity but four of these are for single transects alone and the fifth consists of three transects.

Densities of macroinvertebrate species are given in Table 18. Densities of most species tended to be quite low, although some bivalves tended to have the greatest densities across sectors. For example, *Malleus decurtatus* was quite dense along the shallow (2m) transect in Sector 2. Among ascidians, *Ascidia* sp. had the greatest density on the shallow transect in Sector 2.

Table 17. Species of conspicuous epibenthic invertebrates observed on or adjacent to transects in Polaris Point. Observations of live specimens are denoted by filled circles (●), and records based on dead specimens are denoted by open circles (○).

	Sector 1			Sector 2			Sector 3		
	2 m	4 m	9 m	2 m	4 m	9 m	2 m	4 m	9 m
Porifera:Demospongiae									
Aka sp.	●	●							
Dysidea sp. 3			●				●	●	
Haliclona sp. (blue)	●	●	●	●	●	●	●	●	
orange sponge		●		●	●		●		
Clathria eurypa								●	
Clathria sp. (pink)			●				●	●	
Clathria sp. (red)		●			●			●	
Hyrtios altum							●		
Hyrtios erecta							●	●	
Annelida:Polychaeta									
Protula sp.									●
Sabellastarte indica					●		●	●	
Sabellastarte spectabilis	●	●	●		●	●	●	●	
Mollusca:Gastropoda									
Cerithium munitum	○			○			○	○	
Cerithium zebrum								○	
Clypeomorus bifasciatus								○	
Polinices melanostomus								○	
Cymatium muricinum		●							
Morula margariticola				○					
Mollusca:Bivalvia									
Lithophaga sp.	●	●		●	●		●	●	
Septifer bilocularis				○					
Arca ventricosa				●				○	
Barbatia amygdalumtostum	●		●	●	●				
Barbatia foliacea			●			●	●	○	
Malleus decurtatus	●	●	●	●	●		●	●	
Mimachlamys sp.							○		

Table 17, continued.

	Sector 1			Sector 2			Sector 3		
	2 m	4 m	9 m	2 m	4 m	9 m	2 m	4 m	9 m
Spondylus multimuricatus			●	●			●	●	
Spondylus squamosus		●		●	●	●		●	
Spondylus sp.	●		●						
Saccostrea cucullata	●		●	●	●	●		●	●
Chama lazarus				●	●				
Chama sp.							●		
Fulvia sp.							○		
Tellina robusta									●
Arthropoda:Crustacea									
Alpheus djiboutiensis	●			●					
Callianassid sp.									●
Neaxius sp.							●		
Calcinus spp.	●			●					
Chordata:Ascideacea									
Rhopalaea circula		●	●			●	●	●	●
Rhopalaea sp. A	●					●		●	
Polysyncraton sp. 1								●	
Polycarpa cf. *cryptocarpa*				●	●				

Table 18. Mean densities of conspicuous epibenthic invertebrates observed on transects at Polaris Point.

	Sector 1		Sector 2		Sector 3	
	2 m	4 m	2 m	4 m	2 m	4 m
Annelida:Polychaeta						
Sabellastarte indica				0.2 ± 0.45		0.2 ± 0.45
Sabellastarte spectabilis	0.2 ± 0.45	0.4 ± 0.89		0.4 ± 0.55	0.2 ± 0.45	0.2 ± 0.45
Mollusca:Gastropoda						
Cymatium muricinum		0.2 ± 0.45				
Mollusca:Bivalvia						
Arca ventricosa			0.2 ± 0.45			
Barbatia spp.	0.6 ± 1.34	0.6 ± 0.89	1.2 ± 1.30	1.0 ± 1.00		
Malleus decurtatus	1.6 ± 2.51		9.8 ± 9.07	4.4 ± 3.36	1.4 ± 2.19	1.0 ± 1.41
Spondylus multimuricatus					0.2 ± 0.45	0.6 ± 0.89
Spondylus squamosus	1.4 ± 1.67		2.8 ± 1.48	0.4 ± 0.55		0.2 ± 0.45
Spondylus sp.	0.2 ± 0.45		0.4 ± 0.55			
Saccostrea cucullata	0.2 ± 0.45		0.2 ± 0.45	0.2 ± 0.45		0.6 ± 0.55
Chama lazarus			1.4 ± 0.55	0.4 ± 0.55		
Chordata:Ascidiacea						
Rhopalaea circula		0.6 ± 0.89			0.2 ± 0.45	0.4 ± 0.55
Rhopalaea sp. A	0.4 ± 0.89					0.2 ± 0.45
Ascidia sp.			1.4 ± 1.34	0.4 ± 0.55		0.4 ± 0.89

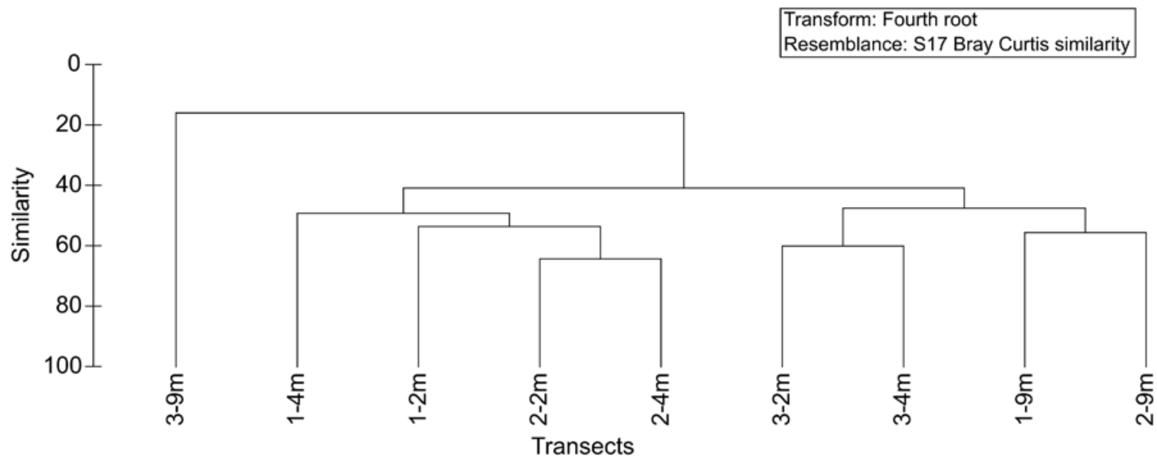

Figure 51. Dendrogram depicting similarities (per cent) in macroinvertebrate species assemblages of transects at Polaris Point as determined by cluster analysis (group linkage). See Figure 48 for transect definitions.

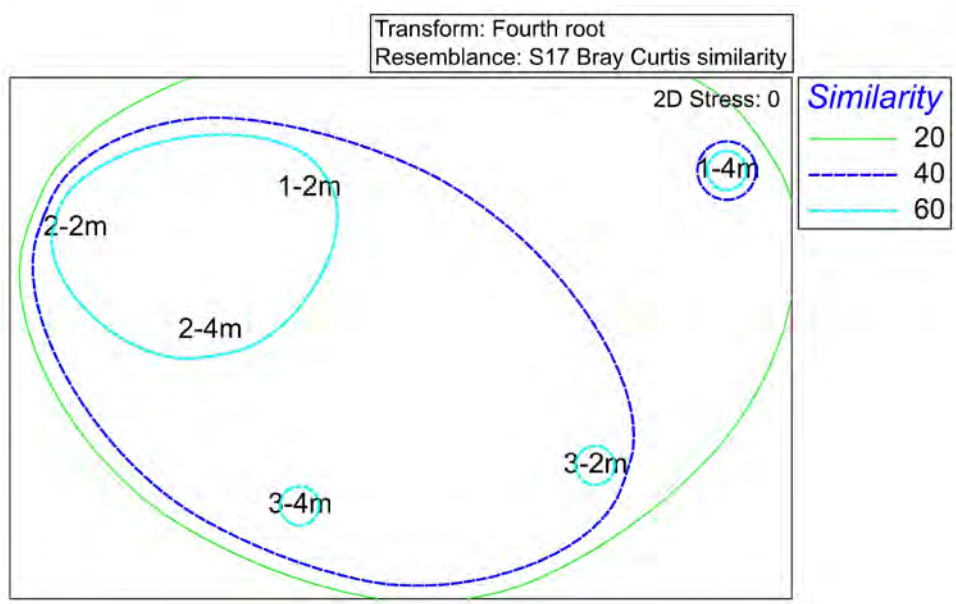

Figure 52. Multi-dimensional scaling (MDS) analysis of similarity in macroinvertebrate species assemblages at Polaris Point. Similarity values indicate the percentage of similarity between transects. See Figure 48 for transect definitions.

Fishes

A checklist of reef fishes with their observed patterns of distribution on transects is given in Appendix 7. A total of 47 species were observed at the Polaris Point site. Species richness ranged from 1 on transect L1 to 26 on transect 2-4 (Figure 53). Mean (± SE) species richness was 10.7 (± 2.8) for all transects combined. The number of fishes per transect ranged from 3 for transect 2-9 to 661 for transect 2-4 (Figure 54). The mean (± SE) number of fishes per transects was 117.7 (± 69.6) for all transects combined. Shannon's H' index of diversity ranged from 0.0 on transect 2-9 to 2.273 on transect 3-2 (Figure 55) but H'. The mean (± SE) value of H' was 1.2876 (± 0.2488) for all transects combined. The relationship between species richness and the number of fishes observed indicated a positive relationship (Figure 56). This relationship was significant ($r^2 = 0.65$, $p < 0.008$, $n = 9$). Overall, species richness and abundance were highest on shallow transects while diversity was highest on deeper transects such as 3-4 and 3-9. Species richness tended to be lowest on a deeper transect (2-9) while abundance and H' diversity were lowest usually on shallow transects (1-2 and 2-2). Fish species richness was relatively low, with just 47 species observed at this site. The assemblage of fishes was similar to those reported for other Inner Harbor habitats with coral (Smith et al., 2008) or no coral but debris on sand or silty substrata (Smith et al., 2008; Donaldson et al., 2010)

The density of each reef fish species observed on transects is given in Appendix 8. Densities ranged from 0.01. to 2.8 fish per m^2. Most species had densities of less than 0.1 per m^2, but two species of cardinalfishes associated with structure, *Apogon lateralis* and *Apogon leptacanthus* (Apogonidae), were found at transect 2-4 at densities of 2.8 and 2.7 per m^2, respectively. The burrowing shrimp goby *Cryptocentrus strigilliceps* (Gobiidae) was found at relatively high densities on shallow transects (1-2 and 2-2).

The dendrogram generated from the cluster analysis (Figure 57) indicated that the 9m transects were distinct from the others, which were variable with similarities in assemblage structure ranging from approximately 35-55%. The relationships between transects with respect to fish assemblage structure are illustrated further in a multi-dimensional space (MDS) plot (Figure 58). Shallow (2m) and deep (4m) transects had very similar fish assemblage structures, while the 9m transects in deep water were (perhaps owing to few data) not similar.

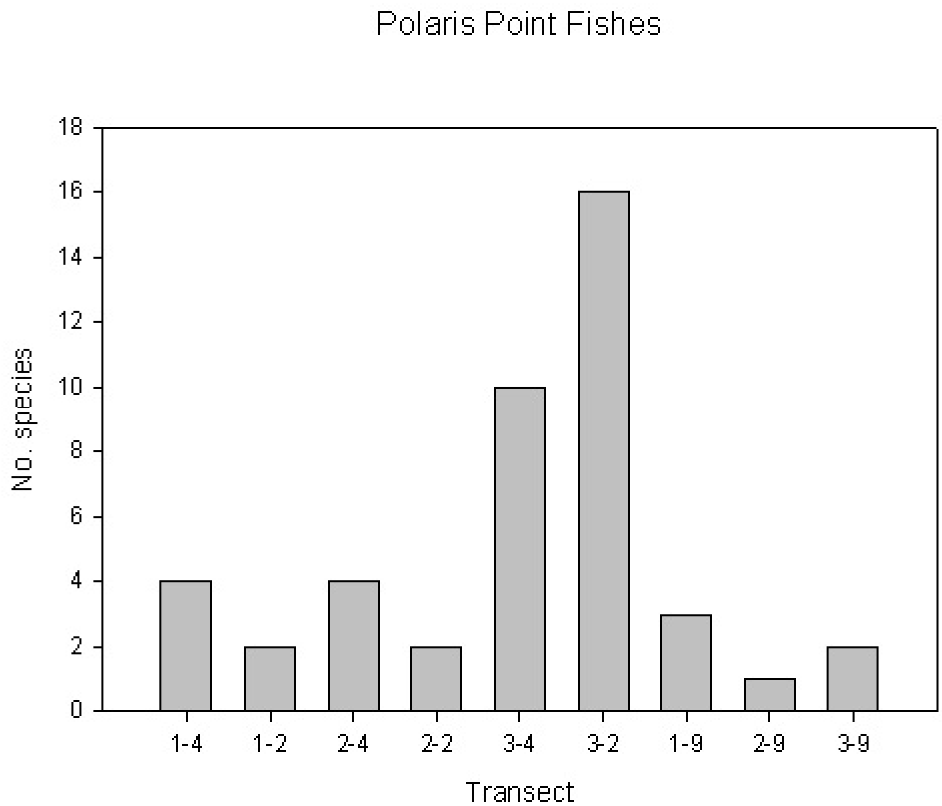

Figure 53. Species richness of reef fishes on transects at Polaris Point. 1-3 = sector number; 2, 4 or 9 = depth (m).

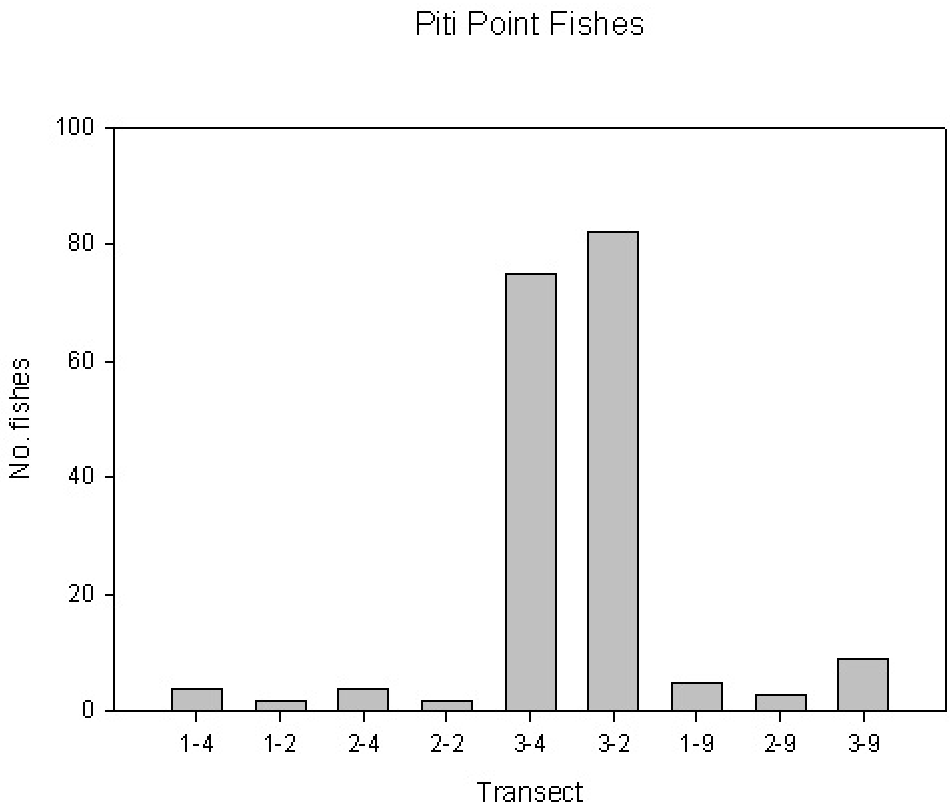

Figure 54. Abundance (number of fishes) of fishes observed on transects at Polaris Point. See Figure 53 for transect definitions.

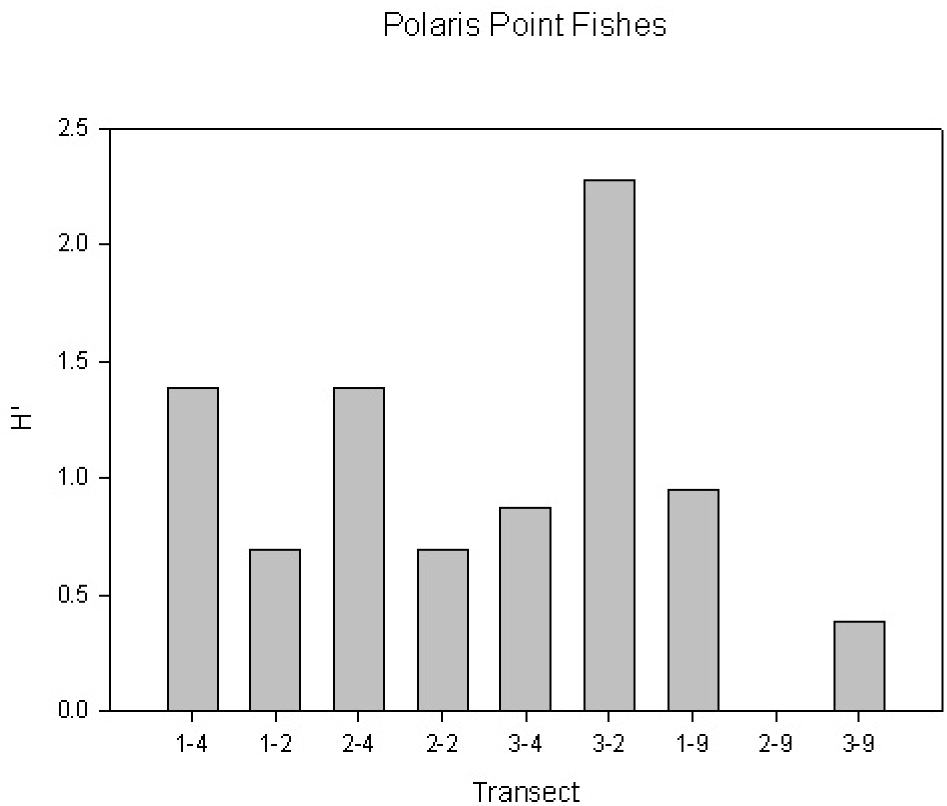

Figure 55. Species diversity (Shannon's H') of reef fishes on transects at Polaris Point. See Figure 53 for transect definitions.

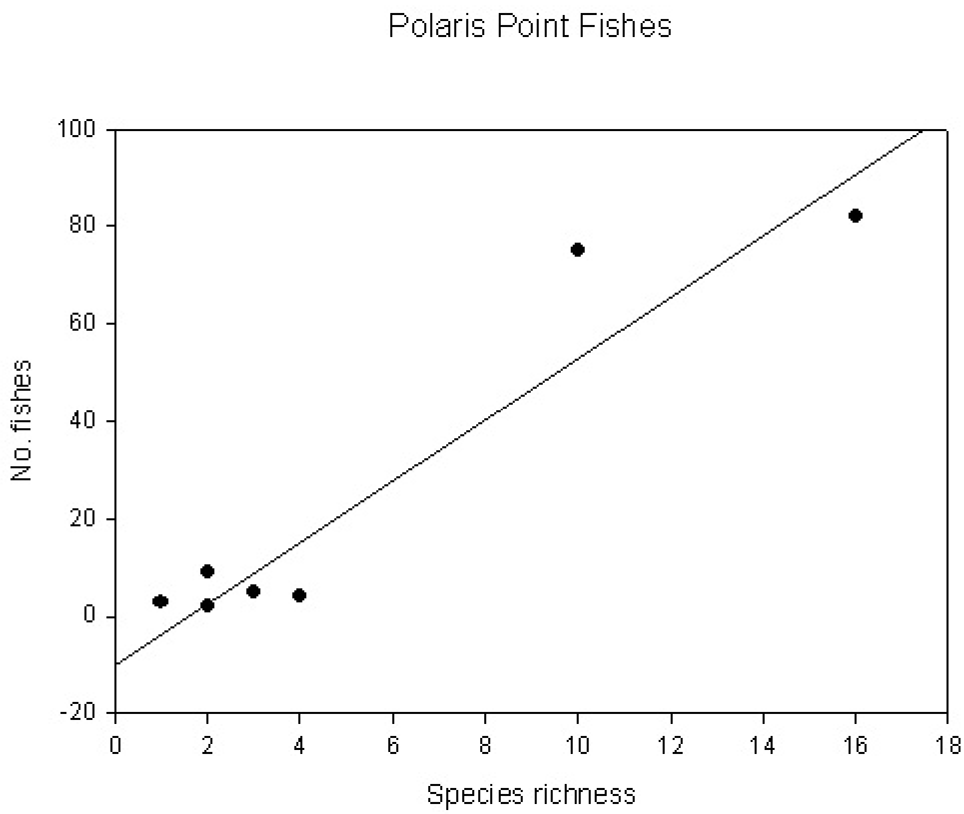

Figure 56. Relationship between species richness and abundance (number of fishes) on transects at Polaris Point. See Figure 53 for transect definitions.

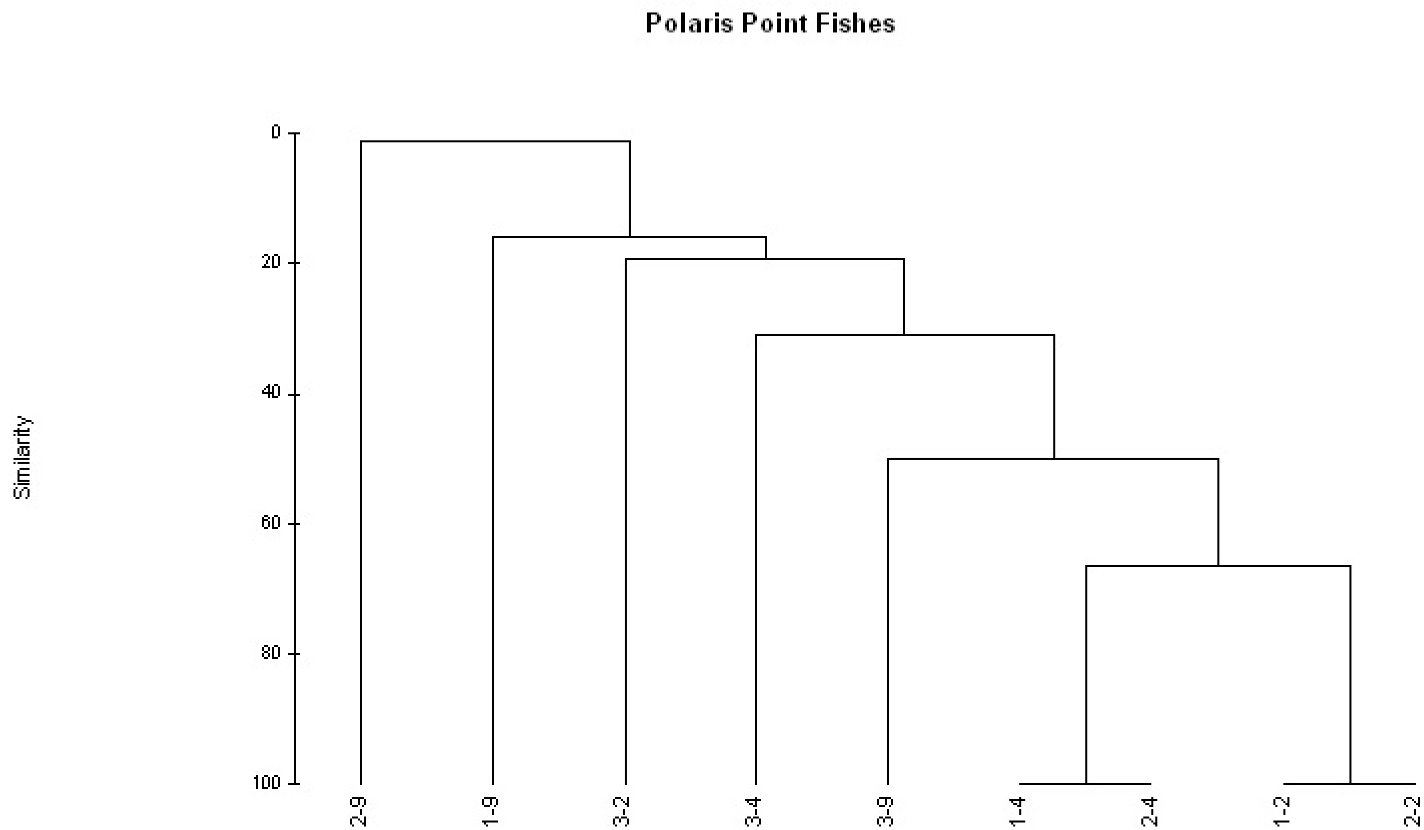

Figure 57. Dendrogram generated from group-linkage cluster analysis of reef fish assemblages on transects at Polaris Point. Similarity values range between 0.0 (no similarity) and 1.0 (complete similarity). See Figure 53 for transect definitions.

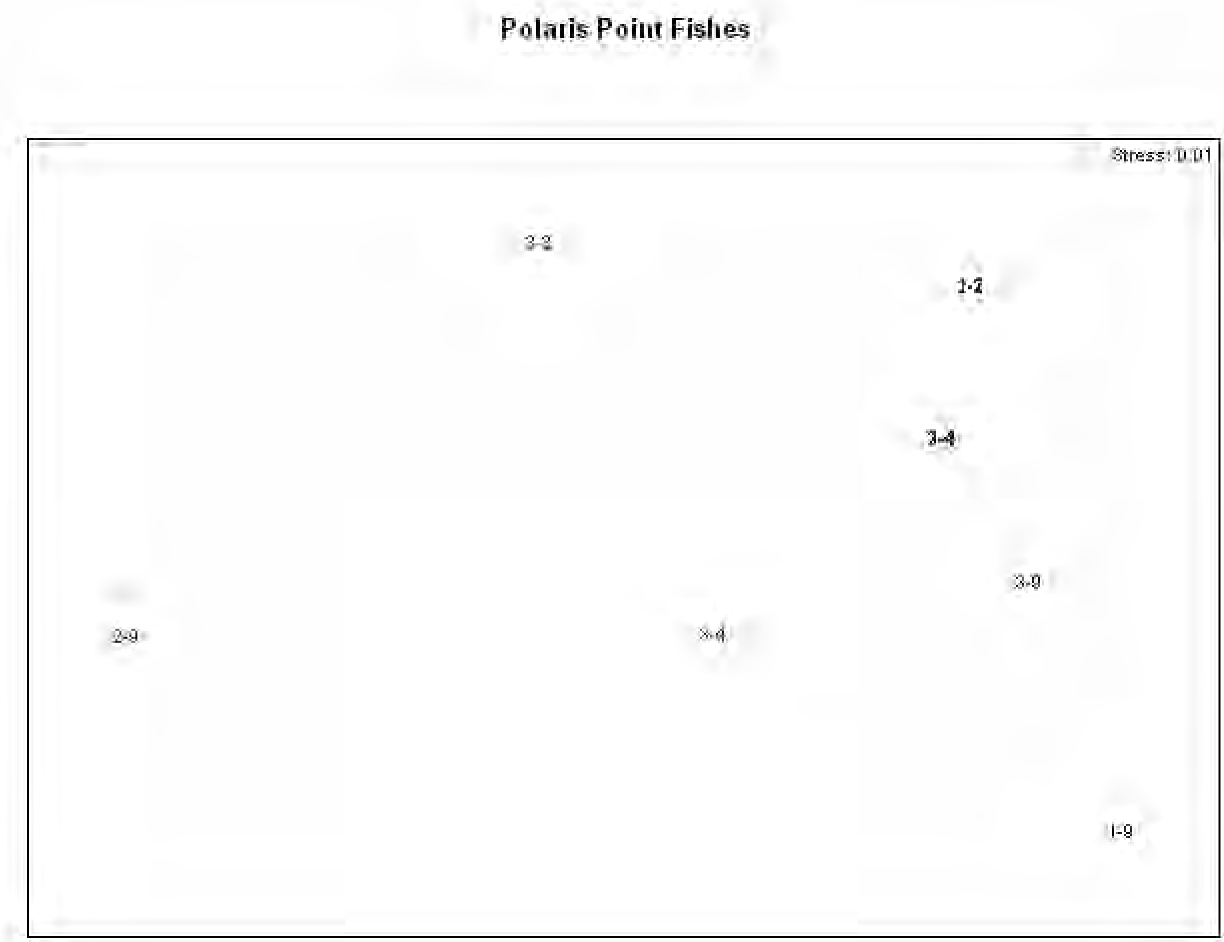

Figure 58. Multidimensional Scaling (MDS) analysis of reef fish assemblages on transects at Polaris Point. The stress value is an indicator of reliability that ranges between 0.00 (very high reliability) and 1.0 (no reliability). See Figure 53 for transect definitions.

Summary

Tipalao Reef

This site and Dadi Reef comprise one of the most habitat diverse, and hence biologically diverse, stretches of coastline on Guam (Paulay et al. 2001). This is especially true of Dadi Reef (Paulay et al. 2001; Smith et al., 2009). While limestone pavement was the most common substratum at Tipalao Reef, benthic macroalgae comprised more than 25% of benthic cover here with 26 species observed. *Halimeda opuntia* was the most commonly observed species. Corals were represented by 45 species. Common species included *Leptastrea purpurea*, *Porites lutea* and *Pocillopora damicornis*. Significant macroinvertebrates included 114 species. Important groups included sponges, various gastropods, two species of giant clam (*Tridacna maxima*, seen commonly in most sectors, and the rarer *T. squamosa*, seen only on a 12m transect in Sector 1), both important as food, as well as the sea urchin *Echinometra mathaei*. The reef fish assemblages observed at this site were typical of semi-protected reef areas and were similar to those reported previously (Paulay et al., 2001; Smith et al., 2009).

No endangered or threatened species were observed in the study area during this survey, however both green (*Chelona mydas*) and hawksbill (*Eretmochelys imbricata*)sea turtles (Reptilia) have been observed in this area at various times (Smith et al. 2009; T.J. Donaldson, personal observations). In addition, spinner dolphins (*Stenella longirostris* , Cetacea) are seen regularly within this area and social groups are frequently followed by locally-operated dolphin-watching tours (Smith et al., 2009; T.J. Donaldson, personal observations). A potentially-threatened species, the black-blotched stingray (*Taeniura meyeni*, Dasyatidae), although not seen during the survey has been reported to inhabit sand flats in this study area (Paulay et al., 2001) and more recently was observed incidentally during the course of other studies within the area (T.J. Donaldson, personal observations).

Dadi Reef

As with Tipalao Reef, benthic macroalgae was an important of benthic cover with 15 species comprising between 23-43% of total cover. There were four more species of corals at this site (31 spp) compared to Tipalao Reef, with *Leptastrea purpurea* and *Pocillopora damicornis* being common as were two other important reef building species, *Porites lutea* and *P. lobata*, that contributed to greater habitat complexity compared to Tipalao Reef (Paulay et al., 2001; Smith et al., 2009; T.J. Donaldson, personal observations). Significant macroinvertebrates at this site were slightly more diverse (118 spp) that at Tipalao Reef. Sponges tended to be more common on reef slopes, while *Trochus niloticus*, an important food species, was present in most sectors and on transects. Two species of sea urchins, *Echinostrephus aciculeatus* and *Echinometrix diadema*, were found commonly on reef flats and shallow (6m) slopes in all but Sector 4. Sea cucumbers (Holothuria), such as *Holothuria atra*, *H. edelus*, and *Bohadschia argus* were also common in sectors 1-3 at this site. The reef fish assemblages observed at this site were also typical of semi-protected reefs and similar in composition to those reported previously for this site. (Paulay et al., 2001; Smith et al., 2009). As stated above, this site was more diverse compared to Tipalao Reef, probably because of the greater habitat complexity at Dadi Reef.

No endangered or threatened species were observed in the study area during this survey, however both green (*Chelona mydas*) and hawksbill (*Eretmochelys imbricata*) sea turtles have also been observed in this area at various times (Smith et al., 2009; T.J. Donaldson, personal observations). As with Tipalao Reef, spinner dolphins (*Stenella longirostris*, Cetacea) are seen regularly also within this area and social groups are followed by locally-operated dolphin-watching tours as well (Smith et al., 2009; T.J. Donaldson, personal observations). The stingray *Taeniura meyeni* has also been reported from this area (Paulay et al., 2001) or observed incidentally (T.J. Donaldson, personal observations)

South Piti Channel

This site supports algal patches and nine species of benthic algae (mainly *Gracilaria salicornia* and *Padina boryana*), but no corals were observed within the survey area. The southern boundary of the site supports mangrove development that provides habitat for some species of adult and juvenile fishes (e.g., *Apogon lateralis*). The diversity of significant macroinvertebrates was relatively low (species) and dominated mainly by bivalves, the gastropod *Cerithium corallium*, and the burrowing shrimp *Alpheus djiboutiensis*, Crustacea) The fish fauna is of low diversity (24 species) and appears to be typical of both mangrove and sand flats seen elsewhere in the Apra Harbor area, and is notable for the abundance of shrimp gobies (mainly *Cryptocentrus strigilliceps*, Gobiidae) and their commensal associates (*A. djiboutiensis*, Crustacea). The site is influenced by tidal fluctuations to the extent that during seasonal minus tides most of the site (Sectors 1-4) is exposed with water collecting in deeper pools that form along the northern boundary (T.J. Donaldson, personal observation). Fishes living at the site have been observed to move across the flat into these deeper pools or off into deeper water in Sector 5; burrowing gobies and other species withdraw into burrows or holes in the substratum (T.J. Donaldson, personal observation).

No endangered or threatened species were observed within the study area during this survey.

Polaris Point

While this site is seemingly unremarkable in terms of diversity (see Smith et al., 2008; Donaldson et al., 2010), it should be noted that the coral colonies observed on the slope here are of relatively recent origin, ca. 60+ years (R.H. Randall, personal communication), and are the product of settlement and colonization of previously-disturbed habitat. Nine species of corals were observed during the survey and of these, certain species (e.g., *Porites lobata*, *P. lutea*, and *P. rus*) are important for reef building and for providing habitat for other species. Sand and mud accounted for most benthic cover, with macroalgae (6 species) playing such a minor part as to being completely absent from Sector 2 transects. Among significant macroinvertebrates, 41 species were observed. More prominent groups included sponges, bivalve molluscs, and the gastropod *Cerithium munitum*. The burrowing shrimp *Alpheus djiboutiensis*, commensal with the shrimp goby *Cryptocentrus strigilliceps*, was seen on shallow transects in sectors 1-2. Fish species richness was relatively low at this site. The assemblage of fishes was similar to those reported for other Inner Harbor habitats with either coral or no coral but debris on sand or silty substrata (Smith et al., 2008; Donaldson et al., 2010).

No endangered or threatened species were observed within the study area during this survey. The potentially threatened scalloped hammerhead shark (*Sphyrna lewini*, Sphyrnidae) has been reported to “drop” newly-born juveniles (“pupping”) in this general area (Myers, 1999) and adults have been reported from the Inner Harbor, in which the Polaris Point site is located, as well (Myers, 1999).

Recommendations

1. Tipalao Reef: This site’s proximity to the Orote Peninsula cliff line exposes it to relatively greater direct wave action compared to Dadi Reef. As such, scoured limestone pavement is dominant, and while coral diversity may be slightly greater there is less apparent habitat complexity here compared to Dadi Reef (T.J. Donaldson, personal observation). Corals and associated organisms would likely be sensitive to human-induced environmental degradation and stress but perhaps less so compared to the more structurally complex Dadi Reef, where large patch reefs exist. Some effort should be made to protect corals in the spur and groove zone down to 6m, particularly on the reef flat extending shoreward from Neye Island, as they are most likely to be affected by activities at this site.

2. Dadi Reef: This site is more protected from direct wave action compared to Tipalao Reef and is distinguished by the presence of relatively large patch reefs, especially at depths below the reef margin (e.g., 6-10m), the provide considerable habitat complexity. The presence of these large patch reefs will pose a challenge as they will likely be sensitive to human-induced environmental degradation and stress. Not all patches appear to be extensive, however, and so some effort should be made to protect those that are both large and seemingly healthy compared to those exposed to silt discharges from the Namo River to the south (Sector 1).

3. South Piti Channel: This habitat is typical of shallow sand flats found elsewhere on Guam and while important for some species (e.g., shrimp gobies and their commensal shrimps), it is not rare. The habitat at this site would be sensitive to human-induced environmental degradation (e.g., thermal discharges) and stress, however, and especially so at low tide. The effects of thermal discharges, should they be made, might be reduced if they do not occur during low tide periods.

4. Polaris Point: Although some species might be considered “weedy” (e.g., the coral *P. rus*) and hence resilient, other species in this area might be sensitive to human-induced environmental degradation and, hence, subject to stress. The habitat is a component of the limited coral reef development within the Inner Harbor but in itself is not rare on Guam. As such, this or adjacent coral habitat within the Inner Harbor should be afforded protection from disturbance.

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APPENDICES

Appendix 1. Checklist of fishes observed on transects at Tipalao Reef, Guam.

Appendix 2. Densities (number per square meter) of fishes observed on transects at Tipalao Reef, Guam.

Appendix 3. Checklist of fishes observed on transects at Dadi Reef, Guam.

Appendix 4. Densities (number per square meter) of fishes observed on transects at Dadi Reef, Guam.

Appendix 5. Checklist of fishes observed on transects at south Piti Channel, Guam.

Appendix 6. Densities (number per square meter) of fishes observed on transects at south Piti Channel, Guam.

Appendix 7. Checklist of fishes observed on transects at Polaris Point, Guam.

Appendix 8. Densities (number per square meter) of fishes observed on transects at Polaris Point, Guam.

Appendix 1. Checklist and distribution of fishes at Tipalao Reef. Fishes are arranged in phylogenetic order.

Family	Common name	Species	Transects															
			Sector 1				Sector 2				Sector 3				Sector 4			
			1 12	1 6	1 ORF	1 MRF	2 12	2 6	2 ORF	2 MRF	3 12	3 6	3 ORF	3 MRF	4 12	4 6	4 ORF	4 MRF
Carcharhinidae	Reef sharks	*Carcharhinus melapterus*	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Muraenidae	Moray eels	*Gymnomuraena zebra*	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Clupeidae	Herrings	*Spratelloides delicatulus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synodontidae	Lizardfishes	*Synodus binotatus*	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Belonidae	Needlefishes	*Strongylura leiura leiura*	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Holocentridae	Squirrelfishes	*Myripristis adusta*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Myripristis murdjan	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
		Sargocentron caudimaculatum	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
		Sargocentron diadema	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0
		Sargocentron punctissimum	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
		Sargocentron spiniferum	0	0	0	0	0	0	0	0	1	2	3	5	0	0	0	0
Fistularidae	Cornetfishes	*Fistularis commersoni*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Scorpaenidae	Scorpionfishes	*Sebastipistes sp. in corals*	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Pterois antennata	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Serranidae	Groupers	*Cephalopholis spiloparea*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cephalopholis urodeta	0	1	0	0	2	5	0	0	2	4	0	0	3	1	0	0
		Epinephelus hexagonatus	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0
		Epinephelus merra	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Cirrhitidae	Hawkfishes	*Cirrhitichthys falco*	9	0	0	0	4	0	0	0	0	0	0	0	1	0	0	0
		Paracirrhites arcatus	2	0	0	0	0	1	0	0	0	3	0	0	0	4	0	0
		Paracirrhites forsteri	0	0	0	0	0	0	0	0	0	2	0	0	0	2	0	0
Pseudochromidae	Dottybacks	*Pseudochromis cyanotaenia*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Apogonidae	Cardinalfishes	*Apogon angustatus*	2	1	0	0	0	0	0	0	0	0	0	0	4	2	0	0
		Apogon nigrofasciatus	0	0	0	0	2	12	0	0	0	0	0	0	0	0	0	0
Malacanthidae	Tilefishes	*Malacanthus latovittatus*	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carangidae	Trevalleys and Jacks	*Caranx melampygus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lutjanidae	Snappers	*Aphareus furca*	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lutjanus fulvus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lethrinidae	Emperor bream	*Lethrinus harak*	1	0	0	0	0	0	0	0	0	5	0	0	0	1	1	1
		Lethrinus obsoletus	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nemipteridae	Monocle bream	*Scolopsis lineata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Mullidae	Goatfishes	*Mulloidichthys flavolineatus*	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
		Mulloidichthys vanicolensis	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
		Parupeneus barberinus	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
		Parupeneus ciliatus	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
		Parupeneus crassilabrus	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
		Parupeneus cyclostomus	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
		Parupeneus multifasciatus	4	2	0	0	1	1	1	0	0	1	3	2	1	1	2	0
Pempheridae	Sweepers	*Pempheris otaitensis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chaetodontidae	Butterflyfishes	*Chaetodon auriga*	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0
		Chaetodon citrinellus	0	0	2	2	1	4	1	0	1	2	0	3	4	0	0	2
		Chaetodon ephippium	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		Chaetodon lunula	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0
		Chaetodon mertensii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chaetodon ornatissimus	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0

		Chaetodon punctatofasciatus	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
		Chaetodon reticulatus	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chaetodon ulietensis	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
		Forcipiger flavissimus	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0
		Heniochus acuminatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pomacanthidae	Angelfishes	*Centropyge flavissima*	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
		Pomacanthus imperator	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
		Pygoplites diacanthus	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pomacentridae	Damselfishes	*Amphiprion chrysopterus*	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0
		Chromis agilis	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chromis margaritifer	0	2	0	0	4	0	0	0	0	0	0	0	0	2	0	0
		Dascyllus reticulatus	0	0	0	0	0	0	0	0	0	1	0	0	0	6	0	0
		Dascyllus trimaculatus	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
		Abudefduf sexfasciatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Abudefduf vaigenensis	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
		Chrysiptera biocellatus	0	0	0	0	0	0	0	3	0	0	0	2	0	0	1	19
		Chrysiptera brownriggi	0	0	8	5	0	40	8	1	2	25	5	1	2	28	3	0
		Chrysiptera brownriggi amabilis	0	0	63	15	0	13	26	7	0	6	107	11	0	26	8	0
		Chrysiptera glauca	0	0	0	20	0	0	0	3	0	0	0	11	0	0	8	0
		Chrysiptera traceyi	10	45	0	0	9	12	0	0	2	6	0	0	2	6	23	0
		Plectroglyphididon dickii	0	0	0	0	0	0	0	0	0	2	1	0	0	3	0	0
		Plectroglyphididon lacrymatus	0	7	0	0	0	0	1	0	0	0	0	0	0	0	0	0
		Plectroglyphididon leucozona	0	0	3	0	0	0	3	0	0	0	8	0	0	0	0	0
		Pomacentrus vaiuli	17	31	0	0	11	4	0	0	1	4	0	0	7	5	1	0
		Pomachromis guamensis	1	0	0	0	35	1	0	0	25	1	0	0	5	0	0	0
		Stegastes albifasciatus	0	0	6	0	0	0	2	4	0	0	2	49	0	0	8	2
		Stegastes fasciolatus	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0
		Stegastes lividus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Stegastes nigricans	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
Labridae	Wrasses	*Bodianus axillaris*	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
		Cheilinus chlororus	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
		Cheilinus oxycephalus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cheilinus trilobatus	0	2	1	0	0	1	0	0	1	3	0	1	3	1	1	0
		Cheilinus undulatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Epibulus insidiator	1	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		Oxycheilinus unifasciatus	3	3	0	0	3	1	0	0	3	2	0	0	3	1	0	0
		Pseudocheilinus octotaenia	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cirrhilabrus katherinae	1	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
		Novaculichthys taeniourus	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
		Anampses meleagrides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Coris aygula	0	2	0	0	0	1	0	0	0	1	0	1	0	0	0	0
		Coris gaimard	4	2	0	0	0	0	1	0	2	1	0	0	2	0	0	0
		Gomphosus varius	0	2	1	0	0	2	0	0	0	0	1	0	0	0	0	0
		Halichoeres biocellatus	4	3	0	0	1	0	0	0	0	0	0	0	2	0	0	0
		Halichoeres hartzfeldii	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
		Halichoeres hortulanus	0	0	2	0	1	2	4	0	1	3	1	2	0	3	1	0
		Halichoeres margaritaceus	0	2	9	11	4	9	14	0	0	0	14	6	3	4	12	0
		Halichoeres marginatus	0	0	0	3	0	0	3	0	0	0	0	4	0	0	0	0
		Halichoeres trimaculatus	0	5	0	13	0	0	1	7	0	1	1	8	0	1	3	10
		Hemigymnus melapterus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
		Hologymnosus doliatus	1	2	0	0	1	0	0	0	1	0	0	0	2	0	0	0
		Macropharyngodon melagris	0	2	0	0	1	1	0	0	0	0	0	0	0	0	0	0

		Pseudocoris yamashiroi	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		Stethojulis bandenensis	2	1	2	2	3	1	5	6	0	0	2	10	0	0	6	8
		Stethojulis strigiventer	0	0	0	0	0	0	0	0	0	1	0	0	0	0	6	0
		Thalassoma amblycephalum	0	0	0	0	4	4	0	0	3	0	0	0	1	0	0	0
		Thalassoma hardwicke	0	0	0	0	0	0	1	1	0	0	1	4	0	0	0	0
		Thalassoma lutescens	1	0	0	0	4	8	0	0	1	3	0	0	0	0	0	0
		Thalassoma purpureum	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
		Thalassoma quinquevittatum	0	11	13	1	2	6	6	0	1	4	7	0	1	20	1	0
		Labroides bicolor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Labroides dimidiatus	9	3	0	0	3	3	0	0	4	4	0	0	1	2	0	0
		Cheilio inermis	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Labridae:Scarinae	Parrotfishes	*Chlorurus frontalis*	2	2	0	0	0	1	1	0	0	1	0	0	0	1	0	0
		Chlorurus microrhinos	0	0	0	1	4	1	0	0	0	0	0	0	6	1	0	0
		Chlorurus sordidus	11	19	4	0	8	5	4	1	4	10	12	2	4	2	0	0
		Scarus altipinnis	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Scarus forsteni	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Scarus oviceps	2	0	0	0	0	1	0	0	4	0	0	0	0	0	0	0
		Scarus psittacus	0	9	0	0	0	0	1	0	3	2	4	3	2	3	2	0
		Scarus schlegeli	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinguipedidae	Sandperches	*Parapercis clathrata*	2	2	0	0	6	2	0	0	3	0	0	0	2	0	0	0
Blenniidae	Blennies	*Aspidontus taeniatus*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		Meiacanthus atrodorsalis	0	2	0	0	2	0	0	0	0	1	0	0	1	0	0	0
		Blenniella chrysospilos	0	0	0	0	0	5	0	0	0	0	3	0	0	2	0	0
		Cirripectes variolosus	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
		Ecsenius bicolor	0	0	0	0	1	2	0	0	2	1	0	0	0	0	0	0
Gobiidae	Gobies	*Amblygobius nocturnus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Amblygobius phaelena	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cryptocentrus strigilliceps	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Ctenogobiops feroculus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Valenciennea strigata	6	0	0	0	4	7	0	0	20	10	0	0	4	4	0	0
		Eviota guttatus	10	2	0	0	4	4	0	0	1	15	0	0	3	14	0	0
		Eviota lachdeberei	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Eviota punctulata	0	0	0	0	0	5	0	0	11	0	0	0	0	0	0	0
		Eviota saipanensis	0	1	0	0	0	0	0	0	0	0	0	0	0	7	0	0
		Gnatholepis anjerensis	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
		Gnatholepis cauerensis	0	2	0	0	3	4	0	0	2	3	0	0	3	4	0	0
		Istigobius decoratus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ptereleotridae	Dartfishes	*Nemaeleotris magnifica*	0	0	0	0	0	0	0	0	0	0	0	0	4	12	0	0
		Ptereleotris evides	2	2	0	0	0	5	0	0	1	17	0	0	0	0	0	0
		Ptereleotris heteroptera	0	0	0	0	0	0	0	0	33	3	0	0	0	0	0	0
		Ptereleotris microlepis	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0
		Ptereleotris zebra	0	0	0	0	0	2	0	0	0	27	0	0	0	23	0	0
Zanclidae	Moorish Idol	*Zanclus cornutus*	1	0	0	0	1	0	3	0	3	3	1	3	0	3	0	0
Siganidae	Rabbitfishes	*Siganus spinus*	0	0	0	0	0	0	2	1	0	0	0	0	0	0	1	0
Acanthuridae	Surgeonfishes	*Acanthurus blochii*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Acanthurus lineatus	0	0	10	0	0	0	4	0	0	0	9	8	0	0	14	4
		Acanthurus nigricans	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
		Acanthurus nigrofuscus	6	16	1	0	10	4	8	18	15	18	2	6	8	4	0	0
		Acanthurus nigroris	0	0	0	0	3	0	0	0	3	2	0	0	2	0	0	0
		Acanthurus olivaceus	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0
		Acanthurus pyroferus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Acanthurus triostegus	0	0	6	0	0	0	4	23	0	0	7	19	0	1	0	15

		Acanthurus xanthopterus	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
		Ctenochaetus hawaiiensis	0	0	0	0	0	2	0	0	0	4	0	0	0	3	0	4
		Ctenochaetus striatus	1	6	0	0	0	1	16	0	3	4	2	2	1	2	1	0
		Naso annulatus	1	2	0	0	1	1	0	0	1	0	0	1	1	0	0	0
		Naso lituratus	8	22	3	0	6	5	1	2	10	5	3	6	17	5	0	0
		Zebrasoma scopas	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Balistidae	Triggerfishes	*Balistapus undulatus*	0	1	0	0	0	1	0	0	0	1	0	0	2	1	0	0
		Melichthys vidua	2	1	0	0	3	1	0	0	2	1	0	0	3	1	0	0
		Rhinecanthus aculeatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
		Rhinecanthus rectangulus	0	0	1	0	0	0	0	0	0	1	0	0	0	0	2	0
		Sufflamen bursa	0	1	0	0	0	5	0	0	1	2	0	0	1	3	0	0
		Sufflamen chrysoptera	2	2	0	0	3	4	0	0	4	3	0	0	3	1	0	0
Monacanthidae	Filefishes	*Amanses scopas*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tetraodontidae	Puffers	*Canthigaster solandri*	0	2	0	0	3	0	1	0	0	2	0	0	0	0	0	0
		Total fishes	139	239	137	74	168	245	125	78	185	231	204	185	116	222	105	71

Appendix 2. Density (number per square meter) of reef fishes on transects at Tipalao Reef.

Family	Common name	Species	Transect: Sector 1: 1 12	1 6	1 ORF	1 MRF	Sector 2: 2 12	2 6	2 ORF	2 MRF	Sector 3: 3 12	3 6	3 ORF	3 MRF	Sector 4: 4 12	4 6	4 ORF	4 MRF
Carcharhinidae	Reef sharks	*Carcharhinus melapterus*	0	0	0	0	0	0	0	0	0	0	0	0.002	0	0	0	0
Muraenidae	Moray eels	*Gymnomuraena zebra*	0	0	0	0.002	0	0	0	0	0	0	0	0	0	0	0	0
Clupeidae	Herrings	*Spratelloides delicatulus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synodontidae	Lizardfishes	*Synodus binotatus*	0	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Belonidae	Needlefishes	*Strongylura leiura leiura*	0	0	0	0	0	0	0	0	0	0	0	0.002	0	0	0	0
Holocentridae	Squirrelfishes	*Myripristis adusta*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Myripristis murdjan	0	0	0	0	0	0.002	0	0	0	0	0	0	0	0	0	0
		Sargocentron caudimaculatum	0	0	0	0	0	0	0	0	0.002	0	0	0	0	0	0	0
		Sargocentron diadema	0	0	0	0	0	0	0.002	0	0	0	0	0.004	0	0	0	0
		Sargocentron punctissimum	0	0	0	0	0	0	0	0	0	0	0	0.002	0	0	0	0
		Sargocentron spiniferum	0	0	0	0	0	0	0	0	0.002	0.004	0.006	0.01	0	0	0	0
Fistularidae	Cornetfishes	*Fistularis commersoni*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scorpaenidae	Scorpionfishes	*Sebastipistes sp. in corals*	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Pterois antennata	0	0	0	0	0	0	0	0	0.002	0	0	0	0	0	0	0
Serranidae	Groupers	*Cephalopholis spiloparea*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cephalopholis urodeta	0	0.002	0	0	0.004	0.01	0	0	0.004	0.008	0	0	0.006	0.002	0	0
		Epinephelus hexagonatus	0	0	0	0	0	0	0	0	0	0.002	0.002	0.002	0	0	0	0
		Epinephelus merra	0	0.004	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0
Cirrhitidae	Hawkfishes	*Cirrhitichthys falco*	0.018	0	0	0	0.008	0	0	0	0	0	0	0	0.002	0	0	0
		Paracirrhites arcatus	0.004	0	0	0	0	0.002	0	0	0	0.006	0	0	0	0.008	0	0
		Paracirrhites forsteri	0	0	0	0	0	0	0	0	0	0.004	0	0	0	0.004	0	0
Pseudochromidae	Dottybacks	*Pseudochromis cyanotaenia*	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0
Apogonidae	Cardinalfishes	*Apogon angustatus*	0.02	0.01	0	0	0	0	0	0	0	0	0	0	0.04	0.02	0	0
		Apogon nigrofasciatus	0	0	0	0	0.02	0.024	0	0	0	0	0	0	0	0	0	0
Malacanthidae	Tilefishes	*Malacanthus latovittatus*	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carangidae	Trevalleys and Jacks	*Caranx melampygus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lutjanidae	Snappers	*Aphareus furca*	0	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lutjanus fulvus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lethrinidae	Emperor bream	*Lethrinus harak*	0.01	0	0	0	0	0	0	0	0	0.05	0	0	0	0.01	0.01	0.01
		Lethrinus obsoletus	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nemipteridae	Monocle bream	*Scolopsis lineata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01
Mullidae	Goatfishes	*Mulloidichthys flavolineatus*	0	0	0	0	0	0	0	0	0	0	0	0.006	0	0	0	0
		Mulloidichthys vanicolensis	0	0	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0
		Parupeneus barberinus	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002	0	0
		Parupeneus ciliatus	0	0	0	0	0	0	0	0	0	0	0	0.002	0	0	0	0
		Parupeneus crassilabrus	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002	0	0
		Parupeneus cyclostomus	0	0	0	0	0	0.006	0	0	0	0	0	0	0	0	0	0
		Parupeneus multifasciatus	0.008	0.004	0	0	0.002	0.002	0.002	0	0	0.002	0.006	0.004	0.002	0.002	0.004	0
Pempheridae	Sweepers	*Pempheris otaitensis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chaetodontidae	Butterflyfishes	*Chaetodon auriga*	0	0	0	0	0	0	0	0	0.004	0	0	0.004	0	0	0	0
		Chaetodon citrinellus	0	0	0.004	0.004	0.002	0.008	0.002	0	0.002	0.004	0	0.006	0.008	0	0	0
		Chaetodon ephippium	0	0	0	0	0.002	0	0	0	0	0	0	0	0	0	0	0
		Chaetodon lunula	0	0	0	0	0	0.004	0.002	0	0	0	0	0	0	0	0	0
		Chaetodon mertensii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chaetodon ornatissimus	0	0.004	0	0	0	0	0	0	0	0.002	0	0	0	0	0	0
		Chaetodon punctatofasciatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002	0	0
		Chaetodon reticulatus	0	0.004	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chaetodon ulietensis	0	0	0	0	0	0	0	0	0	0.004	0	0	0	0	0	0

		Forcipiger flavissimus	0	0.002	0	0	0.002	0	0	0	0	0	0	0	0	0.002	0	0
		Heniochus acuminatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pomacanthidae	Angelfishes	*Centropyge flavissima*	0	0	0	0	0	0.002	0	0	0	0	0	0	0	0	0	0
		Pomacanthus imperator	0	0	0	0	0	0	0	0	0	0	0.002	0	0	0	0	0
		Pygoplites diacanthus	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pomacentridae	Damselfishes	*Amphiprion chrysopterus*	0	0	0	0	0	0.02	0.01	0	0	0	0	0	0	0	0	0
		Chromis agilis	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chromis margaritifer	0	0.02	0	0	0.04	0	0	0	0	0	0	0	0	0.02	0	0
		Dascyllus reticulatus	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0.06	0	0
		Dascyllus trimaculatus	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0
		Abudefduf sexfasciatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Abudefduf vaigenensis	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0
		Chrysiptera biocellatus	0	0	0	0	0	0	0	0.03	0	0	0	0.02	0	0	0.01	0.19
		Chrysiptera brownriggi	0	0	0.08	0.05	0	0.4	0.08	0.01	0.02	0.25	0.05	0.01	0.02	0.28	0.03	0
		Chrysiptera brownriggi amabilis	0	0	0.63	0.15	0	0.13	0.26	0.07	0	0.06	1.07	0.11	0	0.26	0.08	0
		Chrysiptera glauca	0	0	0	0.2	0	0	0	0.03	0	0	0	0.11	0	0	0.08	0
		Chrysiptera traceyi	0.1	0.45	0	0	0.09	0.12	0	0	0.02	0.06	0	0	0.02	0.06	0.23	0
		Plectroglyphididon dickii	0	0	0	0	0	0	0	0	0	0.02	0.01	0	0	0.03	0	0
		Plectroglyphididon lacrymatus	0	0.07	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0
		Plectroglyphididon leucozona	0	0	0.03	0	0	0	0.03	0	0	0	0.08	0	0	0	0	0
		Pomacentrus vaiuli	0.17	0.31	0	0	0.11	0.04	0	0	0.01	0.04	0	0	0.07	0.05	0.01	0
		Pomachromis guamensis	0.01	0	0	0	0.35	0.01	0	0	0.25	0.01	0	0	0.05	0	0	0
		Stegastes albifasciatus	0	0	0.06	0	0	0	0.02	0.04	0	0	0.02	0.49	0	0	0.08	0.02
		Stegastes fasciolatus	0	0	0	0	0	0.02	0	0	0	0.01	0	0	0	0	0	0
		Stegastes lividus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Stegastes nigricans	0	0	0	0	0	0	0	0	0	0	0	0.03	0	0	0	0
Labridae	Wrasses	*Bodianus axillaris*	0	0	0	0	0	0.002	0	0	0	0	0	0	0	0	0	0
		Cheilinus chlororus	0	0	0	0	0	0	0	0	0.002	0	0	0	0	0	0	0
		Cheilinus oxycephalus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cheilinus trilobatus	0	0.004	0.002	0	0	0.002	0	0	0.002	0.006	0	0.002	0.006	0.002	0.002	0
		Cheilinus undulatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Epibulus insidiator	0.002	0.004	0	0	0.002	0	0	0	0	0	0	0	0	0	0	0
		Oxycheilinus unifasciatus	0.006	0.006	0	0	0.006	0.002	0	0	0.006	0.004	0	0	0.006	0.002	0	0
		Pseudocheilinus octotaenia	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cirrhilabrus katherinae	0.01	0	0	0	0.04	0	0	0	0	0	0	0	0	0	0	0
		Novaculichthys taeniourus	0.002	0	0	0	0	0	0	0.002	0.002	0	0	0	0	0	0	0
		Anampses meleagrides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Coris aygula	0	0.004	0	0	0	0.002	0	0	0	0.002	0	0.002	0	0	0	0
		Coris gaimard	0.008	0.004	0	0	0	0	0.002	0	0.004	0.002	0	0	0.004	0	0	0
		Gomphosus varius	0	0.004	0.002	0	0	0.004	0	0	0	0	0.002	0	0	0	0	0
		Halichoeres biocellatus	0.008	0.006	0	0	0.002	0	0	0	0	0	0	0	0.004	0	0	0
		Halichoeres hartzfeldii	0	0	0	0	0	0.002	0	0	0	0	0	0	0	0	0	0
		Halichoeres hortulanus	0	0	0.004	0	0.002	0.004	0.008	0	0.002	0.006	0.002	0.004	0	0.006	0.002	0
		Halichoeres margaritaceus	0	0.004	0.018	0.022	0.008	0.018	0.028	0	0	0	0.028	0.012	0.006	0.008	0.024	0
		Halichoeres marginatus	0	0	0	0.006	0	0	0.006	0	0	0	0	0.008	0	0	0	0
		Halichoeres trimaculatus	0	0.01	0	0.026	0	0	0.002	0.014	0	0.002	0.002	0.016	0	0.002	0.006	0.02
		Hemigymnus melapterus	0	0	0	0	0	0	0	0	0	0	0	0	0.002	0	0	0
		Hologymnosus doliatus	0.002	0.004	0	0	0.002	0	0	0	0.002	0	0	0	0.004	0	0	0
		Macropharyngodon melagris	0	0.02	0	0	0.01	0.01	0	0	0	0	0	0	0	0	0	0
		Pseudocoris yamashiroi	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0
		Stethojulis bandenensis	0.004	0.002	0.004	0.004	0.006	0.002	0.01	0.012	0	0	0.004	0.02	0	0	0.012	0.02
		Stethojulis strigiventer	0	0	0	0	0	0	0	0	0	0.002	0	0	0	0	0.012	0
		Thalassoma amblycephalum	0	0	0	0	0.008	0.008	0	0	0.006	0	0	0	0.002	0	0	0
		Thalassoma hardwicke	0	0	0	0	0	0	0.002	0.002	0	0	0.002	0.008	0	0	0	0
		Thalassoma lutescens	0.002	0	0	0	0.008	0.016	0	0	0.002	0.006	0	0	0	0	0	0

		Thalassoma purpureum	0	0	0	0	0	0	0	0	0	0	0.004	0	0	0	0	0
		Thalassoma quinquevittatum	0	0.022	0.026	0.002	0.004	0.012	0.012	0	0.002	0.008	0.014	0	0.002	0.04	0.002	0
		Labroides bicolor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Labroides dimidiatus	0.09	0.03	0	0	0.03	0.03	0	0	0.04	0.04	0	0	0.01	0.02	0	0
		Cheilio inermis	0	0	0	0	0	0	0	0	0	0.002	0	0	0	0	0	0
Labridae:Scarinae	Parrotfishes	*Chlorurus frontalis*	0.004	0.004	0	0	0	0.002	0.002	0	0	0.002	0	0	0	0.002	0	0
		Chlorurus microrhinos	0	0	0	0.002	0.008	0.002	0	0	0	0	0	0	0.012	0.002	0	0
		Chlorurus sordidus	0.022	0.038	0.008	0	0.016	0.01	0.008	0.002	0.008	0.02	0.024	0.004	0.008	0.004	0	0
		Scarus altipinnis	0.004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Scarus forsteni	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Scarus oviceps	0.004	0	0	0	0	0.002	0	0	0.008	0	0	0	0	0	0	0
		Scarus psittacus	0	0.018	0	0	0	0	0.002	0	0.006	0.004	0.008	0.006	0.004	0.006	0.004	0
		Scarus schlegeli	0.006	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinguipedidae	Sandperches	*Parapercis clathrata*	0.004	0.004	0	0	0.012	0.004	0	0	0.006	0	0	0	0.004	0	0	0
Blenniidae	Blennies	*Aspidontus taeniatus*	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0
		Meiacanthus atrodorsalis	0	0.02	0	0	0.02	0	0	0	0	0.01	0	0	0.01	0	0	0
		Blenniella chrysospilos	0	0	0	0	0	0.05	0	0	0	0	0.03	0	0	0.02	0	0
		Cirripectes variolosus	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0.01	0	0
		Ecsenius bicolor	0	0	0	0	0.01	0.02	0	0	0.02	0.01	0	0	0	0	0	0
Gobiidae	Gobies	*Amblygobius nocturnus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Amblygobius phaelena	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cryptocentrus strigilliceps	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Ctenogobiops feroculus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Valenciennea strigata	0.06	0	0	0	0.04	0.07	0	0	0.2	0.1	0	0	0.04	0.04	0	0
		Eviota guttatus	0.1	0.02	0	0	0.04	0.04	0	0	0.01	0.15	0	0	0.03	0.14	0	0
		Eviota lachdeberei	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Eviota punctulata	0	0	0	0	0	0.05	0	0	0.11	0	0	0	0	0	0	0
		Eviota saipanensis	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0.07	0	0
		Gnatholepis anjerensis	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0
		Gnatholepis cauerensis	0	0.02	0	0	0.03	0.04	0	0	0.02	0.03	0	0	0.03	0.04	0	0
		Istigobius decoratus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ptereleotridae	Dartfishes	*Nemaeleotris magnifica*	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0.12	0	0
		Ptereleotris evides	0.02	0.02	0	0	0	0.05	0	0	0.01	0.17	0	0	0	0	0	0
		Ptereleotris heteroptera	0	0	0	0	0	0	0	0	0.33	0.03	0	0	0	0	0	0
		Ptereleotris microlepis	0	0	0	0	0	0.25	0	0	0	0	0	0	0	0	0	0
		Ptereleotris zebra	0	0	0	0	0	0.02	0	0	0	0.27	0	0	0	0.23	0	0
Zanclidae	Moorish Idol	*Zanclus cornutus*	0.002	0	0	0	0.002	0	0.006	0	0.006	0.006	0.002	0.006	0	0.006	0	0
Siganidae	Rabbitfishes	*Siganus spinus*	0	0	0	0	0	0	0.004	0.002	0	0	0	0	0	0	0.002	0
Acanthuridae	Surgeonfishes	*Acanthurus blochii*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Acanthurus lineatus	0	0	0.02	0	0	0	0.008	0	0	0	0.018	0.016	0	0	0.028	0.01
		Acanthurus nigricans	0	0	0	0	0	0	0	0	0	0	0	0	0.002	0	0	0
		Acanthurus nigrofuscus	0.012	0.032	0.002	0	0.02	0.008	0.016	0.036	0.03	0.036	0.004	0.012	0.016	0.008	0	0
		Acanthurus nigroris	0	0	0	0	0.006	0	0	0	0.006	0.004	0	0	0.004	0	0	0
		Acanthurus olivaceus	0	0	0	0	0	0.004	0	0	0.002	0	0	0	0	0	0	0
		Acanthurus pyroferus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Acanthurus triostegus	0	0	0.012	0	0	0	0.008	0.046	0	0	0.014	0.038	0	0.002	0	0.03
		Acanthurus xanthopterus	0	0	0	0	0	0.002	0	0	0	0	0	0	0	0.002	0	0
		Ctenochaetus hawaiiensis	0	0	0	0	0	0.004	0	0	0	0.008	0	0	0	0.006	0	0.01
		Ctenochaetus striatus	0.002	0.012	0	0	0	0.002	0.032	0	0.006	0.008	0.004	0.004	0.002	0.004	0.002	0
		Naso annulatus	0.002	0.004	0	0	0.002	0.002	0	0	0.002	0	0	0.002	0.002	0	0	0
		Naso lituratus	0.016	0.044	0.006	0	0.012	0.01	0.002	0.004	0.02	0.01	0.006	0.012	0.034	0.01	0	0
		Zebrasoma scopas	0	0	0	0	0	0.002	0	0	0	0	0	0	0	0	0	0
Balistidae	Triggerfishes	*Balistapus undulatus*	0	0.002	0	0	0	0.002	0	0	0	0.002	0	0	0.004	0.002	0	0
		Melichthys vidua	0.004	0.002	0	0	0.006	0.002	0	0	0.004	0.002	0	0	0.006	0.002	0	0
		Rhinecanthus aculeatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

		Rhinecanthus rectangulus	0	0	0.002	0	0	0	0	0	0	0.002	0	0	0	0	0.004	0
		Sufflamen bursa	0	0.002	0	0	0	0.01	0	0	0.002	0.004	0	0	0.002	0.006	0	0
		Sufflamen chrysoptera	0.004	0.004	0	0	0.006	0.008	0	0	0.008	0.006	0	0	0.006	0.002	0	0
Monacanthidae	Filefishes	*Amanses scopas*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tetraodontidae	Puffers	*Canthigaster solandri*	0	0.004	0	0	0.006	0	0.002	0	0	0.004	0	0	0	0	0	0

Appendix 3. Checklist and distribution of reef fishes at Dadi Reef. Fishes are arranged in phylogenetic order.

			Transect															
			Sector 1				Sector 2				Sector 3				Sector 4			
Family	Common n	Species	1 12	1 6	1 ORF	1 MRF	2 12	2 6	2 ORF	2 MRF	3 12	3 6	3 ORF	3 MRF	4 12	4 6	4 ORF	4 MRF
Muraenidae	Moray eels	*Gymnothorax javanicus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synodontidae	Lizardfishe	*Saurida gracilis*	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
		Synodus binotatus	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
Holocentridae	Squirrelfish	*Myrpristis berndti*	0	3	0	0	0	4	0	1	0	4	0	0	0	0	0	0
		Myrpristis kuntee	0	27	0	0	0	0	0	2	0	2	0	0	0	0	0	0
		Myrpristis murdjan	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Myrpristis pralinia	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
		Neoniphon argenteus	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
		Neoniphon opercularis	0	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0
		Sargocentron caudimaculatum	0	2	0	0	0	0	0	1	0	1	0	0	0	0	0	0
		Sargocentron diadema	0	2	1	0	1	0	1	1	0	1	0	0	1	0	0	0
		Sargocentron spiniferum	0	2	0	0	1	2	0	0	0	0	0	0	0	0	0	0
Belonidae	Needlefish	*Strongylura incisus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hemiramphidae	Halfbeaks	*Hemiramphus lutkei*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aulostomidae	Trumpetfisl	*Aulostomus chinensis*	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Scorpaenidae	Scorpionfis	*Pterois antennata*	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
		Pterois volitans	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Caracanthidae	Coralcrouc	*Caracanthus maculatus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Serranidae	Groupers	*Cephalopholis spiloparaea*	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
		Cephalopholis urodeta	2	3	0	0	1	3	0	4	1	6	0	0	3	1	0	0
		Epinephelus fasciatus	0	2	0	0	0	0	0	0	0	0	0	0	4	0	0	0
		Epinephelus hexagonatus	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
		Epinephelus macrodon	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Epinephelus merra	0	1	0	0	2	2	1	4	1	4	0	0	0	1	2	0
		Epinephelus spilotoceps	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cirrhitidae	Hawkfishes	*Cirrhitichthys falco*	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0
		Neocirrhites armatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Paracirrhites arcatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Paracirrhites forsteri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apogonidae	Cardinalfisl	*Apogon angustatus*	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Apogon exostigma	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Apogon luteus	0	2	0	0	63	0	0	0	0	0	0	0	0	0	0	0
		Apogon novemfasciatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cheilodipterus macrodon	0	0	0	0	0	2	0	0	0	3	0	0	0	0	0	0
		Cheilodipterus quinquelineatus	0	3	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Carangidae	Trevallys a	*Caranx melampygus*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		Caranx sexfasciatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lutjanidae	Snappers	*Aphareus furca*	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
		Lutjanus fulvus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lutjanus gibbus	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lutjanus kasmira	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lutjanus monostigmus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haemulidae	Sweetlips	*Plectorhinchus albovittatus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lethrinidae	Emperors	*Gnathodentex aurolineatus*	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0

		Lethrinus harak	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
		Lethrinus obsoletus	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
		Monotaxis grandoculis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nemipteridae	Spinecheel	*Scolopsis lineatua*	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	1
Mullidae	Goatfishes	*Mulloidichthys flavolineatus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Mulloidichthys vanicolensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Parupeneus barberinus	1	1	0	1	0	0	0	0	0	0	0	1	0	0	0	1
		Parupeneus crenilabrus	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
		Parupeneus ciliatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Parupeneus cyclostomus	1	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0
		Parupeneus multifasciatus	0	2	4	6	0	0	0	0	0	0	2	1	1	1	1	1
		Parupeneus pleurostigma	0	0	0	2	0	1	1	0	0	0	0	0	0	0	0	0
Chaetodontidae	Butterflyfisl	*Chaetodon auriga*	1	1	1	0	0	1	0	0	0	0	0	3	0	0	1	0
		Chaetodon bennetti	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chaetodon citrinellus	0	2	2	0	0	0	1	2	0	2	2	0	1	0	2	2
		Chaetodon ephippium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chaetodon kleinii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chaetodon lunula	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
		Chaetodon lunulatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
		Chaetodon mertensii	0	1	0	0	0	1	0	0	2	0	0	0	2	0	0	0
		Chaetodon ornatissimus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chaetodon punctatofasciatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chaetodon reticulatus	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
		Chaetodon trifascialis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
		Chaetodon ulietensis	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
		Chaetodon unimaculatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Focipiger flavissimus	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0
		Forcipiger longirostris	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
		Hemitaurichthys polylepis	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
		Heniochus acuminatus	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
		Heniochus chrysostomus	0	0	0	0	0	1	0	1	1	1	0	0	0	1	0	0
Pomacanthidae	Angelfishes	*Centropyge flavissima*	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
		Centropyge heraldi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Centropyge vrolikii	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
		Pomacanthus imperator	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0
Pomacentridae	Damselfish	*Amphiprion chrysopterus*	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
		Chromis acares	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
		Chromis agilis	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		Chromis atripecoralis	0	0	0	0	0	0	0	12	0	12	0	0	0	0	0	0
		Chromis margaritifer	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0
		Chromis viridis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300
		Dascyllus aruanus	0	0	0	0	0	0	0	0	0	0	0	1	0	0	6	4
		Dascyllus reticulatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Dascyllus trimaculatus	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
		Abudefduf septemfasciatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Abudefduf sexfasciatus	0	6	0	46	0	0	0	201	0	201	0	0	0	0	0	0
		Abudefduf vaigiensis	0	0	0	0	0	0	0	50	0	50	1	0	0	0	0	0
		Amblyglyphididon curacao	0	0	0	0	0	0	0	4	0	4	0	0	0	0	8	0
		Amblyglyphididon ternatensis?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chrysiptera biocellata	0	0	0	1	0	0	0	0	0	0	3	2	0	0	2	3
		Chrysiptera brownriggii brownriggi	0	0	43	2	0	0	2	0	0	0	9	0	0	0	0	0

		Chrysiptera brownriggii amabilis	0	0	59	18	0	0	70	0	0	0	17	0	0	0	5	0
		Chrysiptera glauca	0	0	0	4	0	0	5	0	0	0	0	1	0	0	1	0
		Chrysiptera traceyi	64	388	1	0	196	335	0	199	218	199	0	0	140	60	0	0
		Plectroglyphydodon dickii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Plectroglyphydodon johnstonianus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Plectroglyphydodon lacrymatus	0	1	0	0	0	2	0	17	1	17	0	0	1	5	0	0
		Plectroglyphydodon leucozona	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0
		Pomacentrus amboinensis	8	0	0	0	38	11	0	0	0	0	0	0	0	0	0	0
		Pomacentrus pavo	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19
		Pomacentrus vaiuli	6	48	1	0	23	49	0	13	23	13	0	0	72	24	1	0
		Pomachromis guamensis	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Stegastes albifasciatus	0	0	10	8	0	0	4	0	0	0	6	7	0	0	5	1
		Stegastes fasciatus	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
		Stegastes lividus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	2
		Stegastes nigricans	0	0	0	0	0	0	0	0	0	0	2	1	0	0	1	0
		Cheilinus chlorourus	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Labridae	Wrasses	*Cheilinus fasciatus*	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
		Cheilinus oxycephalus	0	0	0	0	0	0	0	1	4	1	0	0	1	0	0	0
		Cheilinus trilobatus	1	1	0	1	0	0	0	0	0	0	3	1	0	1	0	1
		Cheilinus undulatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Epibulus insidiator	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0
		Oxycheilinus unifasciatus	1	0	0	0	4	3	0	1	2	1	0	0	3	1	0	0
		Cirrhilabrus cyanopleura	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cirrhilabrus katherinae	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
		Pseudocheilinus hexataenia	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
		Pseudocheilinus tetrataenia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Novaculichthys taeniourus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Anampses twisti	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
		Coris aygula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Coris gaimard	0	0	0	0	0	0	0	1	0	0	0	0	3	0	0	0
		Gomphosus varius	0	2	0	0	0	1	0	1	0	2	0	0	0	0	1	0
		Halichoeres biocellatus	0	0	0	0	0	0	0	1	7	0	0	0	19	4	0	0
		Halichoeres hortulanus	0	2	0	0	1	0	0	2	1	0	0	0	0	3	0	1
		Halichoeres margaritaceus	0	0	12	25	0	0	27	1	0	1	5	0	0	0	0	0
		Halichoeres marginatus	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
		Halichoeres trimaculatus	1	3	0	3	0	2	5	0	0	0	3	4	1	2	2	2
		Hemigymnus fasciatus	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
		Hemigymnus melapterus	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
		Macropharyngodon meleagris	0	5	0	0	0	1	0	0	0	0	0	0	1	0	0	0
		Pseudochoris yamashiroi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Stethojulis bandanensis	0	1	5	12	0	0	16	1	1	1	5	7	0	1	5	1
		Stethojulis strigiventer	0	1	2	6	0	0	1	0	0	0	0	0	0	0	0	0
		Thalassoma amblycephalum	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Thalassoma hardwicke	0	1	0	0	0	0	0	4	0	4	0	0	0	2	1	2
		Thalassoma lutescens	0	3	0	0	0	0	0	2	0	2	0	0	2	0	0	0
		Thalassoma quinquevittatum	0	2	14	0	0	0	0	0	0	0	2	0	0	3	1	0
		Labroides dimidiatus	1	3	1	0	4	3	0	5	4	5	0	0	3	3	0	0
		Labroides pectoralis	4	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
		Cheilio inermis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Labridae: Scarinae	Parrotfishe	*Calotomus carolinus*	0	2	0	0	0	1	0	0	1	0	0	0	0	0	0	0
		Chlorurus frontalis	0	0	0	0	0	1	0	1	10	1	0	0	0	4	0	0

		Chlorurus microrhinos	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chlorurus sordidus	0	4	29	0	2	10	5	4	0	4	16	22	1	39	37	35
		Hipposcarus longiceps	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Scarus altipinnis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Scarus forsteni	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Scarus globiceps	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Scarus niger	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		Scarus oviceps	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0
		Scarus psittacus	0	0	8	0	0	1	0	4	1	4	15	0	0	3	8	2
		Scarus schlegeli	0	0	0	0	0	0	0	1	2	1	0	0	0	0	0	0
Pinguipedidae	Sandperch	*Parapercis clathrata*	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Parapercis millepunctata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Blenniidae	Blennies	*Aspiodontus taeniatus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Meiacanthus atrodorsalis	1	4	0	0	0	5	0	0	3	0	0	0	0	2	0	0
		Plagiotremus tapeinosoma	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
		Blenniella chrysopilos	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
		Ecsenius bicolor	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Salarias fasciatus	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0
Callionymidae	Dragonets	*Callionymus simplicicornis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gobiidae	Gobies	*Cryptocentrus strigilliceps*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	5
		Ctenogobiops feroculus	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Amblyeleotris steinitzi	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0
		Vanderhorstia ambanoro	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Amblygobius nocturnus	0	0	0	0	3	0	0	1	0	1	0	0	0	0	0	0
		Amblygobius phaelena	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1
		Oplopomus oplopomus	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Valenciennea strigata	3	4	0	0	0	0	0	0	0	0	0	0	2	4	1	0
		Asterropteryx semipunctatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
		Bathygobius cyclopterus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Coryphopterus neophytus	0	0	0	0	1	1	0	0	1	0	0	0	0	0	1	0
		Eviota albolineata	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
		Eviota guttata	1	4	1	0	0	4	0	4	2	4	0	0	1	1	0	0
		Eviota prasites	0	0	0	0	1	1	0	1	10	1	0	0	4	0	0	0
		Eviota saipanensis	0	1	0	0	0	8	0	0	1	1	0	0	1	0	0	0
		Exyrias belissimus	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
		Gnatholepis anjerensis	3	0	0	0	1	10	0	2	0	0	0	0	0	0	0	0
		Gnatholepis cauerensis	0	0	0	0	16	1	0	2	1	2	0	0	7	3	0	0
		Istigobius decoratus	2	1	0	1	5	2	0	0	0	0	0	0	0	0	0	0
		Istigobius ornatus	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Microdesmidae	Wormfishe	*Gunnellichthys pleurotaenia*	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ptereleotridae	Dartfishes	*Nemaeleotris magnfica*	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
		Ptereleotris evides	0	2	0	0	0	3	0	0	0	0	0	0	1	0	0	0
		Ptereleotris heteroptera	0	4	0	0	50	0	0	0	0	0	0	0	0	0	0	0
		Ptereleotris zebra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphyraenidae	Barracudas	*Sphyraena barracuda*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Siganidae	Rabbitfishe	*Siganus argenteus*	0	0	0	98	0	0	3	1	0	1	0	0	0	0	0	2
		Siganus spinus	0	0	1	0	0	0	0	0	0	0	1	1	0	0	2	1
Zanclidae	Moorish Ido	*Zanclus cornutus*	0	2	1	0	2	0	0	2	0	2	2	3	0	1	1	0
Acanthuridae	Surgeonfis	*Acanthurus lineatus*	0	0	12	1	0	0	3	0	0	0	0	1	0	0	0	0
		Acanthurus leucocheilus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Acanthurus nigricans	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0

		Acanthurus nigricauda	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Acanthurus nigrofuscus	1	23	21	0	11	9	5	7	8	7	30	22	14	10	0	7
		Acanthurus nigoris	0	2	0	0	0	0	0	5	1	5	0	0	0	0	0	0
		Acanthurus olivaceus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Acanthurus triostegus	0	0	0	5	0	0	3	0	0	0	0	2	0	0	3	4
		Acanthurus xanthopterus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
		Ctenochaetus binotatus	0	0	0	0	0	0	0	3	0	3	0	0	0	0	0	0
		Ctenochaetus hawaiiensis	0	4	0	0	0	0	0	10	0	10	0	0	1	9	20	0
		Ctenochaetus striatus	0	3	0	0	1	0	0	4	0	4	1	0	2	8	13	9
		Zebrasoma flavescens	0	0	0	0	0	1	0	2	0	2	0	0	0	0	0	0
		Zebrasoma scopas	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
		Naso annulatus	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
		Naso literatus	1	3	0	0	1	0	0	1	7	1	0	0	17	2	0	0
		Naso vlamingi	0	0	0	0	0	0	0	15	0	15	0	0	1	0	0	0
Monacanthidae	Filefishes	*Amanses scopas*	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
		Pervagor melanocephalus	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Balistidae	Triggerfish	*Balistapus undulatus*	2	1	0	0	1	0	0	4	3	4	0	0	2	0	0	0
		Balistoides viridescens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Melichthys vidua	1	0	0	0	2	1	0	1	1	1	0	0	3	1	0	0
		Odonus niger	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
		Rhinecanthus aculeatus	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	1
		Rhinecanthus rectangulus	0	0	1	0	0	0	2	0	0	0	2	0	0	0	0	0
		Sufflamen bursa	0	1	0	0	1	3	0	0	1	0	0	0	3	1	0	0
		Sufflamen chrysoptera	2	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Ostracionidae	Boxfishes	*Ostracion meleagris*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Tetraodontidae	Pufferfishe	*Canthigaster solandri*	0	2	0	0	0	2	0	0	0	0	0	0	1	2	1	2
		Total fishes	152	615	245	241	444	494	157	628	326	631	127	85	335	215	148	411

Appendix 4. Density (number per square meter) of reef fishes at Dadi Reef.

			Transect															
			Sector 1				Sector 2				Sector 3				Sector 4			
Family	Common n	Species	1 12	1 6	1 ORF	1 MRF	2 12	2 6	2 ORF	2 MRF	3 12	3 6	3 ORF	3 MRF	4 12	4 6	4 ORF	4 MRF
Muraenidae	Moray eels	*Gymnothorax javanicus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synodontidae	Lizardfishe	*Saurida gracilis*	0.002	0.002	0	0	0	0	0	0	0.002	0	0	0	0	0	0	0
		Synodus binotatus	0	0	0	0	0	0	0	0.002	0	0.002	0	0	0	0	0	0
Holocentridae	Squirrelfish	*Myrpristis berndti*	0	0.006	0	0	0	0.008	0	0.002	0	0.008	0	0	0	0	0	0
		Myrpristis kuntee	0	0.054	0	0	0	0	0	0.004	0	0.004	0	0	0	0	0	0
		Myrpristis murdjan	0	0.004	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Myrpristis pralinia	0	0	0	0	0	0	0	0.006	0	0	0	0	0	0	0	0
		Neoniphon argenteus	0	0	0	0	0	0	0	0.002	0	0	0	0	0	0	0	0
		Neoniphon opercularis	0	0.008	0	0	0	0.002	0	0	0	0	0	0	0	0	0	0
		Sargocentron caudimaculatum	0	0.004	0	0	0	0	0	0.002	0	0.002	0	0	0	0	0	0
		Sargocentron diadema	0	0.004	0.002	0	0.002	0	0.002	0.002	0	0.002	0	0	0.002	0	0	0
		Sargocentron spiniferum	0	0.004	0	0	0.002	0.004	0	0	0	0	0	0	0	0	0	0
Belonidae	Needlefish	*Strongylura incisus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hemiramphidae	Halfbeaks	*Hemiramphus lutkei*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aulostomidae	Trumpetfisl	*Aulostomus chinensis*	0	0.004	0	0	0	0	0	0.002	0	0	0	0	0	0	0	0
Scorpaenidae	Scorpionfis	*Pterois antennata*	0	0	0	0	0	0.004	0	0	0	0	0	0	0	0	0	0
		Pterois volitans	0	0.002	0	0	0	0.002	0	0	0	0	0	0	0	0	0	0
Serranidae	Groupers	*Cephalopholis spiloparaea*	0	0	0	0	0.004	0	0	0	0	0	0	0	0	0	0	0
		Cephalopholis urodeta	0.004	0.006	0	0	0.002	0.006	0	0.008	0.002	0.012	0	0	0.006	0.002	0	0
		Epinephelus fasciatus	0	0.004	0	0	0	0	0	0	0	0	0	0	0.008	0	0	0
		Epinephelus hexagonatus	0	0	0	0.002	0	0	0	0	0	0	0	0	0	0	0	0
		Epinephelus macrodon	0	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Epinephelus merra	0	0.002	0	0	0.004	0.004	0.002	0.008	0.002	0.008	0	0	0	0.002	0.004	0
		Epinephelus spilotoceps	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cirrhitidae	Hawkfishes	*Cirrhitichthys falco*	0	0	0	0	0	0	0	0	0	0	0	0	0.012	0	0	0
		Neocirrhites armatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Paracirrhites arcatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Paracirrhites forsteri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apogonidae	Cardinalfisl	*Apogon angustatus*	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Apogon exostigma	0.002	0.004	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Apogon luteus	0	0.004	0	0	0.126	0	0	0	0	0	0	0	0	0	0	0
		Apogon novemfasciatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cheilodipterus macrodon	0	0	0	0	0	0.02	0	0	0	0.03	0	0	0	0	0	0
		Cheilodipterus quinquelineatus	0	0.03	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0
Carangidae	Trevallys a	*Caranx melampygus*	0	0	0	0	0.002	0	0	0	0	0	0	0	0	0	0	0
		Caranx sexfasciatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lutjanidae	Snappers	*Aphareus furca*	0	0	0	0	0	0	0	0.002	0	0.002	0	0	0	0	0	0
		Lutjanus fulvus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lutjanus gibbus	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lutjanus kasmira	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Lutjanus monostigmus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haemulidae	Sweetlips	*Plectorhinchus albovittatus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lethrinidae	Emperors	*Gnathodentex aurolineatus*	0	0	0	0	0	0	0	0	0	0.004	0	0	0	0	0	0
		Lethrinus harak	0	0	0	0	0	0	0	0	0	0	0	0.004	0	0	0	0
		Lethrinus obsoletus	0	0	0	0	0	0	0	0	0	0	0	0.002	0	0	0	0
		Monotaxis grandoculis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nemipteridae	Spinecheel	*Scolopsis lineatua*	0	0	0.002	0	0	0	0	0	0	0.004	0	0	0	0	0	0.002
Mullidae	Goatfishes	*Mulloidichthys flavolineatus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Mulloidichthys vanicolensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Parupeneus barberinus	0.002	0.002	0	0.002	0	0	0	0	0	0	0	0.002	0	0	0	0.002
		Parupeneus crenilabrus	0	0.002	0	0	0	0	0	0.002	0	0	0	0	0	0	0	0

		Parupeneus ciliatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Parupeneus cyclostomus	0.002	0	0	0	0	0	0	0.004	0	0.004	0	0	0	0	0	0
		Parupeneus multifasciatus	0	0.004	0.008	0.012	0	0	0	0	0	0	0.004	0.002	0.002	0.002	0.002	0.002
		Parupeneus pleurostigma	0	0	0	0.004	0	0.002	0.002	0	0	0	0	0	0	0	0	0
Chaetodontidae	Butterflyfisl	*Chaetodon auriga*	0.002	0.002	0.002	0	0	0.002	0	0	0	0	0	0.006	0	0	0.002	0
		Chaetodon bennetti	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chaetodon citrinellus	0	0.004	0.004	0	0	0	0.002	0.004	0	0.004	0.004	0	0.002	0	0.004	0.004
		Chaetodon ephippium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chaetodon kleinii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chaetodon lunula	0	0	0	0	0	0	0	0	0	0	0	0	0	0.004	0	0
		Chaetodon lunulatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002	0
		Chaetodon mertensii	0	0.002	0	0	0	0.002	0	0	0.004	0	0	0	0.004	0	0	0
		Chaetodon ornatissimus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chaetodon punctatofasciatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chaetodon reticulatus	0	0	0	0	0	0	0	0	0.002	0	0	0	0	0	0.002	0
		Chaetodon trifascialis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002	0
		Chaetodon ulietensis	0	0	0	0	0	0	0	0.002	0	0	0	0	0	0	0	0
		Chaetodon unimaculatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Focipiger flavissimus	0	0.002	0	0	0	0	0	0	0	0	0	0	0.004	0	0	0
		Forcipiger longirostris	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002	0	0
		Hemitaurichthys polylepis	0	0	0	0	0	0	0	0	0.002	0	0	0	0	0	0	0
		Heniochus acuminatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0.004	0	0
		Heniochus chrysostomus	0	0	0	0	0	0.002	0	0.002	0.002	0.002	0	0	0	0.002	0	0
Pomacanthidae	Angelfishes	*Centropyge flavissima*	0	0.002	0	0	0	0	0	0	0	0	0	0	0.002	0	0	0
		Centropyge heraldi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Centropyge vrolikii	0	0	0	0	0	0	0	0	0	0.002	0	0	0	0	0	0
		Pomacanthus imperator	0	0	0	0	0	0	0	0.002	0	0.002	0	0	0	0.002	0	0
Pomacentridae	Damselfish	*Amphiprion chrysopterus*	0.02	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0
		Chromis acares	0.01	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0
		Chromis agilis	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0
		Chromis atripecoralis	0	0	0	0	0	0	0	0.12	0	0.12	0	0	0	0	0	0
		Chromis margaritifer	0	0.01	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0	0
		Chromis viridis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
		Dascyllus aruanus	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0.06	0.04
		Dascyllus reticulatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Dascyllus trimaculatus	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0
		Abudefduf septemfasciatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Abudefduf sexfasciatus	0	0.06	0	0.46	0	0	0	2.01	0	2.01	0	0	0	0	0	0
		Abudefduf vaigiensis	0	0	0	0	0	0	0	0.5	0	0.5	0.01	0	0	0	0	0
		Amblyglyphididon curacao	0	0	0	0	0	0	0	0.04	0	0.04	0	0	0	0	0.08	0
		Amblyglyphididon ternatensis?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chrysiptera biocellata	0	0	0	0.01	0	0	0	0	0	0	0.03	0.02	0	0	0.02	0.03
		Chrysiptera brownriggii brownriggi	0	0	0.43	0.02	0	0	0.02	0	0	0	0.09	0	0	0	0	0
		Chrysiptera brownriggii amabilis	0	0	0.59	0.18	0	0	0.7	0	0	0	0.17	0	0	0	0.05	0
		Chrysiptera glauca	0	0	0	0.04	0	0	0.05	0	0	0	0	0.01	0	0	0.01	0
		Chrysiptera traceyi	0.64	3.88	0.01	0	1.96	3.35	0	1.99	2.18	1.99	0	0	1.4	0.6	0	0
		Plectroglyphydodon dickii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Plectroglyphydodon johnstonianus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Plectroglyphydodon lacrymatus	0	0.01	0	0	0	0.02	0	0.17	0.01	0.17	0	0	0.01	0.05	0	0
		Plectroglyphydodon leucozona	0	0	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0
		Pomacentrus amboinensis	0.08	0	0	0	0.38	0.11	0	0	0	0	0	0	0	0	0	0
		Pomacentrus pavo	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.19
		Pomacentrus vaiuli	0.06	0.48	0.01	0	0.23	0.49	0	0.13	0.23	0.13	0	0	0.72	0.24	0.01	0
		Pomachromis guamensis	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Stegastes albifasciatus	0	0	0.1	0.08	0	0	0.04	0	0	0	0.06	0.07	0	0	0.05	0.01
		Stegastes fasciatus	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0
		Stegastes lividus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.06	0.02

		Stegastes nigricans	0	0	0	0	0	0	0	0	0	0	0.02	0.01	0	0	0.01	0
		Cheilinus chlorourus	0	0	0	0	0.004	0	0	0	0	0	0	0	0	0	0	0
Labridae	Wrasses	*Cheilinus fasciatus*	0	0	0	0	0	0	0	0	0.002	0	0	0	0	0	0	0
		Cheilinus oxycephalus	0	0	0	0	0	0	0	0.002	0.008	0.002	0	0	0.002	0	0	0
		Cheilinus trilobatus	0.002	0.002	0	0.002	0	0	0	0	0	0	0.006	0.002	0	0.002	0	0.002
		Cheilinus undulatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Epibulus insidiator	0	0	0	0	0	0.002	0	0	0	0	0	0	0.002	0	0.002	0
		Oxycheilinus unifasciatus	0.002	0	0	0	0.008	0.006	0	0.002	0.004	0.002	0	0	0.006	0.002	0	0
		Cirrhilabrus cyanopleura	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cirrhilabrus katherinae	0	0	0	0	0	0	0	0	0	0	0	0	0.002	0.002	0	0
		Pseudocheilinus hexataenia	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0
		Pseudocheilinus tetrataenia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Novaculichthys taeniourus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Anampses twisti	0	0	0	0	0	0	0	0.002	0	0.002	0	0	0	0	0	0
		Coris aygula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Coris gaimard	0	0	0	0	0	0	0	0.002	0	0	0	0	0.006	0	0	0
		Gomphosus varius	0	0.004	0	0	0	0.002	0	0.002	0	0.004	0	0	0	0	0.002	0
		Halichoeres biocellatus	0	0	0	0	0	0	0	0.002	0.014	0	0	0	0.038	0.008	0	0
		Halichoeres hortulanus	0	0.004	0	0	0.002	0	0	0.004	0.002	0	0	0	0	0.006	0	0.002
		Halichoeres margaritaceus	0	0	0.024	0.05	0	0	0.054	0.002	0	0.002	0.01	0	0	0	0	0
		Halichoeres marginatus	0	0	0.004	0	0	0	0	0	0	0	0	0	0	0	0	0
		Halichoeres trimaculatus	0.002	0.006	0	0.006	0	0.004	0.01	0	0	0	0.006	0.008	0.002	0.004	0.004	0.004
		Hemigymnus fasciatus	0	0	0	0	0	0	0	0	0	0.002	0	0	0	0	0	0
		Hemigymnus melapterus	0	0	0.004	0	0	0	0	0	0	0	0	0	0	0	0	0
		Macropharyngodon meleagris	0	0.01	0	0	0	0.002	0	0	0	0	0	0	0.002	0	0	0
		Pseudochoris yamashiroi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Stethojulis bandanensis	0	0.002	0.01	0.024	0	0	0.032	0.002	0.002	0.002	0.01	0.014	0	0.002	0.01	0.002
		Stethojulis strigiventer	0	0.002	0.004	0.012	0	0	0.002	0	0	0	0	0	0	0	0	0
		Thalassoma amblycephalum	0	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Thalassoma hardwicke	0	0.002	0	0	0	0	0	0.008	0	0.008	0	0	0	0.004	0.002	0.004
		Thalassoma lutescens	0	0.006	0	0	0	0	0	0.004	0	0.004	0	0	0.004	0	0	0
		Thalassoma quinquevittatum	0	0.004	0.028	0	0	0	0	0	0	0	0.004	0	0	0.006	0.002	0
		Labroides dimidiatus	0.002	0.006	0.002	0	0.008	0.006	0	0.01	0.008	0.01	0	0	0.006	0.006	0	0
		Labroides pectoralis	0.008	0	0	0	0	0	0	0.002	0	0.002	0	0	0	0	0	0
		Cheilio inermis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002	0
Labridae: Scarinae	Parrotfishe	*Calotomus carolinus*	0	0.004	0	0	0	0.002	0	0	0.002	0	0	0	0	0	0	0
		Chlorurus frontalis	0	0	0	0	0	0.002	0	0.002	0.02	0.002	0	0	0	0.008	0	0
		Chlorurus microrhinos	0	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chlorurus sordidus	0	0.008	0.058	0	0.004	0.02	0.01	0.008	0	0.008	0.032	0.044	0.002	0.078	0.074	0.07
		Hipposcarus longiceps	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Scarus altipinnis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Scarus forsteni	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Scarus globiceps	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Scarus niger	0.004	0.002	0	0	0.002	0	0	0	0	0	0	0	0	0	0	0
		Scarus oviceps	0	0	0	0	0	0	0	0.004	0	0.004	0	0	0	0	0	0
		Scarus psittacus	0	0	0.016	0	0	0.002	0	0.008	0.002	0.008	0.03	0	0	0.006	0.016	0.004
		Scarus schlegeli	0	0	0	0	0	0	0	0.002	0.004	0.002	0	0	0	0	0	0
Pinguipedidae	Sandperch	*Parapercis clathrata*	0	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Parapercis millepunctata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Blenniidae	Blennies	*Aspiodontus taeniatus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Meiacanthus atrodorsalis	0.01	0.04	0	0	0	0.05	0	0	0.03	0	0	0	0	0.02	0	0
		Plagiotremus tapeinosoma	0.01	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0
		Blenniella chrysopilos	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0
		Ecsenius bicolor	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Salarias fasciatus	0	0	0.01	0	0	0	0.01	0	0	0	0	0	0	0	0.01	0
Callionymidae	Dragonets	*Callionymus simplicicornis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gobiidae	Gobies	*Cryptocentrus strigilliceps*	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0.05

		Ctenogobiops feroculus	0.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Amblyeleotris steinitzi	0	0.01	0	0	0	0	0	0	0	0	0	0	0.02	0	0	0
		Vanderhorstia ambanoro	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Amblygobius nocturnus	0	0	0	0	0.03	0	0	0.01	0	0.01	0	0	0	0	0	0
		Amblygobius phaelena	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0.01	0.01
		Oplopomus oplopomus	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Valenciennea strigata	0.03	0.04	0	0	0	0	0	0	0	0	0	0	0.02	0.04	0.01	0
		Asterropteryx semipunctatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0
		Bathygobius cyclopterus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Coryphopterus neophytus	0	0	0	0	0.01	0.01	0	0	0.01	0	0	0	0	0	0.01	0
		Eviota albolineata	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0
		Eviota guttata	0.01	0.04	0.01	0	0	0.04	0	0.04	0.02	0.04	0	0	0.01	0.01	0	0
		Eviota prasites	0	0	0	0	0.01	0.01	0	0.01	0.1	0.01	0	0	0.04	0	0	0
		Eviota saipanensis	0	0.01	0	0	0	0.08	0	0	0.01	0.01	0	0	0.01	0	0	0
		Exyrias belissimus	0	0	0	0	0	0	0	0.01	0	0.01	0	0	0	0	0	0
		Gnatholepis anjerensis	0.03	0	0	0	0.01	0.1	0	0.02	0	0	0	0	0	0	0	0
		Gnatholepis cauerensis	0	0	0	0	0	0.16	0.01	0	0.02	0.01	0.02	0	0	0.07	0.03	0	0
		Istigobius decoratus	0.02	0.01	0	0.01	0.05	0.02	0	0	0	0	0	0	0	0	0	0
		Istigobius ornatus	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0
Microdesmidae	Wormfishe	*Gunnellichthys pleurotaenia*	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ptereleotridae	Dartfishes	*Nemaeleotris magnfica*	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0
		Ptereleotris evides	0	0.02	0	0	0	0.03	0	0	0	0	0	0	0.01	0	0	0
		Ptereleotris heteroptera	0	0.04	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0
		Ptereleotris zebra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphyraenidae	Barracudas	*Sphyraena barracuda*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Siganidae	Rabbitfishe	*Siganus argenteus*	0	0	0	0.196	0	0	0.006	0.002	0	0.002	0	0	0	0	0	0.004
		Siganus spinus	0	0	0.002	0	0	0	0	0	0	0	0.002	0.002	0	0	0.004	0.002
Zanclidae	Moorish Id	*Zanclus cornutus*	0	0.004	0.002	0	0.004	0	0	0.004	0	0.004	0.004	0.006	0	0.002	0.002	0
Acanthuridae	Surgeonfis	*Acanthurus lineatus*	0	0	0.024	0.002	0	0	0.006	0	0	0	0	0.002	0	0	0	0
		Acanthurus leucocheilus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Acanthurus nigricans	0	0.004	0	0	0	0	0	0	0	0	0	0	0	0.002	0	0
		Acanthurus nigricauda	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Acanthurus nigrofuscus	0.002	0.046	0.042	0	0.022	0.018	0.01	0.014	0.016	0.014	0.06	0.044	0.028	0.02	0	0.014
		Acanthurus nigoris	0	0.004	0	0	0	0	0	0.01	0.002	0.01	0	0	0	0	0	0
		Acanthurus olivaceus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Acanthurus triostegus	0	0	0	0.01	0	0	0.006	0	0	0	0	0.004	0	0	0.006	0.008
		Acanthurus xanthopterus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002
		Ctenochaetus binotatus	0	0	0	0	0	0	0	0.006	0	0.006	0	0	0	0	0	0
		Ctenochaetus hawaiiensis	0	0.008	0	0	0	0	0	0.02	0	0.02	0	0	0.002	0.018	0.04	0
		Ctenochaetus striatus	0	0.006	0	0	0.002	0	0	0.008	0	0.008	0.002	0	0.004	0.016	0.026	0.018
		Zebrasoma flavescens	0	0	0	0	0	0.002	0	0.004	0	0.004	0	0	0	0	0	0
		Zebrasoma scopas	0	0	0	0	0	0	0	0.002	0	0.002	0	0	0	0	0	0
		Naso annulatus	0	0	0.002	0	0	0	0	0	0	0.002	0	0	0	0	0	0
		Naso literatus	0.002	0.006	0	0	0.002	0	0	0.002	0.014	0.002	0	0	0.034	0.004	0	0
		Naso vlamingi	0	0	0	0	0	0	0	0.03	0	0.03	0	0	0.002	0	0	0
Monacanthidae	Filefishes	*Amanses scopas*	0	0	0	0	0	0	0	0	0.002	0	0	0	0	0	0	0
		Pervagor melanocephalus	0	0.002	0	0	0	0	0	0	0	0	0	0	0	0.002	0	0
Balistidae	Triggerfish	*Balistapus undulatus*	0.004	0.002	0	0	0.002	0	0	0.008	0.006	0.008	0	0	0.004	0	0	0
		Balistoides viridescens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Melichthys vidua	0.002	0	0	0	0.004	0.002	0	0.002	0.002	0.002	0	0	0.006	0.002	0	0
		Odonus niger	0.002	0	0	0	0	0	0	0	0	0	0	0	0.002	0	0	0
		Rhinecanthus aculeatus	0	0	0	0	0	0	0	0	0	0	0	0.004	0	0	0.002	0.002
		Rhinecanthus rectangulus	0	0	0.002	0	0	0	0.004	0	0	0	0.004	0	0	0	0	0
		Sufflamen bursa	0	0.002	0	0	0.002	0.006	0	0	0.002	0	0	0	0.006	0.002	0	0
		Sufflamen chrysoptera	0.004	0.002	0	0	0.002	0.002	0	0	0	0	0	0	0	0	0	0
Ostracionidae	Boxfishes	*Ostracion meleagris*	0	0	0	0	0.002	0	0	0	0	0	0	0	0	0	0	0
Tetraodontidae	Pufferfishe	*Canthigaster solandri*	0	0.004	0	0	0	0.004	0	0	0	0	0	0	0.002	0.004	0.002	0.004

Appendix 5. Checklist and distribution of fishes at south Piti Channel. Fishes are arranged in phylogenetic order.

			Transect										
			Sector 1		Sector 2		Sector 3		Sector 4		Sector 5		
Family	Common name	Species	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B1	5B2
Apogonidae	Cardinalfishes	*Apogon lateralis*	0	200	0	140	0	9	0	460	8	50	20
		Apogon leptacanthus	0	1	0	0	0	0	0	2	0	0	6
		Cheilodipterus quinquevittatum	1	0	0	0	0	0	0	0	0	0	2
Carangidae	Trevallys and jacks	*Caranx melampygus*	1	0	0	0	0	0	0	0	0	0	0
Lutjanidae	Snappers	*Lutjanus fulvus*	0	0	2	0	0	0	0	0	0	0	1
Gerreidae	Mojarras	*Gerres acinaces*	3	1	0	0	0	0	0	0	0	0	1
Lethrinidae	Emperors	*Lethrinus harak*	1	0	2	3	1	0	0	6	0	0	1
Pomacentridae	Damselfishes	*Stegastes nigricans*	4	0	0	0	0	0	0	0	0	0	0
Blenniidae	Blennies	*Petroscirtes mitratus*	0	0	0	0	0	0	0	0	1	0	0
Callionymidae	Dragonets	*Anaora tentaculata*	0	3	0	0	1	0	0	0	0	0	0
Gobiidae	Gobies	*Cryptocentrus strigilliceps*	12	9	14	8	23	4	48	12	26	42	3
		Ctenogobiops feroculus	0	0	0	6	0	0	0	0	0	3	3
		Amblygobius nocturnus	0	1	1	0	1	1	0	0	5	3	0
		Amblygobius phaelena	4	4	18	2	9	4	2	4	2	3	3
		Oplopomus oplopomus	0	0	0	0	0	0	0	1	0	0	0
		Vanderhorstia sp. A	5	0	11	0	4	4	1	5	0	3	1
		Asterropteryx semipuncatus	0	1	0	0	1	0	0	0	2	1	3
		Coryphopterus neophytus?	0	2	0	0	0	0	4	3	0	0	0
		Cristatogobius sp. A	0	7	0	1	8	7	0	1	0	0	0
		Gnatholepis anjerensis	0	0	0	0	0	0	3	0	0	0	0
		Istigobius decoratus	0	0	6	5	1	1	5	0	0	0	0
		Istigobius ornatus	0	0	3	3	1	1	0	3	0	0	0
Siganidae	Rabbitfishes	*Siganus argenteus*	0	0	0	0	1	0	0	0	0	0	0
Acanthuridae	Surgeonfishes	*Acanthurus blochii*	3	0	0	0	3	0	0	0	0	0	0
	Total fishes		25	228	53	165	49	31	63	491	44	105	41

Appendix 6. Density (number per square meter) of reef fishes at south Piti Channel.

			Transect										
			Sector 1		Sector 2		Sector 3		Sector 4		Sector 5		
			1A	1B	2A	2B	3A	3B	4A	4B	5A	5B1	5B2
Family	Common name	Species											
Apogonidae	Cardinalfishes	*Apogon lateralis*	0	2	0	1.4	0	0.09	0	4.6	0.08	0.5	0.2
		Apogon leptacanthus	0	0.01	0	0	0	0	0	0.02	0	0	0.06
		Cheilodipterus quinquevittatum	0.01	0	0	0	0	0	0	0	0	0	0.02
Carangidae	Trevallys and jacks	*Caranx melampygus*	0.005	0	0	0	0	0	0	0	0	0	0
Lutjanidae	Snappers	*Lutjanus fulvus*	0	0	0.01	0	0	0	0	0	0	0	0.005
Gerreidae	Mojarras	*Gerres acinaces*	0.015	0.005	0	0	0	0	0	0	0	0	0.005
Lethrinidae	Emperors	*Lethrinus harak*	0.005	0	0.01	0.015	0.005	0	0	0.03	0	0	0.005
Pomacentridae	Damselfishes	*Stegastes nigricans*	0.04	0	0	0	0	0	0	0	0	0	0
Blenniidae	Blennies	*Petroscirtes mitratus*	0	0	0	0	0	0	0	0	0.01	0	0
Callionymidae	Dragonets	*Anaora tentaculata*	0	0.03	0	0	0.01	0	0	0	0	0	0
Gobiidae	Gobies	*Cryptocentrus strigilliceps*	0.12	0.09	0.14	0.08	0.23	0.04	0.48	0.12	0.26	0.42	0.03
		Ctenogobiops feroculus	0	0	0	0.06	0	0	0	0	0	0.03	0.03
		Amblygobius nocturnus	0	0.01	0.01	0	0.01	0.01	0	0	0.05	0.03	0
		Amblygobius phaelena	0.04	0.04	0.18	0.02	0.09	0.04	0.02	0.04	0.02	0.03	0.03
		Oplopomus oplopomus	0	0	0	0	0	0	0	0.01	0	0	0
		Vanderhorstia sp. A	0.05	0	0.11	0	0.04	0.04	0.01	0.05	0	0.03	0.01
		Asterropteryx semipuncatus	0	0.01	0	0	0.01	0	0	0	0.02	0.01	0.03
		Coryphopterus neophytus?	0	0.02	0	0	0	0	0.04	0.03	0	0	0
		Cristatogobius sp. A	0	0.07	0	0.01	0.08	0.07	0	0.01	0	0	0
		Gnatholepis anjerensis	0	0	0	0	0	0	0.03	0	0	0	0
		Istigobius decoratus	0	0	0.06	0.05	0.01	0.01	0.05	0	0	0	0
		Istigobius ornatus	0	0	0.03	0.03	0.01	0.01	0	0.03	0	0	0
Siganidae	Rabbitfishes	*Siganus argenteus*	0	0	0	0	0.005	0	0	0	0	0	0
Acanthuridae	Surgeonfishes	*Acanthurus blochii*	0.015	0	0	0	0.015	0	0	0	0	0	0

Appendix 7. Checklist and distribution of reef fishes at Polaris Point. Fishes are arranged in phylogenetic order.

			Transect								
			Sector 1			Sector 2			Sector 3		
Family	Common name	Species	1 2	1 4	1 9	2 2	2 4	2 9	3 2	3 4	3 9
Muraenidae	Moray eels	*Gymnothorax javanicus*	0	0	1	0	1	0	0	0	0
Holocentridae	Squirrelfishes	*Sargocentron spiniferum*	0	0	0	1	1	0	0	0	0
Apogonidae	Cardinalfishes	*Apogon angustatus*	0	0	0	2	0	0	0	0	0
Apogonidae	Cardinalfishes	*Apogon lateralis*	0	0	0	0	280	0	0	61	0
Apogonidae	Cardinalfishes	*Apogon leptacanthus*	0	0	0	0	270	0	0	0	0
Apogonidae	Cardinalfishes	*Archamia fucata*	0	0	0	0	1	0	0	0	0
Apogonidae	Cardinalfishes	*Cheilodipterus quenquelineatus*	3	0	0	4	6	0	22	3	0
Carangidae	Trevallys and jacks	*Caranx sexfasciatus*	0	1	0	0	10	3	1	0	0
Carangidae	Trevallys and jacks	*Naucrates ductor*	0	0	0	0	1	0	0	0	0
Lutjanidae	Snappers	*Lutjanus fulvus*	1	0	0	1	6	0	0	2	0
Haemulidae	Sweetlips	*Plectorhinchus albovittatus*	0	0	0	0	1	0	0	0	0
Lethrinidae	Emperors	*Lethrinus amboinensis*	1	0	0	0	0	0	0	0	0
Lethrinidae	Emperors	*Lethrinus harak*	0	0	0	0	0	0	2	0	0
Mullidae	Goatfishes	*Parupeneus ciliatus*	0	0	0	0	0	0	1	0	0
Chaetodontidae	Butterflyfishes	*Chaetodon bennetti*	0	0	0	0	5	0	2	0	0
Chaetodontidae	Butterflyfishes	*Chaetodon ephippium*	0	0	0	0	0	0	1	0	0
Chaetodontidae	Butterflyfishes	*Chaetodon lunulua*	0	0	0	0	2	0	0	0	0
Chaetodontidae	Chaetodontidae	*Chaetodon ulietensis*	0	0	0	0	3	0	1	0	0
Pomacentridae	Damselfishes	*Chromis viridis*	0	0	0	0	1	0	0	0	0
Pomacentridae	Damselfishes	*Abudefduf septemfasciatus*	0	0	0	1	0	0	0	0	0
Pomacentridae	Damselfishes	*Amblyglyphididon curacao*	3	0	0	0	1	0	5	0	0
Pomacentridae	Damselfishes	*Pomacentrus amboinensis*	3	2	0	0	7	0	0	1	0
Pomacentridae	Damselfishes	*Pomacentrus pavo*	0	0	0	0	0	0	6	0	0
Labridae: Scarinae	Parrotfishes	*Chlorurus sordidus (ip)*	0	0	0	0	0	0	3	0	0
Labridae: Scarinae	Parrotfishes	*Hipposcarus longiceps*	0	0	0	0	1	0	1	0	0
Blenniidae	Blennies	*Omobranchus obliquus*	0	0	0	1	0	0	0	0	0
Blenniidae	Blennies	*Petroscirtes mitratus*	0	0	0	0	0	0	1	0	0
Blenniidae	Blennies	*Petroscirtes xestus*	1	0	1	0	0	0	0	0	0
Callionymidae	Dragonets	*Callionymus simplicicornis*	0	1	0	0	0	0	0	0	0
Gobiidae	Gobies	*Amblygobius nocturnus*	6	1	0	12	8	0	5	0	0
Gobiidae	Gobies	*Amblygobius phaelena*	1	1	0	1	2	0	9	1	2
Gobiidae	Gobies	*Cryptocentrus caeruleomaculatus*	0	0	0	2	0	0	0	0	0
Gobiidae	Gobies	*Cryptocentrus strigilliceps*	40	0	0	62	2	0	7	1	0
Gobiidae	Gobies	*Ctenogobiops crocineus*	3	0	0	0	0	0	0	0	0
Gobiidae	Gobies	*Vanderhorstia sp. A*	1	0	0	0	0	0	0	0	0
Gobiidae	Gobies	*Oplopomus oplopomus*	0	0	3	3	7	0	0	2	7
Gobiidae	Gobies	*Signigobius biocellatus*	0	0	0	0	1	0	0	0	0
Gobiidae	Gobies	*Asterropteryx semipunctatus*	2	1	0	2	0	0	0	1	0
Gobiidae	Gobies	*Bathygobius cocosensis*	19	0	0	8	0	0	0	0	0
Gobiidae	Gobies	*Bathygobius fuscus*	1	0	0	0	0	0	0	0	0
Gobiidae	Gobies	*Cristatogobius sp. A?*	0	0	0	0	0	0	0	1	0
Gobiidae	Gobies	*Eviota prasites*	0	0	0	0	1	0	0	0	0
Gobiidae	Gobies	*Gladiogobius ensifer*	0	0	0	2	1	0	0	0	0

Gobiidae	Gobies	*Gnatholepis anjerensis*	1	0	0	0	1	0	0	0	0
Gobiidae	Gobies	*Istigobius decoratus*	1	0	0	0	0	0	0	0	0
Acanthuridae	Surgeonfishes	*Acanthurus blochii*	3	2	0	23	41	0	15	2	0
Acanthuridae	Surgeonfishes	*Zebrasoma veliferum*	0	0	0	0	2	0	0	0	0
		Total fishes	90	9	5	125	663	3	82	75	9

Appendix 8. Density (number per square meter) of reef fishes at Polaris Point.

			Transect								
				Sector 1			Sector 2			Sector 3	
Family	Common name	Species	1 2	1 4	1 9	2 2	2 4	2 9	3 2	3 4	3 9
Muraenidae	Moray eels	*Gymnothorax javanicus*	0	0	1	0	0.01	0	0	0	0
Holocentridae	Squirrelfishes	*Sargocentron spiniferum*	0	0	0	0.01	0.01	0	0	0	0
Apogonidae	Cardinalfishes	*Apogon angustatus*	0	0	0	0.02	0	0	0	0	0
Apogonidae	Cardinalfishes	*Apogon lateralis*	0	0	0	0	2.8	0	0	0.61	0
Apogonidae	Cardinalfishes	*Apogon leptacanthus*	0	0	0	0	2.7	0	0	0	0
Apogonidae	Cardinalfishes	*Archamia fucata*	0	0	0	0	0.01	0	0	0	0
Apogonidae	Cardinalfishes	*Cheilodipterus quenquelineatus*	0.03	0	0	0.04	0.06	0	0.22	0.03	0
Carangidae	Trevallys and jacks	*Caranx sexfasciatus*	0	0.01	0	0	0.1	3	0.01	0	0
Carangidae	Trevallys and jacks	*Naucrates ductor*	0	0	0	0	0.01	0	0	0	0
Lutjanidae	Snappers	*Lutjanus fulvus*	0.01	0	0	0.01	0.06	0	0	0.02	0
Haemulidae	Sweetlips	*Plectorhinchus albovittatus*	0	0	0	0	0.01	0	0	0	0
Lethrinidae	Emperors	*Lethrinus amboinensis*	0.01	0	0	0	0	0	0	0	0
Lethrinidae	Emperors	*Lethrinus harak*	0	0	0	0	0	0	0.02	0	0
Mullidae	Goatfishes	*Parupeneus ciliatus*	0	0	0	0	0	0	0.01	0	0
Chaetodontidae	Butterflyfishes	*Chaetodon bennetti*	0	0	0	0	0.05	0	0.02	0	0
Chaetodontidae	Butterflyfishes	*Chaetodon ephippium*	0	0	0	0	0	0	0.01	0	0
Chaetodontidae	Butterflyfishes	*Chaetodon lunulua*	0	0	0	0	0.02	0	0	0	0
Chaetodontidae	Chaetodontidae	*Chaetodon ulietensis*	0	0	0	0	0.03	0	0.01	0	0
Pomacentridae	Damselfishes	*Chromis viridis*	0	0	0	0	0.01	0	0	0	0
Pomacentridae	Damselfishes	*Abudefduf septemfasciatus*	0	0	0	0.01	0	0	0	0	0
Pomacentridae	Damselfishes	*Amblyglyphididon curacao*	0.03	0	0	0	0.01	0	0.05	0	0
Pomacentridae	Damselfishes	*Pomacentrus amboinensis*	0.03	0.02	0	0	0.07	0	0	0.01	0
Pomacentridae	Damselfishes	*Pomacentrus pavo*	0	0	0	0	0	0	0.06	0	0
Labridae: Scarinae	Parrotfishes	*Chlorurus sordidus (ip)*	0	0	0	0	0	0	0.03	0	0
Labridae: Scarinae	Parrotfishes	*Hipposcarus longiceps*	0	0	0	0	0.01	0	0.01	0	0
Blenniidae	Blennies	*Omobranchus obliquus*	0	0	0	0.01	0	0	0	0	0
Blenniidae	Blennies	*Petroscirtes mitratus*	0	0	0	0	0	0	0.01	0	0
Blenniidae	Blennies	*Petroscirtes xestus*	0.01	0	1	0	0	0	0	0	0
Callionymidae	Dragonets	*Callionymus simplicicornis*	0	0.01	0	0	0	0	0	0	0
Gobiidae	Gobies	*Amblygobius nocturnus*	0.06	0.01	0	0.12	0.08	0	0.05	0	0
Gobiidae	Gobies	*Amblygobius phaelena*	0.01	0.01	0	0.01	0.02	0	0.09	0.01	2
Gobiidae	Gobies	*Cryptocentrus caeruleomaculatus*	0	0	0	0.02	0	0	0	0	0
Gobiidae	Gobies	*Cryptocentrus strigilliceps*	0.4	0	0	0.62	0.02	0	0.07	0.01	0
Gobiidae	Gobies	*Ctenogobiops crocineus*	0.03	0	0	0	0	0	0	0	0
Gobiidae	Gobies	*Vanderhorstia sp. A*	0.01	0	0	0	0	0	0	0	0
Gobiidae	Gobies	*Oplopomus oplopomus*	0	0	3	0.03	0.07	0	0	0.02	7
Gobiidae	Gobies	*Signigobius biocellatus*	0	0	0	0	0.01	0	0	0	0
Gobiidae	Gobies	*Asterropteryx semipunctatus*	0.02	0.01	0	0.02	0	0	0	0.01	0
Gobiidae	Gobies	*Bathygobius cocosensis*	0.19	0	0	0.08	0	0	0	0	0
Gobiidae	Gobies	*Bathygobius fuscus*	0.01	0	0	0	0	0	0	0	0
Gobiidae	Gobies	*Cristatogobius sp. A?*	0	0	0	0	0	0	0	0.01	0
Gobiidae	Gobies	*Eviota prasites*	0	0	0	0	0.01	0	0	0	0
Gobiidae	Gobies	*Gladiogobius ensifer*	0	0	0	0.02	0.01	0	0	0	0
Gobiidae	Gobies	*Gnatholepis anjerensis*	0.01	0	0	0	0.01	0	0	0	0
Gobiidae	Gobies	*Istigobius decoratus*	0.01	0	0	0	0	0	0	0	0
Acanthuridae	Surgeonfishes	*Acanthurus blochii*	0.03	0.02	0	0.23	0.41	0	0.15	0.02	0
Acanthuridae	Surgeonfishes	*Zebrasoma veliferum*	0	0	0	0	0.02	0	0	0	0

APPENDIX G
Avian Surveys

Avian Survey Report. AECOM, Inc. June 28, 2010

Avian Survey Report

June 28, 2010

Department of the Navy
Naval Facilities Engineering Command, Pacific
258 Makalapa Drive, Suite 100
Pearl Harbor, HI 96860-3134

NAVFAC
Naval Facilities Engineering Command
NAVFAC PACIFIC

AE Services for Environmental Planning to Support Strategic Forward Basing Initiatives Contract Number N62742-06-D-1870, TO 0016

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1 METHODS AND MATERIALS

Avifaunal communities were surveyed on specific areas identified by NAVFACMAR as having potential future use by the U.S. Military on the island of Guam. Survey sites were located on private, Government of Guam, U.S. military leasehold, and U.S. military properties. Specific areas included; North Finegayan, South Finegayan, Naval Munitions Site, Andersen South, Orote Point, AAFB NW Field and Route 9, Navy Barrigada, GLUP 77, FAA, Cabras, North Barrigada, and Route 15. All transect maps are presented in

Survey sites, transect number, and stations, as well as survey protocol, were established by NAVFACMAR biologists in coordination with TEC, Inc. and AECOM, Inc. Three basic types of field surveys were conducted: Roadside Surveys, Forest Bird Surveys and Endangered Species Surveys.

Field surveys were conducted during five time periods during 2008: February 16-25; March 27-April 6; June 24-28; and December 9-19. There were two field surveys during 2009 (July 16-19 and September 21-24), while one survey was carried in 2010 (January 15).

Three different types of field surveys were conducted; Roadside, Forest Bird, and Endangered Species. All avifaunal surveys were conducted by Mr. Rick Spaulding (TEC), Mr. John Gourley (AECOM) and/or Mr. Glenn Metzler (TEC).

1.1 Roadside Surveys

A modified point count methodology, in conjunction with a fixed line transect was used to enumerate bird detections (Bibby, *et. al*. 2000) for roadside surveys. Total number of detections (no detection direction or distance data was collected) were recorded (visual observations and/or by song) within one 3-minute period at each pre-determined station; no surveys were replicated. In order to minimize double counting, survey stations were positioned a minimum of 150 meters apart.

Roadside Surveys were conducted on seven project site areas during YR 2008 with a total of 102 stations (Table 1). All surveys were conducted either during the morning from sunrise to 1000 hours, or evening after 1700 hours. Though weather conditions were variable, data quality was not compromised by surveying in inclement weather.

TABLE 1
Overview of Roadside Surveys: area surveyed, date, number of stations surveyed, and survey time

Survey Site	Survey Date *(YR 2008)*	Number of Survey Stations	Survey Time *(morning vs. evening)*
North Finegayan	February 16	13	*Morning*
South Finegayan	February 17	11	*Morning*
Navy Magazine	February 24, 25	23	*Morning*
Andersen South	March 29; June 26	21	*Morning*
Orote Point	April 6	5	*Morning*
North Ramp	June 24, 28	6	*Morning*
AAFB NW Field	June, 28	17	*Morning*
WCTS Barrigada	February 18	6	*Evening*

1.2 Forest Bird Surveys:

In forested habitat, bird detections were enumerated using a point count methodology along variable-length straight line transects (Bibby, *et al*. 2000). Survey stations were placed a minimum of 150 meters apart to minimize double counting. All bird species were recorded (visual observations and/or by song) within one 8-minute period at each pre-determined station; no surveys were replicated. Although detection direction and distance estimates were recorded, only relative abundance among species will be discussed.

Forest Bird Surveys were conducted during YRS 2008, 2009, and 2010 on 14 project site areas with a total of 133 stations (Table 2). All surveys were conducted during the morning hours from sunrise to 1000 hours. Though weather conditions were variable, data quality was not compromised by surveying in inclement weather.

Table 2

Overview of the YR 2008 – 2010 Forest Bird Surveys: area surveyed, date, number of transects and stations surveyed

Survey Sites	Survey Date	Number of Survey Transects/Stations
North Finegayan	February 21, 22, 23, 2008 July 16, 2009	9 /21
South Finegayan	February 21, 2008	2 / 4
Navy Munitions Site	February 24, 25, 2008 March 28, 2008 December 15, 18, 19, 2008 July 19, 2009	11 / 29
Navy Munitions Site (Maagas River)	January 15, 2010	1 / 7
Andersen South	March 29, 30, 2008 September 21, 2009	6 / 14
Orote Point	April 6, 2008	4 / 8
AAFB NW Field	June 25, 2008	2 / 4
AAFB NW Field	June 24, 2008	2 / 4
AAFB Route 9	September 22, 23, 24, 2009	3 / 12
Navy Barrigada	February 20, 2008	2 / 4
GLUP 77	March 27, 30, 2008	2 / 4
Federal Aviation Administration	December 9, 11, 2008	3 / 6
Route 15	December 10, 11, 2008	3 / 10
Cabras	July 17, 2009	1 / 4
North Barrigada	September 21, 2009	1 / 2

1.3 Endangered Species Surveys:

The Camp Covington (U.S. Navy) wetland was identified as a unique and limited habitat resource requiring special surveys to determine whether the federally endangered Mariana Common Moorhen (G*allinula chloropus guami*) was present. In order to cover the entire wetland, eleven listening stations were strategically positioned around the perimeter of the wetland. Stations were placed a minimum of 150 meters apart to minimize double counting. All moorhen detections were recorded (visual observations and/or by song) within one 8-minute period; no stations were replicated. A single survey was conducted on December 13 and 16, 2009 during the morning hours between sunrise and 1000 hours. Though weather conditions were variable, data quality was not compromised by surveying in inclement weather.

2 FEDERAL AND TERRITORY LISTED ENDANGERED and THREATENED SPECIES

The Endangered Species Act (ESA) was initially passed by the US Congress in 1973 and has been re-authorized and amended several times. The purpose of the ESA is to conserve "*the ecosystems upon which endangered and threatened species depend*" and recover listed species. Those wildlife species which have been determined to have dangerously low population levels or are in imminent threat of extinction are protected by the U.S. Federal Government under authority of the ESA. Populations of those wildlife species requiring Federal protection are either classified as endangered or threatened. Endangered is defined in Section 3(6) of the ESA as:

> *"...any species [including subspecies or qualifying distinct population segment] which is in danger of extinction throughout all or a significant portion of its range."*

A threatened species is defined in Section 3(19) of the ESA and is defined as:

> *".... any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range."*

With respect to Guam terrestrial wildlife resources, the U.S. Fish and Wildlife Service (USFWS) have classified eight bird species as endangered (Table 3). Of these species, the Micronesian Megapode and Nightingale Reed Warbler were not listed in the Endangered Species Act of Guam as they were considered extirpated from Guam prior to passage of the Act.

The Endangered Species Act of Guam (Guam Public Law 15-36) was passed on 18 June 1979. Presently, there are 12 bird species recognized as having endangered status. This protected species list contains six species not found on the federal endangered species list: White-throated Ground Dove, Mariana Fruit Dove, Rufous Fantail, Micronesian Starling, Micronesian Myzomela, and the Guam Broadbill. Although the Guam Broadbill is considered extinct by the USFWS and subsequently de-listed during 2004 (USFWS 2004b), Guam retained this species on their list (Table 3).

Brief species accounts for Federal endangered/threatened species that may have been encountered during the surveys follow.

1. Common Moorhen (*Gallinula chloropus guami*)

The Mariana subspecies of the Common Moorhen was classified endangered by the USFWS and listed on August 27, 1984 {49 FR 33885}. Takano and Haig (2004) estimated Guam's population of adult moorhens as 90 individuals during a 2001 island population survey. Critical habitat has not been designated for this species. The Endangered Species Act of Guam (Guam Public Law 15-36) also classified this species as endangered.

2. Mariana Swiftlet (*Aerodramus bartschi*)

The Mariana Swiftlet was classified as endangered and listed by the USFWS on August 27, 1984 {49 FR 33885}. Even with the restricted range and low population numbers in Guam, Chantler (1999) does not consider this species globally threatened. No critical habitat has been designated for this species. The Endangered Species Act of Guam (Guam Public Law 15-36) also classified this species as endangered.

Table 3

Federal and Territorial Listed Endangered Species for Guam

PROTECTED AVIFAUNAL SPECIES [1]	**U.S. FEDERAL GOVERNMENT**	**TERRITORY OF GUAM**	**GUAM POPULATION STATUS**
(Mariana) Common Moorhen (*Gallinula chloropus guami*)	Endangered	Endangered	90 adults in 2001 [2]
Mariana swiftlet (*Aerodramus bartschi*)	Endangered	Endangered	low numbers
Guam Rail (*Gallirallus owstoni)*	Endangered	Endangered	*extirpated in wild captive breed*
Micronesian Megapode (*Megapodius l. laperouse)*	Endangered	*- not listed -*	*Extirpated*
Nightingale Reed Warbler (*Acrocephalus luscinius)*	Endangered	*- not listed -*	*Extirpated*
(Guam) Micronesian Kingfisher *(Todiramphus c. cinnamominus)*	Endangered	Endangered	*extirpated in wild* [3] *captive population* [3]
Mariana Crow *(Corvus kubaryi)*	Endangered	Endangered	< 5 [4]
(Guam) Bridled White-eye (*Zosterops c. conspicillatus)*	Endangered	Endangered	*extirpated* [3]
Guam Broadbill (*Myiagra freycineti*)	Delisted	Endangered	*extinct* [5]
White-throated Ground Dove *(Gallicolumba xanthonura)*	*- not listed -*	Endangered	*extirpated* [3]
Mariana Fruit Dove *(Ptilinopus roseicapilla)*	*- not listed -*	Endangered	*extirpated* [3]
Rufous Fantail *(Rhipidura rufifrons)*	*- not listed -*	Endangered	*extirpated* [3]
Micronesian Starling *(Aplonis opaca)*	*- not listed -*	Endangered	very low numbers [3]
Micronesian Myzomela *(Myzomela rubratra)*	*- not listed -*	Endangered	*extirpated* [3]

[1] *Classification and nomenclature follows* Gill and Donsker (2010)
[2] Takano and Haig (2004)
[3] USFWS (2008)
[4] SWCA (2008)
Information obtained from USFWS TESS web site; accessed 10 February 2009, Pacific Animals Plants and Animals Update August 29, 2005 (Listed, Proposed or Candidate species, as designated under the U.S. Endangered Species Act), and GDAWR, Department of Agriculture (2006)

3. Guam Rail (*Rallus owstoni*)

The Guam Rail is classified as endangered and was listed by the USFWS in 1984 {50 CFR 17; 49 FR 33881}. Presently, the Guam Rail only exists in captive breeding populations on Guam, stateside zoos, and as an experimental population on the island of Rota in the Commonwealth of the Northern Mariana Islands (CNMI) (Drahos 2002). No critical habitat has been designated for this species. The

Endangered Species Act of Guam (Guam Public Law 15-36) also classified this species as endangered.

4. Micronesian Megapode *(Megapodius l. laperouse*)

The Marianas Islands subspecies of the Micronesian Megapode was listed as an Endangered species by the USFWS on June 2, 1970 {35 FR 8491-8498}. The megapode was extirpated from Guam "*in the 19th and early 20th centuries*." (USFWS 1998a). Critical habitat has not been designated for this species. The Endangered Species Act of Guam (Guam Public Law 15-36) did not include this species when the Public Law was passed.

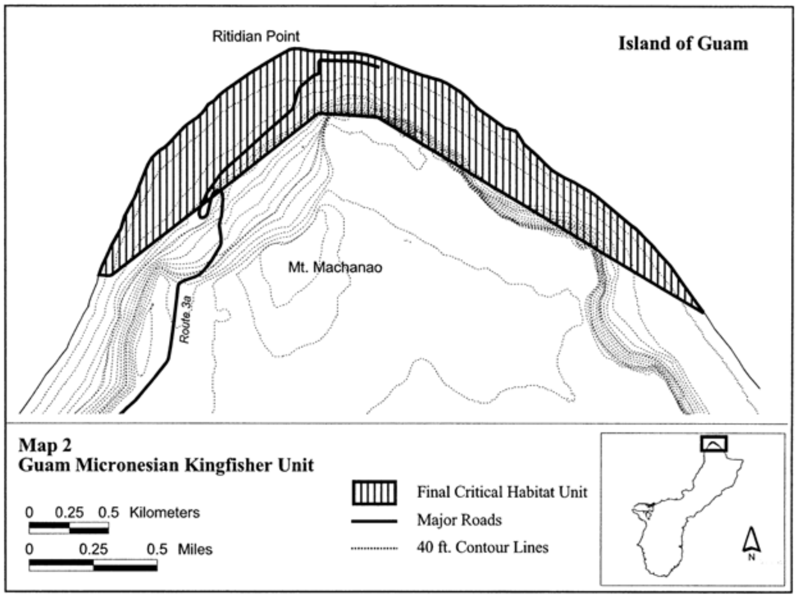
5. Nightingale Reed Warbler (*Acrocephalus luscinius)*

The Nightingale Reed Warbler is classified as endangered and was listed by the USFWS on June 2, 1970 {35 FR 8495}. Although six islands within the Marianas archipelago have historically contained reed-warbler populations, Guam's population was extirpated sometime during the late 1960's. The largest remaining population occurs on Saipan (CNMI) (USFWS 1998b). No critical habitat has been designated for this species (USFWS 1998b). The Endangered Species Act of Guam (Guam Public Law 15-36) did not include this species when the Public Law was passed.

6. Micronesian Kingfisher (*Todiramphus c. cinnamominus)*

The Guam Micronesian Kingfisher was classified as endangered and listed by the USFWS in 1984 {50 CFR 17; 49 FR 33881}. This sub-species is considered extirpated from Guam as the last sighting of a Micronesian Kingfisher was in 1989. Presently, there are approximately 50 individuals in captivity at various US mainland zoos. Critical habitat, designated in 2004, lies along in the extreme northern coastline (Figure 1) encompassing an area of approximately 376 acres (152 hectares) (USFWS 2004b). The Endangered Species Act of Guam (Guam Public Law 15-36) also classified this species as endangered.

Figure 1: Critical habitat map for the Guam Micronesian Kingfisher (USFWS 2004b).



7. Mariana Crow (*Corvus kubaryi*)

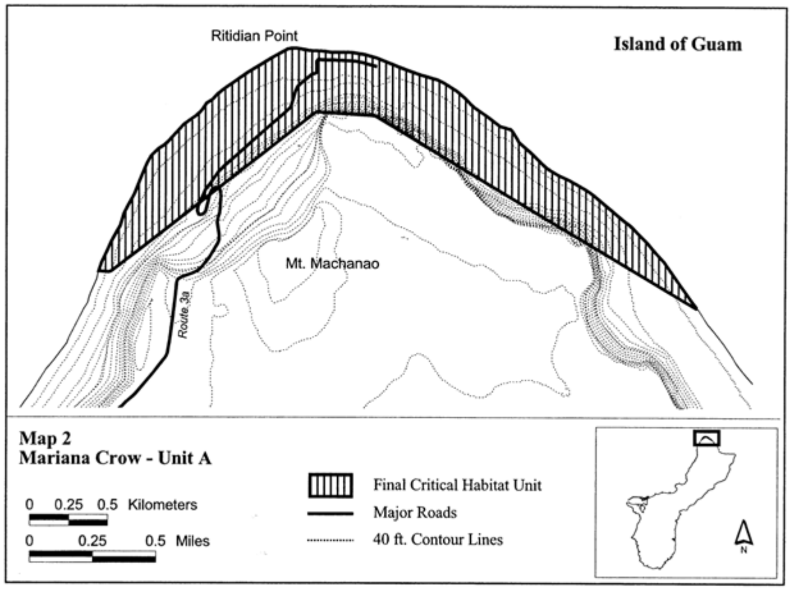
The Mariana Crow was classified as endangered and listed by the USFWS in 1984 {50 CFR 17; 49 FR 33881}. This species is limited to the islands of Guam and Rota (CNMI). In 2006, ten Mariana Crows were known to reside on Guam, all located on Andersen AFB and the Guam National Wildlife Refuge, Ritidian Unit (GDAWR 2006). Extensive surveys carried out between June 2007 and April 2008 indicates the Mariana Crow population may have declined to less than half the 2006 population estimate (SWCA 2008).

Critical habitat was later designated for both Guam and Rota on 28 October 2004 (USFWS 2004b). On Guam, critical habitat lies along in the extreme northern coastline (Figure 2) and encompasses an area of approximately 376 acres (152 hectares). None of the Guam critical habitat is currently occupied by the Mariana crow (USFWS 2004b). The Endangered Species Act of Guam (Guam Public Law 15-36) also classified this species as endangered.

8. Bridled White-eye (*Zosterops c. conspicillatus*)

The Guam sub-species of Bridled White-eye is classified as endangered and was listed by the USFWS in 1984 {50 CFR 17; 49 FR 33881}. The Guam sub-species is endemic to Guam and is now considered extinct as the last observation was recorded during 1983 (USFWS 2008). The species continues to be found on other islands in the Marianas archipelago (i.e., the CNMI). The Endangered Species Act of Guam (Guam Public Law 15-36) also classified the Guam Bridled White-eye sub-species as endangered.

Figure 2: Critical habitat map for the Mariana Crow on Guam (USFWS 2004b).



3 GUAM FEDERAL ESA CANDIDATE SPECIES

A candidate species is a plant or animal species for which USFWS or National Marine Fisheries Service (NMFS) has on file sufficient information on biological vulnerability and threats to support a proposal to list as endangered or threatened, but has not yet done so. A candidate species receives no statutory protection under the ESA; however USFWS or NMFS encourages planners to conserve these species that may warrant future protection under the ESA.

The USFWS Threatened and Endangered Species System was accessed December 2009 and no bird species were identified as Candidate Species for Guam.

4 RESULTS AND DISCUSSION

Twelve avifaunal species were documented from the Roadside and Forest Bird Surveys (Table 4). A total of 549 unique detections (visual and/or audio) were recorded from the 228 stations comprising the Roadside and Forest Bird Surveys (Table 5).

Seven species were common to both the Roadside and Forest Bird Surveys. Unique to the Roadside Surveys included the Whimbrel, Western Cattle Egret, and Common Pigeon, while the Micronesian Starling and Grey-tailed Tattler were identified only during the Forest Bird Surveys (Table 5).

No federally listed endangered or threatened species were identified during any of the surveys. One Guam listed endangered/threatened species was recorded from the Forest Bird Survey. The Micronesian Starling was detected during the AAFB Route 9 survey (Transect B; Station 3) on September 24, 2009. This species was also observed in the same area the day before when the transect was being cut.

TABLE 4:
Avifaunal species Identified During the Surveys

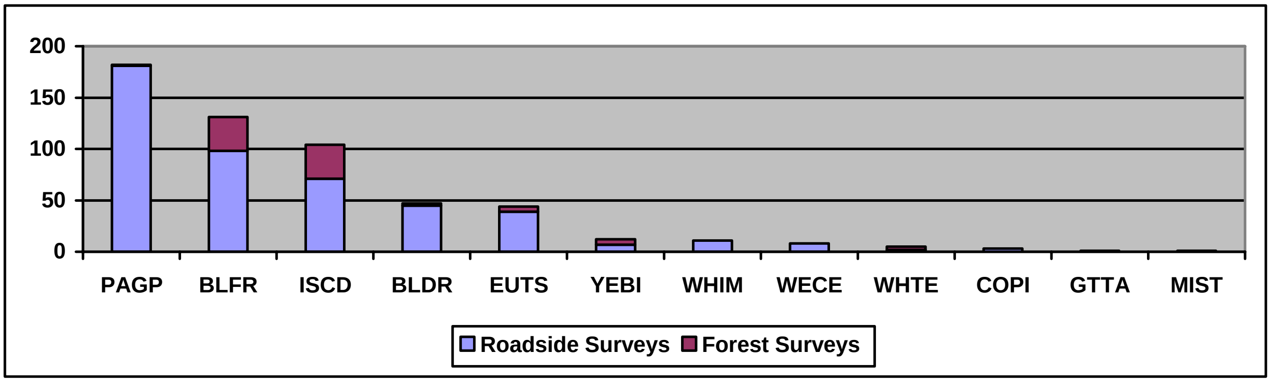
Avifaunal Species	Residence Status[1]
Micronesian Starling *(MIST) (Aplonis opaca)*	Guam listed endangered/threatened species Uncommon resident native - breeding
Yellow Bittern (YEBI) *(Ixobrychus sinensis)*	Common resident native - breeding
White Tern *(WHTE) (Gygis alba)*	Uncommon native resident - breeding
Whimbrel (WHIM) (*Numenius phaeopus)*	Common visitor – not breeding
Pacific Golden Plover (PAGP) *(Pluvialis fulva)*	Common visitor – not breeding [2]
Western Cattle Egret (WECE) *(Bubulcus ibis)*	Common visitor – not breeding
Grey-tailed Tattler (GTTA) (*Tringa brevipes*)	Common visitor – not breeding
Common *Pigeon* (COPI) *(Columba livia)*	Common introduced resident - breeding
Island Collared Dove (ISCD) *(Streptopelia bitorquata)*	Common introduced resident - breeding
Black Drongo (BLDR) *(Dicrurus macrocercus)*	Common introduced resident - breeding
Eurasian Tree Sparrow (EUTS) *(Passer montanus)*	Common introduced resident - breeding
Black Francolin (BLFR) *(Francolinus francolinus)*	Common introduced resident - breeding

NOTES:
[1] Residence status obtained from: Reichel and Glass (1991)
[2] Residence status obtained from: Johnson, *et al.* (2006)
species code follows name. *Taxonomy and nomenclature follows Gill and Donsker (2010).*

4.1 Roadside Surveys:

Roadside Surveys consisted of 102 stations; less than half (41%) of the total number of survey stations (N=246). Yet, detections from the Roadside Surveys (N=465) comprised 85% of the total detections recorded from both surveys. In addition, Roadside Surveys consistently had a higher species diversity and detection rate when compared with the Forest Bird Surveys (Figure 3).

Figure 3. Total number of detections by species by survey type in decreasing order of abundance. Species codes are found in Table 4.



Five species dominated the Roadside Surveys and comprised 93% of all detections. In decreasing order of abundance, the dominate species included: the Pacific Golden Plover (42%); Black Francolin (22%); Island Collared Dove (16%); Black Drongo (10%); and the Eurasian Tree Sparrow (9%) (Figure 3 and Table 5). Of these, only one is classified as a non-exotic: the Pacific Golden Plover. The other four species are introductions and have well established breeding populations (Table 4).

The Black Francolin, native to Southern Asia, was introduced as a game bird to Guam in 1961 by the local Division of Fish and Wildlife in coordination with the U.S. Fish and Wildlife Service (Drahos 2002). The Island Collared Dove, native to the Philippines, Borneo and surrounding islands, was believed to have been introduced by the Spanish perhaps as long as 200 years ago (Engbring and Ramsey 1984). The Black Drongo, native to Taiwan, was first introduced to Rota (CNMI) by the Japanese South Seas Development Company in 1935 in order to control destructive insects (Baker 1951). Since Rota lies approximately 50 km north of Guam, it is believed that the drongo either flew on its own accord or possibly purposely introduced to Guam as the species first appeared in Northern Guam in the early 1960's (Engbring and Ramsey 1984). An Old World native, the Eurasian tree Sparrow was introduced to Guam from 1945-1960 and is commonly found in the urban areas (Engbring and Ramsey 1984).

Habitat typically found during the Roadside Survey would be characterized as urban. This includes disturbed fields, regularly maintained areas, and overgrown (i.e., abandoned) areas.

4.2 Forest Bird Surveys

The Forest Bird Surveys included 126 stations and recorded a total of 84 detections; approximately 15% of all detections from combined Forest Bird and Roadside Surveys.

The Black Francolin and Island Collared Dove dominated the Forest Bird Surveys and comprised 78% of all detections (Figure 3 and Table 5) with each species having an equal number of detections. As previously discussed, these species were intentionally introduced to Guam and have well established breeding populations.

Though not unexpected, surveys in several forested areas documented no birds. For example, no detections were recorded from the 23 stations surveyed in Navy Barrigada, North Barrigada, Navy Munitions Site (Maagas River) and Route 15 areas. Another three areas (Cabras, South Finegayan, and Federal Aviation Administration) only recorded one species from a total of 14 stations; the Island Collared Dove. This species is usually found in disturbed habitat or fields.

TABLE 5:

Overview of the 2008-2010 Guam field survey data: area surveyed, survey type, number stations, species and detections, number of unique species/area, and total number of detections/area

Survey Site	Survey Type	No. of Stations	Species and No. of Detections	No. Species	Total No. Detections
North Finegayan	Roadside Survey	13	Pacific Golden Plover (53) Black Francolin (13) Eurasian Tree Sparrow (7) Island Collared Dove (6) Black Drongo (2)	5	81
North Finegayan	Forest Bird Survey	21	Island Collared Dove (7) Black Francolin (3) Eurasian Tree Sparrow (1)	3	11
South Finegayan	Roadside Survey	11	Pacific Golden Plover (53) Island Collared Dove (28) Black Drongo (16) Eurasian Tree Sparrow (14) Common Pigeon (3) Yellow Bittern (1)	5	115
South Finegayan	Forest Bird Survey	4	Island Collared Dove (4)	1	4
Navy Munitions Site	Roadside Survey	23	Island Collared Dove (13) Black Francolin (11) Pacific Golden Plover (6) Black Drongo (3) White Tern (2)	5	35
Navy Munitions Site	Forest Bird Survey	29	Black Francolin (8) White Tern (3) Island Collared Dove (2) Yellow Bittern (1) Grey-tailed Tattler (1)	5	15
Navy Munitions Site (Maagas River)	Forest Bird Survey	7	*- none -*	*- none -*	*- none -*
Anderson South	Roadside Survey	21	Eurasian Tree Sparrow (5) Black Francolin (4) Pacific Golden Plover (1) Island Collared Dove (2) Yellow Bittern (1)	5	13
Anderson South	Forest Bird Survey	14	Pacific Golden Plover (1) Island Collared Dove (1) Yellow Bittern (1) Black Francolin (3)	4	6
Orote Point	Roadside Survey	5	Pacific Golden Plover (50) Black Francolin (12) Whimbrel (11) Island Collared Dove (1) Black Drongo (4)	5	78
Orote Point	Forest Bird Survey	8	Island Collared Dove (1) Yellow Bittern (1) Black Francolin (1)	3	3
AAFB NW Field	Roadside Survey	17	Black Francolin (41) Island Collared Dove (11) Yellow Bittern (2)	3	54
AAFB NW Field	Forest Bird Survey	4	Black Francolin (5)	1	5

AAFB North Ramp	Roadside Survey	6	Black Francolin (14) Island Collared Dove (4) Black Drongo (11) Eurasian Tree Sparrow (7)	4	36
AAFB North Ramp	Forest Bird Survey	4	Black Francolin (12) Island Collared Dove (6) Eurasian Tree Sparrow (4) Black Drongo (1)	4	23
AAFB Route 9	Forest Bird Survey	12	Micronesian Starling (1) Island Collared Dove (1) Black Drongo (1) Yellow Bittern (1)	4	4
Glup 77	Forest Bird Survey	4	Island Collared Dove (3) Black Francolin (1) Yellow Bittern (1)	3	5
WCTS Barrigada	Roadside Survey	6	Pacific Golden Plover (18) Black Drongo (9) Western Cattle Egret (8) Island Collared Dove (6) Eurasian Tree Sparrow (6) Black Francolin (3) Yellow Bittern (3)	7	53
Navy Barrigada	Forest Bird Survey	4	*- none -*	*- none -*	*- none -*
Federal Aviation Administration	Forest Bird Survey	6	Island Collared Dove (7)	1	7
Route 15	Forest Bird Survey	10	*- none -*	*- none -*	*- none -*
Cabras	Forest Bird Survey	4	Island Collared Dove (1)	1	1
North Barrigada	Forest Bird Survey	2	*- none -*	*- none -*	*- none -*
Camp Covington	Endangered Species Survey	11	*No Common Moorhens detected*	*- N/A -*	*- none -*

Habitat typically found during the Forest Bird Survey was characterized as various types (or grades) of forest (limestone, strand, coconut, secondary, etc.), however disturbed areas, even fields, were often encountered as the transects were walked. Although all stations were sited in forested habitat, other habitat types (i.e., open field, disturbed areas) occurred nearby. For this reason and the fact that certain species of birds can be heard from a distance may help explain the dominance of Black Francolin and Island Collared Dove detections in the Forest Bird Surveys.

4.3 Endangered Species Surveys

No federal endangered Mariana Common Moorhen were detected during the Endangered Species Survey conducted at the Camp Covington wetland complex (U.S. Navy) on December 13 and 16, 2009.

5 CONCLUSIONS

1. No federally listed endangered/threatened species were encountered during the Roadside and Forest Bird surveys.

2. One Guam listed endangered species was recorded during the survey period. One Micronesian Starling was observed during the AAFB Route 9 survey (Transect B; Station 3) on September 24, 2009. This species was also observed area the day prior when the transect was being cut.

3. The five most abundant species identified during Roadside Surveys comprised 93% of all detections and included: the Pacific Golden Plover (42%); Black Francolin (22%); Island Collared Dove (16%); Black Drongo (10%); and the Eurasian Tree Sparrow (9%). The latter four species are introduced species that have well established breeding populations.

   The Pacific Golden Plover is a common non-breeding visitor to Guam.

   The Black Francolin is a common introduced resident that has an established breeding population. A native to Southern Asia, this species was introduced as a game bird to Guam in 1961 (USFWS 1984). The Black Francolin, native to Southern Asia, was introduced as a game bird to Guam in 1961 (USFWS 1984).

   The Island Collared Dove is a common introduced resident that has an established breeding population. A native to the Philippines, Borneo and surrounding islands, this species was believed to have been introduced by the Spanish perhaps as long as 200 years ago. (Engbring and Ramsey 1984).

   The Black Drongo, native to Taiwan, was first introduced to Rota (CNMI) by the Japanese South Seas Development Company in 1935 in order to control destructive insects (Baker 1951). Since Rota lies approximately 50 km north of Guam, it is believed that the drongo either flew on its own accord or was possibly purposely introduced to Guam as the species first appeared in northern Guam in the early 1960's (Engbring and Ramsey 1984).

   An Old World native, the Eurasian tree Sparrow was introduced to Guam from 1945-1960 and is commonly found in the urban areas (Engbring and Ramsey 1984).

4. Habitat typically found during the Roadside Survey was characterized as urban. This includes disturbed fields, regularly maintained areas, and overgrown (i.e., abandoned) areas.

5. The Forest Bird Surveys were dominated by the Black Francolin and Island Collared Dove; comprising 78% of all detections with each species having an equal number of detections.

6. No detections were recorded from 23 Forest Bird stations in Navy Barrigada, North Barrigada, Navy Munitions Site (Maagas River) and Route 15 areas. Only one species, the Island Collared Dove, was documented from 14 stations in three areas; Cabras, South Finegayan, and Federal Aviation Administration.

7. The federally endangered Mariana Common Moorhen was not detected during the Endangered Species Survey around the Camp Covington wetland complex (U.S. Navy) on December 13 and 16, 2009.

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APPENDIX H
Tree Snail Surveys

Tree Snail Surveys on Department of Defense Lands, Guam, in Support of a Marine Corps Relocation Initiative to Various Locations on Guam SWCA Environmental Consultants, Inc. February, 2010; and

Survey of Endangered Tree Snails on Navy-Owned Lands in Guam. Marine Laboratory, Laboratory, University of Guam, UOG Station, Mangilao. 2008

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TREE SNAIL SURVEYS ON DEPARTMENT OF DEFENSE LANDS, GUAM, IN SUPPORT OF A MARINE CORPS RELOCATION INITIATIVE TO VARIOUS LOCATIONS ON GUAM

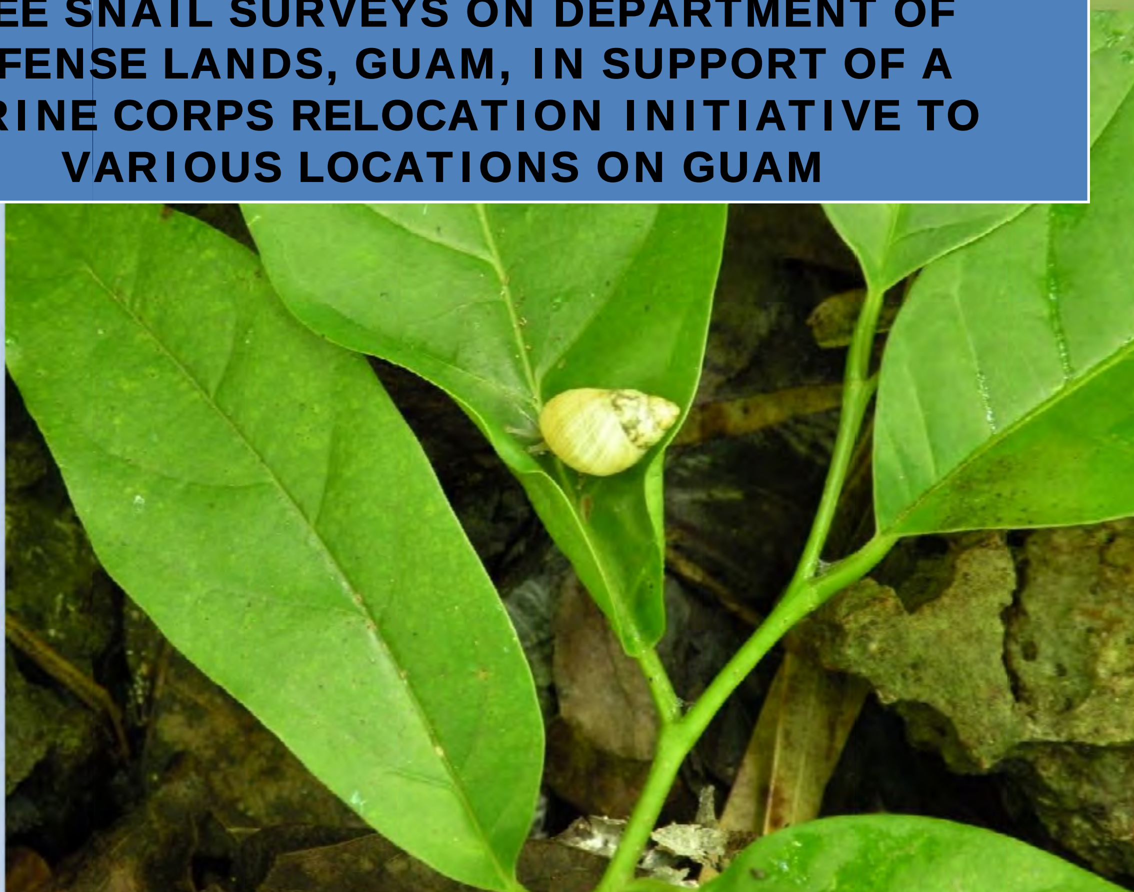

Photo: SWCA

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1.0 INTRODUCTION

Between September and November 2009, surveys for partulid tree snails were conducted as part of the biological inventory for the Joint Guam Program Office (JGPO) Guam and Commonwealth of the Northern Mariana Islands (CNMI) Military Relocation Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS). Surveys were designed to locate, identify, and assess the distribution and abundance of partulid tree snails on Guam's Department of Defense (DoD) lands.

1.1 Species Description, Distribution, and Status

Surveys targeted four species of partulid tree snail (Gastropoda: Partulidae):

- Mariana Islands tree snail (*Partula gibba*)
- Pacific tree snail (*Partula radiolata*)
- Guam tree snail (*Partula salifana*)
- Mariana Islands fragile tree snail (*Samoana fragilis*)

Three of these tree snails (Mariana Islands tree snail, Pacific tree snail, and Mariana Islands fragile tree snail) are federal candidate species for listing under the U.S. Endangered Species Act (USFWS 2005). The Government of Guam identified all four species in the Guam Comprehensive Wildlife Conservation Strategy (GCWCS) as species of greatest conservation need (SOGCN) (GDAWR 2006).

1.1.1 Mariana Islands Tree Snail (*Partula gibba*)

The Mariana Islands tree snail is the most widely distributed tree snail in the archipelago, known from nine islands: Guam, Rota, Aguiguan, Tinian, Saipan, Anatahan, Sarigan, Alamagan, and Pagan (Smith et al. 2008). Once considered the most abundant of the partulids in some areas on Guam (Crampton 1925), the only extant population on the island is known from the Haputo Beach region (Hopper and Smith 1992, Smith et al. 2008). Host plants on Guam the Mariana Islands tree snail are known to associate with include *Alocasia macrorrhiza, Asplenium nidus, Cocos nucifera, Hernandia nymphaeifolia, Neisosperma oppositifolia, Phymatodes scolopendria,* and *Piper guamensis* (Hopper and Smith 1992, Smith et al. 2008).

1.1.2 Pacific Tree Snail (*Partula radiolata*)

The Pacific tree snail is endemic to Guam (Smith et al. 2008). This species replaced *P. gibba* as the predominant partulid species on the island by 1989 (Smith and Hopper 1994). The Pacific tree snail is presently the most abundant partulid on Guam and can be found in the northern, central, and southern regions of the island (Hopper and Smith 1992, Smith et al. 2008). Host plants on Guam the Pacific tree snail are known to associate with include *Annona reticulata, Barringtonia asiatica, C. nucifera, Cycas micronesica, H. nymphaeifolia, Intsia bijuga, Mammea odorata, N. oppositifolia, Pandanus dubius,* and *P. guamensis* (Hopper and Smith 1992, Smith et al. 2008).

1.1.3 Guam Tree Snail (*Partula salifana*)

The Guam tree snail is the most geographically restricted of the partulids in the Mariana Islands. The species is only known from Mt. Alifan (Guam) and two adjacent peaks on the southwest coast of the island (Smith et al. 2008). The species was unexpectedly discovered in 1920, with the collection of 22 individuals (19 adults, three adolescents) just below the peak of Mt. Alifan (Crampton 1925). Despite numerous visits and surveys in regions where the Guam tree snail had been previously collected, this species has not been observed since and is believed to be extinct (Hopper and Smith 1992, Smith and Hopper 1994).

1.1.4 Mariana Islands Fragile Tree Snail (*Samoana fragilis*)

The Mariana Islands fragile tree snail is the only member of its genus to occur outside southeastern Polynesia (Smith et al. 2008). This species was originally deemed widespread but uncommon on the islands of Guam and Rota. In 1989, the Mariana Islands fragile tree snail was considered the least abundant of the three partulids on Guam (Smith and Hopper 1994). Not observed on Guam since 1996, this species was recorded in the Pugua Point region (northern Guam) in 2008 (Smith et al. 2008). This colony of Mariana Islands fragile tree snails is the only one currently known on Guam (Smith et al. 2008). The status of the only other known colony, located on Rota, is undetermined (Smith et al. 2008). Host plants of the Mariana Islands fragile tree snail on Guam include *A. reticulata, A. nidus, B. asiatica, C. nucifera, Derris trifoliata,* and *Triphasia trifolia* (Hopper and Smith 1992, Smith et al. 2008).

2.0 METHODS

2.1 Survey Locations

Tree snail surveys were carried out along transects situated at four DoD locations on Guam: Andersen Air Force Base, Andersen South, Navy Barrigada, and North Finegayan (Figure 1). To increase the possibility of detecting the four target species, transects were set up within habitat containing known host plants utilized by partulid tree snails.

2.2 Tree Snail Surveys

Three survey methods were used to determine the presence of partulid tree snails at each survey location: general visual surveys, detailed visual surveys, and quadrat surveys. These methods are specifically designed to target partulid tree snails and are adapted from those utilized in previous tree snail assessments (Hopper and Smith 1992, Smith et al. 2008).

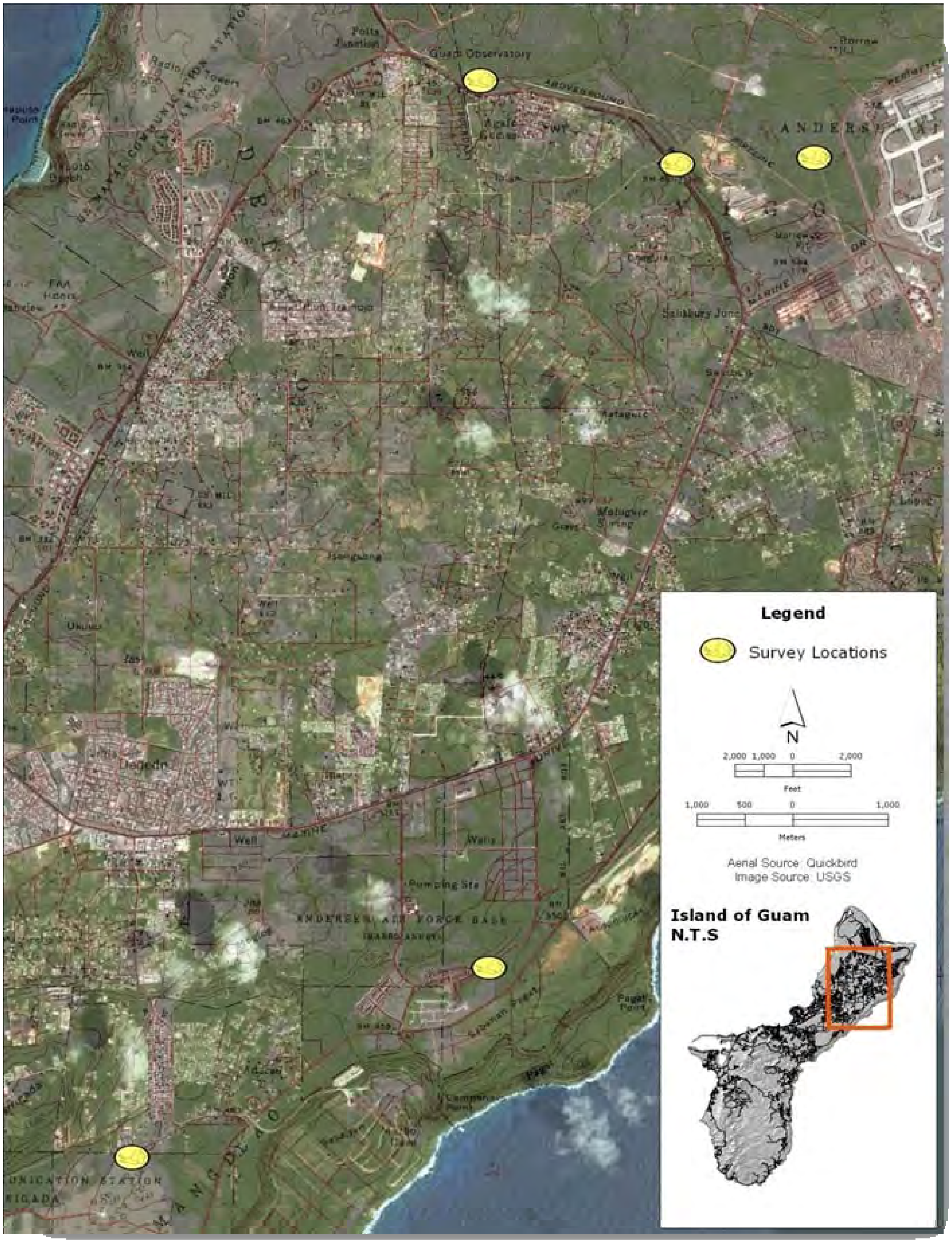

Figure 1. Partulid tree snail surveys were undertaken at five locations on Department of Defense Lands, Guam.

2.2.1 General Visual Surveys

General visual surveys involved up to two trained observers walking each transect searching likely tree snail habitat for the presence of snails. During the general visual survey period, observers also noted specific areas that included an abundance of known partulid host plants, and areas where detailed visual surveys (see Section 2.2.2) would subsequently occur. Information on known partulid host plant species was obtained from Hopper and Smith (1992) and Smith et al. (2008).

2.2.2 Detailed Visual Surveys

Detailed visual surveys were conducted at locations along each transect where known partulid host plants were abundant. At each location, observers intensively examined the leaves and stems of known partulid host plants for up to 30 minutes. If live tree snails were observed, quadrat surveys (see Section 2.2.3) were completed. Following each plant examination, leaf litter was investigated for partulid shells for up to 10 minutes. If snail shells were observed, we noted location and condition of the shell (e.g., weathering, fragmentation, color intensity or bleaching) that may indicate recent presence of the snails. If live partulid tree snails or their empty shells were found during the detailed visual survey period, the location was recorded as supporting tree snails.

2.2.3 Quadrat Surveys

If live partulid tree snails were located within the 30-minute detailed visual survey period, four 25-m^2 quadrats were established under the densest understory, as determined by a spherical densiometer. All partulid tree snails occurring within the quadats and to a height of six feet (ft) (two meters (m)) above were identified to species, and their shell length and height measured to the nearest 0.1 millimeter (mm) with sliding vernier calipers. Host plant species and vertical height of the host plant to 1.6 ft (0.5 m) were recorded for each partulid tree snail observed.

During the quadrat surveys, temperature (°C), relative humidity (RH), and air movement (Beaufort scale) were measured with miniature probes in microhabitats inhabited by partulid tree snails to quantify inhabited microhabitat features (Crampton 1925). Temperature, humidity, and air movement measurements were also taken in uninhabited areas to assess their suitability for supporting tree snail populations. Comparisons of data from inhabited and uninhabited forest will provide a clearer characterization of suitable microclimatic conditions suitable for tree snail survival.

3.0 RESULTS

Between 25 September 2009 and 21 January 2010, a general and detailed visual survey was completed along six transects: three at Andersen Air Force Base, one at Andersen South, one at Navy Barrigada, and one at North Finegayan (Table 1). Total surveyed area was 2450 linear meters (8036 linear feet). No living partulid tree snails (or their shells) were observed during any of the surveys conducted along the five transects (Table 1).

Table 1. Partulid tree snail general and detailed visual survey results on Department of Defense Lands, Guam. AAFB = Andersen Air Force Base, ANDS = Andersen South, NBAR = Navy Barrigada, NFIN = North Finegayan. (m) = meters

General Visual Survey Date	Detailed Visual Survey Date	Transect	Transect Length (m)	# of Partulid Tree Snails Observed
12 October 2009	23 October 2009	AAFB - 5	400	0
1 October 2009	2 October 2009	AAFB - 6[2]	400	0
25 September 2009	25 September 2009	AAFB - 7	400	0
1 October 2009	9 October 2009	ANDS – 7	500	0
29 September 2009[1]	29 October 2009[1]	NBAR - 3[2]	250	0
7 October 2009[1]	6 November 2009[1]	NBAR - 3[2]	250	0
21 January 2010	21 January 2010	NFIN - 9	500	0

[1] Survey was completed over the course of two days due to poor weather conditions.

[2] Flatworms recorded along the transect.

Live introduced lined tree snails (*Drymaeus multilineatus*) were commonly observed along the Navy Barrigada transect (Figure 2). Shells of the introduced giant African snail (*Achatina fulica*) were seen on all five transects. Both live individuals and shells of the introduced snail *Satsuma mercatoria* (no common name) were seen at all five transects. Additionally, live introduced Manokwar flatworms (*Platydemus manokwari*) were observed along two transects (Table 1).

Because no live partulid tree snails were observed during general or detailed visual surveys, no quadrat surveys were completed; therefore, temperature, humidity, and air movement measurements were not taken in areas not inhabited by tree snails.

Figure 2. Lined tree snails (*Drymaeus multilineatus*) were common along the Navy Barrigada transect. Photo: SWCA.

4.0 DISCUSSION

No partulid tree snails were observed during any of the visual surveys conducted on the six transects distributed in four disparate areas (Andersen Air Force Base, Andersen South, Navy Barrigada, and North Finegayan). However, since there were several known host plant species present throughout the survey area, the possibility that tree snails are present in habitat associated with the surveyed transects cannot be dismissed. When development projects arise along or near the survey locations, more extensive surveys should be considered as existing tree snail habitat occurs throughout the area and could support tree snail colonies.

Flatworms were recorded at Navy Barrigada and Andersen Air Force Base. Because the species was not targeted during the tree snail surveys and are more likely seen nocturnally when they are active, flatworms were likely present but undetected at all locations. This flatworm is known to feed on juvenile partulid tree snails in the wild on Guam and Pacific tree snails in captivity, and is believed to be the primary threat to the continued existence of partulid tree snails on Guam, the Mariana Islands, and potentially Oceania (Hopper and

Smith 1992). The authors reported that on Guam where flatworm abundance was high, partulid tree snail colonies were rapidly declining.

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SURVEY OF ENDANGERED TREE SNAILS ON NAVY-OWNED LANDS IN GUAM

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INTRODUCTION

The land snail faunas on islands of the tropical Pacific exhibit spectacular evolutionary radiations (Cowie, 1996), although they are dominated by relatively few families. Despite their diversity, native land snail faunas of the Pacific islands are composed almost entirely of narrow-range endemics. The same factors that favored rapid evolution of endemic land snail biotas from colonists dispersing successfully to islands also imposed extreme sensitivity to environmental disturbances and high rates of extinction on the resulting populations. These constraints among insular endemic species are consequences of small geographic ranges and small populations (Diamond, 1984; Tracy and George, 1992).

These unique native snail faunas are now disappearing rapidly (Lydeard et al., 2004). In the Mariana Islands, Bauman (1996) recorded at least 39 native species of land snails in Rota, and Kurozumi (1994) recorded at least 16 species on the islands north of Saipan. Sixty-eight percent of the Rota snail species are extinct or declining (Bauman, 1996). These and other data suggest that overall perhaps 50% of the land snail fauna has disappeared throughout the Pacific islands as a whole, mostly in recent times (Lydeard et al., 2004).

The family Partulidae consists of predominantly arboreal snails that are limited in geographic distribution to volcanic high islands of the tropical Pacific, ranging from the Marquesas and Austral Islands in the east to the Mariana Islands and Belau in the west (Kondo, 1968; Cowie, 1992). Members of the most primitive order of pulmonate snails, the Partulidae is speciose; Kondo (1968) recognized 126 species. Partulids are also highly endemic, with most species restricted to single islands. Only one species occurs in more than one island group (Cowie, 1992; Johnson et al., 1993).

Partulid populations have declined throughout their range in recent years, in some cases to extinction (Clarke et al., 1984; Murray et al., 1988; Hopper and Smith, 1992; Miller, 1993). In Guam, the endemic Mt. Alifan tree snail, *Partula salifana*, is thought to be extinct (Hopper and Smith, 1992). The tree snail *Partula gibba* has disappeared from historical locations in Guam and Saipan studied by Crampton (1925) in 1920 and by Kondo in 1949 (Smith and Hopper, 1994). No living *Partula gibba* were found in previously reported habitations in Rota, Tinian, and Aguiguan, as well (Smith and Hopper, 1994; Smith, 1995, In Review). Major factors contributing to this broad decline include loss of habitat to agricultural and urban development and introductions of invasive species, including predators intended as biological controls for the giant African snail *Achatina fulica* (Smith and Hopper, 1992; Cowie, 2000, 2001).

The objectives of this survey are to determine the location of Guam tree snails on Navy-owned lands in Guam and to identify the location of suitable habitat and inventory areas that have the highest probability of supporting snail populations. The areas of interest are on NCTS and the Ordnance Annex. Three species of Guam's native tree snails—*Samoana fragilis*, *Partula gibba*, and *Partula radiolata*—are candidate species under the federal Threatened and Endangered Species Act (Federal Register, 1994). All four species, including *Partula salifana*, are listed as endangered species under the Endangered Species Act of Guam (5 GCA, Section 63205.(c)).

TAXONOMIC REVIEW

The Mariana Archipelago (Figure 1) historically supported five species of partulids scattered across seven small islands lying at the northwestern limit of the geographical range of the Partulidae. In the first systematic study of the distribution of Mariana partulids, Crampton (1925) reported four species of partulids from Guam and Saipan. Kondo (1970) added five smaller islands to the range of partulids in the Mariana Islands and described a fifth species endemic to the tiny island (<3 mi^2) of Aguiguan [also known as Aguijan]. However, recent surveys indicate that as many as three of the five Mariana species are either extinct or on the brink of extinction (Hopper and Smith, 1992; Smith and Hopper, 1994; Smith, In Review).

Partula gibba Férussac, 1821 (FIGURE 2)
Synonymy:
Partula mastersi Pfeiffer, 1857
Partula bicolor Pease, 1872

Description: Shell dextral or 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, 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.

Range: *Partula gibba* is the most widely distributed tree snail in the Mariana Islands, occurring on nine islands. This species is known from Guam, Rota, Aguiguan, Tinian, Saipan, Anatahan, Sarigan, Alamagan, and Pagan.

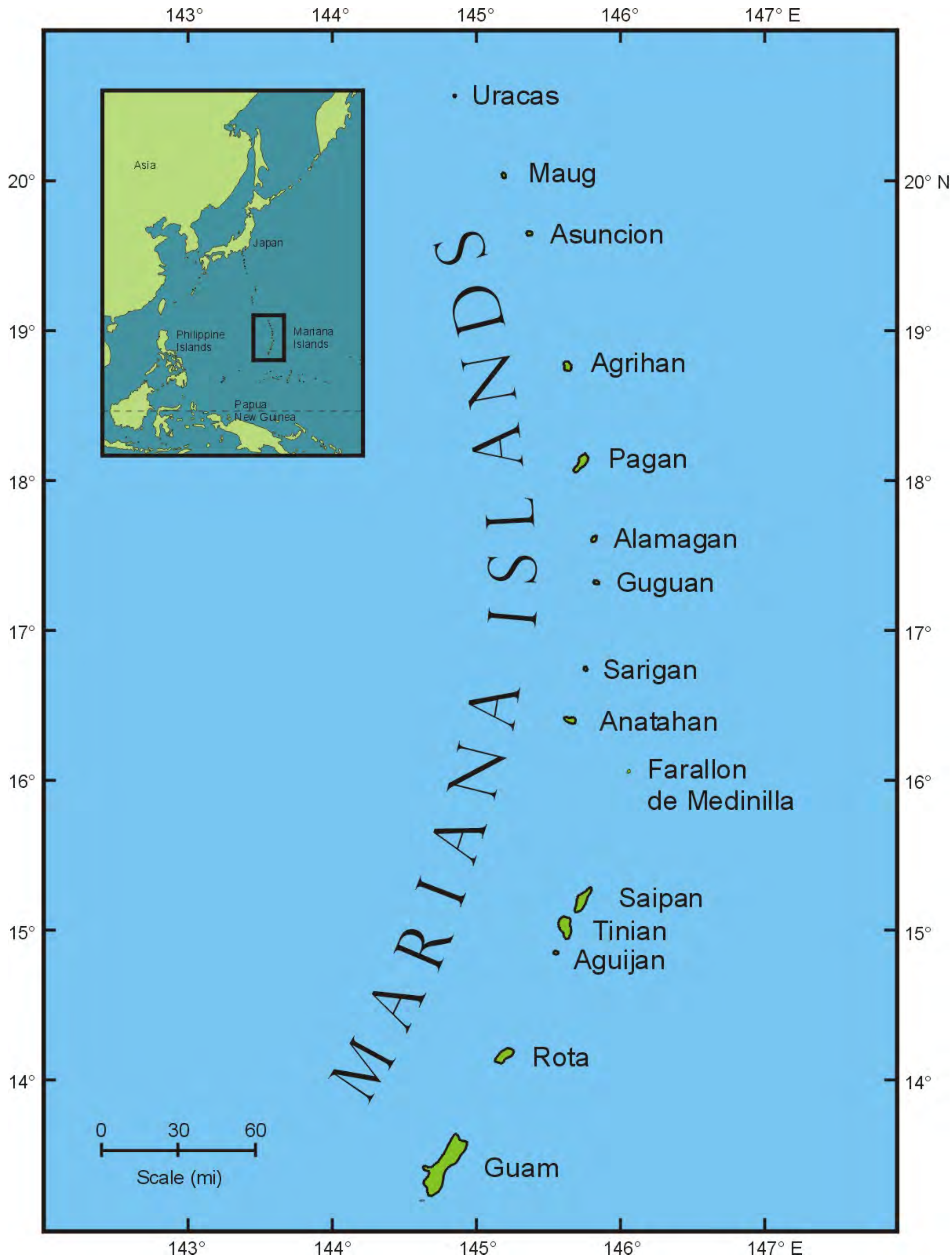


Figure 1. Map of the Mariana Islands. Inset shows the position of the Mariana Islands in relation to Asia and the western Pacific.

Figure 2. *Partula gibba* on *Alocasia macrorrhiza* leaf at Haputo, Guam.

Partula radiolata (Pfeiffer, 1846) (FIGURE 3)
Synonymy:
Bulimus (*Partula*) *radiolata* Pfeiffer, 1846.

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-colored with darker axial rays and brown lines. Adult length 13 to 18.5 mm, width 8 to 12 mm.

Range: *Partula radiolata* is a Guam endemic. It has 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).

Partula salifana Crampton, 1925 (FIGURE 4)
Synonymy:
None.

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

Figure 3. *Partula radiolata* on *Alocasia macrorrhiza* at Haputo, Guam.

Figure 4. *Partula salifana* (paratype, Bishop Museum, Honolulu).

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.

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

Samoana fragilis (Férussac, 1821) (FIGURE 5)
Synonymy:
Partula quadrasi Möllendorff, 1894

Description: Shell dextral, ovate-conic, narrowly and half-covered perforate, fragile, pellucid. Spire conic, the apex somewhat obtuse; whorls typically 4, 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, a little excised; peristome simple, thin, well expanded, the columella dilated above, recurved, forming a distinct angle with the parietal wall. Background color buff-tinted, semi-transparent; narrow darker maculations and whitish banding due to colors of viscera visible through the shell. Adult length 12 to 16 mm, width 10 to 12 mm.

This species exhibits several reproductive characteristics that are unique among Mariana Islands partulids. The eggs are large (4.2 mm × 3.3 mm), and they are encapsulated by a tough, calcareous shell (Crampton, 1925). Further, *Samoana fragilis* reaches sexual maturity before it expands the varical lip that characterizes adults of terminal size (Crampton, 1925; Kondo, 1955). The latter trait has not been reported for any other partulid species.

Range: *Samoana fragilis* is the only member of the genus to occur outside southeastern Polynesia. In the Mariana Islands, *Samoana fragilis* has been reported from Guam and Rota.

METHODS

Forested areas of NCTS and the Guam Ordinance Annex were surveyed by visual census methods adapted from Hopper and Smith (1992) between 21 May and 30 August 2008, plus a resurvey of the Kitts Road area of the ORdinance Annex on 26 February 2008. Mixed mesophytic forest predominated by native species identified as partulid habitat by Hopper and Smith (1992) were the focus of this project. Survey sites were selected from satellite images after consultation with botanists acquainted with the areas. Special attention was given to sites where partulids were previously reported.

Figure 5. *Samoana fragilis* observed on *Annona reticulata* at NCTS, Guam.

At survey sites, broad-leafed tree species were inspected for 30 min, and leaf litter was examined for 10 min in search of fresh ground shells; Hopper and Smith (1992) reported that, when present in an area, snails are generally found within the first 5 min of searching. Search area tracks were recorded by GPS when possible. If no live snails or fresh ground shells were found during the timed search, the site was recorded as not supporting tree snails. When live tree snails were located within the 30-min visual census period, four 25-m^2 quadrats were established under the densest understory, as determined by a spherical densiometer. All snails occurring within the quadrats were identified to species, and their shell length was measured to the nearest 0.1 mm with sliding vernier calipers. Host tree species were recorded for each snail observed.

Temperature, humidity, and air movement were measured with miniature probes in microhabitats inhabited by tree snails to quantify the "more ultimate ecological conditions which determine the distribution of suitable vegetation," and presumably the distribution of tree snails, alluded to by Crampton (1925). Measurements were also taken in uninhabited areas to assess their suitability for supporting snail populations. These data from inhabited and uninhabited forest were compared to elucidate the minimum conditions for the survival of snail populations.

RESULTS

Four partulid colonies were located during the survey, two at NCTS (Figure 6) and two at the Ordinance Annex (Figure 7). Of the four colonies, only the Haputo colony was previously known.

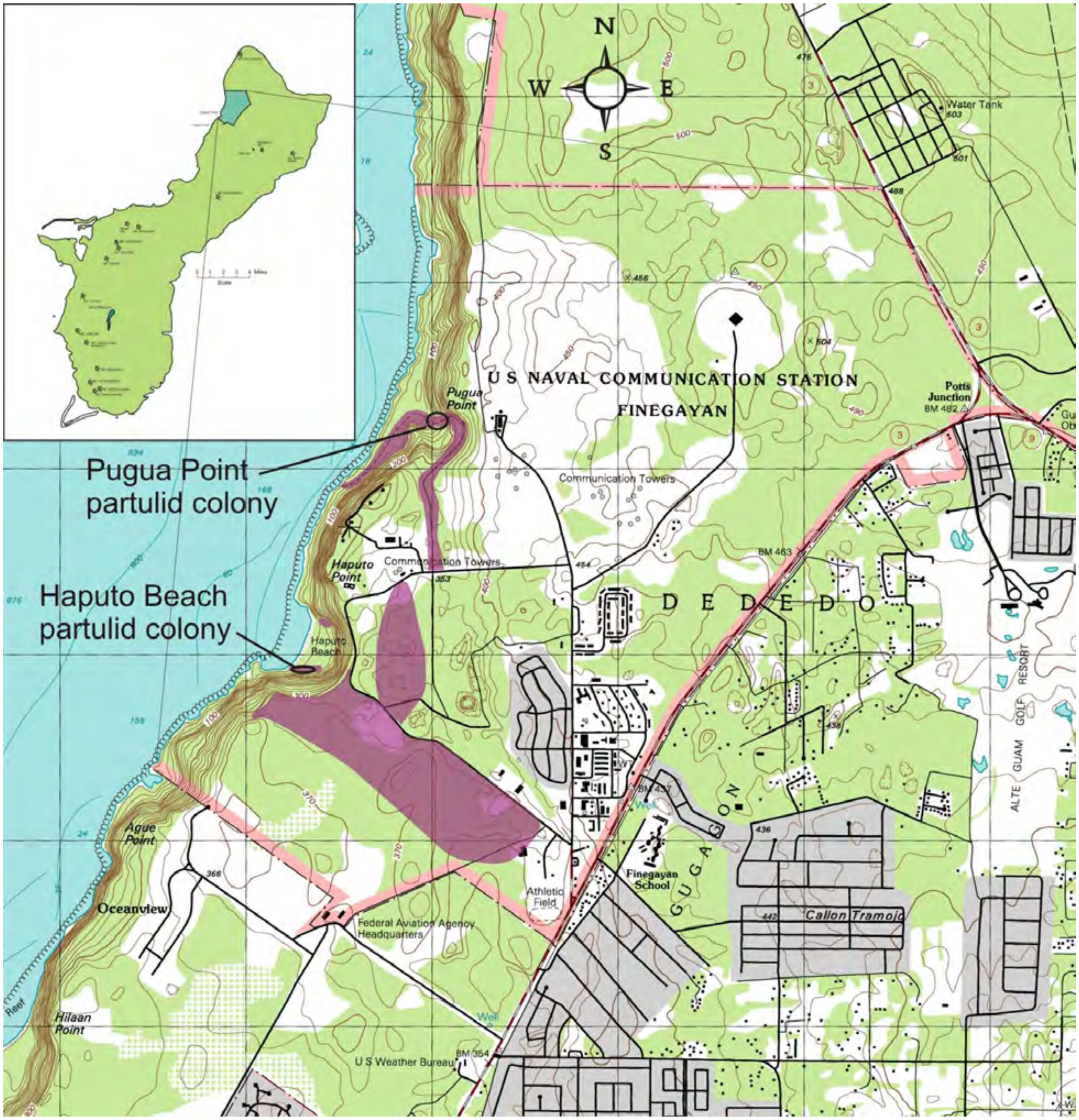


Figure 6. Map of Naval Computer and Telecommunications Station, Finegayan. Surveyed areas are shaded in purple, and locations of partulid colonies are indicated by ellipses.

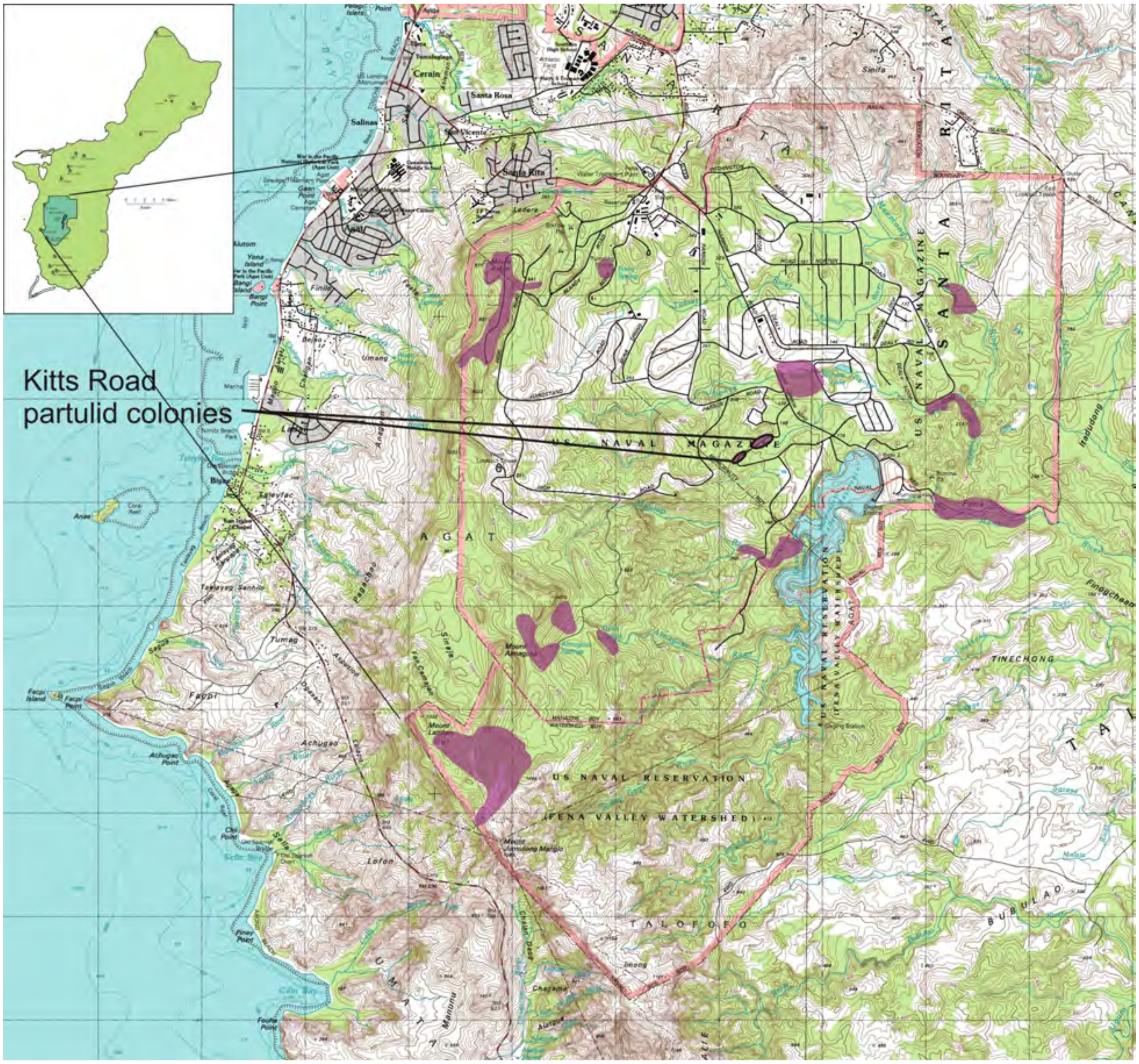


Figure 7. Map of Naval Ordinance Annex. Surveyed areas are shaded in purple, and locations of partulid colonies are indicated by ellipses.

Size-frequency distributions for partulids at the Pugua Point, Haputo Beach, and N. Kitts Road sampling stations are presented in Figures 8, 9, and 10, respectively. In the Pugua Point colony, all three *Partula radiolata* were reproductively mature, as indicated by the presence of a varical lip (see Crampton, 1925). It is not possible to determine the percentage of mature individuals in the *Samoana fragilis* colony because of the unique characteristic of this species to reach maturity before the formation of the varical lip. In the Haputo Beach colonies, some 43% of the *Partula gibba* were reproductively mature, while about 40% of the *Partula radiolata* were mature. Some 33% of the *Partula radiolata* in the N. Kitts Road colony were reproductively mature.

Box plots of the size data for partulid colonies are presented in Figures 11,12, and 13. Box plots provide excellent visual summaries of the smallest observation, the lower quartile (Q1), the median, the upper quartile (Q3), the largest observation, and observations that are considered unusual, or outliers (Tukey, 1977). The box stretches from the lower hinge (defined

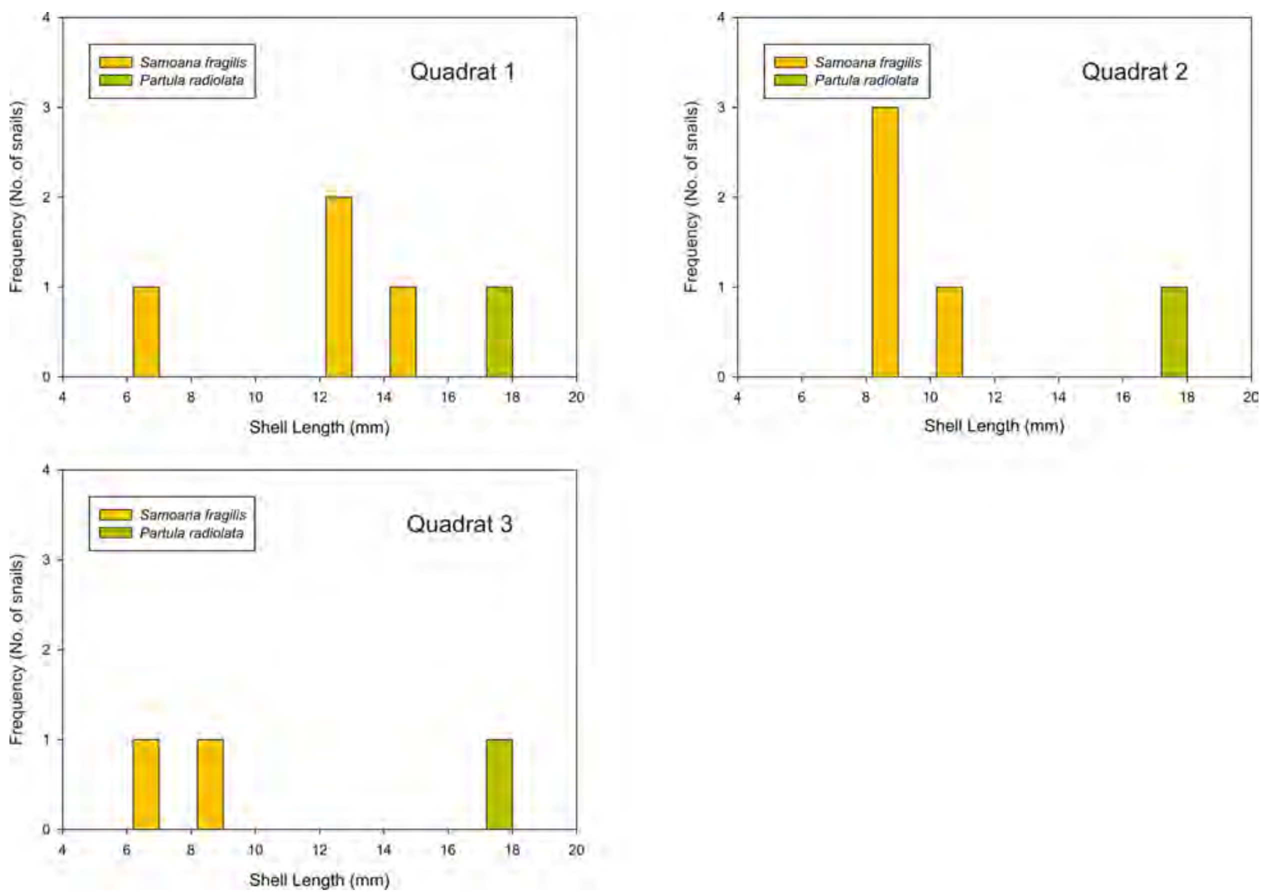


Figure 8. Size-frequency distributions of partulid species at the Pugua Point sampling station, NCTS, Guam. No tree snails were observed in Quadrat 4.

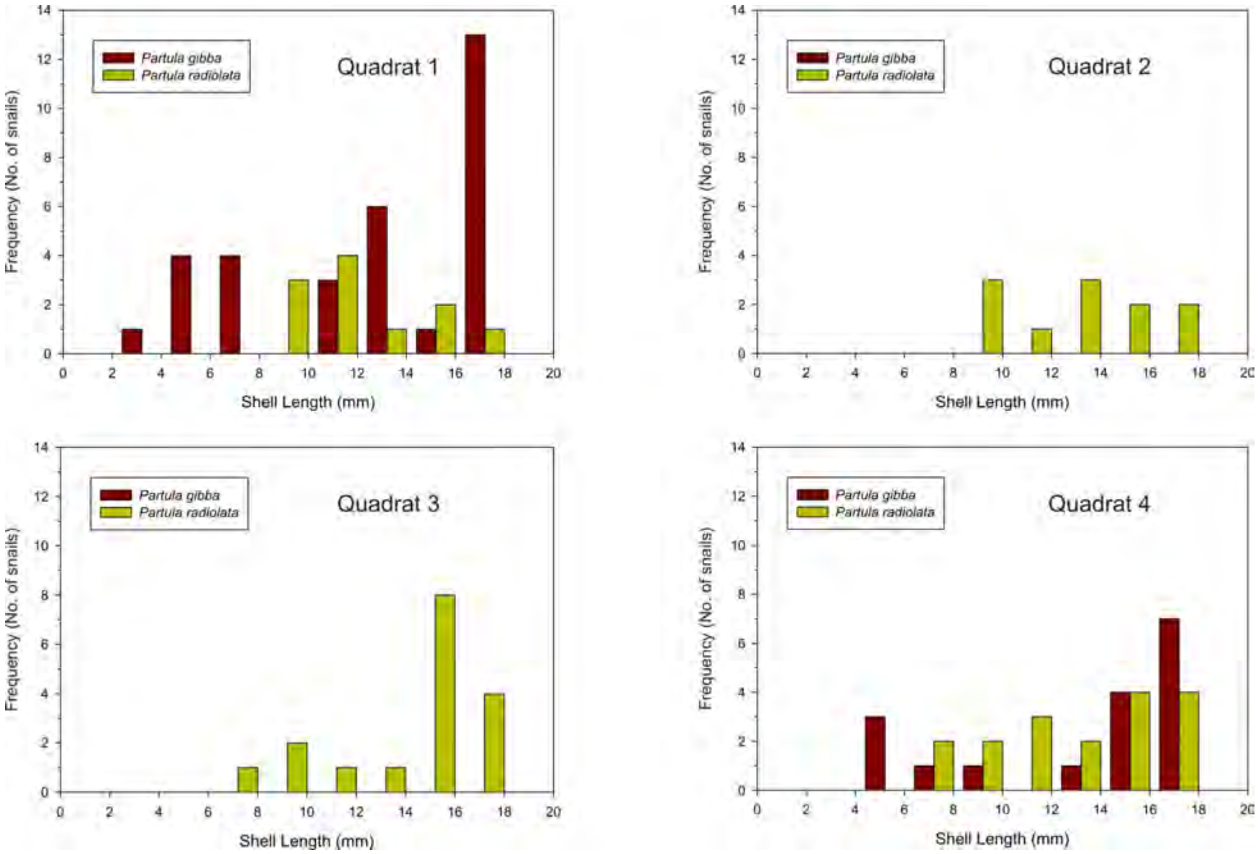


Figure 9. Size-frequency distributions of partulid species at the Haputo Beach sampling station, NCTS. *Partula gibba* was not observed in Quadrats 2 and 3.

as Q1, or the 25th percentile) to the upper hinge (Q3, or the 75th percentile) and therefore contains the middle half of the scores in the distribution. The median is shown as a line across the box. Therefore, one-fourth of the distribution is between this line and the top of the box, and one-fourth of the distribution is between this line and the bottom of the box.

Host plant species for the four colonies of tree snails are presented in Table 1. Of the host plants observed in this study, *Thelypteris* sp. is reported for the first time.

Environmental parameters of the microhabitat of the tree snails are given in Tables 2, 3, and 4, respectively, for Pugua Point, Haputo Beach, and Ordinance Annex. Average canopy cover at Pugua Point was 79% (n=15), and ranged from56% to 97%. At Haputo Beach, average canopy cover was 80% (n=19), and ranged from 67% to 92%.

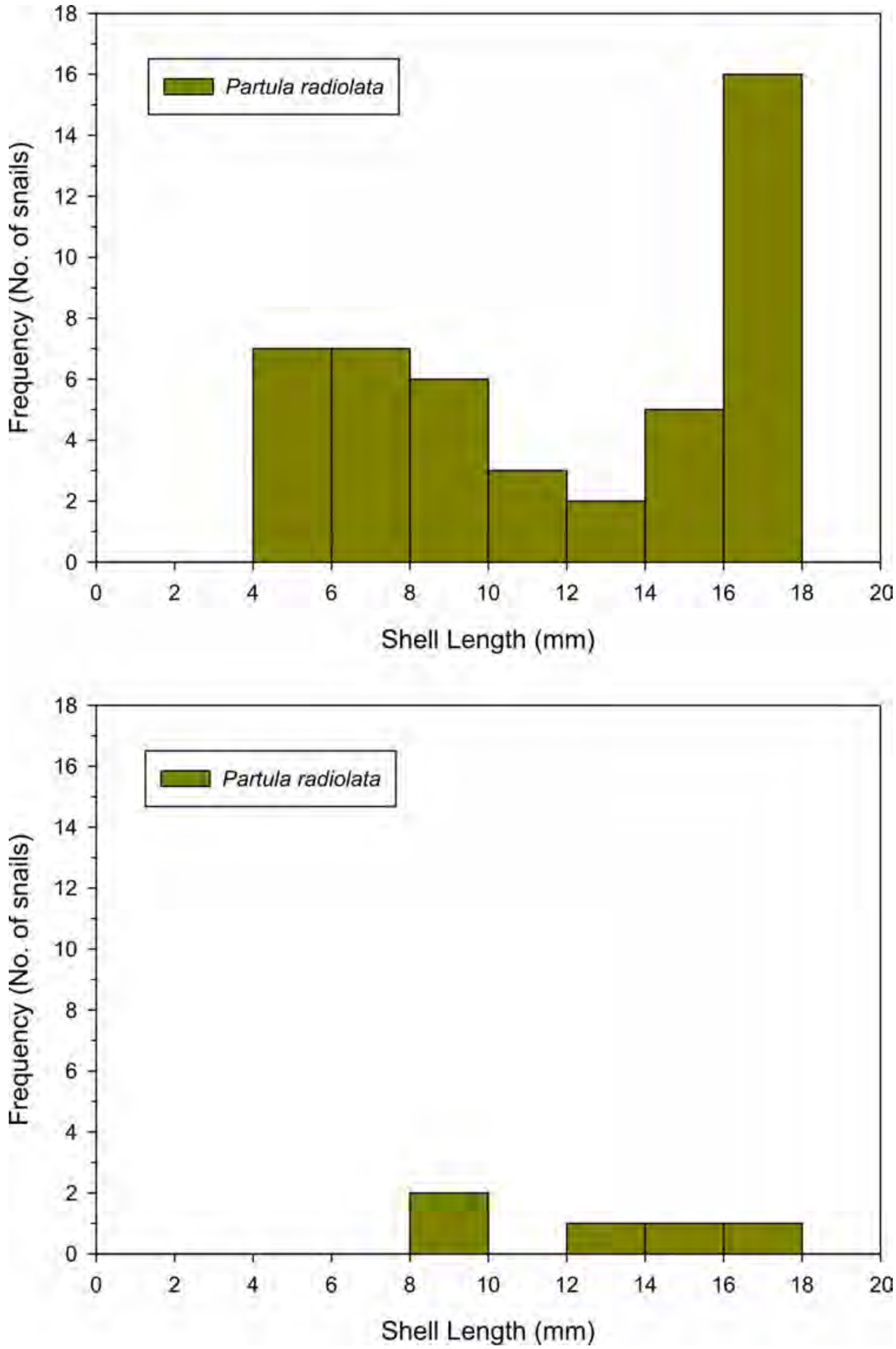


Figure 10. Size-frequency distributions of *Partula radiolata* colonies at the N. Kitts Road sampling station, Naval Ordinance Annex.

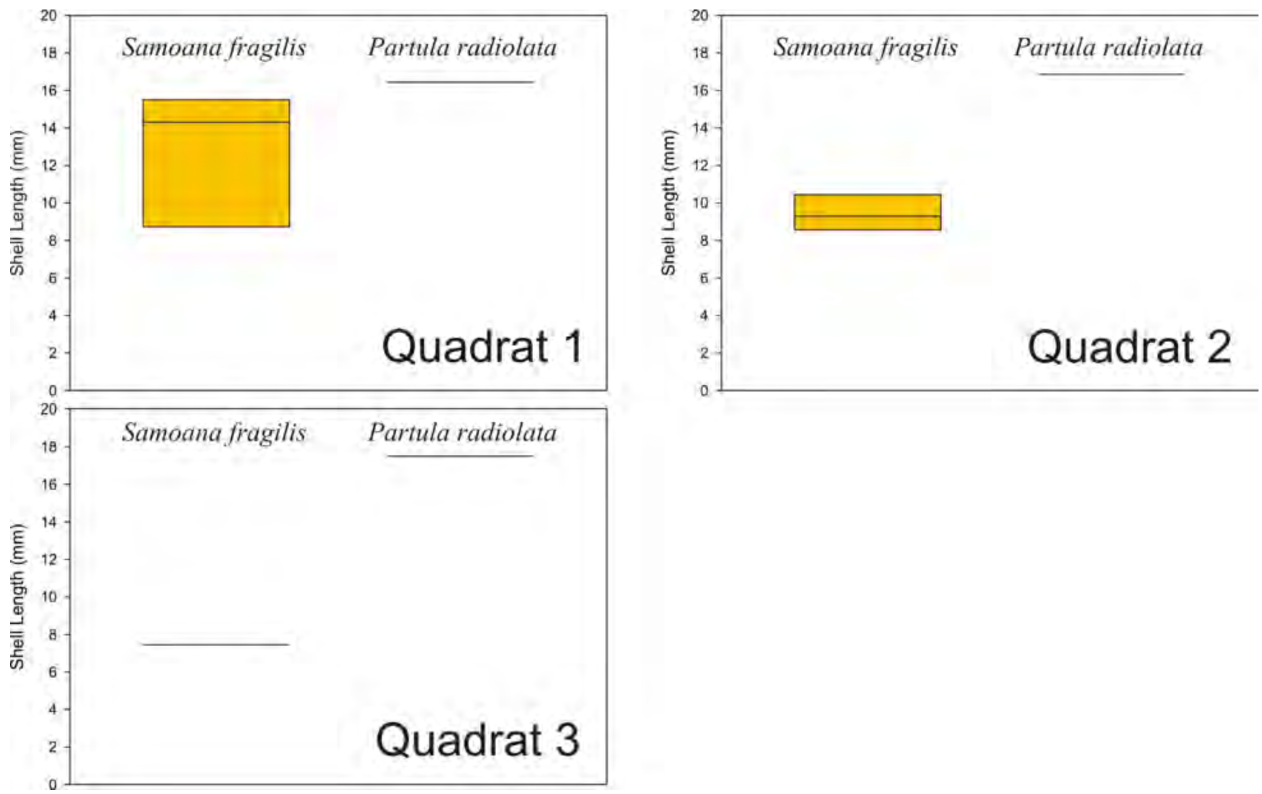


Figure 11. Box plots of shell length of partulid species at the Pugua Point, NCTS sampling station. Lines represent two few data to generate a box.

DISCUSSION

Four colonies of tree snails were observed during this study. The Pugua Point colony is distinct in being dominated by *Samoana fragilis*, a species that has not been observed in Guam since 1996 (A. Asqwith and S.E. Miller, personal communication, March 1996; Smith unpublished data). This is the only colony of *Samoana fragilis* presently known in Guam, and the status of only other reported colony, in Rota, remains to be determined.

Of the four colonies of tree snails found on Naval lands in this study, only the Haputo Beach colony was previously reported (see Hopper and Smith, 1992). None of the colonies were densely populated, and the Haputo Beach population has declined markedly since 1996. In three years of monthly population sampling at Haputo Beach from 1993 to 1995, Smith (unpublished data) found snail densities ranged from a minimum of 4.7 m^{-1} to a maximum of 17.2 m^{-1}. We re-examined the same plot during this survey, and we found that snail density has declined to 2.2 m^{-1}, or fewer than half the minimum density previously observed. This decline has been accompanied, or possibly caused by, a change in forest structure from an understory dominated

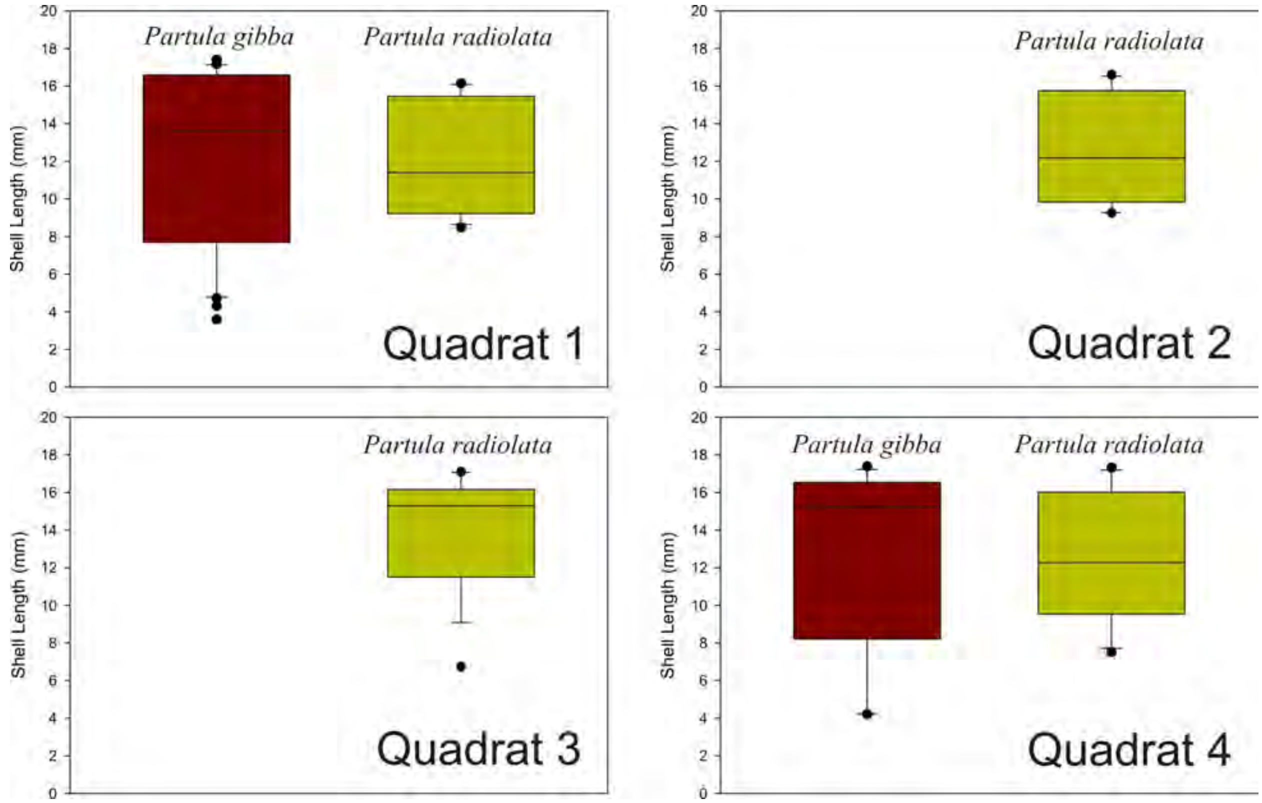
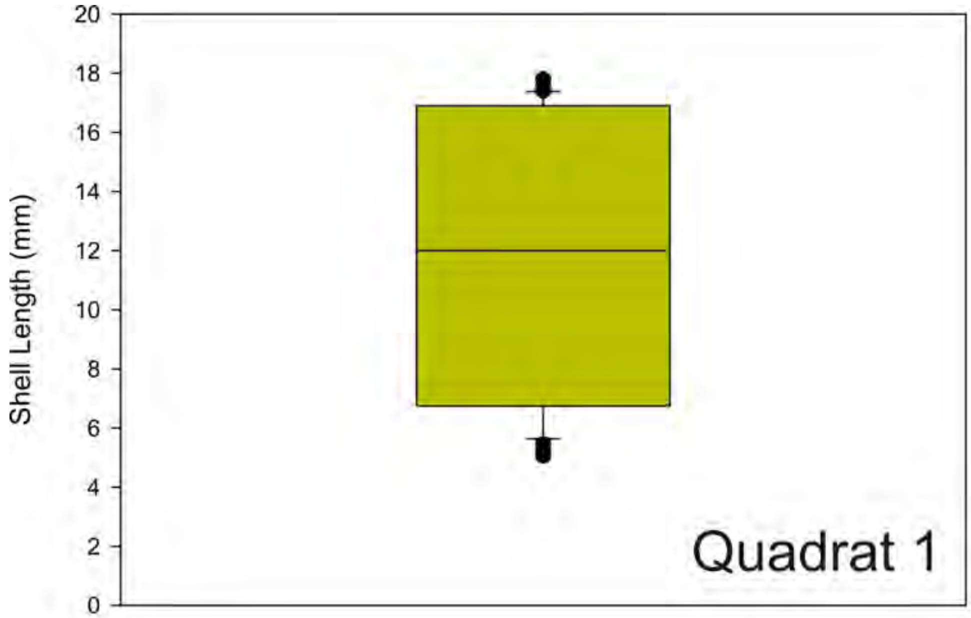


Figure 12. Box plots of shell length of partulids at the Haputo Beach, NCTS sampling station. No *Partula gibba* were observed in Quadrats 2 and 3.

by *Neisosperma oppositifolia*, a preferred host plant species (Hopper and Smith, 1992; Smith, 2007), to one dominated by the fern *Thelypteris* sp., which is here reported as a host plant for the first time. Although partulids were observed on *Thelypteris* sp., only a few snails inhabited them.

Partulids were found throughout the island when Crampton visited Guam in 1920. At sites from Merizo to Ritidian, and from coastal areas to highest elevations. Crampton found snails typically 1 to 3 m above the ground in cool, shaded forest habitats (Crampton 1925; Hopper and Smith, 1992) with high humidity and reduced air movement that might promote dessication. Crampton (1925) described the habitat requirements of the partulid trees snails of the Mariana Islands as: "a sufficiently high and dense growth to provide shade, to conserve moisture, and to effect the production of a rich humus. Hence, the limits to the areas occupied by Partulae are set by the more ultimate ecological conditions which determine the distribution of suitable vegetation." Crampton (1925) further described the intact structure of native Mariana forests as having four general levels: the high trees; the shrubs and *Pandanus*; the cycads and taller ferns; and the succulent herbs. He noted that the Mariana Islands partulid tree snails



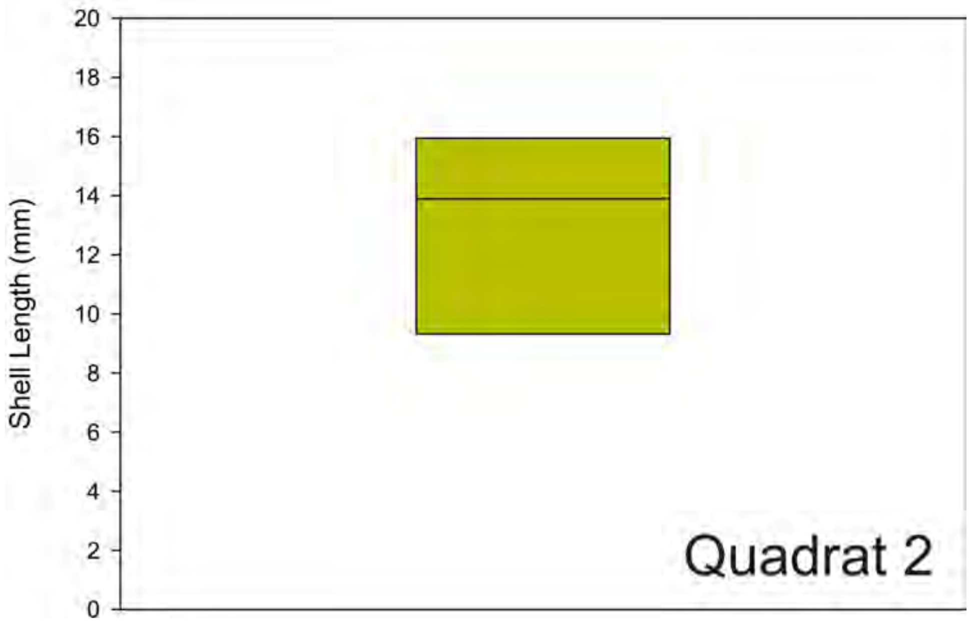


Figure 13. Box plots of *Partula radiolata* shell lengths at the N. Kitts Road, Ordinance Annex sampling station.

Table 1. Plant species hosting arboreal snails at Pugua Point, Haputo Beach, and N. Kitts Road . A filled circle (●) indicates that the snail species was observed on the host plant within one or more quadrats.

Plant taxa	*Partula gibba*	*Partula radiolata*	*Samoana fragilis*
Pugua Point, NCTS			
Annona reticulata		●	●
Haputo Beach, NCTS			
Alocasia macrorrhiza	●	●	
Hernandia sonora	●	●	
Neisosperma oppositifolia	●	●	
Piper guahamense	●	●	
Thelypteris sp.	●	●	
N. Kitts Road, Ordinance Annex			
Hernandia sonora		●	

preferentially live on understory vegetation and did not inhabit the high canopy trees. Habitats satisfying the environmental requirements for tree snails were numerous in the Mariana Islands prior to World War II, including coastal strand vegetation, limestone forest, forested river borders, and lowland and highland forests (Crampton 1925).

Tragically, we found no areas on NCTS or the Ordinance Annex that resemble Crampton's descriptions. While the high trees remain in some areas, the understory has been severely damaged or removed altogether by feral ungulates. Ungulate scats were ubiquitous from the floors of ravines to the summit of Mt. Lamlam. Removal of the understory trees and shrubs has resulted in more xerophytic conditions by allowing greater air motion under the canopy. Air motion promotes desiccation, thereby making conditions unsuitable for the survival of land snails. Data in Tables 2–4 support this conclusion. Ambient temperatures and humidities at the sampling stations are very similar to microhabitat temperatures and humidities. However, ambient air velocities are markedly greater than air velocities in the snails' microhabitat on the undersides of the leaves.

CONCLUSIONS AND RECOMMENDATIONS

Native tree snails in Guam have continued to decline in the last decade. Previously reported colonies at Mt. Alifan have been extirpated since the late 1980s. Elsewhere on Naval

Table 2. Ambient and microhabitat environmental parameters in quadrats at the Pugua Point, NCTS sampling station.

	Temperature (°C)	Relative Humidity (%)	Air Motion (m • sec^{-1})
Quadrat #1			
Ambient	34.7	73.5	0.0–1.1
Annona reticulata	30.5	70.3	0.02
Annona reticulata	30.1	75.5	0.24
Annona reticulata	30.2	75.1	0.06
Annona reticulata	30.3	77.0	0.03
Annona reticulata	31.9	71.2	0.41
Quadrat #2			
Ambient	35.5	77.6	0.0–0.9
Annona reticulata	32.3	61.0	0.25
Annona reticulata	32.3	65.7	0.14
Annona reticulata	31.5	66.2	0.22
Annona reticulata	31.5	66.2	0.62
Quadrat #3			
Ambient	35.9	70.7	0.1–1.0
Annona reticulata	34.1	56.6	0.42
Annona reticulata	33.1	61.6	0.79
Annona reticulata	31.8	69.1	0.34
Quadrat #4			
Ambient	38.0	65.6	0.3–0.8
Annona reticulata	33.9	61.5	0.46
Annona reticulata	33.5	61.9	0.62
Annona reticulata	32.8	60.5	0.23
Annona reticulata	32.4	64.6	0.29
Annona reticulata	32.2	63.4	0.32

Table 3. Ambient and microhabitat environmental parameters in quadrats at the Haputo Beach, NCTS sampling station.

	Temperature (°C)	Relative Humidity (%)	Air Motion (m • sec^{-1})
<u>Quadrat #1</u>			
Ambient	30.9	81.5	0.7–1.0
Alocasia macrorrhiza	28.7	81.1	0.10
Alocasia macrorrhiza	28.4	81.1	0.32
Piper guahamense	28.6	84.2	0.32
Piper guahamense	28.7	84.7	0.03
Thelypteris sp.	28.7	83.7	0.18
Thelypteris sp.	28.7	82.8	0.09
<u>Quadrat #2</u>			
Ambient	31.3	82.1	1.2–1.8
Alocasia macrorrhiza	30.6	75.6	0.56
Alocasia macrorrhiza	30.5	76.0	0.03
Piper guahamense	31.3	74.6	0.21
Piper guahamense	30.9	74.8	0.50
Hernandia nymphaeifolia	30.5	76.3	1.22
Hernandia nymphaeifolia	30.7	75.7	0.44
<u>Quadrat #3</u>			
Ambient	32.4	76.8	0.8–1.4
Neisosperma oppositifolia	31.4	71.5	0.62
Neisosperma oppositifolia	30.9	73.1	0.42
Piper guahamense	30.6	73.5	0.28
Piper guahamense	30.6	74.0	0.21
<u>Quadrat #4</u>			
Ambient	32.5	82.2	0.5–0.8
Alocasia macrorrhiza	30.5	77.9	0.16
Alocasia macrorrhiza	30.4	77.9	0.09
Piper guahamense	30.6	78.5	0.12
Piper guahamense	30.6	77.3	0.29
Thelypteris sp.	30.4	76.9	0.15
Thelypteris sp.	30.6	77.2	0.22

Table 4. Ambient and microhabitat environmental parameters in quadrats at the N. Kitts Road, Ordinance Annex sampling station.

	Temperature (°C)	Relative Humidity (%)	Air Motion (m • sec^{-1})
Quadrat #1			
Ambient	28.1	69.5	0.6–2.9
Hernandia sonora	27.42	69.7	0.1–0.4
Hernandia sonora	26.32	69.7	0.36–0.7
Hernandia sonora	27.12	69.5	0.01–0.02
Hernandia sonora	26.82	69.1	0.01–0.17

lands, dead ground shells are all that remain of once-robust colonies studied by Crampton in 1920. These observations lead to the following recommendations for terrestrial gastropods on Naval lands in Guam.

1. **Conservation management policies should be developed for colonies of endangered snails on Naval lands.**

   Although population declines and extinctions of native taxa are characteristic of the human-populated islands, tree snail colonies on Naval lands should be surveyed on a regular basis to monitor populations of these unique species. Management and conservation efforts should include protection and enhancement of the forest habitat that supports these species. This is especially important for the Pugua Point colony for two reasons: 1) this is the only colony of *Samoana fragilis* known to exist in Guam, and 2) between visits to the Pugua Point site during this survey, a large ifit log (*Intsia bijuga*) was removed from the forest floor in Quadrat 1, indicating that the habitat is at risk of degradation not only by ungulates, but by humans, as well.

2. **Protocols should be developed to manage populations of feral ungulates on Naval lands.**

   Environmental damage resulting from large populations of feral pigs, carabao, and deer at NCTS and Ordinance Annex is extensive. The forested areas of these lands are shrinking, and the structure of the remaining forests has been compromised by overgrazing. In Sarigan in the northern Mariana Islands, the eradication of feral goats was followed by recovery of tree snail populations along with the recovery of the forest in as little as six years (Smith, 2007).

3. **Consideration should be given to construction of ungulate exclusion areas to restore tree snail populations to their former range and former abundance.**

In the absence of ungulate removal, areas fenced to exclude ungulates have been shown to be very effective for restoration of native forests, and, therefore, snail habitat. As noted above, the eradication of feral goats in Sarigan resulted in the growth of dense *Partula gibba* populations, as well as other species of native snails. We examined a small forested area near Bonya Spring on the Ordinance Annex that would be suitable for an exclosure and and habitat enhancement followed by a trial relocation of *Partula gibba*.

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Assessment of Endangered Tree Snails on Department of Defense Lands in Guam

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Introduction

Terrestrial gastropods are possibly the most extinction-prone organisms on oceanic islands (Hadfield et al., 1993; Paulay, 1994). Because most of the land snails on islands are small and relatively drab in appearance, they have not received the attention given to the larger and more formidable vertebrates. Such is the case for the terrestrial snails of the Mariana Islands.

Early reports on terrestrial gastropods of the Mariana Islands were largely taxonomic in character (Férussac, 1821; Pfeiffer, 1846, 1857; Quadras and Möllendorff, 1894a, 1894b). These efforts were followed by investigations of the evolution and status of tree snails in the Family Partulidae (Crampton, 1920; Kondo, 1970; Hopper and Smith, 1992; Smith and Hopper, 1994). Declines and extinctions of terrestrial gastropods of Guam and other Mariana Islands were reported by Hopper and Smith (1992), Smith and Hopper (1994), Bauman (1996), Smith (2008b) and Smith et al. (2008).

While dominated by relatively few families, the land snails on islands of the tropical Pacific exhibit spectacular evolutionary radiations (Cowie, 1996). Despite this diversity, native land snail faunas of the Pacific islands are composed almost entirely of narrow-range endemics. Tragically, these unique native snail faunas are now disappearing rapidly (Lydeard et al., 2004). Documented causes of these extinctions include loss of habitat to agricultural and urban development, alteration of habitat by invasive ungulates, and invasive predators (Hopper and Smith, 1992).

The purpose of this study was to assess endangered tree snail populations on lands proposed for development by the U.S. Department of Defense in Guam, Mariana Islands in support of a Marine Corps relocation initiative to various locations on the island.

Species of Concern

In the first systematic study of the distribution of Mariana partulids, Crampton (1925) reported four species of partulids from Guam, including a newly described, endemic species. Recent surveys indicate that one species of the Guam partulids is extinct, and two other species are on the brink of extinction (Hopper and Smith, 1992; Smith and Hopper, 1994; Smith et al., 2008). As the decline became apparent in the early 1990s, these native snails were listed for protection as endangered species under the Guam Endangered Species Act (5 GCA Chapter 63) and as Candidate Species for protection under the U.S. Endangered Species Act. A taxonomic review of the Guam Partulidae of concern follows.

Partula gibba Férussac, 1821 (FIGURE 1)

Synonymy:

Partula mastersi Pfeiffer, 1857
Partula bicolor Pease, 1872

Description: Shell dextral or 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, white or brown. Aperture oblong-ovate, subquadrangular; peristome reflexed, broadly dilated, usually white, sometimes deep red. Background color variable, chestnut brown to whitish-yellow; also purple. Adult length 14 to 18 mm, width 10 to 14 mm.

Range: *Partula gibba* was the most widely distributed tree snail in Guam in 1920 (Crampton, 1925), but is currently known from just one location (Smith et al., 2008). This species was distributed history in Guam, Rota, Aguiguan, Tinian, Saipan, Anatahan, Sarigan, Alamagan, and Pagan, but extinction have occurred on several islands.

Figure 1. Purple color morph of *Partula gibba* on *Alocasia macrorrhiza* leaf at Haputo, Guam.

Partula radiolata (Pfeiffer, 1846) (FIGURE 2)

Synonymy:

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

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-colored with darker axial rays and brown lines. Adult length 13 to 18.5 mm, width 8 to 12 mm.

Range: *Partula radiolata* is a Guam endemic. It has 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).

Figure 2. *Partula radiolata*, a Guam endemic, on *Alocasia macrorrhiza* at Haputo, Guam.

Partula salifana Crampton, 1925 (FIGURE 3)

Synonymy:
None.

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.

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

Figure 3. *Partula salifana* (paratype, Bishop Museum, Honolulu).

Samoana fragilis (Férussac, 1821) (FIGURE 4)

<u>Synonymy</u>:
Partula quadrasi Möllendorff, 1894

<u>Description</u>: Shell dextral, ovate-conic, narrowly and half-covered perforate, fragile, pellucid. Spire conic, the apex somewhat obtuse; whorls typically 4, 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, a little excised; peristome simple, thin, well expanded, the columella dilated above, recurved, forming a distinct angle with the parietal wall. Background color buff-tinted, semi-transparent; narrow darker maculations and whitish banding due to colors of viscera visible through the shell. Adult length 12 to 16 mm, width 10 to 12 mm.

This species exhibits several reproductive characteristics that are unique among Partulidae. The eggs are large (4.2 mm × 3.3 mm), and they are encapsulated by a tough, calcareous shell (Crampton, 1925). Further, *Samoana fragilis* reaches sexual maturity before it expands the varical lip that characterizes adults of terminal size (Crampton, 1925; Kondo, 1955). The latter trait has not been reported for any other partulid species.

<u>Range</u>: *Samoana fragilis* is the only member of the genus to occur outside southeastern Polynesia. In the Mariana Islands, *Samoana fragilis* has been reported from Guam and Rota.

Figure 4. A juvenile *Samoana fragilis* on *Intsia bijuga* at Pugua Point, Guam.

Methods

Forested areas were surveyed at sites pre-selected by Naval environmental resources personnel (Figure 5). The following areas were surveyed for endangered tree snails:

A. Southern Naval Munitions Site

A total of 2000 m of transects were surveyed for endangered tree snails, including 500-m transects at the EOD pit, Almagosa Springs, the Sadog Gaga River, and the area between EOD pit and Almagosa Springs.

B. Southern Naval Munitions Site – Southern Access Roads

Snail surveys were performed along a 1,126 m transect of Proposed Access Road Option A, extending from the Cetti Bay overlook to the ridge crest below Mt. Lamlam. The survey was restricted to forested areas.

C. FAA

Three transects, 160 m each in length, were surveyed in forested areas.

D. Route 15

Two 500-m transects and one 120-m transect were surveyed in forested areas at this site.

E. Naval Magazine

Three transects totaling 830 m were surveyed at this location (630 m (pipeline), 100 m (NW side of lower Lost River [= Tolaeyuus River]), and 100 m (SE side of lower Lost River [= Tolaeyuus River]).

F. Piti

One 500-m transect was surveyed at this site.

Forested areas along transects were surveyed by visual census methods adapted from Hopper and Smith (1992). Presence or absence of snails was determined by examining leaves of broad-leaved tree species previously reported as host species for partulids (see Hopper and Smith, 1992), including *Hernandia sonora, Guamia mariannae*, *Cynometra ramiflora, Neisosperma oppositifolia, Ochrosia mariannensis, Mammea odorata,* and *Aglaia mariannensis*. All trees occurring within 10 m of the transect line were examined. Some of the designated transects (Sites A–D) were marked by survey teams prior to our work; these transects were subdivided into 10-m segments. For unmarked transects (Sites E–F), we determined overall length and 10-m segments with a hip chain (Chainman II®). Data were recorded for each 10-m segment of all transects. Therefore, each transect consisted of 200-m^2 quadrats. Vegetation along each transect was generally characterized as to species present, population densities of plants, and canopy cover. Observations of dead partulid ground shells were recorded, along with conspicuous dead ground shells of other snail species.

Figure 5. Map of Guam showing locations of the six sites surveyed for endangered tree snails in this study. Each site consists of one or more transects.

RESULTS AND DISCUSSION

Endangered Snails

No living endangered tree snails were observed at any of the sites, totaling 121,120 m^2 in area. Although suitable host tree species were present along most of the transects, the community structure and density of trees were generally not suitable for tree snail habitat. (See Appendix A for detailed descriptions of vegetation on the transects). Crampton (1925) noted that a certain level of complexity in forest structure is necessary to sustain tree snails. A semi-closed canopy is important to shade and cool the underlying forest, but the snails do not inhabit the canopy. Suitable understory vegetation is also required habitat for the snails. Similarly, suitable understory vegetation seldom supports snail colonies without enough canopy structure to cool the forest floor to retain moisture and to provide dead leaves for the snails to consume.

We observed only one dead ground shell of an endangered tree snail (*Partula gibba*) in the total area surveyed, but we also found dead ground shells near transects at three other sites. The FAA transects were near one of the 36 sites where Crampton (1925) observed tree snails, and we observed dead ground shells of *Partula gibba* at three sites (on the trail at Almagosa Spring, on the trail at Route 15–Transect 3, and on the transect at Route 15–Transect 2 (see Figure 5)). Therefore, we can conclude that *Partula gibba*, which Crampton (1925) reported as the most abundant and widely distributed species of tree snail in Guam, historically inhabited at least four of the sites surveyed in this study.

The dead ground shells of *Partula gibba* were very old, but we cannot provide a reliable estimate of how long the shells have been present, because there are few reports on the rate of dissolution of the empty shells of small gastropod shells in leaf litter, and none from Pacific islands. Factors that contribute to dissolution of dead shells include rainfall, pH of soil and leaf litter, exposure to sunlight, and bioerosion (Cadée, 1998, 1999; Barrientos, 2000 Pearce, 2008). Barrientos (2000) reported the complete disappearance of shells <5mm in shell length in ten months in Costa Rica. Menez (2002) reported that exposure to sunlight and small shell size favored postmortem shell deterioration, independently of background coloration. Pearce (2008) reported an average decomposition rate of 6.4% for dead shells in temperate forests, yielding an estimated shell half life of 11.5 years. Cadée (1998, 1999) reported the rate of rainwater dissolution of dead shells at some 1% per month. Thus, the likelihood is quite low that the half-life of an assemblage of small, empty snail shells in litter/soil in temperate or tropical areas is more than a decade or two. Therefore, the dead shells observed in the present study may be no more than about 20–25 yr old, indicating that the decline of Guam’s tree snails may be a relatively recent event.

Figure 6. Dead shell of *Partula gibba* collected on Transect 2 at the Route 15 site. Note the pitted surface of the shell resulting from rainwater dissolution.

<u>Other Land Snails</u>

A complete list of land snail species recorded during this study is presented in Table 1. Of the 12 species observed on the transects, only four species were found alive. Of the 12 species, five are considered invasive species, including three of the four live species.

The geographical distribution of the three most commonly observed species is presented in Table 2. The Okinawan endemic snail *Satsuma mercatoria* was observed on 11 of the 15 transects, and occurred as living specimens on seven transects. The giant African snail *Achatina fulica*, which was introduced into Guam during World War II (Eldredge, 1988), was observed on 12 of the 15 transects, but none were alive. The rosy wolf snail *Euglandina rosea*, which was introduced into Guam to prey upon the giant African snail (Eldredge, 1988), was observed as dead specimens on six transects.

Table 1. Taxonomic list of land snails observed in the present study. A closed circle (●) indicates a living specimen, and an open circle (○) indicates a dead specimen.

Species	Living/Dead	Native/Invasive
Paludinella conica	●	I
Melanoides tuberculata	○	N
Pomacea canaliculata	●	I
Pythia scarabaeus	○	N
Subulina conica	○	N
Succinea piratarum	○	N
Partula gibba	○	N
Achatina fulica	○	I
Euglandina rosea	○	I
Lamprocystis misella	○	N
Satsuma mercatoria	●	I
Veronicella cubensis	●	I

Table 2. Geographic distribution of the three most commonly observed snail species during this survey. A closed circle (●) indicates a living specimen, and an open circle (○) indicates a dead specimen.

Transect	*Satsuma mercatoria*	*Achatina fulica*	*Euglandina rosea*
Sadog Gago	●○	○	○
Almagosa River (upper)	●○	○	
Almagosa Spring	●○	○	○
Almagosa River (lower)	●○	○	○
FFA Transect 1	○	○	○
FFA Transect 2	●○	○	
FFA Transect 3	○		
Rte 15 Transect 1	○		○
Rte 15 Transect 2		○	
Rte 15 Transect 3	○		
Piti Power Plant	●○	○	
Lost River Transect 1		○	○
Lost River Transect 2		○	
Lost River Transect 3	●○	○	
Southern Access Roads, Option A		○	

Invasive Species and Endangered Tree Snails of Guam

Invasive species affect the native snail populations in three ways: 1) by competing for habitat, 2) by preying upon native snails, and 3) by degrading or destroying snail habitat. Although competition between tree snails and invasive species has not been demonstrated by empirical data, two species of invasive snails occur sympatrically with Guam partulids. The first record of *Satsuma mercatoria*, an Okinawan endemic snail (Figure 7) , was at Mongmong in 1984 (B.D. Smith, unpublished data). From that locality, this species rapidly dispersed throughout the island, and specimens were found on Mt. Lamlam by 1989 (B.D. Smith, unpublished data). *Satsuma mercatoria* feeds upon decaying vegetation, as do Guam partulids. Therefore, competition for food may be occurring where the species are sympatric.

A second invasive species of snail that can be found sympatrically with Guam partulids is *Drymaeus multilineatus* (Figure 8), which occurs naturally in southern Florida and the Gulf Coast. This species was first recorded in Guam in 1992 (Smith, 1995). From the Tumon area, the species has dispersed throughout the island. Generally, *Drymaeus multilineatus* inhabits more xerophytic environments than Guam partulids, but the two species do occur sympatrically at several localities in Guam. The diet of *Drymaeus multilineatus* in Guam is unknown, so competition may or may not occur.

Figure 7. A copulating pair of *Satsuma mercatoria* on the underside of a *Hibiscus tiliaceus* limb near the Ylig River, Guam. A third specimen is visible just behind the pair.

Figure 8. The invasive snail *Drymaeus multilineatus* was first reported in Guam in 1992 (Smith, 1995).

Eldredge (1988) reviewed the history of the introduction of the giant African snail *Achatina fulica* in Micronesia followed by introductions of several predatory snail species introduced to control. Introduced accidentally in Guam during World War II, *Achatina fulica* quickly dispersed throughout the island because of its considerable fecundity, becoming an agricultural pest species before the end of the decade. Efforts to control *Achatina fulica* focused on introduction of predators, initially predatory snails. Field testing conducted on Aguiguan under the auspices of the Insect Control Committee for Micronesia of the Pacific Science Board suggested that the cannibal snail *Gonaxis kibweziensis* would be effective in reducing African snail populations, and the cannibal snail was released in Guam and elsewhere. With persistence of large *Achatina fulica* populations through the mid-1950s, a second predatory snail, the rosy wolf snail *Euglandina rosea* was released in Guam in 1957. Neither predatory snail species was very effective against the African snail in Guam.

The triclad planarian *Platydemus manokwari* 'mysteriously' appeared in Guam in 1978 (Muniappan, 1983). This terrestrial flatworm is a generalist predator of snails, so it does not prey only upon *Achatina fulica*, but upon the smaller, more easily subdued native snails (Figure 9). Since its appearance in Guam, *Platydemus manokwari* has spread throughout the island. African snail populations have declined since *Platydemus* appeared, but evidence from other Pacific islands indicates that African snail populations decline naturally after a period of explosive growth, even when no predators are introduced (Tillier and Clarke, 1983). Guam native snail populations have declined significantly along with the African snail, and as many as 67% of the indigenous snail species may now be extinct (B.D. Smith, unpublished data).

Figure 9. A *Playdemus manokwari* crawls away from the empty shell of a *Partula gibba* that it preyed upon. Note that the snail shell is cemented to the tree limb by a very viscous, adhesive mucus produced by the flatworm.

Environmental damage resulting from large populations of ungulates was ubiquitous at the survey sites. Feral pigs and deer have caused extensive damage to the forests of Guam (Smith et al., 2008). Forested areas are overcrowded by ungulates, and consequently forested lands are shrinking. Grazing by deer and uprooting by pigs have affected the structure of the remaining forests, and the habitat has been compromised by overgrazing. However, it may not be too late to save the remaining forests. In Sarigan in the northern Mariana Islands, the eradication of feral goats was followed by recovery of tree snail populations along with the recovery of the forest in as little as six years (Smith, 2008a).

RECOMMENDATIONS

1. **Protocols should be developed to assure that no new invasive species from Okinawa are introduced to Guam and Micronesia as a result of the relocation of the Marine forces.**

It is imperative that the relocation the Marine base from Okinawa to Guam does not introduce new invasive species to Guam and Micronesia. The native species of Guam likely cannot survive another invasive equivalent of the brown tree snake *Boiga irregularis,* which was introduced into Guam with war materiel from the Solomon Islands during World War II and extirpated the native avifauna (Savidge, 1987). The very existence of the Okinawan snail

Satsuma mercatoria in Guam is more than adequate evidence that such introductions are possible.

2. Conservation management policies should be developed for the remaining colonies of endangered tree snails in Guam, especially those on Naval lands.

Although population declines and extinctions of native taxa are characteristic of the human-populated islands, remaining tree snail colonies on Naval lands should be surveyed on a regular basis to monitor populations of these unique species. Management and conservation efforts should include protection and enhancement of the forest habitat that supports these species. This is especially important for the Pugua Point and Haputo colonies (see Smith et al., 2008). Pugua Point is inhabited by the only colony of *Samoana fragilis* known to exist in Guam, Haputo is the only site where *Partula gibba* remains in Guam. Visits to these sites in October 2010 revealed that the colonies are diminishing still, with only five *Samoana fragilis* observed at Pugua Point and only 17 *Partula gibba* observed at Haputo (B.D. Smith, unpublished data).

3. Protocols should be developed to manage populations of feral ungulates on Naval lands.

Environmental damage resulting from large populations of feral pigs and deer in forests throughout the island is extensive. The forested areas of these lands are shrinking, and the structure of the remaining forests has been compromised by overgrazing. In Sarigan in the northern Mariana Islands, the eradication of feral goats was followed by recovery of tree snail populations along with the recovery of the forest in as little as six years (Smith, 2008a).

4. Consideration should be given to construction of ungulate exclusion areas to restore tree snail populations to their former range and former abundance.

In the absence of ungulate removal, areas fenced to exclude ungulates have been shown to be very effective for restoration of native forests, and, therefore, snail habitat. As noted above, the eradication of feral goats in Sarigan resulted in the growth of dense *Partula gibba* populations, as well as other species of native snails.

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We are most grateful for the assistance of Ms. Claudine Camacho of Dueñas, Camacho, & Associates (DCA) in directing us the predetermined transect sites; Ms. Camacho not only provided maps and satellite images showing the locations, she also accompanied us into the field at several sites that were more difficult to find. We thank Ms. Lauren Gutierrez for her assistance in identifying some of the plant species that we encountered. We also thank the officers and staff of COMNAVMAR for their support and assistance in accessing sites on Department of Defense lands.

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APPENDIX A: FIELD NOTES RECORDED DURING AN ASSESSMENT OF ENDANGERED TREE SNAILS ON DEPARTMENT OF DEFENSE LANDS IN GUAM

TABLE OF CONTENTS

INTRODUCTION

In addition to determining the abundance of tree snails at the pre-selected sites, a secondary objective of the study was to record observations of various environmental factors that could possibly provide some insight in regard to present and historical snail distribution, diversity, and abundance. Factors that were thought to influence such information at transect sites include: 1) general physical geography, 2) type of rock unit that the transect area is developed upon, 3) type of soil developed within the transect area, 4) type of vegetation developed within the transect area, 5) physical and biological disturbance of soil and vegetation within the transect area, 6) snail predators observed within the transect area, and 7) presence of other dead or alive snail species within the transect area,

For each site, a brief 'Introduction' is given in which the location of the site is described, along with an explanation of how the site was accessed and weather conditions during the site survey. In the following order, short descriptions of the 'General Physiographic and Geologic Setting of the Survey Site', 'Soil Development Within the Survey Site', 'Vegetation Within the Survey Site', and 'Snail Survey Results' are provided for each survey site.

The 'General Physiographic and Geologic Setting of the Survey Site' section provides a brief description of the terrain, slope, and geologic rock formation exposed at the site, and where appropriate, a short historical development of the rock unit is given. The 'Soil Development within the Survey Site' section gives a brief classification of the soil, soil color, drainage characteristics, and soil origin. The 'Vegetation within the Survey Site' section describes the forest type (savanna, limestone forest, etc.), forest stature, and predominant or conspicuous species of the canopy, second story, ground story, and ground cover. The 'Snail Survey Results' section provides the number and identification (taxa) of living tree snails observed, along with their host vegetation species, as well as the number and identification of dead snails observed along the transect.

Locations of the snail surveys are shown on sections of USGS topographic quadrangle maps and GoogleEarth satellite images. During reconnaissance surveys of the transect sites, one of us (Randall) recorded all the observations and comments at each site in waterproof field notebooks. These notes were written in abbreviated form, along with hastily drawn sketches, and then they were transcribed within a day or two for clarity and comprehension while fresh in the observer's mind. Photos were also taken to support our observations and data.

LOG OF ACTIVITIES

1. March 27, 2009: Sadog Gago River Valley Transect No. 1 (see RHR 1810 Field Notes).

2. May 1, 2009: Almagosa River Valley, EOD Upper Transect No. 2(see RHR 1811 Field Notes).

3. May 6, 2009: Almagosa Spring, Transect No. 9, Stations 250 m thru 500; and Transect No. 9 Annex (see RHR 1812 Field Notes).

4. May 8, 2009: Almagosa Spring, Transect No. 9, Stations 250 m thru 0 m (See RHR 1812 Field Notes).

5. May 11, 2009: Almagosa River Valley, EOD Lower Transect No. 11 (see RHR 1813 Field Notes).

6. May 15, 2009: FFA, Transect No. 3 and Transect No. 2 (see RHR 1814 Field Notes).

7. May 19, 2009: FFA, Transect No. 1 (see RHR 1814 Field Notes).

8. May 22, 2009: Rt. 15, Transect No. 1 and Transect No. 2 (see RHR 1815 Field Notes).

9. May 29, 2009: Rt. 15, Transect No. 3 (see RHR 1815 Field Notes).

10. June 2, 2009: Piti Power Plant No. 1 (see RHR 1816 Field Notes).

11. July 7, 2009: Tolaeyuus River Transect No. 1 and Transect No. 2 (see RHR 1817 Field Notes).

12. July 9, 2009: Tolaeyuus River Transect No. 3 (see RHR 1817 Field Notes).

13. July 22, 2009: Naval Magazine, Option 1, Rt. 4 Access Road, Transect 1 (see RHR 1818 Field Notes).

RHR 1810 FIELD NOTES

(Sadog Gago River Valley Transect)

Date: March 27, 2009

Geographic Location: Guam, Sadog Gago River Valley

<u>Introduction</u>

This is the first field excursion of the land snail survey project conducted by Barry D. Smith (Associate Professor at the University of Guam Marine Laboratory) and Richard H. Randall (Professor Emeritus at the University of Guam Marine Laboratory) to fulfill the objectives of a 'Proposal to Assess Endangered Tree Snails on Department of Defense Lands in Guam'.

During the late afternoon of March 26, 2009, Mr. Barry Smith of the University of Guam Marine Laboratory notified me that our first field excursion for the land snail survey project would take place March 27, 2009 at the U. S. Navy Ordnance Annex, and I was asked to meet him at the University of Guam Marine Laboratory at 0700. He informed me that the survey was located in the upper valley of the Sadog Gago River and it that would be accessed by kayak from the north end of Fena Reservoir to its mouth at the southern end of the reservoir. From there we would hike upstream from the river mouth to the transect area located just above its confluence with the Imong River (Map Fig. 1810-1). We briefly discussed what kind of equipment and gear to take along for the excursion. Map Figure 1810-2 shows the approximate location of Transect No. 1.

On the morning of the 27th, we met at the University of Guam Marine Laboratory at 0700, where we loaded our gear into his pickup truck and then proceeded to the Main U. S. Navy Base at Apra Harbor, where we obtained passes to enter the U. S. Naval Ordnance Annex. Upon arrival at the U. S. Naval Ordnance Annex at 0830, we awaited just outside the main gate for arrival of Ms. Claudine Camacho and her field assistants from Dueñas, Camacho & Associates (DCA), who were to accompany us to the survey transect location. Upon their arrival we transferred to their vehicle, entered the reservation and proceeded to the EOD (Explosive Ordnance Disposal) Office, where we each read a one-page 'Training Brief' for contractors working on the base near the disposal site. After signing the training brief and login sheet, we proceeded via a macadam paved roadway to the northwest shore of Fena Reservoir, where an old pier was located. The shoreline region here had been cleared of woody vegetation and is presently being maintained as a grassy lawn. The beachside shoreline had at some earlier time been nourished with a veneer of base course-fill that appeared to be of Alifan Limestone, judging from its fossil content and textural characteristics; probably obtained from the nearby Mt. Alifan Borrow Pits.

The weather was mostly cloudy and punctuated with scattered squall-like light rain showers.

<u>Access to the Transect Site</u>

Fena Reservoir Leg

Three persons of the DCA Team brought a Coleman Ram 15-foot canoe for their mode of transportation to the mouth of the Sadog Gago River, and we were to use two single-person 10-foot kayaks that were already stored at the shoreline site for our transportation (Text Figures 1810-1 and 1810-2). There was a mild northeasterly wind present that produced small wavelets on exposed parts of the reservoir; on more protected parts, the water surface was relatively smooth. With such a mild wind the kayaks handled quite nicely, and we made the trip from the launch area to the Sadog Gago River mouth, a distance of 2.6 km, in about one hour. The reservoir water level was about 1.5 m lower than a rather pronounced high-water mark along the shoreline; probably the dam spillway elevation. Water clarity was quite clear in respect to other times that I have been on the reservoir, and appeared to be free of submerged and floating aquatic vegetation, except along shallow muddy shoreline regions at river mouths, where the most conspicuous vegetation was partly emergent bright green beds of the aquatic fern *Ceratopteris gaudichaudii* (Text Figures 1810-3, 1810-4, and 1810-5). Such fern beds were quite abundant around the sandy and muddy shallows of the southern part of the reservoir, particularly around the mouth of the Sadog Gago River, where still-living stranded patches were found growing on emergent sandbars. A partly emergent specimen was collected from the river mouth; the specimen was pressed, dried, and donated to Dr. Lynn Raulerson for inclusion into the University of Guam Herbarium (Spec. No. 1810-3). While traversing the length of the reservoir, several surface disturbances by fish were noted, and at the mouth of the river, light-colored spawning female tilapia (*Oreochromis mossambicus*) were observed along with darker-colored males in shallow, coarse-grained sand flats.

General Physiographic and Geologic Setting of the Survey Site

West Shore of Fena Reservoir Leg

The entire land region surrounding Fena Reservoir and its flooded valleys is developed upon the Bolanos Pyroclastic Member (Miocene) of the Umatac Formation (Tracey et al., 1964). Although Tracey et al. (1964) mapped a narrow corridor of Dandan Flow Member deposits to the Fena Reservoir shoreline at the location where we launched our kayaks, we could not find any evidence of such deposits. Instead, we found Bolanos pyroclastic deposits with numerous limestone pebble- to cobble-sized clasts of the Geus River Member embedded within the deposits. A partially embedded cobble was collected (Spec. No. RHR 1810-2), which is described in the 'Collections' section below. At the reservoir, these deposits are dominated by tuff breccias, conglomerates, and sandstones consisting largely of fragmented andesite. The following remarks and observations are restricted to shoreline reservoir deposits exposed between a previous well marked high water line and the present lower water level along the western shoreline. At several places, 1.0–1.5-m vertical exposures of the deposits were observed by paddling close to the shoreline, as shown in Text Figures 1810-6 and 1810-7. The freshest exposed deposits of the rock are a dark grayish-brown to greenish-brown with an overall speckled appearance. Weathered deposits are a lighter, speckled gray to pink or red where intensely weathered. All the exposed sections that we observed within the shoreline exposures contained abundant granule- to boulder-sized limestone fragments, as well as thin, interbedded conglomeritic limestone lenses of the Geus River Member (Oligocene) of the Umatac Formation intercalated within the volcanic matrix (Text Figures 1810-6 and 1810-7). These limestone inclusions ranged from well rounded to angular in shape, and when fractured, revealed a white, dense, compact, fine-grained to conglomeratic recrystallized detrital limestone. When observed with a hand lens, some of the larger identifiable fragments included foraminifers, molluscs, calcareous algae, and corals. The limestone clasts consist of fragments as well as whole and worn coral colonies. In Schlanger's (1964) classification system, these clasts include limestones from reef-wall facies, lagoon facies, forereef facies, transitional facies, and basin facies—all mixed together, indicating that they have been transported from their original sites of deposition and have become incorporated into the pyroclastic volcanic deposits of the Bolanos Pyroclastic Member, probably by explosive volcanism and subsequent transport. Angular and sub-rounded clasts indicate little transport, whereas worn rounded clasts indicate considerable more exposure to erosion and transport. In addition to limestone fragments intercalated within the volcanic matrix, horizontal lenticular beds of conglomeritic limestone up to 1 m or more in thickness and up to 50 m or more in horizontal extent were observed at six locations as well. Text Figures 1810-6 and 1810-7 show one of these lenticular beds in a vertical exposed section along the western shoreline of Fena Reservoir. The lithology of these lenses is the same hodgepodge of facies as that of the limestone clasts intercalated within the volcanic matrix above and below it. At places the lens accumulation is rather contiguous and of a pure detrital limestone, with little sign of volcanic contamination, and possibly originated as a detrital accumulation from a nearby reef facies during a lull in active volcanism. Such analogs are found in the active northern volcanic islands of the Mariana Islands, where small apron and incipient fringing reefs develop during a lull in volcanic activity. Such reefs in the northern volcanic islands accumulate peripheral beds of forereef detrital reef material, which then become overlain with pyroclastic deposits from renewed volcanism. No beds that could be inferred as a reef facies were observed at Fena Reservoir.

Sadog Gago River Valley Leg

We beached our canoe and kayaks on a sandbar at the mouth of Sadog Gago River (Text Figure 1810-8), which debouches at the very southern tip of the reservoir. The following description is based upon hiking observations between the river mouth and upstream to about 750 m beyond the confluence of the Imong River. From some maps of this region there appears to be some confusion as to which of these rivers is a tributary of the other. From our observations, as well as from earlier investigations (Field Notes RHR 1234), it appears that the Imong River is smaller in relation to volume flow than the Sadog Gago River. Thus, the Sadog Gago River is here considered the main river that debouches into the reservoir, and the Imong River is a tributary of it. During flood stage, the river apparently becomes a raging torrent, because high-water drift debris was noted at approximately 4–5 m above the river floor at the confluence of the Imong River.

The V-shaped river valley of the Sadog Gago is cut into the Bolanos Pyroclastic Member of the Umatac Formation, and where exposed (mainly in the river bed) is similar in lithology to that is exposed at places along the Fena Reservoir shoreline. Like the exposures along the Fena Reservoir shoreline, abundant limestone clasts of Geus River Member are intercalated into the pyroclastic deposits. At its mouth, the river is presently about 10–15 m wide (Text Figure 1810-8) and gradually narrows upstream. The actual river mouth location is ephemeral, migrating upstream when the reservoir water level rises and downstream as the water level lowers. The water flows as a shallow, rippling current over a relatively flat, gently sloping bed of volcanic rock, except for a few deeper pools of wading depth, as shown in Text Figure 1810-9. Small aquatic snails (*Thiara granifera*) form dense aggregations along the lower river valley, where shallow water flows over algal-coated bedrock, as shown in Text Figures 1810-10, 1810-11, and 1810-12.

From the present river mouth to the transect location, the river bed rises from the reservoir spillway elevation of 33.8 m (111 ft) to 54.8 m (180ft). Thus, the river has a brisk, riffle-like flow along much of its length. Slower-moving water occurs in pools that are generally less than 10 m in length. One waterfall was encountered, where the water cascaded over a high-gradient slope (ca. 30 to 40 degrees) about 30 m long, with a total fall of about 4 to 5 m (Text Figure 1810-13). A deep plunge pool, possibly 3 m or more in depth, is eroded into stream bedrock at the base of the falls. Near the river mouth, several relatively recent, large rotational slumps have exposed concave slip faces up to about 10 m in height. These slip faces display weathered pink to red pyroclastic tuff. Overall bedrock topography of the river consists of an irregular flight of low, stair step-like offsets, generally less than 50 cm high, that are controlled by joint spacing in the volcanic rock. At three locations the volcanic bedrock is interrupted by lenticular beds of limestone that have the same overall lithology as the shoreline limestone beds along the Fena Reservoir. One of these limestone beds located at the confluence of the Imong

River displays several tilted large limestone blocks up to 1 m in thickness and 3–4 m in length. These blocks have been wedged out from their original horizontal position, as shown in Text Figure 1810-14. Similar, but thinner (< 1 m thick) limestone lenses outcropped on valley slopes well above the riverbed elevation along Transect Stations 410 m and 450 m, at a higher elevation than the riverbed lens. Commonly, loose limestone cobbles and boulders could be found downslope of these thin lenses.

The bedrock river floor is mostly veneered with coarse sand- to boulder-sized material along low gradient slope stretches that are interrupted at places by bare bedrock stretches of variable length along higher slope gradient regions. Conspicuous block-sized pieces of volcanic and limestone rock are also scattered along the riverbed, as well. Although some sand-sized material is trapped among the coarser clasts, most occurs as ephemeral small bars along low-gradient stretches that accumulate as the river flow is reduced from high-flow to low-flow condition. With the next high-flow event, these clasts will again be re-mobilized and transported downstream. Most of the loose river floor clastic material consists of tuffaceous sandstone that is similar in texture to that of the river bedrock, but more variable in color, depending upon the degree of weathering. Less-weathered clasts are a dark grayish-brown to greenish-brown with an overall speckled appearance, like that of the river floor bedrock. More-weathered clasts include various speckled shades of pale brown, green, and pink. Many of the gravel- to cobble-sized clasts that are subaerially exposed on bars are so weathered that, during short periods of low flow conditions, they become partly to completely disintegrated by desiccation into a pile of loose fragmented material. It is not uncommon to find ten or more such clasts in varying stages of disintegration within a 1-m^2 area of such exposed loose material (Text Figure 1810-14). Much less abundant, but conspicuous among the dark-colored pyroclastic volcanic clasts, are worn, dense, white limestone clasts of various sizes of the Geus River Member, as well as weathered, pale tan to pale green pebbles and cobbles of tuffaceous shale and mudstone. Since no deposits of such shale and mudstone were noted in the lower river valley, their origin must be from beds farther upstream of our transect area, possibly riverbed outcrops of the Alutom Formation (Eocene-Oligocene). Occasionally, relatively un-weathered porphyritic basalt cobbles and boulders were observed that probably are remnants of the Dandan Flow Member of the Umatac Formation.

The snail survey transect parallels the north slope of the Sadog Gago River Valley, with its eastern end located about 250 m upriver from the confluence of the Imong River and extending 500 m upstream in a general westerly direction. The transect's location was predetermined by biologists from Hawaii. The transect was subdivided into 10-m segments, and thus, consisted of 50 sectors. Along the transect, both slopes of the V-shaped valley are steep to very steep. At many locations, the slopes extend right down to the river bank without any intervening shore-side terrace or flood plain. Wherever a riverside terrace or flood plain occurs, it is generally narrow, often less than 20 m in width and generally less than 2 m in elevation above the adjacent river bedrock floor. Such terraces are subject to flooding during periods of heavy rainfall. The transect follows a somewhat meandering course along the steep valley slope, but at several locations it extends downslope onto short stretches of low-lying river terraces as well.

Soil Development Within the Survey Site

Soils on the northern valley slope at the transect site are classified as Akina-Agfayan association, steep, No. 12 (Soil Survey of Territory of Guam, 1988), with the Akina component formed from residuum dominantly derived from tuff and tuff breccia and conglomerate, and the Agfayan component formed from residuum dominantly derived from marine deposited tuffaceous (pyroclastic) sandstones. Such soils within the transect area are very shallow on steep slopes, and deep to shallow on narrow riverside terraces. Short stretches of exposed limestone beds, similar in lithology to those observed in the river bed, were also encountered as well. At very steep places along the transect, the soil is grayish brown to gray, extremely thin, and well drained, with some exposed patches of bare pyroclastic sandstone bedrock, particularly along the western part. Soils are more poorly drained and thickest where the transect intercepts riverside terraces, and they range from well- to moderately-drained where the terrace grades into steep slopes, moderately-drained on the wider terraces, and poorly-drained and muddy where swale-like depressions occur. On these less-well-drained terraces, the soil contains abundant decomposed organic material and is dark gray to black in color.

Soils within the transect area, as well as at other places located downstream from the transect site, were so disturbed by the activities of wild pigs that it was thought worthy of description. Disturbance on low riverside terraces was especially severe, where nearly 100 % of the ground surface was disturbed by wild pigs. Evidence of their soil rooting and mud wallows is prevalent everywhere. Where swale-like depressions occur, muddy wallows are commonly developed, some of which are 10 m or more in dimension and 30 cm or more deep. At places, standing water was noted in the deeper wallows, even during the dry season. Pig disturbance on steep valley slopes is less prominent, patchier in distribution, and generally restricted to areas where plant tubers and roots have been rooted out for food. In addition to rooting on steep slopes, pigs also turn over numerous loose rocks and decaying logs in search for food. At two very steep sectors along the western end of the transect, more than 90 % of a previously monotypic stand of wild ginger approximately 15 m in its longest dimension was destroyed by pigs rooting out and eating the fleshy rootstocks. Although we have not observed wild pigs feeding on live ground snails, domesticated pigs do so, and it is suspected that their wild counterparts will also prey upon them as well, particularly on the thin-shelled centimeter-sized species.

Although no deer were observed during the snail survey, evidence of their abundance was ubiquitous in fresh fecal pellets, narrow trails, tracks, and browsed vegetation.

Vegetation Within the Survey Site

Within the transect area, the overall vegetation can be classified as a ‘dissected volcanic mountainous upland ravine type’ as defined by Fosberg (1959, 1960). Ravine forest that occupies the steeply sloping land at the transect site is rather typical of that described by Fosberg, in that it is composed of a mixture of tree, shrub, vine, and herbaceous species that generally form a forest of a low uneven stature and is somewhat bushy and tangled at places. Vegetation within the transect area can be divided into two distinct subtypes consisting of that developed on the drier, well-drained thin soil of steep valley slopes, and that developed on the wetter, more poorly-drained deeper soil of the riverside low terraces. Following is a brief account of some of the more common species of vegetation found within these two subtypes along the transect area.

Vegetation on the Steep Slopes: Although there is no overall predominant tree species occurring on steep slopes within the transect area, there are scattered patches or clumps of trees dominated by one or two species. Most conspicuous of such patches are those of *Pandanus dubius* and *Pandanus tectorius*, which provide the only dense, well-shaded understory habitat on the steep slopes. These two *Pandanus* species, particularly *Pandanus tectorius*, also occur as scattered individuals, mostly as seedling trees 1–2 m in height. A tree that was once uncommon in this area is *Vitex parviflora*, but this species is now quite abundant at the transect site, particularly along the upper valley slope where it grades into the ridge top. It is reported that this species has been introduced from the Philippines, and it now has become widespread in both limestone and volcanic soils through dispersal of viable seeds that remain in pig feces. A few scattered trees were encountered along the transect line, and an unusually large tree approximately 45 cm in diameter was observed along the riverside at the confluence of the Imong River. *Cycas circinalis* trees were once more widespread and abundant on the steep slopes, judging from the number of dead fallen and leafless still-standing trees present. However, only a few widely scattered living specimens in very poor condition occur in the area now as a result of scale insect infestation. Only a few widely scattered individual trees and small sprawling patches of *Hibiscus tiliaceus* trees were observed on the thin, well-drained soil of the steep slopes. Except for the above-mentioned *Pandanus* patches, most trees on steep slopes are somewhat small and scattered, which gives the overall forest an open, well-lighted stature. Open patches that had been transformed into dense weed communities 10 m or more in diameter were encountered along the transect.

Vegetation on the Riverside Terraces: Where riverside terraces occur, the vegetation is quite different than that of the ravine forest described above. Riverside terraces are dominated primarily by mature coconut (*Cocos nucifera*) and betel-nut (*Areca catechu*) trees, giving the terraces an overall taller, denser, and more even canopy stature. It is mostly the mature coconut trees that contribute to the taller and denser nature of the canopy. Betel-nut trees at the transect site are mostly shorter than the coconut trees and thus form a middle story, which adds to the overall canopy-middle story density. The understory is dominated by coconut and betel-nut seedlings and young seedling trees a few meters tall. These seedlings are so abundant at places that, along with abundant fallen leaf fronds and coconuts, they impede passage. Another conspicuous component of the riverside terraces is *Freycinetia reineckei*, which occurs as a large woody climber on trees and as sprawling terrestrial clumps. Another smaller woody climber is *Medinilla rosea*, which is locally abundant. Along the riverside edge of the terrace, a few tangled *Hibiscus tiliaceus* trees were observed with a single *Barringtonia racemosa* tree. Conspicuous ferns were *Asplenium nidus* and *Microsorum punctatum* that formed large rosettes of long linear leaves up to 1 m or more in length. In general there is a greater diversity of vegetation that forms a narrow band along the riverside margin of the terraces where there is more available light.

Snail Survey Results

The number and identity of both living and dead snails that were observed on the ground and on vegetation were recorded within each of the 10-m sectors of the transect. When snails were observed on vegetation, the host plant species was also recorded. Representative specimens of each morphological species of snail were collected for identification in the laboratory. Results of snail observations by both team members are tabulated in Table A-1.

Nine living *Paludinella conica* snails were observed, with eight found on the green upper surface of *Pandanus tectorius* leaves and one found within the folds of dead leaves that accumulate on lower parts of a branch. Three bleached dead *Euglandina rosea* shells were found on the surface of bare exposed soil, one of which located between Stations 70 m and 80 m was photographed (Text Figure 1810-15). Because live specimens of this species have become quite rare as a result of predation by an introduced triclad planarian (*Platydemus manokwari*), most dead specimens would now be buried in the soil or beneath organic litter accumulation on the soil surface, so their dead shells are probably are more abundant than indicated.

Eight bleached dead *Achatina fulica* snail shells were found on the surface of bare exposed soil. As with the dead *Euglandina rosea* shells above, most dead specimens would now be buried in the soil or beneath organic litter accumulation on the soil surface, so their dead shells are probably are more abundant than indicated. One living and one dead *Satsuma mercatoria* snail shells were found on the surface of organic ground litter.

No living or dead endangered tree snails were observed within the transect area.

Table A-1. Land snails recorded by two observers surveying 10-m sectors of the Sadog Gago River transect.

Transect Sector	Species Observed	Number of Specimens	Habitat
0–10	None		
10–20	None		
20–30	None		
30–40	None		
40–50	None		
50–60	None		
60–70	*Satsuma mercatoria*	1	Found living on ground
70–80	*Euglandina rosea*	1	Dead specimen on ground (see Text Figure 1810-15)
80–90	*Euglandina rosea*	1	Dead specimen on ground
	Achatina fulica	7	Dead specimen on ground
90–100	*Paludinella conica*	1	On living *Pandanus tectorius* leaf
100–110	Paludinella conica	1	On basal dead *Pandanus tectorius* leaf
110–120	None		
120–130	*Paludinella conica*	1	On basal dead *Pandanus tectorius* leaf
130–140	None		
140–150	None		
150–160	None		
160–170	None		
170–180	None		
180–190	None		
190–200	None		
200–210	*Paludinella conica*	1	On living *Pandanus tectorius* leaf
210–220	None		
220–230	None		
230–240	None		
240–250	*Paludinella conica*	1	On living *Pandanus tectorius* leaf
250–260	None		
260–270	*Paludinella conica*	1	On living *Pandanus tectorius* leaf
	Euglandina rosea	1	Dead specimen on ground
270–280	None		
280–290	None		
290–300	*Achatina fulica*	1	Dead specimen on ground
300–310	None		
310–320	None		
320–330	*Paludinella conica*	1	On living *Pandanus tectorius* leaf
330–340	None		
340–350	None		
350–360	None		
360–370	*Paludinella conica*	1	On living *Pandanus tectorius* leaf
370–380	None		
380–390	None		
390–400	*Paludinella conica*	1	On basal dead *Pandanus tectorius* leaf
400–410	None		
410–420	*Satsuma mercatoria*	1	Dead specimen on ground
420–430	None		
430–440	None		
440–450	None		
450–460	None		
460–470	None		
470–480	None		
480–490	None		
490–500	None		

Remarks about the Snail Obsevations

Our observations of land snails were restricted to a general visual search of the ground and vegetation, and therefore, they could be considered a rapid reconnaissance search. At each 10-m sector, a meandering search was made in a 10-m wide corridor on each side of the transect line, with particular attention given to previously reported host species of endangered tree snails. Therefore, the surveyed area of the transect was some 10,000 m^2. No systematic quadrat search of ground litter or soil samples was conducted. In such a reconnaissance search, the probability of observing land snails depends more or less upon favorable conditions in which they are actively foraging about on the surface of leaves, bare ground, and ground litter. Active foraging of land snails in the daytime is more favorable during times of cloudy skies, high humidity, shaded habitats, and little wind or air movement, which for the most part were the conditions during our search. In addition to favorable weather conditions and shade, there are also target species of vegetation on which snails are more likely to be found. When such target vegetation species occurred within a sector they were given preference during the search.

Collections

Geologic Specimens:

Specimen Number: RHR 1810-1.
Specimen Name: Limestone sample from the Geus River Member.
Number of Specimens Coll.: 1
Geographic Location and Collecting Station: Mariana Islands, Guam, Sadog Gago River; Coll. Sta.: RHR 1810-CS-1, Specimen collected from a limestone lens at the confluence of the Sadog Gago and Imong Rivers (see Map Figure 1 for location).
Geologic Formation: Geus River Member (Oligocene) of the Umatac Formation embedded in pyroclastic deposits of the Bolanos Pyroclastic Member (Miocene) of the Umatac Formation.
Elevation: 46 m
Notes: At this location the Sadog Gago River has cut through a lens-like bed of presumably Geus River Member limestone >1 m in thickness. This specimen was collected from the upper surface of an *in situ* section of the lens. The fractured face is an intense white color that displays recrystallization. From hand lens inspection the specimen is a detrital limestone composed of unidentifiable fragments in a sand and mud matrix that was deposited probably in a lagoonal environment or forereef facies. Fractured pieces of the limestone lens at various elevations all revealed a similar lithology. See Text Figure 1810-14 for a view of the lens from which the specimen was collected. The lithology of this specimen is quite similar to abundant riverbed limestone clasts that are embedded in the Bolanos Pyroclastic Member both above and below the limestone lens. For a detailed description of this sample thin-section analysis is needed.

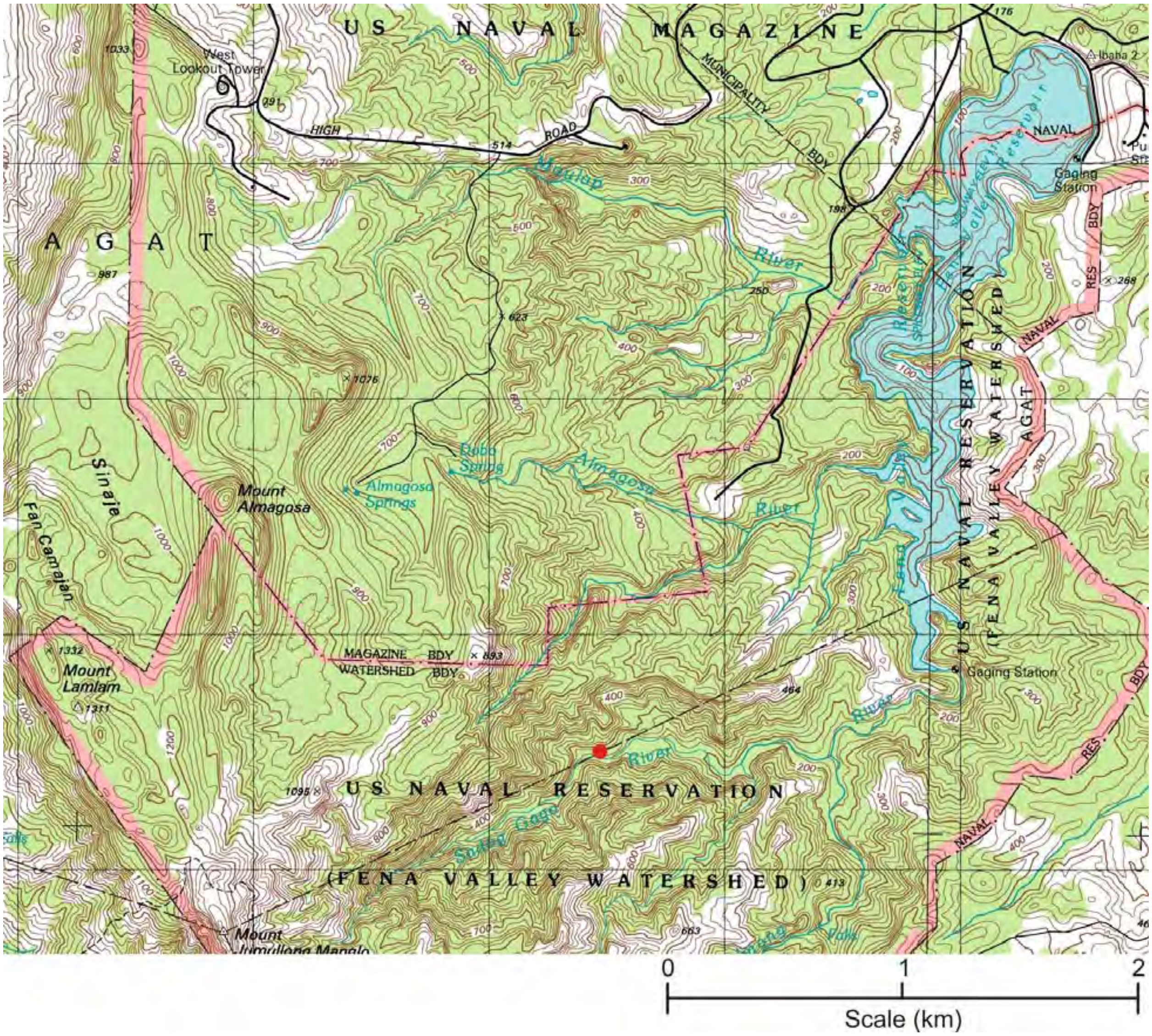
Specimen Number: RHR 1810-2.
Number of Specimens Coll.: 1 (a single intact cobble that was fractured into two pieces).
Specimen Name: Limestone sample from the Geus River Member.
Geographic Location and Collecting Station: Mariana Islands, Guam, Sadog Gago River; Coll. Sta.: RHR 1810-CS-2, Specimen collected from the exposed northwest shoreline of Fena Reservoir about 50 m south of an old pier structure (see Map Figure 1 for location).
Geologic Formation: Limestone of the Geus River Member (Oligocene) of the Umatac

Formation embedded in pyroclastic deposits of the Bolanos Pyroclastic Member (Miocene) of the Umatac Formation.
Elevation: 33 m
Notes: At this location Bolanos Pyroclastic Member deposits form a 30 to 45 degree slope to the water level of Fena Reservoir. The surface is hummocky and has numerous pebble- to cobble-sized, rounded, limestone clasts of the Geus River Member embedded in it. Chips of a half dozen or so of the partially embedded chips were sampled, with all but one being of a typical white, dense, compact, detrital limestone of the Geus River Member similar to that of Specimen 1810-1 described above. The exceptional chip was similar in all respects to the others, but was a uniform light brown in color, and the entire cobble was collected for further thin section study.

Plant Specimen:

Specimen Name: *Ceratopteris gaudichaudii* Brongniart, 1821
Specimen Number: 1810-3
Number of Specimen Collected: 1
Geographic Location and Collecting Station: Guam, at the mouth of the Sadog Gago River where it debouches into the south end of Fens Reservoir. Collecting Station: RHR 1810-CS-2: The specimen was collected from a slightly emergent sandbar at the mouth of the Sadog Gago River at the south end of Fena Reservoir.
Geologic Formation: Bolanos Pyroclastic Member (Miocene) of the Umatac Formation.
Soil Type: River sandbar accumulation of fragmented pyroclastic sand-sized grains deposited at the mouth of the Sadog Gago River. There was very little mud intermixed with the sand-sized grains.
Type of Community: Freshwater aquatic, flowing river.
Elevation or Depth: 32 m (about 2 m lower than the dam spillway elevation of Fena Reservoir. Plant emergent, but with roots extending down into the saturated zone of the sandbar it was growing on.
Notes: See Text Figures 1810-4 and 1810-5 for photos of the sporophyte and gametophyte generations respectively of this aquatic fern. Both the sterile and fertile fronds of the sporophyte generation are terete, with the fertile ones here distinguished by a brown strip of sori. This particular plant was collected on a low emergent sandbar, and had long filamentous roots that extended downward into the saturated zone of sand. The overall fern formed a much branched bushy clump with the main stems up to 1 cm in diameter and the smaller terminal branches 1 to 2 mm in diameter. The young fronds are edible. These ferns grow quite rapidly, as upon three weeks of growing in a pan of water exposed to the sun, the fern doubled its biomass. Later the fern was pressed and dried and given to Dr. Lynn Raulerson at the University of Guam for inclusion in the herbarium. While cleaning the specimen for pressing, a half dozen *Thiara granifera* snails ranging from < 1 to 3 mm in length were washed out from the root mats.

MAP FIGURES



Map Figure 1810-1. A section of the Agat and Talofofo USGS Quadrangle Maps spliced together showing the mid part of the Sadog Gago River Valley transect (red dot) and other geographic areas mentioned in the text.

Map Figure 1810-2. A satellite image showing the location and approximate midpoint (red dot) of the Sadog Gago River Valley transect within the 'Volcanic Uplands of Gently Sloping Foothills Cut by Major Streams' physiographic unit in southern Guam. Vegetation consists of a mosaic pattern of forested areas (dark green) and savanna grassland areas (light green). Letter symbols: A = Southern end of Fena Reservoir, B = Sadog Gago River, C = Imong River.

TEXT FIGURES

Text Figure 1810-1. Three members of the Dueñas, Camacho & Associates survey team paddling their Coleman canoe on Fena Reservoir to the Sadog Gago River mouth.

Text Figure 1810-2. Snail survey team member Randall paddling a 10-ft kayak on Fena Reservoir to the Sadog Gago River mouth.

Text Figure 1810-3. Lush shoreline beds of a bright green aquatic fern, *Ceratopteris gaudichaudii*, growing along the western bank of Fena Reservoir near the Sadog Gago River mouth. Note the fern beds occur at two levels consisting of a lower partly submerged level and an upper level about 75 cm higher on an emergent sandbar. The young fronds of the fern are edible. In the background is a good example of a dense upland ravine type of forest. For a detail of the fern plant see Text Figures 1810-4 and 1810-5.

Text Figure 1810-4. A detail of the sporophyte of the aquatic fern, *Ceratopteris gaudichaudii*, that was collected from the mouth of the Sadog Gago River at the south end of Fena Reservoir. Both the sterile and fertile fronds are terete, with the latter here distinguished by a brown strip of sori. This particular plant was collected on a low emergent sandbar, which had long, filamentous roots that extended downward into the saturated zone of sand. The overall fern formed a much branched bushy clump with the main stems up to 1 cm in diameter and the smaller terminal branches 1 to 2 mm in diameter. The young fronds are edible. These ferns grow quite rapidly, as three weeks after this collected fern was grown in a pan of water exposed to the sun, the fern doubled its biomass. Later the fern was given to Dr, Lynn Raulerson at the University of Guam for inclusion in the herbarium.

Text Figure 1810-5. A view of the much smaller gametophyte generation of the aquatic fern, *Ceratopteris gaudichaudii*, that is growing near the base of the above much larger sporophyte generation plant shown in Text Figure 1810-4 above. Another smaller gametophyte is growing immediately above the larger one. Both of these gametophytes arose independently within the entangled basal mass of fibrous roots of the sporophyte plant during a three-week period that it was kept in a pan of rainwater. In contrast to the slender terete fronds of the sporophyte plant, the above gametophytes have thin flat fronds, and in the lower one a central terete frond of the newly developing sporophyte generation can be seen. The lower larger gametophyte is 6 cm across in its longest dimension.

Text Figure 1810-6. The western shoreline of Fena Reservoir that shows a well-marked high water line about 1.5 m above the present reservoir water level. Here the upper half of the exposed high-water shoreline shows a conglomeritic bed of Geus River Member limestone. Such beds up to 1 m or more thick are exposed at a number of places around the reservoir shoreline. At this shoreline location the bordering upland ravine forest has a more open shrubby stature than that shown in Text Figures 1810-2 and 1810-3. For a detail of this shoreline exposure of Geus River Limestone, see Text Figure 1810-7.

Text Figure 1810-7. A detailed view of an exposed shoreline conglomeritic bed of Geus River Member limestone shown in Text Figure 1810-6. The exposed part of the lenticular limestone bed is at least 1 m thick, and may further extend upward into the vegetation above the high-water level. This lenticular bed pinches out at both ends (not shown in photo) and has a maximum length of about 50 m. Below the limestone bed, abundant gravel- to boulder-sized pieces of Geus River Member limestone are enclosed in a darker matrix of Bolanos pyroclastic deposits. For a more detailed description of the Geus River Member Limestone at this and other nearby locations see the text.

Text Figure 1810-8. The mouth of the Sadog Gago River at the south end of Fena Reservoir, where we beached the kayaks and canoe and hiked upstream to the transect site. When Fena Reservoir is at dam spillway level, its water extends about a 100 m further upstream. The exposed sandbars here consists of an upper layer of mostly sand-sized clasts that accumulates when the reservoir water level is higher, and there little current because of the river mouth being shifted upstream. When the reservoir water level is lower the river mouth shifts downstream, such as during the time of this survey, and the upper sandbar of finer material is eroded away and coarser material below is exposed. During flood stage, even boulder-sized clasts are transported to the river mouth, as can be seen in the foreground. Note the white limestone clasts intermixed within the darker colored clast of Bolanos pyroclastic material.

Text Figure 1810-9. An upstream view of the Sadog Gago River a short distance above the reservoir spillway water level. Here the riverbed forms long shallow pools (foreground) where the bedrock consists of tuff and tuff breccia that are separated by shorter high-gradient slopes (background) where the bedrock consists of more resistant volcanic conglomerate in a matrix of tuff and tuff breccia. Note how the more resistant conglomerate in a tuff and tuff breccia matrix forms a low scarp in the right foreground, whereas the less resistant tuff and tuff breccia exposed lower on the left shoreline forms a low erosional slope. At this location, river bedrock topography is controlled by the jointing pattern in the rock, which in the foreground can be seen to cut diagonally across the riverbed. The river valley slopes here is steep and V-shaped with a lumpy surface that is a result of mass creep and slumping of the volcanic rock that is here deeply weathered into a punky saprolite. Vegetation on the right side of the river valley slope is of a savanna type that is almost completely dominated by *Miscanthus floridulus* (sword grass), while the vegetation on the left slope is of a transitional grassland savanna-ravine forest variant that consists of a patchy mixture of *Miscanthus floridulus* and ravine forest species.

Text Figure 1810-10. A detailed view of the river bedrock of tuff with embedded small scattered granule- to pebble-sized limestone clasts of the Geus River Member. Note the abundance of small *Thiara granifera* snails at the boundary of the exposed tuff and water. These snails were very abundant in such habitats between the river mouth and waterfalls shown in Text Figure 1810-13, but were not observed above it.

Text Figure 1810-11. *Thiara granifera* aquatic snails aggregated on the algal-coated river bedrock.

Text Figure 1810-12. A detail of the *Thiara granifera* snails shown in Text Figure 1810-11. These snails were most abundant on algal-coated substrates as in the above figure. Note the whorled arrangement of the shell ornamentation and in variation in the shell color.

Text Figure 1810-13. A river falls (steep cascade) about 5 m high located between the Sadog Gago River mouth at Fena Reservoir and the Imong River confluence. Here erosion has cut down through a thick layer of volcanic conglomerate and breccia (lower left and upper left) to a layer of tuff that is exposed in the river bedrock and far river bank slope. Note that the conglomerate and breccia in the upper left is in steep contact with the bedrock tuff (probably a fault), which is the probable origin of the falls. At the base of the falls, a deep plunge pool has been eroded into the volcanic tuff, forming an overhanging ledge of more resistant conglomerate and tuff breccia above it.

Text Figure 1810-14. The confluence of the smaller Imong River (background) flowing into the larger Sadog Gago River (foreground) through two blocks of limestone. In the foreground is an accumulation of rounded to sub-rounded boulders and cobbles veneering river bedrock, mostly of tuff and tuff breccia of the Bolanos Pyroclastic Member in varying stages of weathering (dark gray, brown, tan, and pink), with a few scattered white clasts of Geus River Member limestone. At this location, the Sadog Gago River has cut through a bed of presumably Geus River Member limestone >1 m in thickness. The block on the left is apparently in place, >1 m thick, and continues along the Imong River bank, whereas the block on the right has been wedged out from the bed and is tilted. Several similar large limestone blocks (not in view) are located on the opposite stream bank and downstream of the river junction. The limestone from both blocks is an intense white detrital deposit that is similar in lithology to the exposed lens shown in Text Figures 1810-6 and 1810-7 at Fena Reservoir and limestone clasts embedded within the Bolanos Pyroclastic Member. The gray splotchy areas of the blocks are where the surface is discolored by weathering and endolithic algae. This limestone lens outcrop is considerably higher in elevation than those along the Fena Reservoir shoreline.

Text Figure 1810-15. A dead, bleached white *Euglandina rosea* snail shell found exposed on the soil surface between transect Stations 70 m and 80 m.

RHR 1811 FIELD NOTES
(Almagosa River Valley, EOD Upper Transect No. 2)

Date: May 1, 2009

Geographic Location: Guam, Almagosa River Valley (Upper Valley)

<u>Introduction</u>

During the afternoon of April 29, 2009, Mr. Barry Smith of the University of Guam Marine Laboratory notified me that our field excursion for the second land snail survey project would take place May 1, 2009 at the U. S. Naval Ordnance Annex, and I was asked to meet him at the University of Guam Marine Laboratory at 0730. He informed me that the survey was located immediately southeast of the Explosive Ordnance Disposal (EOD) pit on the south side of the Almagosa River valley and that the site would be accessed by hiking from the disposal pit (Map Figures1811-1 and 1811-2). We briefly discussed what kind of equipment and gear to take along for the excursion.

On the morning of the May 1, I met Barry Smith at the University of Guam Marine Laboratory at 0730, where we loaded our gear into his pickup truck and then proceeded to the Main U. S. Navy Base at Apra Harbor to obtain personal passes and a vehicle pass to enter the U. S. Naval Ordnance Annex. Upon our arrival at U. S. Naval Ordnance Annex, we proceeded to the EOD Office where we signed their login sheet.

During our survey the weather was cloudy with frequent light to heavy rain showers occurring about 60 to 70 percent of the time.

<u>Access to the Transect Site</u>

From the EOD Office we proceeded via a macadam paved roadway to the EOD Access Road. Unfortunately the access road was chained off, and we decided to walk the 1.1 km distance to the EOD pit. In route to the EOD pit we could hear a vocal chorus of frogs (*Rana* sp.) as we passed over the Maulap River Bridge.

The disposal pit itself is a flattened, mowed area about 150 m across that appears to have originally been formed by a large rotational slump, with the steep slip face encircling about half of the pit area (Text Figure 1811-1). The slump surface has been leveled with fill, some of which contains abundant limestone clasts (pebble to small boulder size), which appear to be of Alifan Limestone. A small earthen-covered bunker occupies the east side of the flattened disposal area. A cluster of small craters encircled with varying amounts of ejecta debris were present in the central area of the flattened mowed area. Apparently there has been a recent wildfire at the site on the upslope slip face of the slump as shown in Text Figures 1811-1 and 1811-2.

Although we do not know what size ordnance is disposed at the site, there is certainly little evidence of disturbance to the surrounding habitat from such detonations, except within the small flattened mowed area itself. The Naval Ordnance Annex personnel should be commended for maintaining a disposal site that displays such a minimal amount disturbance to surrounding natural habitat.

There are two snail survey transect sites within the Almagosa River Valley watershed region located between the EOD site and the mouth of the Almagosa River at Fena Reservoir: one (Transect No. 2) in the upper valley region and the second (Transect No. 3) in the lower valley region. Map Figures 1811-1 and 1811-2 show the location of Transect No. 2 for the survey in this section of Appendix A.

The trail head is located on the southeast corner of the loop roadway that encircles the EOD pit; it had been marked earlier with orange spray paint on the macadam roadside. For future reference it can also be recognized by a small clump of coconut palm trees surrounded by a dense stand of *Vetiveria zizanioides* grass, which dominates much of the lower loop roadside (Text Figure 1811-1). This roadside grass quickly grades into a short, steep, forested slope that leads down to a narrow coconut-dominated floodplain terrace along the north side of the Almagosa River. Considering that Guam was in the dry season at the date of this survey, there was a moderate flow of water in the Almagosa River bed, and in spite of the current rainy weather, the water was clear with no hint of turbidity.

Upon crossing the river, we noticed the presence of abundant tufaceous-stromatolite build-up at many places on the rocky streambed floor (Text Figures 1811-3 and 1811-4). These stromatolitic deposits are up to 30 cm thick, with the lower submerged regions consisting of a surface coating of greenish, filamentous, cyanophytic algae where the tufa is actively being deposited. At places, subaerially exposed parts of the build-ups revealed a characteristic layered yellowish tan color where being actively eroded. Such stromatolitic build-ups are commonly found in streambeds of southern Guam rivers, particularly where their headwaters originate from springs located at the volcanic contact of the base of limestone outcrops. The origin of the Almagosa River is located at several such springs located at the basal contact of the Alifan Limestone (see Map Figure 1811-1). Transect No. 2 begins at the crest of a short steep forested slope on the south side of the river crossing shown in Text Figure 1811-3.

<u>General Physiographic and Geologic Setting of the Survey Site</u>

The drainage basin of the Almagosa River at the Transect No. 2 location is developed upon the Bolanos Pyroclastic Member (Miocene) of the Umatac Formation. At this river site these deposits are dominated by breccias, conglomerates, and sandstones consisting largely of fragmented andesite. The following remarks and observations are here restricted to the part of the drainage basin in the immediate region between the trail head and terminal end of Transect No. 2.

The freshest exposed deposits of these pyroclastic rocks were found where the trail head crossed the Almagosa River (Text Figures, 1811-3 and 1811-4). Freshest deposits are a dark grayish-brown to greenish-brown, with an overall speckled appearance. At places more weathered deposits are a lighter speckled gray to pink or red. All the exposed outcrops of rock that were observed within the river bedrock were found to contain abundant granule- to boulder-sized limestone fragments of the Geus River Member of Oligocene age intercalated within the volcanic matrix (Text Figure 1811-3 and 1811-4). These limestone inclusions ranged from well-rounded to angular in shape, and, when fractured, revealed a white, dense, compact fine-grained to conglomeratic, recrystallized detrital limestone that contains foraminifers, molluscs, calcareous algae, and corals. The limestone clasts consist of fragments as well as whole and worn coral colonies. In Schlanger's (1964) classification system, these clasts include limestones from reef-wall facies, lagoon facies, forereef facies, transitional facies, and basin facies all mixed together, which indicates they have been transported from their original sites of deposition and have become incorporated into the pyroclastic volcanic deposits of the Bolanos Pyroclastic Member, probably by explosive volcanism and subsequent transport. Angular and sub-rounded clasts indicate little transport, whereas worn rounded clasts indicate considerably more exposure to erosion and transport. At this particular river crossing site, no horizontal lenticular beds of limestone, like those earlier described in the nearby Sadog Gago riverbed and along the western shoreline of Fena Reservoir (See RHR 1810 Field Notes), were observed. Except for an occasional weathered boulder, the remainder of the transect area is mantled with an unknown thickness of soil that in turn is veneered with organic litter, except at the terminal end of the transect, where erosion in a small ravine has exposed several vertical meters of a yellow-brown-red saprolite. Also, near the terminal end of the transect, several porphyritic basalt boulders were found that were probably residual remnants of the Dandan Flow Member of the Umatac Formation.

A loose, isolated limestone fossil coral (Spec. No. 1811-1) of the Geus River Member was collected at Transect Station 10 m (see description in the 'Collections'). A sample of reddish brown saprolite exposed along the west bank where the trail head crossed the Almagosa River was also collected (see description in the 'Collections' section below).

The snail survey transect for the most part extends across relatively flat, low-to-moderately sloping ridge tops, with minor sections where upper valley slopes grade into ridge top land (Text Figure 1811-1). The location of the transect was predetermined by biologists from Hawaii, and it was subdivided into 10-m sectors. Therefore, the transect contained 50 sectors and covered an area of 10,000 m^2.

Soil Development Within the Survey Site

Soils on the northern valley slope at the transect site are classified as Akina-Atate association, steep, No. 17 (Soil Survey of Territory of Guam, 1988), with the Akina component formed from residuum dominantly derived from tuff and tuff breccia and conglomerate. The Atate component is formed from residuum dominantly derived from tuff and tuff breccia.

Such soils within the transect area appeared to be quite deep within flattened regions of low slope, and moderately deep to shallow within regions of increased slope. At most places along the transect, soil appeared to be moderately well-drained, particularly at the crests of valley slopes. At small swale-like depressions, the soils are more poorly drained, and at a few places contained small shallow areas of standing water. At most places along the transect, soil surface was covered with abundant organic litter, but where pig rooting occurred the soil ranged from brownish yellow to brownish red. In general this transect is less disturbed by wild pigs than the Sadog Gago River valley transect, particularly along regions dominated by coconut trees. A possible reason for this may be that upland coconut forests in this area are drier than those on low riverside terraces, particularly during the dry season.

Vegetation Within the Transect Area

Within the transect area, the overall vegetation can be broadly classified as a mosaic of isolated patches of 'grassland-savanna type' within a more widely distributed continuous and interconnected expanse of 'dissected volcanic mountainous upland ravine type,' as defined by Fosberg (1960), and shown in Map Figure 1811-2. Upland ravine forest vegetation only occurred at 6 stations (12 percent of the overall transect), and at no station did the transect traverse across what could be called a 'grassland-savanna type' of vegetation. More specifically, the transect route somewhat torturously traversed through what could be more appropriately called variants of the 'dissected volcanic mountainous upland ravine type' of vegetation. The most abundant of theses variants, consisting of 60 percent of the transect stations, was occupied by coconut forest. The next most abundant variant, consisting of 28 percent of the transect stations, was occupied by a shrubby, open transition forest of low stature, where the regions dominated by coconut palm graded into patches of grassland savanna. Following is a brief account of some of the more common species of vegetation found within the above vegetation types along the transect line.

Coconut Forest on Low to Moderately Sloping Ridge Top Land: This vegetation type occurred along 60 percent of the transect line as a contiguous section of 30 sectors between Station 40 m and Station 330 m. Such forests were for the most part restricted to low to moderately sloping land on ridges between more steeply sloping valley land. Coconut palm trees (*Cocos nucifera*) overwhelmingly dominated the forest, as shown in Text Figure 1811-5, with tall to medium height palms forming an upper- and mid-story. Abundant coconut seedling trees up to 3 meters tall formed a lower story, along with scattered herbaceous weedy vegetation. Conspicuous among the herbaceous vegetation, particularly in wetter swales, was an abundant triangular stemmed sedge, *Scleria polycarpa*, about 1 m high. *Areca catechu* (betelnut palm) ranged from nearly absent to scattered among the coconut trees. Fallen coconut fruits and fronds littered the ground everywhere. Above this lower story vegetation, the forest had a rather airy open stature. Except for seedling coconut trees and piles of fallen fronds, the forest was rather easy to travel through compared to the dense ravine vegetation. A few pig wallows were present in some wetter swales.

Shrubby Open Transition Forest of Low Stature where the Regions Dominated by Coconut Palm Graded into Patches of Grassland Savanna: This vegetation type occurred along 28 percent of the transect line as a contiguous section of 14 sectors between Station 330 m and Station 470 m. Such forests occurred where the transect line ran somewhat tangent to, but not within, savanna grassland patches, and along the upper slope crest, before dipping into a ravine forest at Station 470 m. Here the forest is shrubby, of low stature, and commonly patchy, with no overall dominant kind of tree or shrub. Some of the larger conspicuous patches consisted of clumps of *Pandanus tectorius* that were sometimes intermixed with *Cocos nucifera*, as shown in Text Figure 1811-6. A somewhat unusual monotypic shrubby patch of *Cassia alata* about 10 m in diameter was encountered within the transect area. Other conspicuous components of shrubby and weedy patches included *Hibiscus tiliaceus*, *Psidium guajava*, and *Hyptis capitata*.

Upland Ravine Type Vegetation on Steep Valley Slopes: Ravine forest was described by Fosberg (1960) as composed of a mixture of tree, shrub, vine, and herbaceous species that generally form a forest of a low uneven stature that is somewhat bushy and tangled at places. This type of ravine forest occurred within only a few transect stations at the beginning (0 to 30 m) along the crest of the Almagosa River valley and at the transect end (470 to 500 m), where it dipped downward into the head of a steep ravine slope (Text Figure 1811-7). This vegetation type was distinct from the coconut palm forest into which it rather abruptly graded in transect sectors between 0 and 40. Within this short ravine forest section, the most conspicuous species were clumps of *Pandanus* trees and vines of *Freycinetia reineckei*, somewhat similar to that shown in the Almagosa River valley crossing in Text Figure 1811-3.

Text Figure 1811-7 shows a dense tangled ravine forest that was encountered at the terminal end of the transect between Stations 470 m and 500 m. Conspicuous vegetation within this short section of ravine forest include *Pandanus tectorius*, *Pandanus dubius*, vines of *Freycinetia reineckei*, *Areca catechu*, and *Hibiscus tiliaceus*. Other conspicuous vegetation of the ravine forest includes the red bell-shaped flowers of *Medinilla rosea* (Text Figure 1811-8) and moss and liverworts (Text Figure 1811-9).

Snail Survey Results

Results of snail observations by both survey members are tabulated in Table A-2. No living or dead endangered tree snails were observed within the 50 transect sectors, nor were any observed from the trail head to the transect location. Of the non-endangered land snails, only four specimens were observed within the 50 transect sectors; two dead and one living *Satsuma mercatoria*, and one dead *Achatina fulica*.

Table A-2. Land snails recorded by two observers surveying 10-m sectors of the Almagosa River Valley, EOD Upper Transect No. 2.

Transect Sector	Species Observed	Number of Specimens	Habitat
0–10	*Satsuma mercatoria*	1	Found living on ground
	Satsuma mercatoria	1	Dead specimen on ground
10–20	None		
20–30	None		
30–40	None		
40–50	None		
50–60	None		
60–70	None		
70–80	None		
80–90	None		
90–100	None		
100–110	None		
110–120	None		
120–130	None		
130–140	None		
140–150	None		
150–160	None		
160–170	None		
170–180	None		
180–190	None		
190–200	None		
200–210	None		
210–220	None		
220–230	None		
230–240	None		
240–250	None		
250–260	None		
260–270	None		
270–280	None		
280–290	None		
290–300	None		
300–310	None		
310–320	None		
320–330	None		
330–340	None		
340–350	None		
350–360	None		
360–370	None		
370–380	None		
380–390	None		
390–400	None		
400–410	None		
410–420	None		
420–430	None		
430–440	None		
440–450	None		
450–460	None		
460–470	None		
470–480	*Achatina fulica*	1	Dead specimen on ground
480–490	None		
490–500	*Satsuma mercatoria*	1	Dead specimen on ground

Remarks about the Snail Observations

The above land snail observations were restricted to a general visual search of the ground and above ground vegetation, and thus could be considered a rapid reconnaissance search. At each 10-meter sector a meandering search was made in a 10-meter wide corridor on each side of the transect line. Although a random search of ground litter and soil investigation was made, no systematic quadrate samples of such were conducted. In such a reconnaissance search, the probability of observing land snails depends more or less upon favorable conditions in which they are actively foraging about on the surface of leaves, bare ground, and ground litter. Active foraging movements of land snails in the daytime are more likely during times of cloudy skies, high humidity, shaded habitats, and little wind or air movement, which for the most part were the conditions during our search. When host vegetation species for land snails occurred within a sector they were given preference during the search (see list in Part 1).

Several factors that could account for only four land snail specimens being observed include: 1) a near lack of host tree species in coconut forest habitat, 2) the upland coconut forest habitat does not provide dense shade and has an open, airy lower story, 3) the coconut and open shrubby transition habitats are less humid and drier, particularly during the dry season, and 4) constant predation by the flatworm (*Platydemus manokwari*), and wild pigs that most likely feed on small easily crushed ground snails. Although no systematic search was made for the predatory flatworm, none were observed during random searches through ground litter or under rocks. The scarcity of dead snail shells may be a result of their rapid dissolution on the acidic volcanic soils and decomposing ground litter.

Other Observations

While driving to the transect site within the Naval Ordnance Annex, a number of black francolins (*Francolinus francolinus*), yellow bitterns (*Ixobrychus sinensis*), turtle-doves (*Streptopelia bitorquata*), and wild pigs (*Sus scrofa*) were observed. Although no deer were observed during the snail survey, there was evidence of their presence in abundant fresh fecal pellets, narrow trails, tracks, and browsed vegetation. Leaves of young *Pandanus* and low-lying clumps of *Freycinetia reineckei* vines were particularly observed to be browsed, most likely by deer. Geckos and skinks were commonly observed during the snail survey.

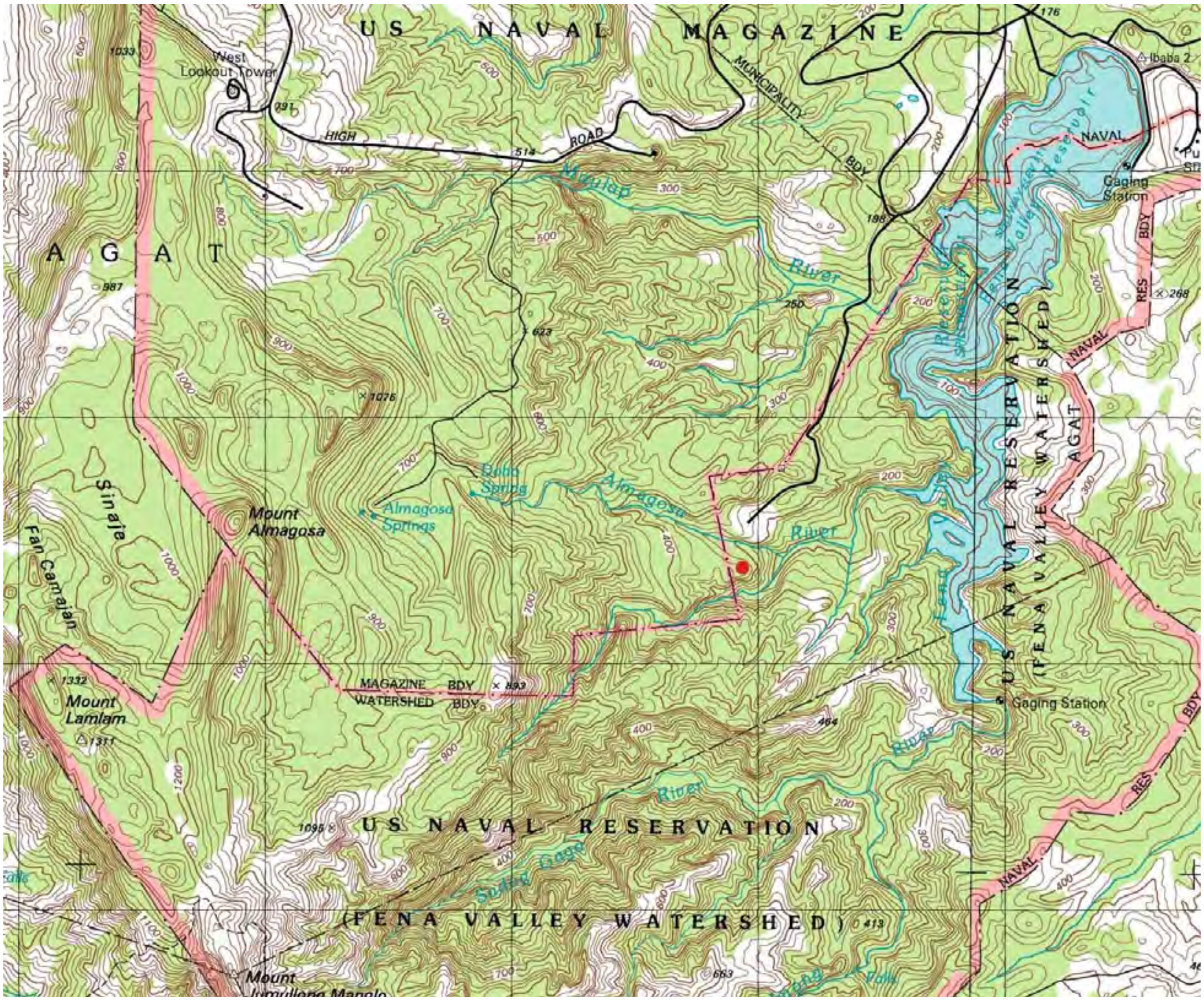
COLLECTIONS

Specimen Number: RHR 1811-1.
Number of Specimens Coll.: 1 piece
Specimen Name: Fossil colony of part of a colony of *Leptastrea* that is close to *Leptastrea transversa*.
Geographic Location and Collecting Station: Almagosa River bank about 100 m above its confluence with the Upper Fork, located near the crest of the river valley slope at Sta. 10 m along the transect line. (Collecting Station RHR 1812-CS-1).
Geologic Formation: Bolanos Pyroclastic Member of the Umatac Formation.
Elevation: 73 m
Notes: This fossil of *Leptastrea* was found loose on the soil surface. Such loose isolated clasts of Geus River Member limestone were commonly observed while traversing up the steep Almagosa River valley to the head of Transect 3. Although this clast could possibly be a

younger remnant of Alifan Limestone that once covered much of the upland volcanic land, its lithology and lower elevation, as well as that of other loose clasts observed in the region suggests that it is most likely a Geus River Member limestone clast, similar to those embedded in the Bolanos pyroclastic rock in the nearby Almagosa River bed.

Specimen Number: RHR 1811-2.
Number of Specimens Coll.: 1 piece
Specimen Name: Sample of pyroclastic deposit that is weathered into saprolite.
Geographic Location and Collecting Station: Almagosa River bank about 100 m above its confluence with the Upper Fork (Collecting Station RHR 1812-CS-2). The saprolite sample was collected on the south bank of the Almagosa River just below at the head of Transect No. 3.
Geologic Formation: Bolanos Pyroclastic Member of the Umatac Formation.
Elevation: 73 m
Notes: The sample is reddish brown when dry (more intense when wet) and consists of a punky, weakly consolidated, but coherent mass. Recent riverbank erosion had exposed the location from which it was collected. After being soaked in freshwater overnight, the sample was completely disassociated into reddish brown grains of the same size class as the grains in the nearby river bedrock of Bolanos tuff deposits. Such saprolite deposits on steep terrain are thus quite unstable when wet and subject to gravitational creep and slumping. (Sample not retained).

MAP FIGURES



Map Figure 1811-1. A section of the Agat and Talofofo USGS Quadrangle Maps spliced together showing the mid part of the Almagosa River Valley, EOD Upper Transect No. 2 (red dot), and other geographic areas mentioned in the text.

Map Figure 1811-2. A satellite image showing the location and approximate midpoint (red dot) of the Almagosa River Valley, EOD Upper Transect No. 2, 1 within the 'Volcanic Uplands of Gently Sloping Foothills Cut by Major Streams' physiographic unit in southern Guam. Vegetation consists of a mosaic pattern of forested areas (dark green) and savanna grassland areas (light green). Letter symbols: A = Fena Reservoir, B = Almagosa River, C = Explosive Ordinance Disposal (EOD) area.

TEXT FIGURES

Text Figure 1811-1. A view to the southeast of the EOD pit taken from the upper slip face scarp of a rotational slump. At the time the photo was taken, earlier heavy rainfall had filled the crater pits with water, which have been invaded by hundreds of toads (*Bufo marinus*) and frogs (*Rana* sp.), the latter of which filled the air with their raucous calls. In the background is a general view of a mosaic of isolated patches of ‘grassland-savanna’-type vegetation within a more widely distributed continuous expanse of ‘dissected volcanic mountainous upland ravine type’ forest vegetation.

Text Figure 1811-2. A detail of the burned-over area shown in Text Figure 1811-1. In the foreground are new shoots of *Miscanthus floridulus* (dark green) and *Curcuma* cf. *australasica* (light green) that have regenerated from rootstocks after a recent wildfire. Recurring wildfires in volcanic highland areas favor the succession of such fire resistant species, thus promoting the mosaic of savanna grassland areas shown in Map Figure 1811-2 and Text Figure 1811-1.

Text Figure 1811-3. An upstream view of the Almagosa River bed, showing typical dissected volcanic mountainous upland ravine type vegetation on both sides, and tufaceous-stromatolite build-ups of carbonate deposits (light tan regions) on the exposed bedrock. Where the build-ups are submerged, carbonate material is actively being deposited around the cell wall sheaths of cyanophytic filamentous algae that give the surface a greenish color. The gray exposed river bedrock is composed of fairly unweathered volcanic rock of the Bolanos Pyroclastic Member of the Umatac Formation, which here is a conglomeritic mixture of pebble- to boulder-sized clasts embedded in a matrix of tuff and tuff breccia. A detail of the stromatolite deposits was photographed in Text Figure 1811-4. The numerous white inclusions embedded in volcanic river bedrock are pebble- to small cobble-sized limestone pieces of Geus River Member.

Text Figure 1811-4. A detail of a tufaceous-stromatolite build-up shown in Text Figure 1811-2, which shows the emergent yellowish tan deposits and submerged mottled greenish tan to brown deposits. Above the stromatolite build-up, a clump of grass and moss have gained a foothold on an embedded volcanic boulder-sized clast. For scale, the geology hammer is 33 cm long.

Text Figure 1811-5. A typical view the coconut forest that occurred along 60 percent of the 10 meter stations along Transect 2. Within this type of forest, coconut seedlings abundantly cover the ground surface, along with dead fronds and nuts in varying stages of decomposition.

Text Figure 1811-6. A dense patch of coconut palms and *Pandanus tectorius* partly bordered in the foreground by *Miscanthus floridulus* (sword grass). Phalanges of the pendant ripe, orange-colored *Pandanus* fruits will soon fall to the ground. The orange pulp of the phalanges, as well as the seeds, are reported to be edible, but the pulp is high in calcium oxalate, and the seeds are difficult to separate from the hard endocarp. From an earlier experience in sampling the pulp and fruit, I would relegate both as an emergency source of food at best.

Text Figure 1811-7. A view of dense tangled ravine forest at the distal end of Transect No. 2.

Text Figure 1811-8. A clump of bright red, bell-shaped flowers of the woody climber, *Medinilla rosea*, located in a ravine forest at the distal end of Transect No. 2. The individual flowers are about a centimeter long.

Text Figure 1811-9. A detail of two species of moss and a 6 cm diameter liverwort growing on the trunk of an *Areca catechu* (betelnut palm) tree located in a ravine forest at the distal end of Transect No. 2. Note the circular cup-shaped reproductive fruiting bodies with tan centers on the liverwort.

RHR 1812 FIELD NOTES

(Land Snail Survey, Transect No. 9and Transect 9 Annex)

Date: May 6, 2009 and May 8, 2009

Geographic Location: Guam, Mountainous Ridge and Valley Land West of Almagosa Spring; Transect No. 9 and Transect 9 Annex.

Introduction

During the afternoon of May 5, 2009, Mr. Barry Smith of the University of Guam Marine Laboratory notified me that our field excursion for the third land snail transect survey would take place May 6, 2009 at the U. S. Naval Ordnance Annex, and I was asked to meet him at the University of Guam Marine Laboratory at 0730. He informed me that the survey was located immediately southeast of the Explosive Ordnance Disposal (EOD) pit in the southern part of the Almagosa River valley that would be accessed by hiking from the disposal pit (Map Fig. 1812-1). We briefly discussed what kind of equipment and gear to take along for the excursion. During the night it had rained quite heavily.

On the morning of the May 6, I met Barry Smith at the University of Guam Marine Laboratory at 0730, where we loaded our gear into his pickup truck and then proceeded to the Main U. S. Navy Base at Apra Harbor, where we obtained personal passes and a vehicle pass to enter the U. S. Naval Ordnance Annex. Upon our arrival at U. S. Naval Ordnance Annex, we proceeded to the EOD Office where we signed the login sheet. This time we asked them to unlock the chain at the head of the EOD Road, which they immediately did. When we reached the EOD site, it was raining quite heavily, and we drove to the upper part of the EOD loop roadway and parked where we could have on overlook view of the Almagosa River Valley (see Text Figure 1811-1 for a view from the overlook). Upon leaving our vehicle. we walked to the scarp edge that overlooks the disposal site. The chorus of frog calls from the water-filled detonation crater holes below was almost deafening. After taking some photos from the upper scarp, we drove to the trail head site below and examined some of the water-filled detonation craters to get a glimpse of the frogs. As we approached the water-filled craters, the frogs would quickly cease their calls and slip beneath the water surface. In addition to the frogs, a dozen or more toads could be seen in each crater, most of which were in amplexus. We located the marked trail head along the loop roadway and proceeded down a steep slope to the bottom of a ravine and then up a similarly steep slope to a very narrow ridge crest from where we could see the Almagosa River in the valley floor below. Somewhat to our surprise the river was a raging torrent, 2–3 m above normal flow level, and we could see abundant debris (coconuts and dead fronds, tree limbs, and logs) being carried downstream. Realizing that we could not conduct the transect survey under such conditions, we aborted the lower river site and decided to survey the upstream Almagosa Spring transect site instead.

On May 6, 2009 we surveyed Transect No. 9 Annex during the morning and half of Transect No. 9 in the afternoon from Station 250 m to 500 m; on May 8, 2009 we surveyed the remaining half of Transect No. 9 from Station 250 m to 0 m. Data from both of these surveys are incorporated into RHR 1812 Field Notes.

Access to the Survey Site

We accessed the survey site via the Naval Ordnance Annex High Road, which travels through dense ravine type forest near the Almagosa Spring area (Text Figure 1812-1). At the Almagosa Springs site, water issues from two cave openings (a third, Dobo Spring, is located about 450 m downstream but was not visited) in the Alifan Limestone, where it is in contact with the underlying volcanic rock (Bolanos Pyroclastic Member of the Umatac Formation) at an elevation of about 218 m. Spring water from the two springs at the head of the Almagosa River is diverted by the U. S. Navy through ten-inch pipes that emerge from the cave openings. Water that is not utilized by the U. S. Navy forms the headwater of the Almagosa River. Steel cages at the cave openings prevent unauthorized access into the cave openings proper. The smaller of the cave openings can be accessed via a footbridge over the main river channel that issues from the larger cave opening.

Upon driving to the Almagosa Springs site (headwater of the Almagosa River), we were moderately surprised to see that the river channel was also a raging torrent of water like that we saw earlier at the EOD site (Text Figure 1812-2). At both spring exit sites, the caged cave openings were completely filled by gushing torrents of water, with about 90 percent of the flow issuing from the larger, northernmost cave, as shown in Text Figure 1812-3. I had never before seen such a volume of water flowing from the cave openings, particularly during a dry season. Evidently, the rainfall in the southern mountains of Guam during the previous evening was quite heavy. Water issuing from the cave openings was mildly turbid, which is a result of the rapidity of surface water percolation downward into the porous Alifan Limestone to underground caves and channels to the spring openings.

We were previously advised that the trail head to Transect No. 9 was located at Almagosa Spring, and after a short search we found a tape marker on the north end of the footbridge. We interpreted the marker as the beginning of Transect No. 9. The trail markers were about 10 m apart, and we proceeded to conduct the snail survey in a southwest direction up a very steep slope to Station 290 m, where the red-taped markers suddenly disappeared at the top of a narrow sharp ridge. From the summit of the ridge, we contacted Ms. Claudine Camacho of DCA via mobile phone for assistance. Ms. Camacho, who marked the trail and the transect line, informed us that we were not yet at the starting point of the transect. She directed us to continue northward on the ridge crest for about 30 m to two *Guettarda speciosa* trees on the knife edge ridge crest, where we would find within a 5-m radius, a 4-ft-high orange pole stake and survey marker. While Barry Smith was in phone contact with Ms. Camacho, I quickly located the two *Guettarda speciosa* trees, pole, and survey marker. The survey marker appeared to be of Japanese origin (a 2-in diameter brass slug in a 4-in^2 concrete post that bore the letters A P, followed by two sets of three parallel lines beneath which the numerals 23 were stamped into the metal). The marker was not noted on the U. S. Geological Agat Quadrangle map that we carried with us. At the survey marker, our GPS receiver indicated an elevation of 289 ± 17 m. We were instructed to follow a tape-marked trail from the two *Guettarda speciosa* trees directly down into the adjacent steep-sloped valley to its floor, where it would intercept Transect 9 at Station 250 m. The transect line extended southeastward from Station 260 m to Station 500 m and northwestward from Station 260 m to Station 0 m, more or less along the axis of the valley floor. We quickly located the marked trail down a very steep slope to Station 250 m of Transect No. 9, and decided to survey the southeastern half of Transect No. 9 first.

Although we mistakenly conducted a 290 m snail survey up the steep slope from Almagosa Springs to the top of the adjacent ridge, the snail survey data are here incorporated into the overall survey data as Transect No. 9 Annex.

The weather during both Transect 9 and Transect 9 Annex was partly to completely cloudy with several light to moderately heavy rain showers on May 6, and cloudy to partly with scattered light rainfall from passing squalls.

General Physiographic and Geologic Setting of the Survey Site

Both Transect No. 9 and Transect No. 9 Annex occur entirely within the 'Rough Summit Land' of dissected karst limestone physiographic unit described by Tracey et al. (1959, 1964). The rough summit land is developed entirely upon Alifan Limestone of Late Miocene age that caps part of the north-south trending mountain chain of southern Guam (Map Figures 1812-1 and 1812-2), mostly around and between the summits of Mt. Alifan, Mt. Almagosa, and Mt. Lamlam (Text Figures 1812-4 and 1812-5). Rough summit land has formed by solution and recrystallization of a greatly jointed and faulted limestone formation that was originally much thicker and extensive than at the present. No surface streams occur in the rough summit land, as all drainage is downward into the porous underlying limestone. Such downward movement is quite rapid through sinks, caves, and fault zones that have formed preferential subsurface groundwater channels. Upon reaching more impervious basement volcanic rocks, most of this downward percolating groundwater then moves laterally along the limestone-volcanic rock interface, probably following a preexisting drainage pattern of the volcanic rock, where it emerges as springs at the peripheral margin of the limestone unit. Extreme recrystallization followed by erosion of rock has resulted in the development of the sharp elongate ridges characteristic of the rough summit land. Topographically, the overall land unit is characterized by high knobs, sharp elongate ridges, irregular enclosed depressions (dolines) encircled with steep slopes to vertical walls, scarps, and cone-shaped peaks. Although erosion has not yet reached basement rocks upon which the limestone overlies, such topography can be generally characterized as mature karst.

The survey of the southern half of Transect No. 9 from Station 250 m to its southeastern end at Station 500 m was conducted on the afternoon of May 6, 2009, and its northern half from Station 250 m to its northwestern end at Station 0 m was conducted on May 9, 2009. Transect No. 9 Annex was surveyed on the morning of May 6, 2009.

General Physiographic and Geologic Setting Within Transect No. 9 Area: Transect No. 9 is situated in a narrow valley between two steep-sloped, knife-edge ridges southeast of Mt. Almagosa peak (Map Figures 1812-1 and 1812-2). Within the steep-sided valley, the transect runs along the north-south trending axis of an oval-shaped doline about 750 m long. Within this doline, the limestone surface is eroded into a rugged, karrenfeld topography of solution-pitted and jagged-sculptured pinnacles and thin, knife-edge ridges of 1–2 m relief that are separated by open cracks, holes, and fissures ranging from a few centimeters to 1 m in width (Text Figure 1812-6). In places, elongate fissures revealed a prominent retrolinear pattern of intersecting joints. At the south end of the transect, extensive erosion between jointing planes has produced scattered isolated blocks of limestone up to 5 m high and wide. Local sink holes are common, with several encountered along the transect that were up to 10 m in diameter. Between Transect

Stations 410 m and 440 m, a large sink was encountered that was about 10 m across and that was formed by a cave ceiling collapse. A short investigation of the sink revealed peripheral cavernous areas with numerous large stalactites and stalagmites and a number of unexplored openings that extended downward to an unknown depth. Progress in such topography is precarious and slow, as much of the limestone surface is covered by a thick carpet of moss up to 5 cm or more in thickness. Although much of the solution pinnacled surface affords stable footing, thin spires and ridges can break under one's weight, and loose pieces of rock can move and cause one to lose their footing (Text Figure 1812-6). Progress through this terrain is further impeded by dense forest.

At the north end of the transect, between Stations 200 m and 0 m, the transect turns westward out of the karrenfeld topography and up the lower western slope of the valley. Transition from the karrenfeld region was rather abrupt, and that could be correlated with a sudden increase in slope steepness and reduced ruggedness of the limestone outcrop, mainly as a result of less relief by in-filling of cracks, fissures, and holes by minor amounts of soil and abundant gravel- to cobble-sized limestone fragments. Most of this fragmented material has been accumulated by sheet-wash and talus from higher elevations of the adjacent steep western valley slope.

General Physiographic and Geologic Setting Within Transect No. 9 Annex Area: From the Almagosa trail head, Transect No. 9 Annex follows up a rather steep slope for approximately 290 m in a general southwesterly direction to the knife-edge ridge top that overlooks the valley in which Transect No. 9 is located (Map Figures 1812-1 and 1812-2). From the trail head at Almagosa Springs, the transect follows a limestone outcrop along the base of a scarp between Stations 0 m to 30 m, then up over the scarp face to Station 40 m, from whence it traverses across a gentle upward slope and flat, patchy, soil-covered terrace to the base of another limestone scarp about 3 m high at Station 110 m. From the top of the scarp at Station 140 m, the transect continues up a steep slope of limestone outcrop and thin patches of soil to the base of another limestone scarp about 4 m high at Station 200 m. From the top of the scarp at 210 m, the transect continues up a steep slope of rocky outcrop to the ridge crest at Station 270 m, from whence it runs in a southeasterly direction along the ridge crest to Station 290 m, where we could no longer find any taped transect markers. It was at this location where we realized that we were probably not on the real Transect No. 9 and called Ms. Camacho for verification.

<u>Soils</u>

Transect No. 9: The sparse soils developed on the rough summit land at the transect site are classified as Ritidian-Rock outcrop complex, 15 to 60 percent slopes, No. 44 (Soil Survey of Territory of Guam, 1988). Approximately 80 percent of the transect stations between 200 m and 500 m consisted of limestone outcrop with virtually no visible soil accumulation at all. Although no soil on such rock outcrop was apparent, organic litter (sometimes intermixed with rock fragments) in various stages of decomposition commonly occurred in cracks, fissures, and holes. Water drainage in these areas of limestone outcrop is very rapid downward into the porous underlying limestone. Such downward movement is facilitated through sinks, caves, and fault zones that have formed preferential subsurface groundwater channels, and thus available water is very low. Available water for vegetation mostly occurs as that retained in small pore spaces in the limestone rock, along with some that is retained in surface organic material. Where the limestone overlying volcanic rock is thin (up to 10 m thick), it is probable that tree roots could penetrate downward to the volcanic contact, where lateral movement of water may be available.

The remaining 20 percent of the transect stations between 200 m and 0 m are occupied by limestone outcrop, with scattered local patches of a thin (<10 cm thick), extremely cobbly accumulation of Ritidian clay loam. Such patches of soil consist of 60 to 90 percent of limestone fragments, ranging from gravel- to cobble-sized clasts. Most of this fragmented material has been accumulated by sheet-wash and talus from higher elevations of the adjacent steep western valley slope. The clay loam component is very well-drained, dark reddish brown, and mildly to moderately alkaline, and it is mainly derived from dissolution of the coralline limestone.

Transect No. 9 Annex: Soil characteristics along Transect No. 9 Annex are essentially the same as that described above at Transect No. 9 between stations 0 m and 200 m, except were a pronounced terrace occurred between Stations 40 m and 110 m. Soil accumulation was more apparent on the terrace than at any other transect stations along either of the transect areas, particularly in a swale-like depression that contained an unknown thickness of soil and accumulated organic material in various stages of decomposition.

Vegetation of the Transect Survey Sites

Within both Transect No. 9 and Transect No. 9 Annex areas, the overall vegetation can be broadly classified as a ‘mixed mesophytic, broad-leafed evergreen forest’ as defined by Fosberg (1960). Along both transect areas, such forests are developed upon relatively pure coralline rock outcrop of the Alifan Formation at an elevation generally ranging between 220–285 min elevation. Although it is difficult to determine how much this montane limestone forest has been changed from its original state by humans, it probably has been affected least at this location in comparison to many other limestone forests of Guam. The introduction of invasive species of animals and plants, such as pigs, deer, goats, food crops, and tree and weed species, has probably caused the greatest alteration of the forest from its original state along the transect area. Even so, this mountain limestone forest is in a more pristine condition than that found in other limestone forested localities of Guam, possibly except for where inaccessible limestone cliff habitats occur.

Transect No. 9: Although the forest in this transect area can be broadly classified as a ‘mixed mesophytic, broad-leafed evergreen forest’ growing on limestone outcrop, there are several distinct ‘types’ of it that deserve mentioning. Following is a brief account of some of the more common species of vegetation found within these distinct ‘types’ of limestone forest along Transect No. 9.

Merrilliodendron Forest Type: About 30 contiguous stations between transect Stations 200 m and 500 m are overwhelmingly dominated by *Merrilliodendron megacarpum* trees and seedlings. The terrain along this section of the transect is located within an enclosed, elongate doline that sloped gently downward toward Station 500 m, and was mostly within a limestone outcrop that has developed into a rugged karrenfeld topography of solution-pitted and jagged-sculptured pinnacles and thin, knife-edge ridges of 1–2 m relief that are separated by open cracks, holes, and fissures ranging from a few centimeters to 1 m in width (Text Figure 1812-6). Except for organic surface litter, the limestone outcrop is nearly devoid of any surface accumulation of soil. Tree roots extend right down into the porous rock, particularly into narrow cracks and fissures. A peculiar aspect of the *Merrilliodendron megacarpum* trees is their relatively small size and low to moderate stature. Trees with trunk diameters >20 cm diameter are uncommon. Largest of the trees form a dense, medium-height canopy, with small trees forming a lower canopy. Although numerous seedlings are present at ground level, they are not a serious impediment to passage through the forest. Because of the large leaves of this species, the understory is quite shaded, but the seedlings and small, lower-stature trees appear to tolerate such regions quite well. Beneath this shaded canopy, there is a conspicuous absence of weedy herbaceous species, but their absence may also be partly caused by a loosely open-textured bryophytic species that forms a dense layer up to 5 cm or more thick that covers nearly all exposed limestone surfaces (Text Figure 1812-6).

Other conspicuous but minor components of vegetation observed within the *Merrillodendron* forest type are woody vines of *Freycinetia reineckei* and a few scattered *Areca catechu* (betelnut palm) trees. At Station 340 m to 350 m, the transect line passed tangentially to a small muddy swale about 10–15 m in diameter that was dominated by meter-high ferns and weedy herbaceous species. This swale is of interest, because it may represent a location where erosion has exposed basement rocks, possibly the Talisay Member of the Alifan Limestone Formation that underlies the Alifan Limestone. The swale may also represent a cave collapse that has been mostly infilled with clayey sheetwash and organic muck.

Mixed Forest Type: The remaining 20 contiguous stations between transect Stations 0 m and 200 m are occupied by a mixed assemblage of forest species more typical of pure limestone outcrop. Transition from the *Merrilliodendron* forest type was rather abrupt, and that could be correlated with a sudden increase in slope steepness and reduced ruggedness of the limestone outcrop, mainly as a result of less relief by in-filling of cracks, fissures, and holes by minor amounts of soil and abundant gravel- to cobble-sized limestone fragments. Most of this fragmental material has been accumulated by sheetwash and talus from higher elevations of the adjacent steep western valley slope. The forest between Stations 50 m and 200 m here consists of scattered dense patches of *Pandanus tectorius* and *Hibiscus tiliaceus*, with intervening areas of mixed species of small- to medium-sized trees that form a more open forest with a rather low upper story and weedy ground cover (Text Figure 1812-7). Several small open areas (< 10 m across) dominated by shrubs and weeds were encountered near the transition zone, one of which that had a large *Intsia bijuga* tree at its margin (Text Figure 1812-8). Between transect Stations 0 m and 50 m, the slope became quite steep, and the forest was dominated by a rather dense understory of *Guamia mariannae* and scattered *Triphasia trifolia* trees. Other conspicuous components of the mixed forest type included *Guettarda speciosa*, *Aglaia mariannensis*, *Cananga odorata*, *Intsia bijuga*, *Medinilla rosea*, *Ficus prolixa*, *Freycinetia reineckei*, and *Cestrum diurnum*.

Transect No. 9 Annex: Forest characteristics along Transect No. 9 Annex are essentially that of the ‘mixed forest type’ described above at Transect No. 9, except were a pronounced terrace occurred between Stations 40 m and 110 m. On the terrace, the forest consisted of a few rather large scattered trees with the intervening regions dominated by large ferns up to 1.5 m high. The most conspicuous of the large trees is a *Artocarpus mariannensis* with large buttress roots (Text Figure 1812-9). At the lower part of this terrace, a conspicuous patch of *Miscanthus floridulus* was growing in an open area. Another difference in vegetation at this transect is the presence of scattered *Merrilliodendron megacarpum* that occurred from Station 110 m to the very top of the ridge crest at Station 270 m. Along the ridge crest, many of the trees are scrubby and wind sculptured, particularly *Aglaia mariannensis*, *Triphasia trifolia*, *Cestrum diurnum*, and *Premna obtusifolia*. Several conspicuous trees that were photographed include the orange fruits of a *Fagraea galilai* tree (Text Figure 1812-10), that is probably the same tree from which Dr. Stone (1970) made his collections, a cluster of conspicuous red fruits of a woody *Freycinetia reineckei* vine (Text Figure 1812-11), the red fruits of a *Discocalyx megacarpa* shrub (Text Figure 1812-12), and an unusual, red-colored bracket fungus (Text Figure 1812-13).

Results of the Field Snail Survey at Transect No. 9

Results of snail observations by both survey members are tabulated in Table A-3. Two living and 8 dead *Satsuma mercatoria* snails were observed on the ground; 20 dead *Achatina fulica* were observed on the ground; 11dead *Euglandina rosea* were observed on the ground; 2 dead *Pythia scarabaeus* were observed on the ground; and 1 dead *Subulina octona* was observed on the ground. No living or dead endangered land snails were observed along the transect.

Table A-3. Land snails recorded by two observers surveying 10-m sectors of the Almagosa Spring, Transect No. 9.

Transect Sector	Species Observed	Number of Specimens	Habitat
(250 m to 0 m conducted on May 8, 2009)			
0-10	*Satsuma mercatoria*	1	Dead specimen on ground
10–20	None		
20–30	None		
30–40	None		
40–50	*Achatina fulica*	4	Dead specimens on ground
	Euglandina rosea	1	Dead specimen on ground
50–60	None		
60–70	None		
70–80	None		
80–90	*Achatina fulica*	4	Dead specimen on ground
90–100	*Satsuma mercatoria*	1	Dead specimen on ground
100–110	None		
110–120	*Achatina fulica*	1	Dead specimen on ground
120–130	None		
130–140	None		
140–150	*Achatina fulica*	1	Dead specimen on ground
150–160	None		
160–170	None		
170–180	None		
180–190	None		
190–200	None		
200–210	None		
210–220	None		
220–230	None		
230–240	None		
240–250	None		
(250 m to 500 m conducted on May 6)			
250–260	None		
260–270	*Satsuma mercatoria*	1	Found living on ground
270–280	*Satsuma mercatoria*	1	Dead specimen on ground
280–290	None		
290–300	*Achatina fulica*	1	Dead shell inhabited by live *Coenobita brevimanus*
300–310	None		
310–320	None		
320–330	None		
330–340	None		
340–350	None		
350–360	None		
360–370	*Subulina octona*	1	Dead specimen on ground; in leaf litter
370–380	None		
380–390	None		
390–400	None		
400–410	*Satsuma mercatoria*	1	Found living on ground
410–420	None		
420–430	*Achatina fulica*	>10	Dead specimens on floor of a collapsed cave
	Euglandina rosea	>10	Dead specimens on floor of a collapsed cave
430–440	None		
440–450	None		
450–460	*Satsuma mercatoria*	2	Dead specimen on ground
460–470	*Satsuma mercatoria*	3	Dead specimens on ground
	Pythia scarabaeus	2	Dead specimens on ground
	Achatina fulica	3	Dead specimens on ground
470–480	None		
480–490	None		
490–500	*Achatina fulica*	2	Dead specimen on ground

Remarks about the Snail Observations

Weather conditions during our search, especially on May 5, were favorable for snail activity. The weather was cloudy with scattered light to heavy rain showers. In addition to favorable weather conditions and shade, there are also host species of vegetation on which snails are more likely to be found (see Hopper and Smith, 1992). When such host vegetation species occurred within a sector, they were given preference during the search.

A conspicuous increase in number of land snails of southern Guam was found in limestone forest habitat in comparison to nearby previous volcanic forest habitats.

Results of the Field Snail Survey at Transect No. 9 Annex

Although our survey of the 290-m trail up the steep slope from Almagosa Springs to the top of the adjacent ridge was not part of our scope of work, we have incorporated the data into the overall survey. Results of snail observations on Transect No. 9 Annex tabulated in Table A-4.

At Transect No. 9 Annex, we observed 1 living and 16 dead *Satsuma mercatoria* on the ground; 19 dead *Achatina fulica* on the ground; 9 dead *Euglandina rosea* on the ground; 10 dead *Pythia scarabaeus* on the ground; and 3 dead *Partula gibba* on the ground (Text Figure 1812-14). The dead shells of *Partula gibba* observed on this transect indicate that the area was historically inhabited by this species, but no living endangered land snails were observed along the transect.

Other Observations

As we entered the Almagosa Spring Site, we observed a male deer (*Cervus mariannus*) and five wild pigs (*Sus scrofa*) cross the road in front of us, and at every location where any standing water was present, we were serenaded by a chorus of frogs, particularly at a shallow wetland pool of water near the spring. Although three of the wild pigs were dominantly black-skinned, the remaining two were mostly white-skinned. Upon arriving at the spring, we observed another white-skinned pig that remained motionless for about 15 seconds before dashing into the vegetation.

Table A-4. Land snails recorded by two observers surveying 10-m sectors of the Almagosa Spring, Transect No. 9 Annex

Transect Sector	Species Observed	Number of Specimens	Habitat
0–10	*Satsuma mercatoria*	1	Dead specimen on ground
10–20	None		
20–30	*Satsuma mercatoria*	1	Dead specimen on ground
30–40	*Satsuma mercatoria*	11	Dead specimens on ground
40–50	*Partula gibba*	1	Dead specimen on ground
50–60	None		
60–70	*Achatina fulica*	1	Dead specimen on ground
70–80	None		
80–90	None		
90–100	*Achatina fulica*	1	Dead specimen on ground
100–110	None		
110–120	*Achatina fulica*	3	Dead specimens on ground
	Partula gibba	1	Dead specimen on ground
	Pythia scarabaeus	1	Dead specimen on ground
	Satsuma mercatoria	1	Dead specimen on ground
120–130	None		
130–140	*Euglandina rosea*	1	Dead specimen on ground
140–150	*Achatina fulica*	1	Dead specimen on ground
150–160	None		
160–170	None		
170–180	None		
180–190	None		
190–200	None		
200–210	None		
210–220	None		
220–230	*Satsuma mercatoria*	1	Dead specimen on ground
	Achatina fulica	1	Dead specimen on ground
230–240	*Achatina fulica*	4	Dead specimens on ground
	Pythia scarabaeus	2	Dead specimens on ground
	Euglandina rosea	5	Dead specimens on ground
240–250	*Satsuma mercatoria*	1	Dead specimen on ground
	Achatina fulica	1	Dead specimen on ground
250–260	*Achatina fulica*	1	Dead specimen on ground
	Pythia scarabaeus	1	Dead specimen on ground
	Euglandina rosea	1	Dead specimen on ground
260–270	*Satsuma mercatoria*	1	Found living on ground
	Achatina fulica	1	Dead specimen on ground
270–280	*Euglandina rosea*	1	Dead specimen on ground
280–290	*Partula gibba*	1	Dead specimen on ground
	Euglandina rosea	1	Dead specimen on ground
	Pythia scarabaeus	6	Dead specimens on ground
	Achatina fulica	5	Dead specimen on ground

COLLECTIONS

Specimen Data for Geologic Materials Collected:

Specimen Number: RHR 1812-1
Number of Specimens Coll.: 1
Specimen Name: Alifan Limestone composed closely packed branching corals.
Geographic Location and Collecting Station: Mariana Islands, Guam Almagosa Springs; Coll. Sta.: RHR 1812-CS-1, outcrop on steep slope above Almagosa Springs at about 8 m elevation above and 20 m to the south of Almagosa Spring itself.
Geologic Formation: Alifan Limestone Formation
Elevation: 232 m
Notes: This specimen was collected on a steep slope (about 60 percent) of a limestone outcrop. The specimen was in place (horizontal attitude), but loose, and was wedged out. The specimen is composed of horizontally oriented, closely packed branching corals pieces that are in contact with each other, with void spaces in-filled with mudstone. The branches are terete in cross section and of two size classes, with the larger diameter (10 mm) pieces appearing to be a branching *Porites* sp.; and smaller diameter (5 to 7 mm) pieces appearing to be an arborescent branching *Acropora* species, which are significantly thicker than the arborescent branching *Acropora* species in Spec RHR 1812-2.

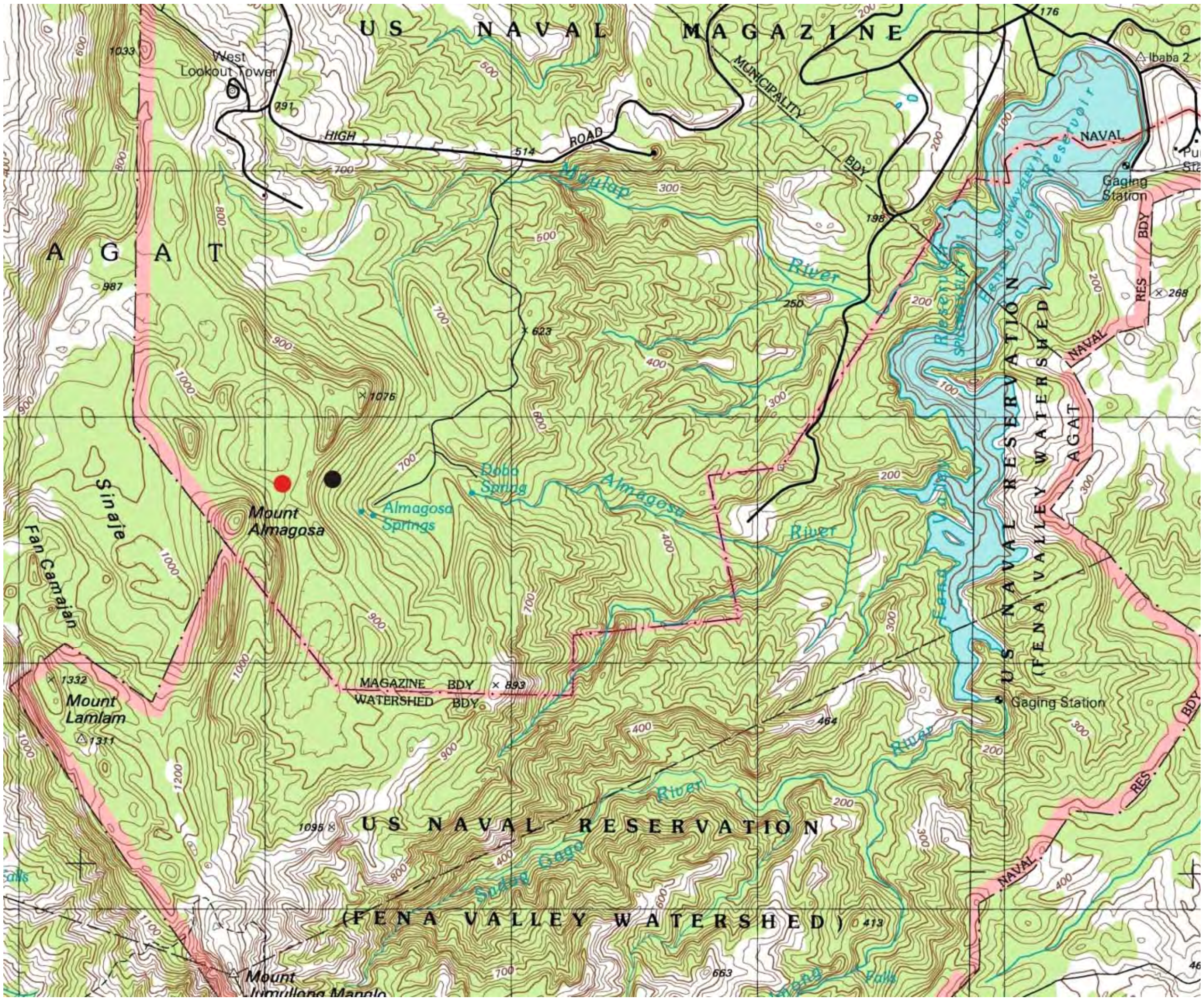
Specimen Name: Fossil branching corals in hand specimen of Alifan Limestone.
Number of Specimens Coll.: 1
Specimen Number: RHR 1812-2.
Geographic Location and Collecting Station: Mariana Islands, Guam Almagosa Springs; Coll. Sta.: RHR 1812-CS-2, on steep slope above Almagosa Springs, at about 38 m elevation above and 30 m to the south of Almagosa Spring itself.
Geologic Formation: Alifan Limestone Formation
Elevation: 268 m
Notes: This specimen was collected on a steep slope (about 60 percent) at the top of a local scarp of a limestone outcrop. The specimen was in place (horizontal attitude), but loose, and was wedged out. The specimen is composed of horizontally oriented, closely packed, branching corals pieces that are in contact with each other, with void spaces in-filled with mudstone. The branches are terete in cross section and 3–5 mm in diameter, and appear to be a very small branching arborescent *Acropora* species. The branching *Acropora* pieces in this specimen are significantly smaller in diameter than those in Spec. RHR 1812-1, and are smaller than any present living arborescent branching *Acropora* species.

Specimen Name: Sample of Alifan Limestone.
Number of Specimens Coll.: 1
Specimen Number: RHR 1812-3.
Geographic Location and Collecting Station: Mariana Islands, Guam Almagosa Springs; Coll. Sta.: RHR 1812-CS-3, specimen collected on a steep slope above Almagosa Springs, at about 66 m elevation above and 50 m to the south of Almagosa Spring itself.
Geologic Formation: Alifan Limestone Formation
Elevation: 286 m
Notes: This specimen was collected near the crest of a steep slope (about 70 percent) above

Almagosa Springs. The specimen was in place (horizontal attitude), that was broken loose from an outcrop surrounded by much fine to coarse loose limestone fragments, which mostly appears to have accumulated by sheet-wash. The fractured face is an intense white color that displays intense recrystallization. From hand lens inspection the specimen is a detrital limestone composed of broken pieces of mollusc shells and other unidentifiable fragments in a sand and mud matrix that was deposited in a lagoonal environment. The specimen is strikingly different from specimens RHR 1812-1 and 1812-2 that were collected lower on the same slope.

Specimen Name: Sample of Alifan Limestone.
Number of Specimens Coll.: 2 pieces.
Specimen Number: RHR 1812-4. (larger pc. 1812-4a, and smaller pc. 1812-4b)
Geographic Location and Collecting Station: Mariana Islands, Guam, about 500 m southwest of Almagosa Springs; Coll. Sta.: RHR 1812-CS-4. Specimen collected within an oval-shaped doline about 750 m long situated in a valley between two steep-sloped, knife-edge ridges southeast of Mount Almagosa peak (see Map Figure 1812-1 for location). Within this doline, the limestone surface is eroded into a rugged, karrenfeld topography of solution-pitted and jagged-sculptured pinnacles and thin, knife-edge ridges of 1–2 m relief that are separated by open cracks, holes, and fissures that range from a few centimeters to a meter in width. At the south end of the doline, extensive erosion between jointing planes has also produced scattered isolated blocks of remnant limestone up to 5 m high and wide, from which the specimens were collected.
Geologic Formation: Alifan Limestone Formation
Elevation: 262 m
Notes: This specimen was collected about 1 m above the base of one of the remnant blocks of limestone described above. The block appears to be in place. The fractured face has an overall pink color that displays very intense recrystallization (sugary appearance). Upon inspection at 30x magnification, the pink color is due to surface staining by clay in voids and fractures. The specimen is so recrystallized that it is difficult to determine its original composition, but from its overall texture it appears to be a detrital limestone. Possibly thin section analysis would reveal more detail.

MAP FIGURES



Map Figure 1812-1. A section of the Agat and Talofofo USGS Quadrangle Maps spliced together and showing the mid parts of the Almagosa Spring, Transect No. 9 (red dot)and Transect No. 9 Annex (black dot), and other geographic areas mentioned in the text.

Map Figure 1812-2. A satellite image showing the location and track of the Almagosa Spring, Transect No. 9 (red dot) and Transect No. 9 Annex (black dot), within the 'Rough Summit Land' of dissected karst limestone physiographic unit in southern Guam. Vegetation consists of a mosaic pattern of forested areas (dark green) and savanna grassland areas (light green). Letter symbols: A = Explosive Ordinance Disposal (EOD) area, B = Almagosa Springs, C = ridge between Transect 9 and Transect 9 Annex, and D = road to Almagosa Springs.

Text Figure 1812-1. View of a volcanic mountainous upland ravine type forest developed on the north side of the Almagosa River about 50 meters downstream of the Almagosa Spring. In the background are several *Cocos nucifera* trees whose trunks are covered with *Freycinetia reineckei* vines, to the left is a clump of *Bambusa vulgaris* canes, and to the right is an open branching *Hibiscus tiliaceus* tree.

Text Figure 1812-2. The trail head at a footbridge that crosses over the Almagosa River to a smaller second cave spring opening. Normally at this location the Almagosa River has just a trickle of water flowing in it.

Text Figure 1812-3. A torrential outflow of water from the main spring site cave opening at Almagosa Springs. The wire cage from which the water is gushing is about 1.2 m tall, wide, and high, which gives some idea of the amount of water pouring from the opening.

Text Figure 1812-4. A part of the rough limestone summit land showing a round-topped, unnamed mountain peak 328 m high located about 750 m north of Transect No. 9. Photo taken from the crest of a steep north-south trending limestone ridge between Transect 9 to the left and Transect 9 Annex to the right.

Text Figure 1812-5. A view to the northeast from the crest of a steep, north-south trending limestone ridge between Transect 9 to the left and Transect 9 Annex to the right. To the left is the steep east-facing slope and peaks of rough Alifan limestone summit land, which to the right grades into a forested lower, more gentle, dissected, sloping, hilly terrain developed upon several isolated outliers of Alifan limestone surrounded by volcanic rocks of the Dandan Flow Member of the Umatac Formation.

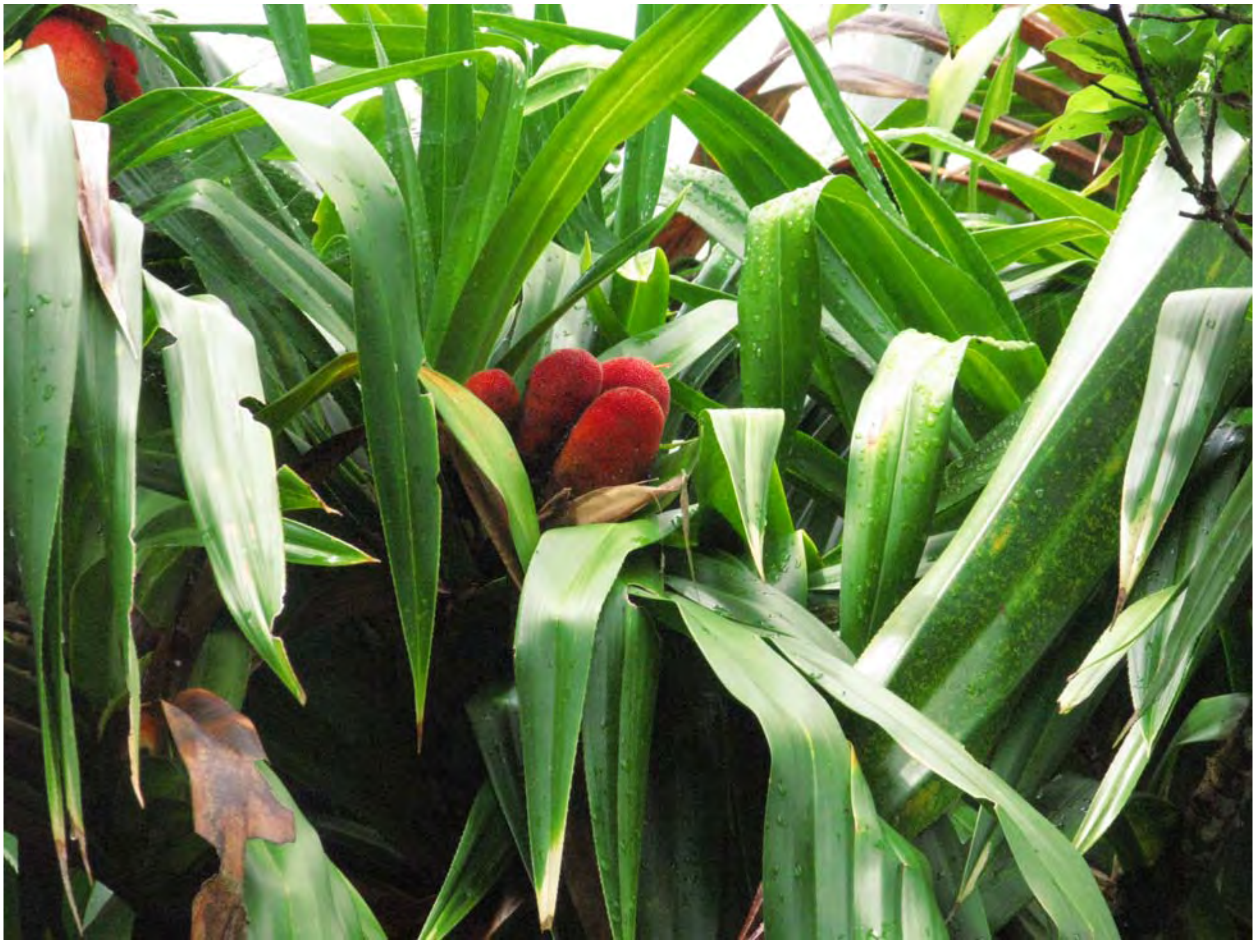
Text Figure 1812-6. A view at Transect 9, Station 220 m that shows how the limestone surface is eroded into a rugged, karrenfeld topography of solution-pitted and jagged-sculptured pinnacles and thin, knife-edge ridges of 1–2 m relief that are separated by open cracks, holes, and fissures that range from a few centimeters to 1 m in width. For scale of the irregular karren topography, one of the survey members (Randall) is standing beside a moss-covered pinnacle. Added to the unsure footing is the presence of mats of moss that conceal holes and fissures. Along this sector of the transect, a dense forest of relatively small *Merrilliodendron megacarpum* trees and seedlings (vegetation on right) dominate the karst surface. On the left a tree is densely covered with vines of *Freycinetia reineckei*.

Text Figure 1812-7. A typical view of the forest along Transect 9, between Stations 50 m and 200 m that consists of scattered patches of *Pandanus tectorius* and *Hibiscus tiliaceus*, with intervening areas of mixed species of shrubs and small- to medium-sized trees that form a more open forest with a rather low upper story and weedy ground cover.

Text Figure 1812-8. One of a number of small open areas along Transect 9, between Stations 50 m and 200 m, that is dominated by shrubs and weeds. At the far side of the weedy-bushy area is a large *Intsia bijuga* tree festooned with numerous ferns and orchids. Other conspicuous trees are *Pandanus tectorius*, *Pandanus dubius*, and a *Cycas circinalis* with pendant fern fronds of *Nephrolepis acutifolia* hanging below it.

Text Figure 1812-9. A large, isolated *Artocarpus mariannensis* tree with large buttress roots was found growing on an intervening terrace along the steep terrain of Transect 9 Annex, between Stations 40 m and 110 m. Ground cover on the terrace is dominated by large ferns up to 2 m high.

Text Figure 1812-10. A cluster of conspicuous reddish-orange fruits of a *Fagraea galilai* tree growing on the steep slope of Transect 9 Annex, between Stations 210 m and 220 m, that may be the same tree from which Dr. Stone (1970) made his collections.



Text Figure 1812-11. A cluster of conspicuous red fruits of a woody *Freycinetia reineckei* vine growing on the steep slope of Transect 9 Annex between Stations 260 m and 270 m.

Text Figure 1812-12. A cluster of conspicuous red fruits of a *Discocalyx megacarpa* shrub growing on the steep slope of Transect 9 Annex between Stations 240 m and 250 m.

Text Figure 1812-13. An unusual red-colored bracket fungus growing on the steep slope of Transect 9 Annex between Stations 70 m and 80 m.

Text Figure 1812-14. A dead shell of *Partula gibba* found on the ground surface at Transect 9 Annex between Stations 40 m and 50 m.

RHR 1813 FIELD NOTES
(Land Snail Survey, Transect No. 3)

Date: May 11, 2009

Geographic Location: Guam, Almagosa River Valley (Lower Valley)

Introduction

During the afternoon of May 10, 2009, Mr. Barry Smith of the University of Guam Marine Laboratory notified me that our next field excursion for the snail survey project would take place May 11, 2009 at the U. S. Naval Ordnance Annex, and I was asked to meet him at the University of Guam Marine Laboratory at 0730. He informed me that the survey was located immediately east of the Explosive Ordnance Disposal (EOD) pit on the lower part of the Almagosa River valley, and that it would be accessed by hiking from the EOD pit (Map Figure 1813-1). We briefly discussed what kind of equipment and gear to take along for the excursion.

On the morning of the May 11, I met Barry Smith at the University of Guam Marine Laboratory at 0730, where we loaded our gear into his pickup truck. We then proceeded to the Main U. S. Navy Base at Apra Harbor, where we obtained personal passes to enter the U. S. Naval Ordnance Annex. Upon our arrival at U. S. Naval Ordnance Annex, we proceeded to the EOD Office where we signed their login sheet.

During our survey the weather was sunny to partly cloudy with no rain showers.

Access to the Survey Site

From the EOD Office we proceeded via a macadam paved roadway to the EOD access road. The access road fortunately was not chained off, and we proceeded directly to the EOD pit. The frogs (*Rana* sp.) were not quite as vocal as we passed over the Maulap River Bridge and at the EOD pit as they were in the rain of May 6, probably because of the day's sunny weather. For a view of the disposal pit see Text Figure 1811-1.

There are two snail survey transect sites within the Almagosa River Valley watershed region, located between the EOD site and the mouth of the Almagosa River at Fena Reservoir: one (Transect No. 2 that was conducted on May 6) in the upper valley region (above the Upper Fork of the Almagosa River) and the second (Transect No. 3) to be conducted today in the lower valley region (below the Upper Fork of the Almagosa River). Map Figure 1813-1 shows the general topography of the EOD transect site, and Map Figure 1813-2 shows an aerial view of the Transect No. 3 area. Transect No. 3 starts at an approximate upstream elevation of 73 m and ends at a downstream elevation of 48 m.

The trail head for Transect No. 3 is located on the eastern part of the loop roadway, about 50 m north of Transect No. 2 trail head, that encircles the EOD pit. The entry had been marked earlier with orange spray paint on the macadam roadside. The trail head penetrates through a dense band of *Vetiveria zizanioides* grass, which dominates much of the lower loop roadside, then traverses down a short steep forested valley slope, then up a steep opposite slope, across a narrow ridge crest, and down a steep slope to the north side of the Almagosa River. There was a moderate flow of clear water in the Almagosa River, which is quite different from the turbid high water conditions that caused us to abort conducting this transect on May 8. Recent drift debris along the river banks indicates that river height at that date was about 3 m above the river flow today. At the river crossing, there were no tufaceous-stromatolite build-ups like those noted on the rocky streambed floor farther upstream where we crossed the river during the earlier Transect No. 2 survey. A short distance downstream from our river crossing we found the marked beginning of Transect No. 3, which is 500 m long.

General Physiographic and Geologic Setting of the Survey Site

The following remarks and observations are restricted to a part of the drainage basin in the immediate region between the trail head and terminal end of Transect No. 3. Although the drainage basin of the Almagosa River at the Transect No. 3 location is mostly developed upon the Bolanos Pyroclastic Member (Miocene) of the Umatac Formation, some local fault-exposed outcrops of Alutom deposits of Eocene and Oligocene age and bedded layers of tufaceous-stromatolite deposits also occur within the transect area. The freshest exposed deposits of the pyroclastic rocks were found where the trail head crossed the Almagosa River. These deposits are a dark gray to grayish-brown, grading to greenish-brown with an overall speckled appearance. At the river crossing, all the exposed outcrops of bedrock contained abundant granule- to cobble-sized limestone fragments of the Geus River Member of Oligocene age intercalated within the volcanic matrix. These limestone inclusions ranged from well-rounded to angular in shape, and when fractured, revealed an intense white or mottled pink and tan, recrystallized, dense compact, fine-grained to conglomeratic detrital limestone. A typical cobble-sized limestone clast that was chiseled out from the river bedrock (Sample No. 1813-1) is described below in the 'Collections' section. At this particular river crossing site, no horizontal lenticular beds of limestone, like those earlier described in the nearby Sadog Gago riverbed and along the western shoreline of Fena Reservoir, were observed.

Between transect Stations 0 m to 120 meters, the route traversed diagonally up slope and across a low to gently sloping riverside terrace, ranging from 1–5 m above the adjacent river bed. Except for a few scattered, loose tuffaceous cobbles and rock fragments, the terrace surface is thinly mantled with a dark-colored soil that in turn is veneered with abundant organic litter. Between Stations 40 m and 50 m, a pig wallow revealed yellowish clay that underlies the dark soil and surface litter (Text Figure 1813-1).

From Station 120 m the transect descends down a very steep slope to Station 180 m located in the riverbed at the base of a waterfalls about 10 m in height (Text Fig. 1813-2). The upper half of this steep slope (between Stations 120 m and 150 m) consists of a nearly vertical scarp of rock outcrop, which abruptly grades into a steep talus slope of blocks and boulders to Station 180 m at the river bed, which is also strewn with blocks and boulders to the base of the waterfalls. I immediately recognized that the moss-covered rocky outcrop at the scarp was not of Bolanos pyroclastic deposits. Upon sampling the outcrop, I found most of the scarp face be of a layered travertine-like deposit, but much less dense. After more sampling it became clear that the layered deposits were not travertine, but layered tufaceous-stromatolite deposits that veneered the underlying Bolanos pyroclastic deposits. These veneering tufaceous-stromatolite deposits extended laterally from the transect line farther south and north to the upper waterfall lip. A sample (No. 1813-2) of the tufaceous-stromatolite deposit was collected from the scarp face between transect Stations 140 m and 150. More sampling revealed that the tufaceous-stromatolite deposits were up to 30 cm or more thick at places, implying that flowing river water had cascaded over the scarp face to deposit the veneer at sometime in the past. From the transect line to the upper lip of the present Almagosa River Valley falls is about 30 m farther north of the tufaceous-stromatolite covered scarp face and about 10 m lower, which means that from the time water flowed over scarp face at the transect line, the riverbed has since migrated 30 m northward and deepened it's valley by about 10 m. Therefore, the falls has migrated upstream by about 30 m. The timescale for such physiographic changes to have occurred is in the order of tens of thousands of years.

A steep talus slope of blocks and pebble- to cobble-sized rubble has accumulated at the base of the scarp between transect Stations 150 m and 180 m at the riverbed. Most of the exposed block and boulder surfaces of this slope are also covered with tufaceous-stromatolite deposits, particularly where they abut against the scarp face. Text Figure 1813-3 shows a moss-covered boulder of Bolanos pyroclastic material at transect Station 160 m that is covered with a 5–10 cm layer of tufaceous-stromatolite deposits, from which Sample No. 1813-3 was collected. Modern analogs of such tufaceous-stromatolite deposits are quite common in rivers and streams of southern Guam, such as those shown in the Almagosa River upstream of this transect in Text Figure 1811-3. All such modern tufaceous-stromatolite buildups are mostly composed of calcite crystals that are deposited on the cell wall sheaths of filamentous cyanophytic algae during photosynthesis. This process can be demonstrated in the laboratory by placing a piece of a cyanophyte-covered deposit submerged in river water under a microscope. When viewed with the proper amount of light, the calcite crystals can be observed on the filamentous cell wall sheaths. The vertical fractured face of Sample No. 1813-2 displays the typical banded (layered) nature of tufaceous-stromatolite buildups of alternating brown and tan layers that range from 1–3 mm thick. Generally, the darker brown bands are denser and deposited during dry season low- to intermittent no-flow river conditions, and the thicker tan colored less dense bands are deposited during wet season higher river flow conditions. Unlike tree rings, the number of such annual layers of tufaceous-stromatolite deposits generally cannot be used to estimate the age or rate of deposition of a deposit, as flood water conditions can easily erode the more porous, freshly deposited layers. Therefore, a boundary between layers can represent a hiatus of an unknown number of years. Nevertheless, once a buildup is no longer subject to erosion from sediment movement in riverbeds, such as the above deposits, they can resist erosion fairly well in relation to aragonitic limestone because of their calcitic composition.

An unnamed river, which I will call the Lower Fork of the Almagosa River, joins the Almagosa River about 30 m south of the waterfalls (Text Fig. 1813-4). The confluence of these rivers is somewhat unusual, in that the Almagosa River and the Lower Fork are aligned in the same north-south trend, and at their confluence the Almagosa River makes an abrupt right-angle turn to the west as shown on Map Figures 1813-1 and 1813-2. Upon inspecting the waterfall we were surprised to find that the lower vertical two-thirds of its scarp face was composed of distinct alternating beds of tuffaceous shale, mudstone, and fine- and medium-grained sandstone, with individual beds ranging from 1–10 cm or more in thickness. The coarser-grained beds also contain a few small (up to 5 mm long) black vesicular clasts of basalt. The rock breaks into blocky rectangular pieces, and is well indurated, particularly in respect to the Bolanos pyroclastic deposits exposed on the upper third of the falls. The shale-mudstone layers are pale green to tan, the medium-grained sandstone is gray, and the fine-grained sandstone is light gray to a grayish tan. The contact between the beds is distinct and somewhat undulating, resembling that of a turbidity flow. The lower two-third of the falls is quite distinctive from the Bolanos deposits above it, and it appears to be that of the Alutom Formation (Eocene-Oligocene). A rock sample was collected at the base of the waterfall (Rock Sample No. 1813-4), which shows the typical characteristics of the bedded rock exposed in the lower two-thirds of the waterfall. The overall vertical section of the lower falls has been exposed by a normal fault that strikes north-south along the west banks of the Almagosa River and its Lower Fork, as shown on Map Figures 1813-1 and 1813-2. The base of the lower waterfalls unit is not exposed, and is in fault contact with the down thrown Bolanos pyroclastic deposits. There was no evidence of clayey Talisay Member (Oligocene) deposits at the contact of the Bolanos pyroclastic deposits and Alutom deposits. Both the Almagosa and Lower Fork Rivers now flow over the down thrown side of the Bolanos pyroclastic deposits. Text Figure 1813-5 shows an upstream view of the Almagosa Riverbed about 220 m north of the waterfalls, and Text Figure 1813-6 shows a downstream view of the riverbed about 280 m north of the waterfalls. A detail of the riverbed Bolanos pyroclastic deposits at this location is shown in Text Figure 1813-7.

At Transect Station 450 m, the transect line turns abruptly uphill across a fault talus slope to a ridge top at Station 500 m.

Soil Development Within the Survey Site

Soils developed within the lower Almagosa River valley along the transect site are classified as Akina-Agfayan association, steep, No. 12 (Soil Survey of Territory of Guam, 1988), with the Akina component formed from residuum dominantly derived from tuff and tuff breccia and conglomerate, and the Agfayan component formed from residuum dominantly derived from marine-deposited tuffaceous sandstone.

Such soils within the transect area appeared to be quite deep within flattened regions of low slope (between Transect Stations 0 m and 130 m), thin and patchy with abundant rock exposure on steep scarps and rocky talus slopes between Transect Stations 130 m and 180 m, thin and patchy with abundant rock outcrop along the base of a fault scarp between Transect Stations 180 m and 470 m, and moderately deep on a ridge crest between Transect Stations 470 m and 500 m. Along the transect, soil appeared to be moderately well-drained, particularly at the steeper sloped regions, but at small swale-like depressions and where the transect runs with a few meters of the river bank, the soils are more poorly drained, and at a few places contained small shallow areas of standing water (Text Fig. 1813-2). At most places along the transect, soil surface was covered with abundant dark-colored soil intermixed with organic litter, but where pig rooting exposed deeper soils, the color ranged from brownish yellow to brownish red (Text Fig. 1813-1).

Vegetation Within the Survey Site

Within the transect areas, the vegetation can be broadly classified as variants of a ‘dissected volcanic mountainous upland ravine type’ as defined by Fosberg (1960). Between Transect Stations 0 m and 130 m, the forest consists of a coconut forest on gentle-sloping riverside terrain along the south side of the Almagosa River. Coconut palm trees (*Cocos* *nucifera*) dominate the forest forming an upper- and mid-story assemblage, as shown in Text Figures 1813-1 and 1813-8. Abundant coconut seedling trees up to 3 m tall, along with scattered shrubs and herbaceous weedy vegetation, form a lower story. Conspicuous among the herbaceous vegetation, particularly in swales, was an abundant 1-m-high, triangular-stemmed sedge *Scleria polycarpa*. *Areca catechu* (betelnut palm) ranged from nearly absent to scattered among the coconut trees. Fallen coconut fruits and fronds littered the ground everywhere.

Between Transect Stations 130 m and 180 m the terrain forms an upper, steep-sloped scarp and lower, less-steep talus slope of cobbles and blocky boulders. This well-drained short sector is dominated by low woody shrubs on the steeper upper part and by trees and shrubby vegetation on the talus slope.

At Station 180 m the transect route crosses to the west side of the Almagosa River and follows along the base of a very steep fault scarp within a few meters of the river bank from Station 180 m to Station 470 m (Text Figures 1813-5 and 1813-6). Vegetation along nearly all of these transect sectors is subject to being flooded when the river is in flood stage. Seeps and small springs are also common along this sector as well. Common vegetation along these riverside sectors includes *Cocos nucifera*, *Areca catechu*, *Pandanus tectorius*, *Calophyllum inophyllum*, *Hibiscus tiliaceus*, *Cananga odorata*, *Bambusa vulgaris*, and *Hyptis capitata*.

Between Transect Stations 470 m and 500 m, the transect traverses up a short steep slope to its crest. On the slope crest, the deeper, well-drained soil is dominated by an upper story of *Cocos nucifera*, *Areca catechu*, and *Vitex negundo* trees and second story of *Pandanus tectorius* trees, with a dense, lower story of coconut seedlings, shrubs, and weeds (Text Figure 1813-9).

<u>Snail Survey Results</u>

Results of snail observations by both survey members are tabulated in Table A-5 below. Observed on the transect were 9 dead and 1 living *Satsuma mercatoria* snail shells on the ground; 15 dead *Achatina fulica* snail shells on the ground; 1dead *Euglandina rosea* snail shell on the ground; 3 dead *Melanoides tuberculata* snail shells (an aquatic species) on the ground; and 1 dead *Pythia scarabaeus* snail shell on the ground. No living or dead endangered tree snails were observed within the 50 transect sectors, nor were any observed from the trail head to the transect location.

Table A-5. Land snails recorded by two observers surveying 10-m sectors of the Almagosa River Valley (Lower Valley).

Transect Sector	Species Observed	Number of Specimens	Habitat
0–10	*Satsuma mercatoria*	1	Dead specimen on ground
10–20	None		
20–30	None		
30–40	None		
40–50	*Satsuma mercatoria*	1	Dead specimen on ground
50–60	*Satsuma mercatoria*	1	Dead specimen on ground
60–70	*Satsuma mercatoria*	1	Dead specimen on ground
70–80	*Satsuma mercatoria*	1	Dead specimen on ground
80–90	None		
90–100	*Achatina fulica*	2	Dead specimens on ground
100–110	None		
110–120	None		
120–130	*Euglandina rosea*	1	Dead specimen on ground
130–140	*Achatina fulica*	5	Dead specimens on ground
	Satsuma mercatoria	2	Dead specimens on ground
140–150	*Achatina fulica*	2	Dead specimens on ground
150–160	*Pythia scarabaeus*	1	Dead specimen on ground
160–170	*Achatina fulica*	4	Dead specimens on ground
170–180	*Melanoides tuberculata*	3	Dead specimens on ground; all three collected
180–190	*Achatina fulica*	1	Dead specimen on ground
190–200	*Satsuma mercatoria*	1	Dead specimen on ground
200–210	*Melanoides tuberculata*	1	Dead specimen on ground
210–220	None		
220–230	None		
230–240	None		
240–250	None		
250–260	None		
260–270	None		
270–280	None		
280–290	None		
290–300	*Achatina fulica*	1	Dead specimen on ground; shell inhabited by live *Coenobita brevimanus*
300–310	None		
310–320	None		
320–330	None		
330–340	None		
340–350	None		
350–360	None		
360–370	None		
370–380	None		
380–390	None		
390–400	None		
400–410	None		
410–420	None		
420–430	*Satsuma mercatoria*	1	Found living on ground
	Satsuma mercatoria	1	Dead specimen on ground
430–440	None		
440–450	None		
450–460	None		
460–470	None		
470–480	None		
480–490	None		
490–500	None		

COLLECTIONS

Geologic Specimens:

Specimen Number: RHR 1813-1.
Specimen Name: Sample of a limestone clast from the Gues River Member of the Umatac Formation.
Number of Specimens Coll.: 3 pieces (larger piece 1813-1a, middle sized piece 1813-1b, and smaller piece 1813-1c).
Geographic Location and Collecting Station: Mariana Islands, Guam Almagosa River Valley; Coll. Sta.: RHR 1813-CS-1. Specimen collected from the Almagosa River bedrock about 200 m southeast of the U. S. Naval Magazine EOD site where Transect No. 3 trail head crosses the Almagosa River (see Map Fig. 1813- 2 for location). Geologic Formation: Geus River Member (Oligocene) of the Umatac Formation (Miocene).
Elevation: About 60 m
Notes: At this site many in-place clasts of limestone, ranging from granule- to cobble-size, were partially embedded in the river bedrock of the Bolanos pyroclastic deposits. Most of the embedded clasts stood out in relief above the surrounding pyroclastic deposits, although some were flush with it as well. Loose clasts of limestone that had been weathered out from the pyroclastic deposits were also present where river sediments had accumulated. Most exposed clasts were of an intense white detrital limestone, but some were pink as well. Three pieces of a sub-rounded limestone cobble about 15 cm in diameter dia. were collected (about one-half of the cobble). The fresh fractured surfaces displayed an irregular overall pinkish color with white and light brown mottling. Under magnification of a hand lens, the white mottling areas were found to consist mostly of various sized angular limestone fragments, and the light brown mottling areas consisted of angular to lens-shaped inclusions of granular pyroclastic material weathered to clay. Except for the clay inclusions the limestone is recrystallized, very compact, and hard. The overall fabric appears to be a primary; an accumulation of detrital reef material contaminated with clay and volcanic clastic material that became lithified, then fragmented by explosive volcanism, then became sub-rounded by reworking and transport, and finally was intercalated into water-lain pyroclastic deposits of the Bolanos Pyroclastic Member of the Umatac Formation.

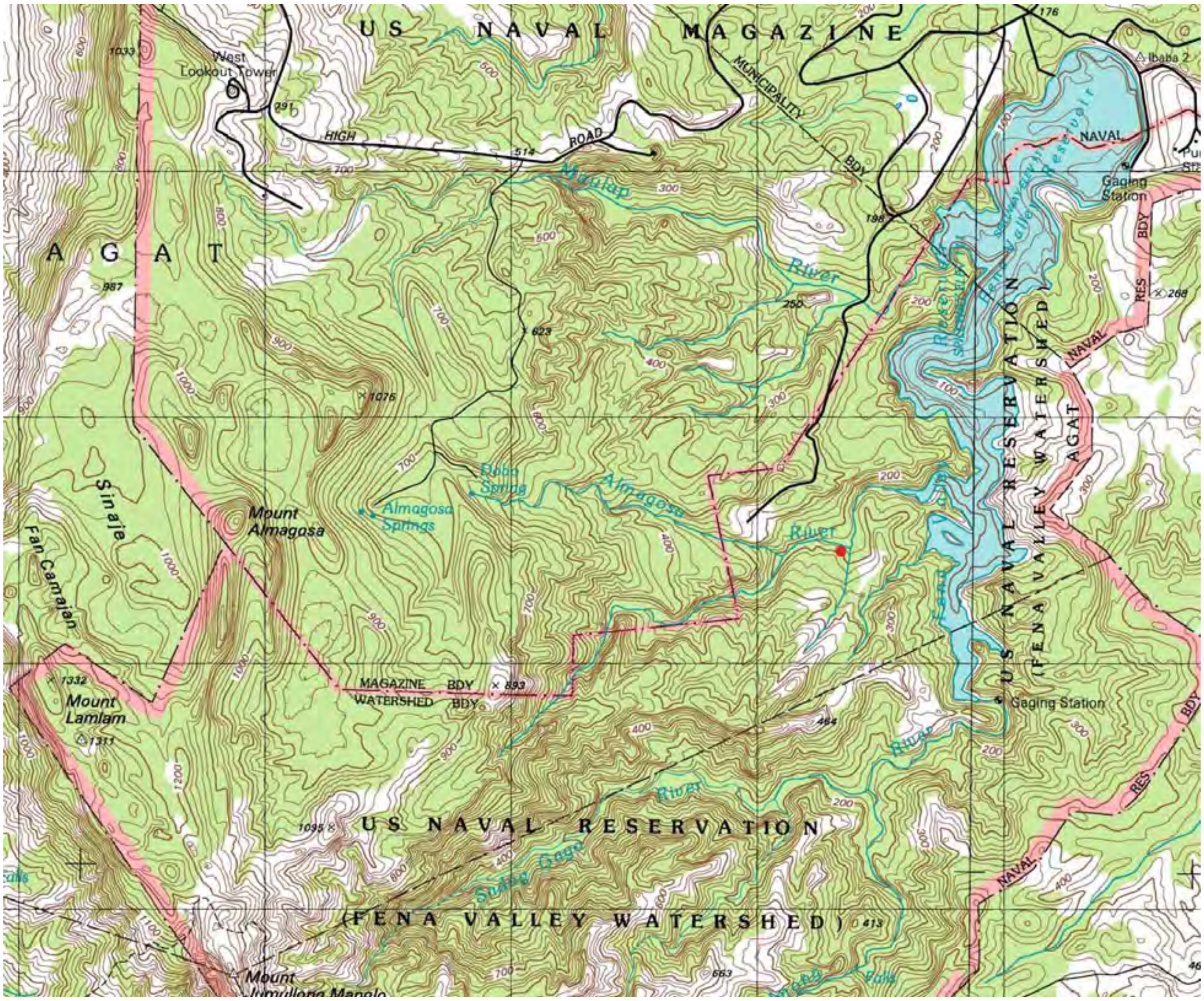
Specimen Number: RHR 1813-2.
Specimen Name: Sample of a tufaceous-stromatolite deposit.
Number of Specimens Coll.: 1 piece.
Geographic Location and Collecting Station: Mariana Islands, Guam Almagosa River Valley; Coll. Sta.: RHR 1813-CS-2: Specimen collected between Transect Stations 140 m and 150 m from the face of a vertical scarp face located about 30 m south of a waterfalls located about 30 m upstream from the confluence of the Almagosa and Lower Almagosa Fork Rivers (see Map Fig. 1813-1 for location).
Geologic Formation: Holocene or possibly Late Pleistocene deposits on Miocene Bolanos Pyroclastic Member rocks of the Umatac Formation.
Elevation: About 60 m

Notes: This sample has a maximum thickness of 5 cm, and, on vertical fracture, displays alternating light tan to dark tan layers 1–3 mm t hick. The sample is more compact and lacks the vertical palisade texture of Sample 1813-3 below.

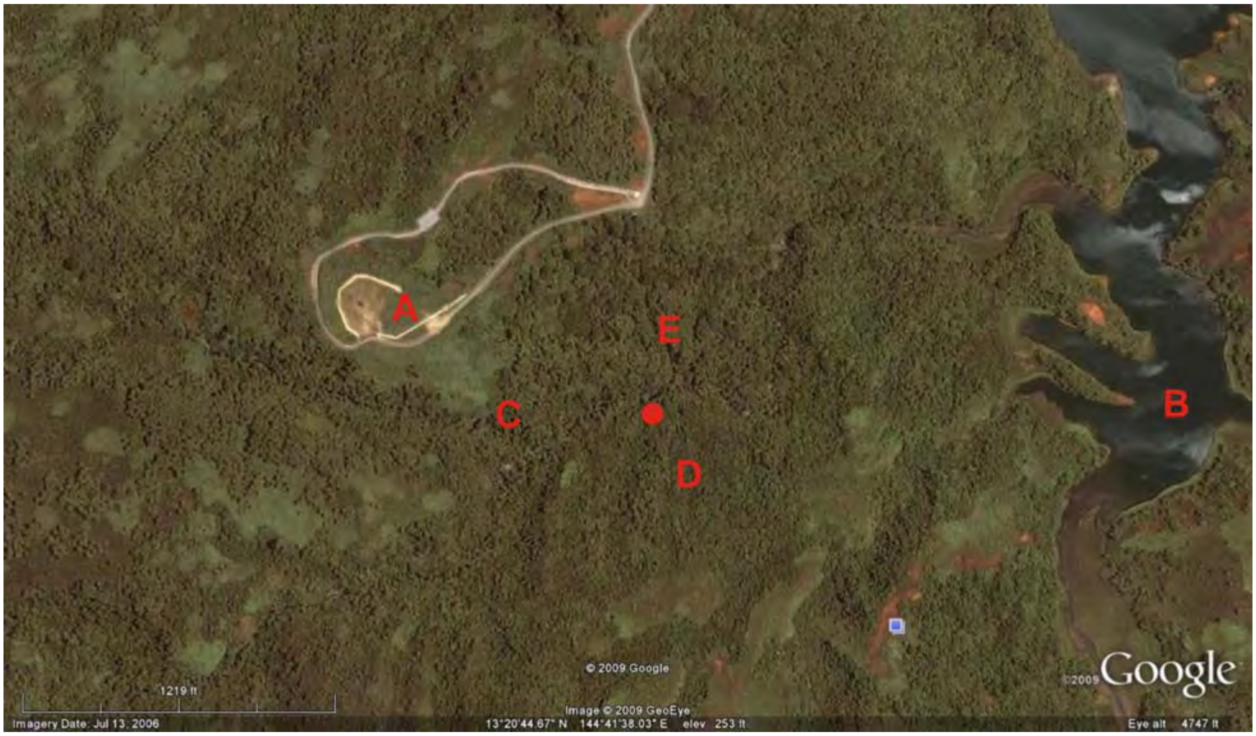
Specimen Number: RHR 1813-3.
Specimen Name: Sample of a tufaceous-stromatolite deposit.
Number of Specimens Coll.: 1 piece.
Geographic Location and Collecting Station: Mariana Islands, Guam Almagosa River Valley; Coll. Sta.: RHR 1813-CS-2: Specimen collected at Transect Stations 160 m from a moss-covered talus slope boulder figured in Text Figure 1813-5, located about 30 m south of a waterfalls located about 30 m upstream from the confluence of the Almagosa and Lower Almagosa Fork Rivers (see Map Fig. 1813-1 for location).
Geologic Formation: Holocene or possibly Late Pleistocene deposits on Miocene Bolanos Pyroclastic Member rocks of the Umatac Formation.
Elevation: About 60 m
Notes: This sample has a maximum thickness of 7 cm, and on the surface and vertical fracture displays a vertical palisade-like texture. Most of these palisade range from 2–4 mm in diameter (see Sample 1813-2 description above for comparison).

Specimen Number: RHR 1813-4.
Specimen Name: Sample of a rock composed of distinct alternating beds of tuffaceous shale, mudstone, and fine- and medium-grained sandstone.
Number of Specimens Coll.: 1 piece.
Geographic Location and Collecting Station: Mariana Islands, Guam Almagosa River Valley. Coll. Sta.: RHR 1813-CS-2: located at Transect 3, Station 160 m, from the lower two-thirds of a waterfalls shown in Text Fig. 1813-2.
Geologic Formation: ?Alutom Formation (Eocene-Oligocene).
Elevation: About 60 m
Notes: Upon inspecting the waterfall, we were surprised to find that the lower vertical two-thirds of its scarp face was composed of distinct alternating beds of tuffaceous shale, mudstone, and fine- and medium-grained sandstone, with individual beds ranging from 1–10 cm or more in thickness. The coarser-grained beds also contain a few small (up to 5 mm long) black vesicular clasts of basalt. The rock breaks into blocky rectangular pieces, and is well indurated, particularly in respect to the Bolanos pyroclastic deposits exposed on the upper third of the falls. The shale-mudstone layers are pale green to tan, the medium-grained sandstone is gray, and the fine-grained sandstone is light gray to a grayish tan. The contact between the beds is distinct and somewhat undulating, resembling that of a turbidity flow.

MAP FIGURES



Map Figure 1813-1. A section of the Agat and Talofofo USGS Quadrangle Maps spliced together and showing the mid parts of the Almagosa River, Lower Valley, Transect No. 3 (red dot), and other geographic areas mentioned in the text.



Map Figure 1813-2. A satellite image showing the location and track of the Almagosa River, Lower Valley, Transect No. 3 (red dot) within the 'Volcanic Uplands of Gently Sloping Foothills Cut by Major Streams' physiographic unit. Vegetation consists of a mosaic pattern of forested areas (dark green) and savanna grassland areas (light green). Letter symbols: A = Explosive Ordinance Disposal (EOD) area, B =Fena Reservoir , C = Almagosa River, D = Lower Fork of Almagosa River, and E =Fault along the Almagosa River.

TEXT FIGURES

Text Figure 1813-1. A small pig wallow and surrounding ground area disturbed by pig rooting along Transect No. 3 between Stations 40 m and 50 m.

Text Figure 1813-2. An upstream view of a waterfall on the Almagosa River, located about 30 m upstream from its confluence with the Lower Almagosa Fork. The waterfall has its origin as a result of a normal fault that is shown on Map Figure 1813-2. Since this faulting event, the falls has migrated about 30 m upstream (westward) and deepened its valley by about 10 m. During these erosional processes, the riverbed has also been shifted to the right (north) by about 30 m. As the falls slowly migrated upstream, it has left behind scattered blocks of rock up to 2 m or more across in its downstream riverbed (foreground) that have been plucked or wedged out along joint fractures in falls scarp face. The irregular blocky appearance of falls scarp face is the result of such plucking and wedging action. The upper third of the falls face consists of tuff and tuff breccia characteristic of the Bolanos Pyroclastic Member deposits, while the lower two-thirds of the scarp consists of fault-exposed, bedded, pyroclastic shale-mudstone and sandstone characteristic of the Alutom Formation.

Text Figure 1813-3. A boulder of Bolanos pyroclastic rock located at transect Station 160 m that is covered with a 5–10 cm layer of tufaceous-stromatolite deposits. Although the tufaceous-stromatolite deposit is moss-covered, the concentric layers of the deposit are quite visible. Rock Sample No. 1813-3 was collected from the upper part of the boulder. For scale the geology hammer is 33 cm long.

Text Figure 1813-4. An upstream view at the confluence of the Lower Almagosa Fork (upper left) with the Almagosa River (upper right and foreground). The Almagosa River course makes an abrupt 90 degree right turn to the west at the confluence, and below the confluence is in a north-south alignment with the Lower Fork. The waterfall (not in view) is presently located about 30 m farther upstream from the confluence of the Lower Fork. The large blocks at the confluence and lower left are Alutom pyroclastic deposits that have been wedged out along rectangular jointing planes in the lower waterfall scarp face. At this particular time the volume flow in the Almagosa was about twice that of the Lower Fork.

Text Figure 1813-5. An upstream view of the north-flowing Almagosa River at Transect Station 400 m. Here the riverbed consists of a low-gradient stretch veneered with boulder- and cobble-sized material, mostly of Bolanos pyroclastic material and a few scattered Alutom boulders derived from fault exposed deposits at the falls located about 220 m upstream. The left river bank here grades into a low riverside terrace. The transect line follows along the west bank (right side) of the river a few meters inland along the base of a steep slope of talus debris accumulated along the north-south fault scarp. Vegetation along the transect line here is a typical 'upland ravine type' found in river valleys of the dissected upland mountain streams and rivers in Guam. The patch of tall light green grass along the right riverbank is *Vetiveria zizanioides*, a species recently introduced to prevent erosion within the Fena Watershed Reserve.

Text Figure 1813-6. A downstream view of the north-flowing Almagosa River at Transect Station 460 m. Here the riverbed consists of a high-gradient stretch of bare river bedrock of Bolanos pyroclastic rocks. Note how much of the riverbed topography is controlled by joints that diagonally across it. For a detail of the Bolanos pyroclastic bedrock see Text Figure 1813-7. The right (east) river bank here grades into a low riverside terrace, and the left (west) river abruptly grades into the base of a steep slope of talus debris accumulated along the north-south fault scarp. The transect line follows along the west bank (left side) of the river a few meters inland. Vegetation along the transect line is a typical 'upland ravine type' found in river valleys of the dissected upland mountain streams and rivers in Guam.

Text Figure 1813-7. A detail of the Almagosa River bedrock of tuff and tuff breccia of the Bolanos Pyroclastic Member located at Transect Station 460 m. The scattered white clasts embedded within the Bolanos pyroclastic deposits are fragments of Geus River Member limestone. For scale the pocket knife is 11 cm long.

Text Figure 1813-8. A general view of a coconut forest growing on gentle-sloping riverside terrain at that occurs between Transect Stations 0 m and 130 m.

Text Figure 1813-9. A general view of a *Cocos nucifera-Pandanus tectorius* forest growing on a slope crest between Transect Stations 470 m and 500 m.

RHR 1814 FIELD NOTES
(FFA Transect Nos. 1, 2, and 3)

Date: May 15 and 19, 2009

Geographic Location: Guam, Federal Aviation Agency.

Introduction

Three snail transects were conducted in the Federal Aviation Agency (FFA) area, as shown on Map Figures 1814-1 and 1814-2. Because all three transects are in the same general forested area on the limestone plateau of northern Guam, they are all included in RHR 1814 Field Notes. Each transect is 160 m long and consists of 16 10-m-long sectors. Transects 1 and 2 were surveyed on May 15, 2009, and Transect 3 was surveyed on May 19, 2009.

Access to the Transect Areas

The Transect 1 trail head is located on the road to the now abandoned Oceanview FFA housing area, 400 m northwest of its junction with highway Rt. 3. From the south side of the road the trail head leads in a general southwest direction for about 60 m to Station 1 m, from where it traverses more or less in a south direction to its terminus at Station 160 m.

To reach the Transect 2 trail head, take the road to the now abandoned Oceanview FFA housing area 1.5 km northwest from its junction with highway Rt. 3 to the abandoned FFA Headquarters Buildings, where it junctions with an unimproved graveled roadbed that leads southwest 600 m to the trail head on the right side of the road. From the roadside the trail head leads in a northwest direction for 50 m to Station 1 m, where it continues in a northwest direction to its terminus at 160 m.

Transect 3 is about 90 m southwest from the Transect 2 trail head. From the left side of roadway the trail head leads in a southeasterly direction for about 65 m to Station 1 m, from where it traverses in a general southwesterly direction to its terminus at 160 m.

The weather was sunny with scattered clouds without any rain showers, except for the survey of Transect 2, when a light rain squall fell immediately after it was completed.

General Physiographic and Geologic Setting of the Survey Sites

All three transects are located on the elevated limestone plateauland of northern Guam on the FAA Reservation about midway between highway Rt. 3 and the abandoned FAA Oceanview housing area (Map Figures 1814-1 and 1814-2). The topography here is flat to slightly undulating and between 104–110 m elevation above sea level. There is no drainage system of stream or rivers on the plateau surface, because the limestone is so porous that rainfall percolates directly downward to a freshwater lens system. Where soil is well developed, rainwater may temporarily pond in low areas or swales.

All three transects are located on several facies of the Mariana Limestone Formation of Pliocene and Pleistocene age. Transects 1 and 3 lie entirely within the Detrital Facies. The inner one-third of Transect 2 lies within the Detrital Facies, and the outer two-thirds grade into Molluscan Facies. Within the transect areas, both facies are a friable to well-cemented, coarse- to fine-grained, generally porous, white detrital limestone of lagoonal origin. The Molluscan Facies differs in containing abundant casts and molds of molluscs, and the limestone within the Transect 2 is more properly a Detrital Coral-Molluscan Subfacies, because corals are more abundant than molluscs. At all three transects the limestone surface is generally composed of loose pebble- to cobble-sized pieces that have been loosened by tree root plucking and wedging action and weathered in to a micro-epikarst surface, as shown in Text Figure 1814-1.

A very coarse-grained and extremely brecciated sample of limestone (Specimen 1814-3-T1) was collected at Station 160 m on Transect 1. On Transect 2, Specimens 1814-1-T2 and 1814-2-T2 were collected at Stations 100 m and 90 m, respectively. Both specimens were parts of massive *Porites* colonies that contained abundant boring bivalve molluscs. Also at Transect 2, Station 160 m, an unusual loose, intense white, very dense compact cobble of limestone was collected (Specimen 1814-4-T2). This cobble was unusual in that it had no discoloration by endolithic algae whatsoever, and although it had a lumpy surface, the irregularities were smooth and rounded, with no evidence of weathering or solution pitting, as if it had been tumble polished. At Transect 3 Station 110 m, a worn specimen of a *Leptastrea* sp. (Specimen 1814-5-T3) was collected. For more detailed descriptions of these five rock samples, see the 'Collections' section below.

<u>Soils</u>

Soils in all three transect areas are developed on raised limestone plateauland, and are classified as No. 25 Guam Cobbly Clay Loam on 0 to 3 percent slopes (Soil Survey of Territory of Guam, 1988). Such soils are very shallow, well drained, range from <5–15 cm in thickness, and for the most part are formed from residuum derived from weathered limestone. Abundant gravel- to cobble-sized limestone clasts are present virtually everywhere on the soil surface (Text Figure 1814-1). The sparse soil that is present is dark reddish-brown in color (Text Figure 1814-2). Locally rugged limestone bedrock is exposed at the surface, particularly along Transect 2. Permeability of the soil is rapid, and the underlying limestone is so porous that surface drainage by streams and rivers is absent. At all three transect areas there was extensive soil disturbance by wild pigs

<u>Vegetation of the Transect Areas</u>

The overall vegetation within the three transect areas can be broadly classified as a 'modified, mixed mesophytic, broad-leafed evergreen forest on elevated limestone terraces and plateaus' as defined by Fosberg (1959, 1960), where the term 'modified' means 'changed from its original nature by humans.' The aerial view of the transect areas in Map Figure 1814-2 reveals that, although the three transect areas are forested, the overall area is in reality a mosaic of forested patches, patchy areas of weedy and scrubby brush, abandoned Oceanview housing and old FAA headquarter buildings, and U. S. Naval Communications Station Finegayan Housing Area.

Such modified forests in the transect areas have a thinner, more irregular upper canopy than primary tropical forests, and as a result have a more tangled, bushy understory growth. Because of their somewhat scattered and isolated distribution, the canopy trees are conspicuous. The only such canopy trees observed within the transect areas were *Artocarpus mariannensis* and *Elaeocarpus joga* (Text Figure 1814-3).

The second story trees form a more even canopy, with common species that include larger trees of *Vitex negundo*, *Neisosperma oppositifolia*, *Pandanus tectorius*, *Pandanus dubius*, *Intsia bijuga*, *Hibiscus tiliaceus*, and *Cocos nucifera* (Text Figures 1814-3, 1814-4, 1814-5, and 1814-6). Of these species, *Vitex negundo* commonly forms nearly monotypic patches within the transect areas (Text Figure 1814-4).

Understory forest species are of lower stature than the second story, with a bushy, tangled aspect that is difficult to pass through at most places. Common understory species include smaller trees and seedlings of the above second story species, along with *Triphasia trifolia*, *Piper guahamense*, *Morinda citrifolia*, *Flagellaria indica*, *Guamia mariannae*, and *Cassia alata* (Text Figures 1814-5, 1814-6, 1814-7, 1814-8, and 1814-9).

Common large herbaceous groundcover species observed were *Nephrolepis hirsutula* (Text Figures 1814-4, 1814-5, and 1814-6), *Flagellaria indica* (Text Figure 1814-9), *Polypodium punctatum*, *Asplenium nidus*, *Mikania scandens*, and *Chromolaena odorata*. Groundcover herbaceous plants add to the difficulty of making passage through the understory, particularly *Nephrolepis hirsutula*, which can reach a height of nearly 2 m.

<u>Results of the Field Snail Survey</u>

Results of snail observations by both survey members are tabulated in Tables A-6–A-8 below. On FFA Transect 1, 1 bleached, dead *Achatina fulica*; 11 bleached, dead *Satsuma mercatoria*; 1 bleached, dead *Euglandina rosea*; and 2 bleached, dead *Pythia scarabaeus* were observed on the rocky ground surface. No living or dead endangered snails were observed.

Along FFA Transect 2, 1 living *Satsuma mercatoria* and 24 dead, bleached shells, and 1 dead, bleached *Achatina fulica* were observed on the rocky ground surface. No living or dead endangered snails were observed.

Along FFA Transect 3, only 2 dead, bleached *Satsuma mercatoria* shells were observed on the rocky ground surface. No living or dead endangered snails were observed.

Table A-6. Land snails recorded by two observers surveying 10-m sectors of FAA Transect 1.

Transect Sector	Species Observed	Number of Specimens	Habitat
0–10	*Satsuma mercatoria*	1	Dead specimen on ground
10–20	None		
20–30	*Satsuma mercatoria*	4	Dead specimens on ground
30–40	*Satsuma mercatoria*	2	Dead specimens on ground
40–50	None		
50–60	None		
60–70	*Satsuma mercatoria*	1	Dead specimen on ground
	Achatina fulica	1	Dead specimen on ground
70–80	None		
80–90	*Satsuma mercatoria*	1	Dead specimen on ground
90–100	*Euglandina rosea*	1	Dead specimen on ground
100–110	None		
110–120	*Pythia scarabaeus*	1	Dead specimens on ground
	Satsuma mercatoria	2	Dead specimens on ground
120–130	None		
130–140	None		
140–150	None		
150–160	*Pythia scarabaeus*	1	Dead specimen on ground

Table A-7. Land snails recorded by two observers surveying 10-m sectors of FAA Transect 2.

Transect Sector	Species Observed	Number of Specimens	Habitat
0–10	*Satsuma mercatoria*	1	Dead specimen on ground
10–20	None		
20–30	None		
30–40	None		
40–50	*Satsuma mercatoria*	1	Dead specimen on ground
50–60	*Satsuma mercatoria*	2	Dead specimens on ground
60–70	None		
70–80	*Satsuma mercatoria*	1	Found living on ground
	Satsuma mercatoria	1	Dead specimen on ground (Text Figure 1813-12)
80–90	None		
90–100	*Satsuma mercatoria*	2	Dead specimens on ground
100–110	*Satsuma mercatoria*	3	Dead specimens on ground
110–120	*Satsuma mercatoria*	3	Dead specimens on ground
120–130	None		
130–140	*Satsuma mercatoria*	5	Dead specimens on ground
140–150	*Satsuma mercatoria*	3	Dead specimens on ground
	Achatina fulica	1	Dead specimen on ground
150–160	*Satsuma mercatoria*	3	Dead specimens on ground

Table A-8. Land snails recorded by two observers surveying 10-m sectors of FAA Transect 3.

Transect Sector	Species Observed	Number of Specimens	Habitat
0–10	None		
10–20	None		
20–30	None		
30–40	None		
40–50	None		
50–60	None		
60–70	None		
70–80	*Satsuma mercatoria*	2	Dead specimens on ground
80–90	None		
90–100	None		
100–110	None		
110–120	None		
120–130	None		
130–140	None		
140–150	None		
150–160	None		

COLLECTIONS

Geologic Specimens:

Specimen Number: Specimen 1814-3-T1
Number of Specimens Coll.: 1 piece
Specimen Name: A detrital limestone.
Geographic Location and Collecting Station: Guam, northern limestone plateauland, within the U. S. Federal Aviation Agency Reservation land. Collecting Station: RHR 1814-CS-2). The sample was collected on Transect 3, Station 160 m, as shown on Map Figure 1814-1.
Geologic Formation: Detrital Facies of the Mariana Limestone Formation.
Elevation: 110 m
Notes: This is a coarse- to fine-grained detrital limestone that contains some *Halimeda* debris. The rock is extremely brecciated, with small void areas partially filled with crushed sand- to granule-sized fragments. The specimen was collected parallel to a northeast-southwest strike of vertical joints mapped by Tracey et al. (1964), and is probably a brecciated fault zone associated with it.

Specimen Number: Specimen 1814-1-T2
Number of Specimens Coll.: 1
Specimen Name: Fossil Scleractinia coral, Porites Sp.

Geographic Location and Collecting Station: Guam, northern limestone plateauland, within the U. S. Federal Aviation Agency Reservation land. Collecting Station: RHR 1814-CS-1. The sample was collected on Transect 2, Station 100 m, as shown on Map Figure 1814-1.
Geologic Formation: Detrital Facies of the Mariana Limestone Formation.
Elevation: 110 m
Notes: This *Porites* specimen was collected *in situ* from a surface outcrop of a massive colony that has been mostly weathered away. All that remains of the colony is a patch of contiguous irregular-shaped, protruding masses that collectively occupied a region of about 40 cm in diameter. A central clump was collected (11.8 cm long,6.8 cm wide, and 7.1 cm high) that has part of a *Lithophaga* bivalve mollusc protruding from its upper surface. Although the corallum and mollusc are altered to calcite, the sub-millimeter-sized *Porites* corallites are very well preserved. The corallites are clumped into bundles of radiating fascicles, which indicates that the colony probably had a lumpy surface, and the embedded *Lithophaga* mollusc suggests a lagoonal habitat.

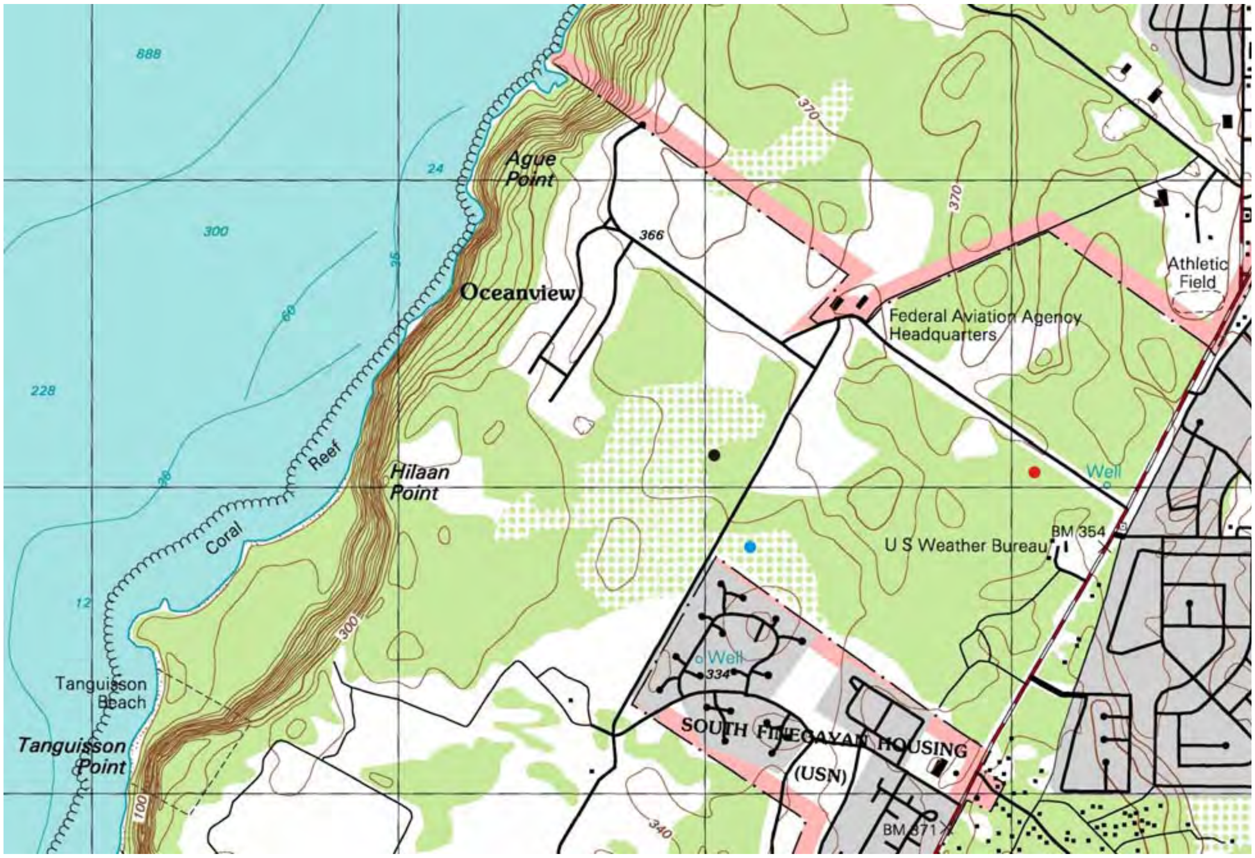
Specimen Number: Specimen 1814-2-T2
Number of Specimens Coll.: 1
Specimen Name: Fossil Scleractinia coral, *Porites* sp.
Geographic Location and Collecting Station: Guam, northern limestone plateauland, within the U. S. Federal Aviation Agency Reservation land. Collecting Station: RHR 1814-CS-2.The sample was collected on Transect 2, Station 90 m, as shown on Map Figure 1814-1.
Geologic Formation: Detrital Facies of the Mariana Limestone Formation.
Elevation: 110 m
Notes: This *Porites* specimen was collected *in situ* from a surface outcrop of a massive colony that has been mostly weathered away. All that remains of the colony is a patch of contiguous irregular-shaped protruding masses that collectively occupied a region of about 20 cm in diameter. A central clump was collected that has several *Lithophaga* bivalve molluscs protruding from its upper surface. Although the corallum and molluscs are altered to calcite, the sub-millimeter-sized *Porites* corallites are very well preserved.

Specimen Number: Specimen 1814-4-T2
Number of Specimens Coll.: 1 piece (later fractured into two pieces a and b)
Specimen Name: A limestone mudstone.
Geographic Location and Collecting Station: Guam, northern limestone plateauland, within the U. S. Federal Aviation Agency Reservation land. Collecting Station: RHR 1814-CS-3). The sample was collected on Transect 2, Station 160 m, as shown on Map Figure 1814-1.
Geologic Formation: Molluscan Facies of the Mariana Limestone Formation.
Elevation: 110 m
Notes: This sample was collected because of its unusual color and surface texture. At the collection site, the surface was strewn with loose pebbles and cobbles as a result of being wedged or plucked out from the underlying coherent limestone by root pressure, a very common occurrence on the surface of limestone deposits that are occupied by forest. Normally the exposed surfaces of such loose material becomes discolored, in respect to a freshly fractured surfaces, to various shades of gray by endolithic algae and other organisms within the 1-mm

surface layer of the rock, as shown in Text Figure 1814-1. In stark contrast to the surrounding loose gray limestone rocks, this one was a brilliant uniform white color. The second unusual feature of this sample was its very smooth lumpy surface. Normally the exposed surface of limestone in such forested areas is weathered into an irregular, micro-epikarst surface of valleys and swale-like depressions, sharp knife-edge ridge crests, and solution pits. In this sample, the lumpy surface features are smoothed and rounded as if it had been tumble polished. Under 10X magnification, the polished surface displays at places a network of shallow scratch-like lines that intersect at varying angles, while at other places it appears smooth. Upon breaking the cobble into two pieces, very white conchoidal fractured surfaces of a recrystallized, very fine-grained mudstone were revealed, with little to no visible grains present. The sample most likely formed in a lagoonal environment within a small cryptic pocket of accumulated lime mud, and subsequently lithified into a fine-grained mudstone (micrite). The only explanation I can put forth for its smooth white surface is that it was buried and weathered for some time in a soil environment, then quite recently exhumed, probably by pig rooting that was quite evident at the site. The specimen has not been exposed long enough to acquire a weathered gray endolithic bored surface rind.

Specimen Number: Specimen 1814-1-T3
Number of Specimens Coll.: 1
Specimen Name: Fossil Scleractinia coral, *Leptastrea* sp.
Geographic Location and Collecting Station: Guam, northern limestone plateauland, within the U. S. Federal Aviation Agency Reservation land. Collecting Station: RHR 1814-CS-1. The sample was collected on Transect 3, Station 110 m, as shown on Map Figure 1814-1.
Geologic Formation: Detrital Facies of the Mariana Limestone Formation.
Elevation: 110 m
Notes: The specimen is poorly preserved, and was collected loose on the limestone surface.

MAP FIGURES



Map Figure 1814-1. A section of the Ritidian USGS Quadrangle Map showing the mid part of the FFA Transects 1 (red dot), 2 (black dot), and 3 (Blue dot), and other geographic areas mentioned in the text.

Map Figure 1814-2. A satellite image showing the location and track of the FFA Transects 1, 2, and 3 within the 'Flat-lying Limestone Plateauland' physiographic unit of the northwestern coastal area of northern Guam. Vegetation consists of a mosaic pattern of forested areas (dark green) and disturbed grass- weed areas (light green). Letter symbols: A =U. S. Naval Housing, B =Abandoned FFA Housing Area, C = Abandoned FFA Headquarters, D = Rt. 3 Highway.

TEXT FIGURES

Text Figure 1814-1. A typical view of loose pebble- to cobble-sized limestone clasts that generally cover the thin stony soils in the transect areas. The sparse soil that is present is commonly hidden by a layer of organic plant litter. The rock surfaces pictured above are occupied by a 1-mm-thick layer of endolithic algae that impart a gray color to the limestone surfaces, which are in turn commonly covered with moss, particularly in areas of dense shade. Several rocks in the foreground have been over-turned to show the normal white color of the limestone. For scale the geology hammer is 33 cm long.

Text Figure 1814-2. A small open area at Transect 2 that shows the typical reddish brown color of Guam Cobbly Clay Loam soil. The above area of soil has been exposed by wild pigs rooting the loose rocks away in local swale where soil accumulation is somewhat thicker. The seedlings at the lower left are from the fruits of a nearby *Morinda citrifolia* tree.

Text Figure 1814-3. A view of the forest at Transect 1, Station 120 m. In the center background is a tall canopy tree of *Artocarpus mariannensis* (breadfruit). Such canopy trees are widely scattered. In the foreground are typical second story trees of *Vitex negundo*, *Hibiscus tiliaceus, Neisosperma oppositifolia*, and seedlings of *Pandanus tectorius*.

Text Figure 1814-4. A view of the forest at the terminal end of Transect 3 (Station 160 m) showing a local cluster of *Cocos nucifera* at the left, a dense groundcover of ferns *(Nephrolepis hirsutula*), and a large patch of young *Vitex negundo* in the background.

Text Figure 1814-5. A view of the forest at Transect 3, Station 110 m, showing a dense stand of *Vitex negundo* and *Hibiscus tiliaceus* trees in the background, and a very dense groundcover of *Nephrolepis hirsutula* ferns in the foreground.

Text Figure 1814-6. A view of the forest at Transect 2, Station 160 m, showing second story *Cocos nucifera* and *Vitex negundo* trees, a dense lower story of *Hibiscus tiliaceus* at the left, and a dense ground cover of *Nephrolepis hirsutula* ferns with scattered *Cocos nucifera* seedlings.

Text Figure 1814-7. A view of the forest at Transect 2, Station 80 m, dominated by second story *Guamia mariannae* trees. A groundcover of ferns is mostly absent here because of dense shade from numerous *Guamia mariannae* trees and their tall slender seedlings.

Text Figure 1814-8. A view of the forest at Transect 2, Station 40 m, showing a dense tangled understory of shrubby tangled small seedling trees, shrubs, and vines.

Text Figure 1814-9. A view of the forest at Transect 1, Station 30 m, showing a dense entanglement of *Flagellaria indica* and *Mikania scandens* vines in the background that are supported by second story and shrubby understory trees. Such tangled patches greatly hinders progress through along the transects. In the foreground is a terminal cluster of flowers on a vine of *Flagellaria indica*.

RHR 1815 FIELD NOTES
(Route 15 Transect No. 1, 2, and 3)

Date: May 22 and 29, 2009

Geographic Location: Guam, Sabanan Pagat and Pagat Terrace Areas.

Introduction

Three land snail transects are located along the northeastern coastal region of Guam, as shown in Map Figures 1815- 1, 1815-2, 1815-3 and 1815-4. Two of these, Transects1 and 2 are located on the high limestone plateauland of Sabanan Pagat, and Transect 3 is located at lower elevation on a coastal terrace called Pagat. Because all three transects are located on forested limestone land, they are all included in RHR 1815 Field Notes. Transect 1, which was surveyed on May 22, was originally planned to be 500 m long. However, we were able to survey only Stations 0 m to 120 m, because the remaining stations between 120 m to 500 m had been recently bulldozed, with all the forest cover removed (Text Figure 1815-1). Transects 2 and 3 are each 500 m long, and were surveyed on May 22 and May 29, respectively.

The weather was sunny with scattered clouds without any rain showers during the three transect surveys.

General Physiographic and Geologic Setting, Soils, and Vegetation in the Vicinity of Transect 1

General Physiography and Geology

Transect 1 is located on the elevated limestone plateauland of northern Guam between Rt. 15 and the northeastern peripheral plateau escarpment between an area known as Lumuna to the north and an area known as Asdonlucas to the south (Map Figures 1815-1 and 1815-3). The plateau topography here is flat to undulating, and generally slopes gently downward to the southwest into an area of several enclosed doline depressions. At several locations, low hills rise up above the general topography. There is no drainage system of stream or rivers on the plateau surface, because the limestone is so porous that rainfall percolates directly downward to a freshwater lens system or underlying volcanic substratum from where it follows the limestone-volcanic interface to the shoreline. The Transect 1 trail head is located at an active rock quarry site that we accessed via the Guam Racetrack along Rt. 15.

From the north end of the quarry, the transect extends southeastward across the high limestone plateauland to an elevated peripheral rampart at the upper edge of a vertical escarpment (Text Figures 1815-1 and 1815-2). Elevation along the transect ranges from 166 m at Station 0 m to 171 m at Station 120 m, located at the base of a prominent solution rampart along the plateau escarpment. Although this transect was originally planned to be 500 m in length, we had to terminate it at Station 120 m, because the remainder of the stations between 120 m and 500m had been freshly bulldozed, with the forest cover completely removed (Text

Figure 1815-1). Between Stations 0 m and 120 m, the limestone surface is weathered into jagged karrenfeld topography of sharp ridges and depressions with up to 2 m or more of local relief. Tracey et al. (1964) mapped this region of the plateau as a Reef Facies of the Mariana Limestone. Our rock sampling along both the forested and bulldozed transect areas revealed a reef facies dominated by coral-algal framestones and bafflestones, with scattered pockets of detrital material. Within such detrital pockets, whole and ghost cavities of *Halimeda* segments were a conspicuous constituent. No rock samples were collected along the transect area.

Soil Development Within the Survey Site

Within the general area of Transect 1, the soil is developed on raised limestone plateauland that is mapped as No. 43 Ritidian-Rock Outcrop Complex on 3 to 15 percent slopes (Soil Survey of Territory of Guam, 1988). The surface within the transect area is mostly limestone rock outcrop and scattered loose limestone clasts, and where soil is present, it is generally restricted to small pockets that are generally overlain with a layer of organic debris in various stages of decomposition. Such soil pockets are very shallow, well-drained, range from less <5–15 cm in thickness, and for the most part are formed from residuum derived from weathered limestone. Where present, soil is a dark, reddish-brown, cobbly clay loam. Permeability of the soil is rapid, and the underlying limestone is so porous that surface drainage by streams and rivers is absent.

Vegetation Within the Survey Site

The overall vegetation within the transect area can be broadly classified as a ‘modified, mixed mesophytic, broad-leafed evergreen forest of elevated limestone terraces and plateaus’ as defined by Fosberg (1959, 1960), with the term ‘modified’ meaning ‘changed from its original nature by humans.’ The aerial view of the Transect 1 region in Map Figure 1814-2 reveals that, although the transect area itself is forested, areas immediately to the north and west have been mostly cleared of forest by quarrying operations. Regions previously cleared for such operations, but not being actively quarried at the present, have grown up into a patchy mosaic of weeds, grasses, and bushy scrub vegetation.

The forest along the transect line displays a somewhat scattered and isolated distribution of canopy trees, a more uniform and denser layer of second story trees, a dense shrubby understory, and a ground cover of seedling trees and herbaceous vegetation. Most conspicuous of the canopy trees were isolated trees of *Artocarpus mariannensis* and *Macaranga thompsonii*. The second story vegetation forms a more even stature of trees, with common species that include regions dominated by *Mammea odorata*, *Eugenia reinwardtiana*, *Guamia mariannae*, and *Neisosperma oppositifolia*; and more scattered trees of *Eugenia thompsonii*, *Intsia bijuga*, *Ficus prolixa*, *Cycas circinalis*, and *Pandanus tectorius*. A large *Eugenia thompsonii* tree with numerous panicles of dark purplish-red fruits around the basal trunk region was encountered between Transect Stations 70 m and 80 m (Text Figures 1815-3 and 1815-4). The understory layer of vegetation ranged from a dense and tangled growth of shrubs, vines, and seedlings to being nearly absent where dense stands of *Mammea odorata*, *Guamia mariannae*, *Eugenia* *reinwardtiana*, and *Neisosperma oppositifolia* provided regions of deep shade. Common understory species include small seedling trees of canopy and second story species, *Triphasia trifolia*, *Piper guahamense*, *Morinda citrifolia*, *Pipturus argenteus*, and *Flagellaria indica* vines. Ground cover of small seedling trees, ferns, and herbaceous vegetation ranged from dense in areas of less shade to nearly absent in regions of dense shade. Common large herbaceous groundcover species observed were *Nephrolepis hirsutula*, *Flagellaria indica*, *Polypodium punctatum*, *Asplenium nidus*, *Mikania scandens*, and *Chromolaena odorata*. Groundcover herbaceous plants add to the difficulty of making passage through the understory.

General Physiographic and Geologic Setting, Soils, and Vegetation in the Vicinity of Transect 2

General Physiography and Geology

The Transect 2 trail head is accessed from the main entrance to the Guam Racetrack facility via an unimproved roadway that extends 0.69 km in a southeast direction to the edge of the limestone plateauland, from whence it extends for 500 m in a general westward direction. Transect 2 starts near the peripheral escarpment at Station 0 m and ends about 150 m inland from the peripheral escarpment at Station 500 m (Map Figures 1815-1 and 1815-3). This region of the plateauland is locally called Sabanan Pagat. The plateau topography here is flat to undulating, and slopes gently downward to the southwest. There is no drainage system of stream or rivers on the plateau surface, because the limestone is so porous that rainfall percolates directly downward to a freshwater lens system or underlying volcanic substratum, where it follows the limestone-volcanic interface to the shoreline. Soil is mostly absent, and where present, is restricted to small accumulations in depressions. Elevation along the transect ranges from 170 m at Station 0 m to 158 m at Station 500 m. Between Stations 0 m and 500 m, the limestone surface is weathered into jagged karrenfeld topography of sharp ridges and depressions, with up to 2 m or more of local relief (Text Figures 1815-5 through 1815-9). Tracey et al. (1964) mapped this region of the plateau as a Reef Facies of the Mariana Limestone. Our rock sampling along transect revealed a reef facies dominated by coral-algal framestones and bafflestones, with scattered pockets of detrital material. No rock samples were collected along the transect area.

Soil Development Within the Survey Site

The soil within the general area of Transect 2 is developed on raised limestone plateauland that is mapped as No. 43 Ritidian-Rock Outcrop Complex on 3 to 15 percent slopes (Soil Survey of Territory of Guam, 1988). Within the transect area the surface is mostly limestone rock outcrop and scattered loose limestone clasts, and where soil is present, it is generally restricted to small pockets that are generally overlain with a layer of organic debris in various stages of decomposition. Such soil pockets are very shallow, well-drained, range from less <5–15 cm in thickness, and for the most part are formed from residuum derived from weathered limestone. Where present, soil is a dark, reddish-brown, cobbly clay loam. Permeability of the soil is rapid, and the underlying limestone is so porous that surface drainage by streams and rivers is absent.

Vegetation Within the Survey Site

The overall vegetation within the Transect 2 area can be broadly classified as a 'modified, mixed mesophytic, broad-leafed evergreen forest of elevated limestone terraces and plateaus' as defined by Fosberg (1959, 1960), with the term 'modified' meaning 'changed from its original nature by humans.' The aerial view of the Transect 2 region in Map Figure 1814-3 reveals that, although the transect area itself is forested, the area immediately to the west appears to have been mostly cleared of forest sometime in the past and has since grown up into a patchy mosaic of weedy, grassy, and bushy scrub vegetation. Farther west of this disturbed region, a large rectangular region about 500 m long and 250 m wide has recently been cleared of all vegetation.

In general, the vegetation along the transect line is similar in species composition to that at Transect 1, except for the overall stature, which is lower. The forest displays a somewhat scattered and isolated distribution of canopy trees, a more uniform and denser layer of second story trees, a shrubby understory, and a ground cover of seedling trees and herbaceous vegetation. Most conspicuous of the canopy trees were isolated trees of *Ficus prolixa*, *Artocarpus mariannensis*, and *Macaranga thompsonii*. The second story vegetation forms a more even stature of trees with common species that include regions dominated by *Mammea odorata*, *Guamia mariannae*, *Eugenia reinwardtiana*, *Neisosperma oppositifolia*, *Aglaia mariannensis*, and more scattered trees of *Eugenia thompsonii*, *Intsia bijuga*, *Ficus prolixa*, *Cycas circinalis*, *Pandanus tectorius*, and *Ochrosia mariannensis*. Small *Guamia mariannae* and *Eugenia reinwardtiana* trees were particularly abundant along the entire transect, forming nearly monotypic stands at places, as shown in Text Figures 1815-7 and 1815-8. A large *Eugenia thompsonii* tree that had hundreds of both flowers and red to purple fruits around the basal part of main tree trunk was encountered between Transect Stations 10 m and 20 m. Most of the *Cycas circinalis* trees that were still standing were dead or badly infected with a scale insect. The understory layer of vegetation ranged from a tangled growth of shrubs, vines, and seedlings to being nearly absent where dense stands of *Mammea odorata*, *Guamia mariannae*, *Eugenia reinwardtiana*, and *Neisosperma oppositifolia* provided regions of deep shade. Common understory species include small seedling trees of canopy and second story species, *Triphasia trifolia*, *Piper guahamense*, *Morinda citrifolia*, *Pipturus argenteus*, and *Flagellaria indica* vines. Ground cover of small seedling trees, ferns, and herbaceous vegetation ranged from dense in areas of less shade to nearly absent in regions of dense shade. Common large herbaceous groundcover species observed were *Nephrolepis hirsutula*, *Flagellaria indica*, *Polypodium punctatum*, *Asplenium nidus*, *Mikania scandens*, and *Chromolaena odorata*. Where dense, groundcover herbaceous plants add to the difficulty of making passage through the understory vegetation. Near the transect trail head, a few low, bushy trees of *Ochrosia mariannensis* were photographed; one with bright yellow fruits (Text Figures 1815-10 and 1815-11) and another with bright red fruits (Text Figure 1815-12). Intermixed with the *Ochrosia mariannensis* trees were several shrubby trees of *Ximenia americana* with small pale yellow fruits (Text Figure 1815-13).

General Physiographic and Geologic Setting, Soils, and Vegetation in the Vicinity of Transect 3

General Physiography and Geology

The Transect 3 trail head is accessed from an unimproved road that junctions with Rt. 15, about 0.90 km south of the main Guam Racetrack entrance. From Rt. 15 this roadway extends in a southeasterly direction for 0.62 km to the edge of the plateau escarpment. From the edge of the escarpment, a trail leads steeply downward from an elevation of 128 m to 61 m. A ranch house (Text Figure 1815-14) is located at the landward edge of Pagat Terrace (Map Figures 1815-2 and 1815-4). From the ranch house, the trail head route extends across the terrace in an easterly direction for 260 m, where it intercepts Transect Station 280 m. Text Figures 1815-15a and 1815-15b and 1815-16 show views of Pagat Terrace from the upper margin of the plateau escarpment, and Text Figure 1815-17 shows a view from Pagat Terrace looking up the plateau escarpment. Although this plateau escarpment is very steep, our journey down and back up it was made considerably easier by a well-maintained rock and concrete trail constructed by the Cepeda Family. Before such an improved trail existed back in the 1960s, I can remember how rigorous a climb down and back up the escarpment was when Phillip Moore, a high-school teacher and colleague, and I visited Mr. Juan Cepeda, a Guam Surahano who lived at the ranch house at the base of the escarpment.

Transect 3 is located on an elevated forested limestone terrace below the Sabanan Pagat plateau escarpment within an area locally known as Pagat. The transect itself traverses along the outer one-third of Pagat Terrace, the uppermost of at least three prominent terraces developed at this location between the high limestone plateau surface and present sea level (Map Figures 1815-2 and 1815-4). The overall terrace is oval shaped, about 1.6 km long, and pinches out to steep-sloped escarpments north and south of the transect area. At the transect area, the terrace has a maximum width of about 470 m. The general terrace topography is mostly flat to gently sloping in a seaward direction, except at its southern end where the surface rises upward from 55 m to 73 m, forming a broad dome-shaped eminence (Map Figure 1815-2). In general the transect line runs from Station 0 m to Station 280 m in a northeasterly direction along the landward side of the domed-shaped eminence, then at Station 280 m the transect line turns eastward to Station 500 m (Map Figure 1815-4). A steep to precipitous escarpment forms the seaward margin of the terrace, which at places has a well-developed solution rampart along its upper margin and conspicuously rises up above the general terrace surface. The terrace surface along the transect consists of limestone outcrop that is solution weathered into an epikarst topography that ranges in relief from <25 cm to 2 m or more (Text Figures 1815-18, 1815-19, 1815-20, 1815-21, 1815-22, and 1815-23). In general such epikarst relief is lowest on the landward half of the terrace and highest on the outer half, particularly on the outer margin where elevated solution ramparts are well developed.

Tracey et al. (1964) mapped the entire Pagat Terrace, as well as the escarpment slope that leads up to the general northern plateau surface, as the Detrital Facies of the Mariana Limestone Formation, except for the oval shaped dome at the southern end of the terrace, which is mapped as a Reef Facies. Although we investigated the escarpment slope only in the vicinity of the switchback trail that the Cepeda Family constructed, accessible outcrops along the steep slope mostly revealed a framestone development dominated by abundant reef-building corals and crustose coralline algae, with scattered pockets of detrital material. We are in general agreement with Tracey's assignment as a detrital facies on the Pagat Terrace, but with local scattered patches where reef corals predominated, particularly along the northern one-half between Stations 280 m and 500 m. Our rock sampling between Transect Stations 70 m and 280 m, which traversed along the landward slope of the dome-shaped eminence, revealed a detrital facies that contained many scattered corals and *Tridacna maxima* bivalves. Our rock sampling between Transect Stations 0 m and 70 m revealed a nearly pure *Halimeda* Subfacies of closely packed segments. Samples of the *Halimeda* facies were collected at Transect Station 0 m (Specimen No. RHR 1815-1-T3), and at Transect Station 70 m (Specimen No. RHR 1815-2-T3).

Upon retracing our route back to the transect trail head we decided to make a short reconnaissance onto the upper surface of the dome-shaped eminence adjacent to Transect Station 70 m. At this location we made our way up to the dome surface via a very rugged, steep slope between two vertical scarps. A series of prominent northwest-southeast trending ridges cut diagonally across the dome surface, which appears to have been formed by solution weathering along jointing planes, similar to the strike of joints mapped by Tracey et al. (1964) north and south of the dome. Relief is 5 m or more at places between the ridge crests and valleys. Examination of numerous rock samples, both on the dome's peripheral slope and upper surface, revealed a detrital subfacies of closely packed *Halimeda* segments, identical to the rock samples examined between Transect Stations 0 m and 70 m. The *Halimeda* segments on the dome's upper surface were completely altered to calcite, whereas many of those from the lower adjacent transect stations still retained an internal chalky white palisade texture, probably of aragonite. A sample of the *Halimeda* subfacies was collected from the pinnacled ridges (Specimen No. RHR 1815-3-T3). See the 'Collection' section below for more detailed descriptions of the *Halimeda* subfacies samples. Although we investigated only a small part of the dome's upper surface, we were somewhat surprised to find such a pure *Halimeda* facies, since it was mapped as a reef facies by Tracey et al. (1964). Although we did not have time to map the overall extent of this *Halimeda* subfacies, we now know that it is at least 70 m in extent along Transect 3. It is tempting speculate more on the geologic history of the Pagat Terrace, but to do so would require a much more extensive reconnaissance of the entire regional area.

Other rock samples and fossils collected from Pagat Terrace include a worn, partial fossil of *Fungia* cf. *paumotensis* collected between Transect Stations 420 m and 430 m, a loose plate of *Hydnophora* cf. *exesa* collected between Transect Stations 190 m and 200 m, part of a colony of *Astreopora* sp. collected between Transect Stations 220 m and 230 m, part of a loose, thick plate of travertine collected between Transect Stations 460 m and 470 m, and one-half of a lithified paleosol nodule collected between Transect Stations 0 m and 10 m. See the 'Collection' section below for more detailed descriptions of the above five specimens.

Soil Developed Within the Survey Site

Soil developed on limestone land of Pagat Terrace within the general area of Transect 3 is mapped as No. 43 Ritidian-Rock Outcrop Complex on 3 to 15 percent slopes (Soil Survey of Territory of Guam, 1988). The surface within the transect area is mostly limestone rock outcrop and scattered loose limestone clasts, and where soil is present, it is generally restricted to small pockets generally overlain with a layer of organic debris in various stages of decomposition. Such soil pockets are very shallow, well-drained, range from <5–15 cm in thickness, and for the most part are formed from residuum derived from weathered limestone. Wherever exposed soil is present, it is generally a dark, reddish-brown, cobbly clay loam, as shown in Text Figure 1815-20. Permeability of the soil is rapid and the underlying limestone is so porous that surface drainage by streams and rivers is absent.

Although the soil is mapped as No. 43 Ritidian-Rock Outcrop Complex on 3–15 percent slopes within the general area of Transect 3, it varies in places, particularly between Transect Stations 0 m to 70 m, where it is yellowish brown rather than reddish brown (Text Figure 1815-20). This part of the transect coincides with a region of rock outcrop that consists predominantly of a detrital *Halimeda* subfacies (see description in the above geology section). Also within this region, scattered pockets of a lithified yellowish brown paleosol are present, which were not observed along the remainder of the transect stations. Both *in situ* pockets embedded within the limestone matrix as well as loose nodules of the paleosol were present. One-half of one of the loose paleosol nodules was collected between Transect Stations 0 m and 10 m (Specimen No. RHR 1815-8-T3).

The soil along the trail head between the ranch house and where it intercepts Transect Station 280 m, although still quite cobbly, is much more abundant than along Transects 1 and 2. This region coincides with the inner landward one-half of the terrace, where relief of the limestone outcrop is relatively low and flat. Within this region several patches of the forested terrace land has been modified into an agro-forest, as shown in Text Figures 1815-15a, 1815-15b, and 1815-16.

Vegetation Within the Survey Site

The overall vegetation within Transect 3 area can be broadly classified as a ‘modified, mixed mesophytic, broad-leafed evergreen forest of elevated limestone terraces and plateaus’ as defined by Fosberg (1959, 1960), with the term ‘modified’ meaning changed from its original nature by humans.’ An aerial view of Transect 3 region in Map Figure 1814-4 reveals that a dense limestone forest occupies Pagat Terrace, as well as the steep escarpment leading down to the terrace from the peripheral northern limestone plateau (Text Figs 1815-15a, 1815-15b and 1815-16) and the flight of narrow terraces and escarpments bordering the seaward side of Pagat Terrace. The limestone forest occupying the remainder of Pagat Terrace is much less disturbed in terms of its original stature and community structure than most forests lands on the northern plateauland of Guam, except for an area of several hectares in the vicinity of the Cepeda Ranch House that has been modified into an agro-forest community. Although the vegetation along the

Transect 3 is similar in many respects to that along Transects 1 and 2, it is more variable in species composition and stature, particularly where the northern half abuts alongside the seaward margin of the agro-forested land.

The forest displays a somewhat scattered and isolated distribution of canopy trees, a more uniform and denser layer of second story trees, a somewhat patchily distributed shrubby understory, and a ground cover of seedling trees and herbaceous vegetation. Most conspicuous of the canopy trees were isolated trees of *Ficus prolixa*, *Artocarpus mariannensis*, *Neisosperma oppositifolia*, and *Macaranga thompsonii*. Several *Macaranga thompsonii* trees with trunk diameters in excess of 75 cm were observed along the southern one-half of the transect. The second story vegetation forms a more even stature of trees, with common species that include *Mammea odorata*, *Guamia mariannae*, *Eugenia reinwardtiana*, *Neisosperma oppositifolia*, *Aglaia mariannensis*; and more scattered trees of *Eugenia thompsonii*, *Intsia bijuga*, *Ficus prolixa*, *Cycas circinalis*, *Pandanus tectorius*, *Hibiscus tiliaceus*, and *Ochrosia mariannensis* (Text Figure 1815-18). *Guamia mariannae*, *Mammea odorata*, and *Eugenia reinwardtiana* trees were particularly abundant along the entire transect, and at places formed nearly monotypic stands, as shown in Text Figures 1815-19 and 1815-21. *Hibiscus tiliaceus* formed dense tangled mazes of branches at several places along the northern half of the transect (Text Figure 1815-23). Most of the *Cycas circinalis* trees that were still standing were dead or badly infected with a scale insect (Text Figure 1815-22). The understory layer of vegetation ranged from a tangled growth of shrubs, vines, and seedlings (Text Figure 1815-18 and 1815-23) to being nearly absent where dense stands of *Mammea odorata*, *Guamia mariannae*, *Eugenia reinwardtiana*, and *Neisosperma oppositifolia* provided regions of deep shade (Text Figures 1815-19 and 1815-21). Common understory species include small seedling trees of canopy and second story species, *Triphasia trifolia*, *Piper guahamense*, *Morinda citrifolia*, *Pipturus argenteus*, *Hibiscus tiliaceus*, and *Flagellaria indica* vines. Ground cover of small seedling trees, ferns, and herbaceous vegetation ranged from dense in areas of less shade to nearly absent in regions of dense shade. Passage through dense understory and ground cover vegetation was quite difficult at places. Common large herbaceous groundcover species observed were *Nephrolepis hirsutula*, *Flagellaria indica*, *Polypodium punctatum*, *Asplenium nidus*, *Mikania scandens*, and *Chromolaena odorata*. Weedy ground cover vegetation dominated a few small open areas; particularly along the northern half of the transect, as shown in Text Figure 1815-20.

Since the transect line tangentially intercepted the agro-forest area between stations 250 m and 310 m, a short description of the region is given. Some of the common fruit trees encountered were *Annona muricata* (soursop), *Annona squamosa* (sugar apple), *Carica papaya* (papaya), *Citrus aurantium* (sour orange, Text Figure 1815-24), *Phyllantus acidus* (Tahitian gooseberry or Iba', Text Figure 1815-25), *Psidium guajava* (guava), and *Averrhoa bilimbi* (cucumber tree, Text Figure 1815-26).

Other Observations along the Transect

Considerable ground disturbance by wild pigs was observed at most locations along the Rt.15 transects in the form of extensive rooting in soil pockets and overturned loose limestone cobbles and boulders. At places the disturbance occurred on the entire available ground surface, particularly in the agro-forested areas, where pigs frequently visited to forage on freshly fallen fruit.

Although we did not encounter any deer, their fecal pellets and browsed vegetation was evident along the entire transect.

We observed a remarkable abundance of the blue butterfly, *Euploea leucostictos*, between Transect 3 Stations 50 m and 70 m, where hundreds were emerging from their chrysalises attached to small *Guamia mariannae* branches.

Results of the Field Snail Survey

Results of snail observations by both survey members are tabulated in Tables A-6–A-8 below. Twelve dead shells of three species of land snails were encountered in 2,400 m^2 surveyed on Route 15 Transect 1. Ten dead, bleached *Satsuma mercatoria* shells, 1 dead, bleached *Euglandina rosea* shell, and 1 dead, bleached *Pythia scarabaeus* shell were observed on the rocky ground surface. No living or dead endangered snails were observed on Route 15 Transect 1.

Eight dead shells of five species of land snails were encountered in 10,000 m^2 surveyed on Route 15 Transect 2. Two dead, bleached *Satsuma mercatoria* shells, 3 dead, bleached *Achatina fulica* shells, 1 dead *Lamprocystis misella* shell, 1 dead *Partula gibba* shell, and 1 dead *Euglandina rosea* shell were observed on the ground surface. No living and only one dead endangered tree snail was observed at Station 310–320 m on Route 15 Transect 2.

Six dead shells of three species of land snails were encountered in 10,000 m^2 surveyed on Route 15 Transect 3. Three dead, bleached *Satsuma mercatoria* shells and 3 dead, bleached *Pythia scarabaeus* shell were observed on the ground surface. No living or dead endangered snails were observed.

Table A-9. Land snails recorded by two observers surveying 10-m sectors of Route 15 Transect 1.

Transect Sector	Species Observed	Number of Specimens	Habitat
0–10	None		
10–20	None		
20–30	None		
30–40	*Satsuma mercatoria*	2	Dead specimens on ground
40–50	*Pythia scarabaeus*	1	Dead specimen on ground
50–60	None		
60–70	None		
70–80	None		
80–90	None		
90–100	None		
100–110	*Euglandina rosea*	1	Dead specimen on ground
	Satsuma mercatoria	5	Dead specimens on ground
110–120	*Satsuma mercatoria*	3	Dead specimens on ground
120–500	(Not surveyed; area cleared by bulldozer)		

Table A-10. Land snails recorded by two observers surveying 10-m sectors of Route 15 Transect 2.

Transect Sector	Species Observed	Number of Specimens	Habitat
0–10	None		
10–20	None		
20–30	*Achatina fulica*	2	Dead specimens on ground
30–40	None		
40–50	None		
50–60	None		
60–70	None		
70–80	None		
80–90	None		
90–100	None		
100–110	None		
110–120	None		
120–130	None		
130–140	None		
140–150	None		
150–160	None		
160–170	None		
170–180	None		
180–190	None		
190–200	*Lamprocystis misella*	1	Dead specimen on ground
200–210	None		
210–220	None		
220–230	None		
230–240	None		
240–250	None		
250–260	None		
260–270	None		
270–280	None		
280–290	None		
290–300	None		
300–310	None		
310–320	*Partula gibba*	1	Dead specimen on ground
320–330	*Euglandina rosea*	1	Dead specimen on ground
330–340	None		
340–350	*Satsuma mercatoria*	1	Dead specimen on ground
350–360	None		
360–370	None		
370–380	None		
380–390	None		
390–400	*Satsuma mercatoria*	1	Dead specimen on ground
400–410	None		
410–420	None		
420–430	None		
430–440	None		
440–450	None		
450–460	None		
460–470	None		
470–480	None		
480–490	*Achatina fulica*	1	Dead specimen on ground
490–500	None		

Table A-11. Land snails recorded by two observers surveying 10-m sectors of Route 15 Transect 3.

Transect Sector	Species Observed	Number of Specimens	Habitat
0–10	*Satsuma mercatoria*	2	Dead specimen on ground
10–20	None		
20–30	None		
30–40	None		
40–50	None		
50–60	None		
60–70	None		
70–80	None		
80–90	None		
90–100	None		
100–110	None		
110–120	None		
120–130	None		
130–140	None		
140–150	None		
150–160	None		
160–170	None		
170–180	*Pythia scarabaeus*	1	Dead specimen on ground
180–190	None		
190–200	None		
200–210	None		
210–220	None		
220–230	None		
230–240	*Pythia scarabaeus*	1	Dead specimen on ground
240–250	*Pythia scarabaeus*	1	Dead specimen on ground
250–260	None		
260–270	None		
270–280	None		
280–290	None		
290–300	None		
300–310	None		
310–320	None		
320–330	None		
330–340	None		
340–350	None		
350–360	None		
360–370	None		
370–380	*Satsuma mercatoria*	1	Dead specimen on ground
380–390	None		
390–400	None		
400–410	None		
410–420	None		
420–430	None		
430–440	None		
440–450	None		
450–460	None		
460–470	None		
470–480	None		
480–490	None		
490–500	None		

COLLECTIONS

Geologic Specimens:

Specimen Numbers: RHR 1815-1-T3 and RHR 1815-2-T3
Number of Specimens Coll.: 2
Specimen Name: *Halimeda* limestone samples.
Geographic Location and Collecting Station: Guam, Pagat Terrace, a peripheral scarp terrace of the northeastern limestone plateauland. Collecting Station: RHR 1815-CS-1. Specimen RHR 1815-1-T3 was collected on Transect 3, Transect Station 0 m, and Specimen RHR 1815-2-T3 was collected on Transect Station 70 m, as shown on Map Figure 1815-1.
Geologic Formation: Detrital Facies of the Mariana Limestone Formation.
Elevation: 110 m.
Notes: Specimen RHR 1815-1-T3 was collected from an in-place surface exposure of rock, and Specimen RHR 1815-2-T3 was collected loose on the surface. Both specimens are identical in respect to composition and texture. Within a radius of 10 m of each collection site, ten random samples yielded similar limestone rock composed predominantly of closely packed *Halimeda* segments. Most of the segments are entire and show little evidence of transport. Fresh fractured surfaces of the rock have a rather porous overall texture, with the individual fractured *Halimeda* segments revealing a chalky interior, possibly of aragonite. Random sampling between Transect Stations 0 m and 70 m all revealed rocks similar in texture and composition to the two collected specimens (see notes below for Specimen RHR 1815-3-T3).

Specimen Number: Specimen RHR 1815-3-T3
Number of Specimens Coll.: 1
Specimen Name: *Halimeda* limestone sample. Geographic Location and Collecting Station: Guam, Pagat Terrace, a peripheral scarp terrace of the northeastern limestone plateauland. Collecting Station: RHR 1814-CS-2. The specimen was collected on Transect 3, about 20 m southeast of Station 70 m, on the upper peripheral margin of a dome-like eminence, as shown on Map Figure 1815-1.
Geologic Formation: Detrital Facies of the Mariana Limestone Formation.
Elevation: 110 m.
Notes: Specimen RHR 1815-3-T3 appears to be a continuation of the *Halimeda* facies described above for Specimens RHR 1815-1-T3 and RHR 1815-2-T3, but at about 8 m higher elevation on the surface of a dome-like eminence. The dome surface is extensively weathered along the strike of NW-SE jointing planes into a ridge-and-valley topography of about 3–5 m relief. Both the ridge and valley surfaces are weathered into a solution pitted epikarst topography of narrow knife-like ridges, pinnacles, cracks, and open fissures from which this sample was collected. In respect to texture and composition, this sample is identical to the above Specimens RHR 1815-1-T3 and RHR 1815-2-T3, except for the fractured *Halimeda* segments, which have been altered internally to calcite.

Specimen Number: RHR 1815-4
Number of Specimens Coll.: 1
Specimen Name: Fossil *Fungia* specimen.
Geographic Location and Collecting Station: Guam, peripheral scarp terrace of the northern limestone plateauland, on Pagat Terrace. Collecting Station: RHR 1815-CS-1. Specimen RHR 1815-4-T3 was collected on Transect 3, between Transect Stations 420 m and 430 m, as shown on Map Figure 1815-1.
Geologic Formation: Detrital Facies of the Mariana Limestone Formation.
Elevation: 110 m.
Notes:

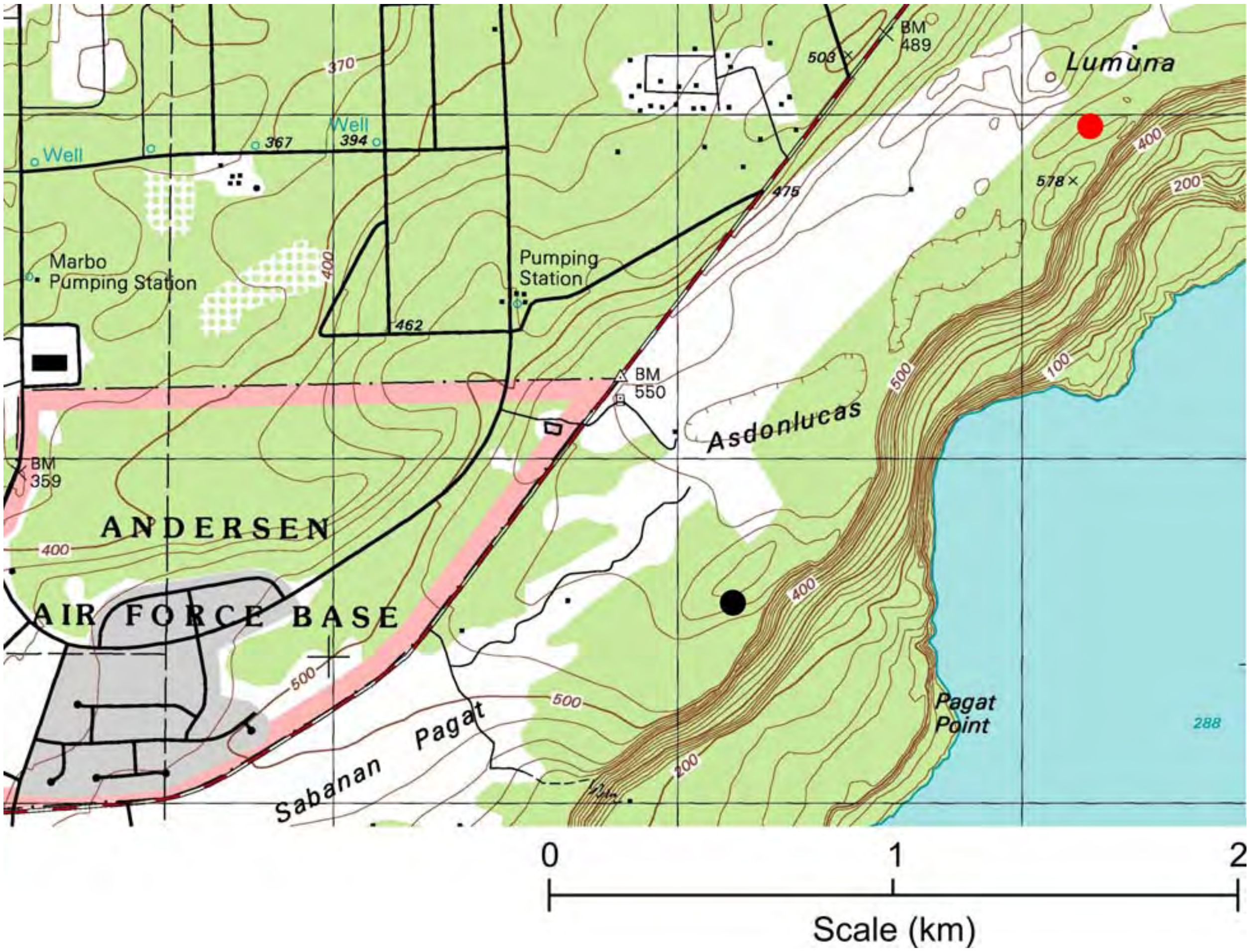
Specimen Number: RHR 1815-5
Number of Specimens Coll.: 1
Specimen Name: Fossil *Hydnophora* specimens..
Geographic Location and Collecting Station: Guam, peripheral scarp terrace of the northern limestone plateauland, on Pagat Terrace. Collecting Station: RHR 1815-CS-1. Specimen RHR 1815-5-T3 was collected on Transect 3, between Transect Stations 190 m and 200 m, as shown on Map Figure 1815-1.
Geologic Formation: Detrital Facies of the Mariana Limestone Formation.
Elevation: 110 m.
Notes:

Specimen Number: RHR 1815-6
Number of Specimens Coll.: 1
Specimen Name: Fossil *Astreopora* specimens..
Geographic Location and Collecting Station: Guam, peripheral scarp terrace of the northern limestone plateauland, on Pagat Terrace. Collecting Station: RHR 1815-CS-1. Specimen RHR 1815-6-T3 was collected on Transect 3, between Transect Stations 190 m and 200 m, as shown on Map Figure 1815-1.
Geologic Formation: Detrital Facies of the Mariana Limestone Formation.
Elevation: 110 m.
Notes:

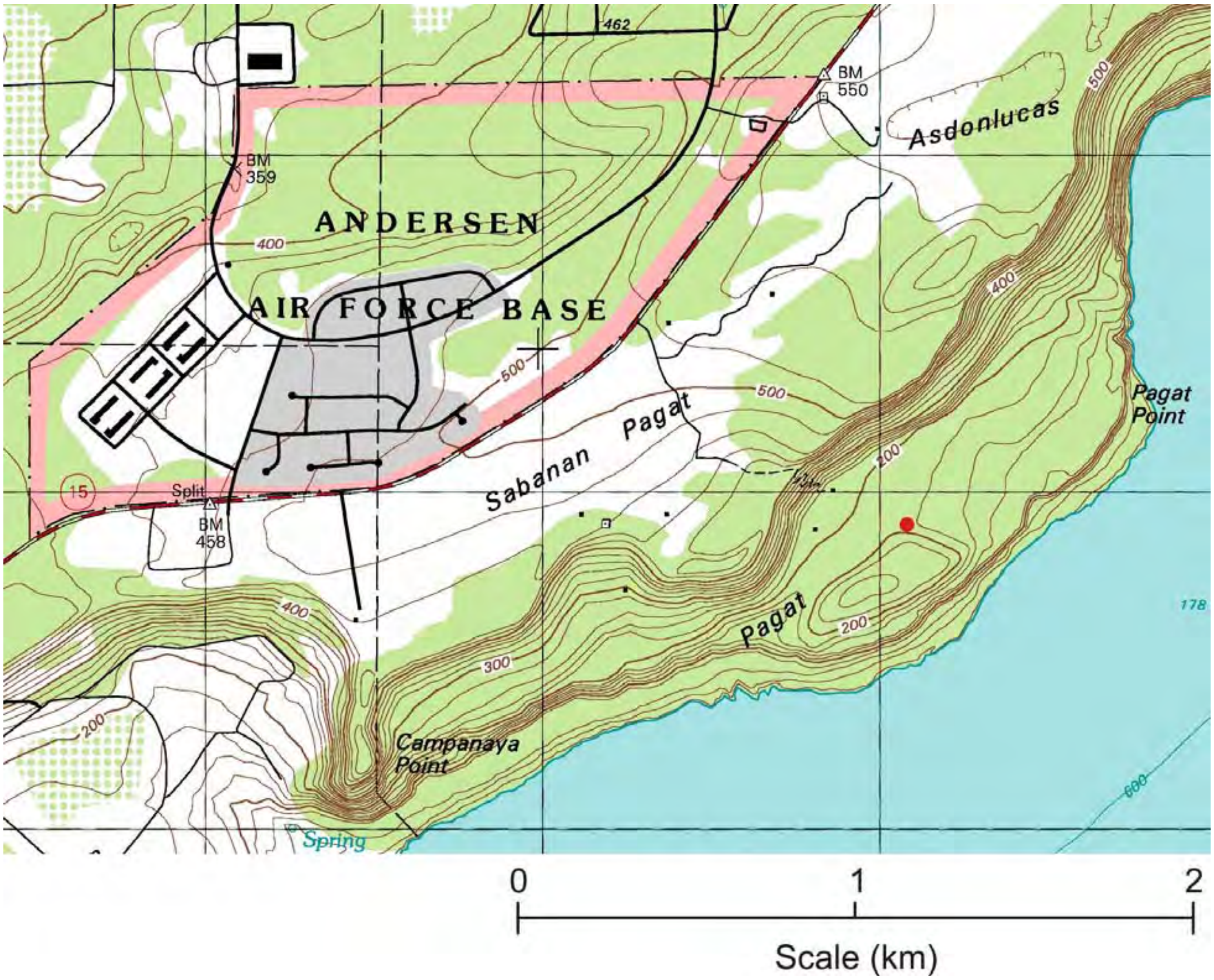
Specimen Number: RHR 1815-7-T3
Number of Specimens Coll.: 1
Specimen Name: Travertine sample..
Geographic Location and Collecting Station: Guam, peripheral scarp terrace of the northern limestone plateauland, on Pagat Terrace. Collecting Station: RHR 1815-CS-1. Specimen RHR 1815-7-T3 was collected on Transect 3, between Transect Stations 0 m and 10 m, as shown on Map Figure 1815-1.
Geologic Formation: Detrital Facies of the Mariana Limestone Formation.
Elevation: 110 m.
Notes:

Specimen Number: RHR 1815-8
Number of Specimens Coll.: 2
Specimen Name: Fossil soil sample.
Geographic Location and Collecting Station: Guam, peripheral scarp terrace of the northern limestone plateauland, on Pagat Terrace. Collecting Station: RHR 1815-CS-1. Specimen RHR 1815-8-T3 was collected on Transect 3, between Transect Stations 460 m and 470 m, as shown on Map Figure 1815-1.
Geologic Formation: Detrital Facies of the Mariana Limestone Formation.
Elevation: 110 m.
Notes:

MAP FIGURES



Map Figure 1815-1. A section of the Dededo USGS Quadrangle Map showing the mid part of the Route 15 Transects 1 (red dot), and 2(black dot), and other geographic areas mentioned in the text.



Map Figure 1815-2. A section of the Dededo USGS Quadrangle Map showing the mid part of the Route 15 Transect 3 (red dot), and other geographic areas mentioned in the text.

Map Figure 1815-3. A satellite image showing the location and approximate midpoint of the Route 15 Transects 1 (red dot) and 2 (yellow dot) within the 'Flat-lying Limestone Plateauland' physiographic unit of the northeastern coastal area of northern Guam. Vegetation consists of a mosaic pattern of forested areas (dark green) and disturbed and grass-weed areas (brown to white). Letter symbols: A = Transect 1, B = Transect 2, C = Active quarry and race track areas, and D = Rt. 15 Highway.

Map Figure 1815-4. A satellite image showing the location and track of the Route 15 Transect 3 within the 'Flat-lying Limestone Plateauland' physiographic unit of the northeastern coastal area of northern Guam. Vegetation consists of a mosaic pattern of forested areas (dark green) and disturbed and grass-weed areas (light green). Letter symbols: A = Transect 3, B = Sabanan Pagat, C = Pagat Terrace, D = Rt. 15 Highway, E = Raised dome on Pagat Terrace, F = Cepeda Ranch House, and G = Pagat Point.

TEXT FIGURES

Text Figure 1815-1. A freshly bulldozed area of forested land between Stations 120m and 500 m at Transect 1.

Text Figure 1815-2. A view from the upper margin of the peripheral plateau escarpment adjacent to the bulldozed region of Transect 1. The forest below is located about 1.5 km north of Pagat Point. Except for some plant introductions by humans, limestone forests on coastal terraces such as this are probably closer to their pre-habitation state than at any other location on Guam. Fringing platform reefs are absent along the northeast shorelines of Guam, such as at this location, and instead are occupied by narrow, supratidal, wave-washed, erosional bench platforms generally less than 10 m wide (not visible). Even so, seaward of the bench platforms veneering reef-building communities are present (reef organisms growing on a substrate not of their own making), and apron reefs (reef-building organisms growing on a substrate of their own making, but have not yet accreted it upward to sea level equilibrium). Such veneering and apron reef communities are represented above by the inshore grayish green regions that are punctuated by light green channel floors and terrace like fans of carbonate sediment. Normally the upper margin of peripheral limestone escarpments are occupied by a narrow, elevated solution ramparts, but here it has slumped away, leaving a window to the terrace below and a slump scarp remnant at the left. The needle-like branchlets of a *Casuarina equisetifolia* tree branch are visible at the right.

Text Figure 1815-3. A cluster of fruits of a *Eugenia thompsonii* tree located along Transect 1 between Stations 80 m and 90 m. The fruits develop from panicles that mostly extend out from the trunk or larger branches. Less mature fruits are red to maroon that ripen to a dark purple color, such as those in the photo.

Text Figure 1815-4. Fallen and still attached dark purple fruits of the *Eugenia thompsonii* tree shown in Text Figure 1815-3. The fruit-bearing panicles commonly develop from the lower part of the main trunk. Since these fruits are reported to be edible, it is somewhat strange that the above fallen and lower clusters of fruit have not been eaten by wild pigs that are common in this forested region.

Text Figure 1815-5. A view of epikarst topography at Transect 2 between Stations 30 m and 40 m. Shown here is the lateral surface of an elongate ridge that displays an irregular jagged solution pitted surface typical of forested epikarst topography. Although soil is absent here, such rock outcrops can support a dense, mixed limestone forest and understory of shrubs and herbaceous plants that extend their roots down into the rock surface via solution voids, fissures, and joints for moisture and nutrients, as can be seen in the lower left corner. Plant nutrients are mostly supplied by decomposition of organic litter that accumulates on the rocky surface. Relief from the bottom of the photo to the ridge crest is about 2 m.

Text Figure 1815-6. A view of moss covered epikarst topography at Transect 2 between Stations 140 m and 150 m. The rocky surfaces are commonly covered with a thick layer of moss (bryophytes) where a thick upper story and understory of vegetation provide dense shade, such as at this location. Also shown here is a typical accumulation of f dead leaves and branches that will eventually undergo decomposition. For scale the geology hammer is 33 cm long.

Text Figure 1815-7. A view of forested epikarst topography at Transect 2 between Stations 250 m and 260 m that is here dominated by *Guamia mariannae* and *Eugenia reinwardtiana* trees. Here the epikarst topography has somewhat less relief and irregularity than shown in Text Figures 1815-5 and 1815-6, mainly as a result of being father inland from the swale behind the plateau escarpment and solution rampart. There is also some accumulation of stony soil in holes and pockets here that tends to damp out irregularities in the rock surface.

Text Figure 1815-8. A view of forested epikarst topography at Transect 2 between Stations 400 m and 410 m that is dominated by *Guamia mariannae* and *Eugenia reinwardtiana* trees here. The epikarst topography here has slightly less relief and irregularity than shown in Text Figures 1815-5, 1815-6, and 1815-7, mainly as a result of being progressively father inland from the plateau escarpment and solution rampart. In the foreground a thin layer of soil (hidden below leaf litter) has accumulated between pieces of mostly loose rock. For a detail of the loose rock, see Text Figure 1815-9.

Text Figure 1815-9. A detailed view of mushrooms growing from a dead branch and forested epikarst topography at Transect 2, between Stations 470 m and 480 m. The surface here is dominated by loose, solution-weathered and pitted, cobble-sized limestone clasts that tend to fill in depressions and low areas between limestone outcrops, thus reducing relief in forested epikarst topography. The origin of most such loose clasts is from the wedging action of growing tree roots that penetrate into and fracture the limestone.

Text Figures 1815-10. Leaves and yellow fruits of a low, bushy *Ochrosia mariannensis* tree located at the trail head of Transect 2. Most of the fruit clusters present on this tree consist of three or more fruits.

Text Figure 1815-11. A detail of the yellow fruits of the low, bushy *Ochrosia mariannensis* tree shown in Text Figure 1815-10.

Text Figure 1815-12. A detail of the leaves and red fruits of a low, bushy *Ochrosia mariannensis* tree growing beside the tree with yellow fruits shown in Text Figures 1815-10 and 1815-11. Most of the fruit clusters present on this tree consist of two fruits.

Text Figure 1815-13. A detail of the fruits of a small shrubby *Ximenia americana* tree growing at the trail head of Transect 2.

Text Figure 1815-14. Cepeda family ranch house located on the inner part of the Pagat Terrace.

Text Figure 1815-15a. A view of the northern one-third of Pagat Terrace Pagat terrace from the plateau escarpment.

Text Figures 1815-15b. A view of the middle one-third of Pagat Terrace Pagat terrace from the plateau escarpment.

Text Figure 1815-16. A view of the southern one-third of Pagat Terrace Pagat terrace from the plateau escarpment.

Text Figure 1815-17. A view from Pagat Terrace looking up the escarpment to the peripheral margin of the high northern limestone plateau. The trail up the escarpment begins just to the left of the large limestone block, from where it switchbacks up the steep to precipitous slope to the top. Coconut trees are absent on the steep escarpment, except for a few planted along the perimeter of the grassy area in the foreground.

Text Figure 1815-18. A view of Transect 3 between Stations 50 m and 60 m showing dense understory and ground cover vegetation. Although there is virtually no soil accumulation at this location, roots of the vegetation extend downward into the rock via cracks, fissures, and holes to access moisture and nutrients. At this location the transect traverses across a low limestone ridge that has about 2–3 m of local relief. In the upper foreground an *Ochrosia mariannensis* tree is shown with a cluster of two yellow fruits.

Text Figure 1815-19. A view of Transect 3 between Stations 270 m and 280 m, showing second story vegetation dominated by *Guamia mariannae*, *Mammea odorata*, and *Eugenia reinwardtiana* trees. Ground cover vegetation here is mostly absent except for a few scattered seedling trees. Here the rocky outcrop has a low relief that consists of numerous loose cobble-sized clasts of limestone that have mostly been loosened the wedging action of tree roots.

Text Figure 1815-20. A view of Transect 3 between Stations 330 m and 330 m showing a small open area dominated by herbaceous weeds and shrubs. This was the only region along this transect where a thin, shallow soil of rubbly-clay loam was exposed. The clearing appears to be maintained by pigs wallowing during the wet season. The principal herbaceous plants around the perimeter of the clearing is *Chromolaena odorata*, *Lantana camara*, and *Mikania scandens*. In densely forested regions, such open weedy communities are generally created in tree fall gaps, and thus are somewhat an ephemeral community that will most likely again be restored to forest from seedling trees.

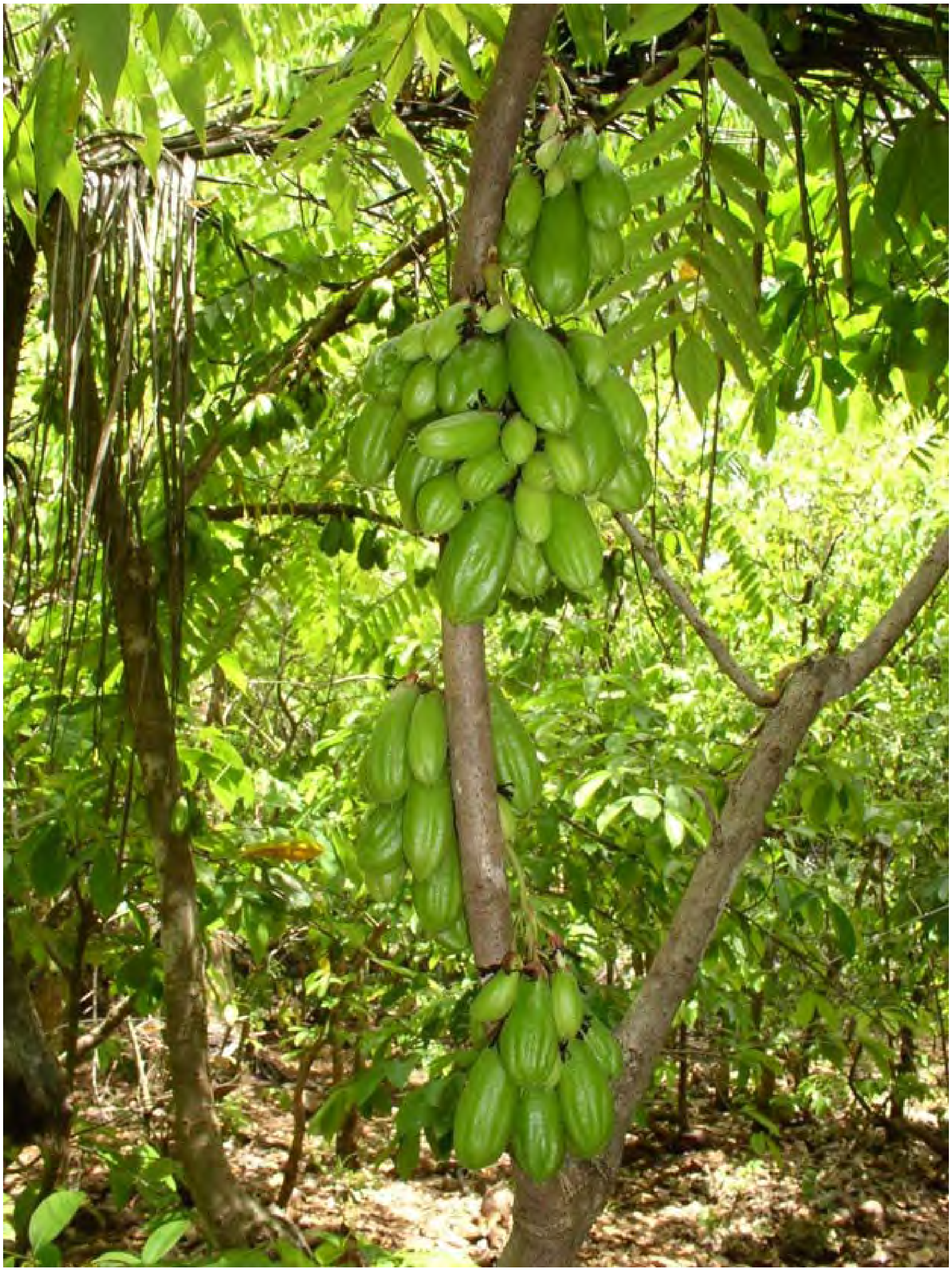
Text Figure 1815-21. A view of Transect 3 between Stations 340 m and 350 m showing second story vegetation dominated by *Guamia mariannae* and *Eugenia reinwardtiana* trees. Ground cover vegetation here is mostly absent except for a few scattered seedling trees. Here the rocky outcrop has a low relief that consists of numerous loose cobble-sized clasts of limestone that have mostly been loosened the wedging action of tree roots.

Text Figure 1815-22. A view of a large fallen *Cycas circinalis* tree located at Station 360 on Transect 3 that was heavily infested with scale insects. Prior to the introduction of scale insects to Guam, *Cycas circinalis* were quite abundant, healthy, and thriving on Pagat Terrace, but now nearly all such trees observed consists of dead standing or fallen tree trunks or are still standing with a heavily scale infested crown of stunted fronds. The still green stunted fronds of the above tree have been recently broken off from the crown by deer that like to bed down on such fresh leaf material.

Text Figure 1815-23. A view of Transect 3 between Stations 390 m and 400 m, showing a dense entangled forest cover of *Hibiscus tiliaceus* trees in which the branches grow in all directions. Such thickets are the result of regeneration of trees toppled during storms and drooping peripheral branches that develop roots upon contacting the ground. Progress through such tangled *Hibiscus thickets* is a slow process. In the foreground, dark green-leaved seeding trees of *Mammea odorata* form a scattered ground cover.

Text Figure 1815-24. *Citrus aurantium* (sour orange) tree growing near the Cepeda ranch house.

Text Figure 1815-25. *Phyllantus acidus* (Tahitian gooseberry or iba') tree growing near the Cepeda ranch house.



Text Picture 1815-26. *Averrhoa bilimbi* (cucumber tree) growing near the Cepeda ranch house.

RHR 1816 FIELD NOTES
(Piti Power Plant Transect No. 1)

Date: June 2, 2009

Geographic Location: Guam, Piti Power Plant in the Masso Area.

Introduction

Piti Power Plant Transect 1 is located on low coastal alluvial land bordered by Cabras Marina complex of boat docking facilities on the west, Rt. 11 and the Piti power generating facilities on the north, Rt. 1 (Marine Corps Drive) on the east, and Dry Dock Island Road (Pol Causeway) on the south (Map Figures 1816-1 and 1816-2). Although this transect was not pre-located and flagged at 10-m intervals, we were advised to proceed in establishing one 500-m that would be most representative of the least disturbed region within the above prescribed area. A satellite aerial map of the region revealed that the least disturbed region would be a diagonal traverse as shown on Map Figure 1816-2. The transect trail head is located on the north side of Dry Dock Island Road, 75 m east of the intersection of a pipeline and roadway that leads to the Cabras Marina complex of boat docking facilities. Station 0 m begins 10 m inland from the roadside at the margin of a small *Phragmites karka* reed marsh. From Station 0 m, the transect extends 500 m in a northeast direction, as depicted in Map Figure 1816-2.

During our survey the weather was sunny to partly cloudy with no rain showers.

General Physiographic and Geologic Setting of the Survey Site

Traditionally the local name of the low coastal lowland within the Piti Transect area is referred to as the Masso region. This name is probably derived from its close association with the nearby Masso River, which before land filling and construction of the Dry Dock Island Road was contiguous with a broad band of swamp-marsh-land that originally bordered the entire eastern part of Apra Harbor.

Elevation within the transect area is <3 m above sea level, with scattered local depressions of standing water. Because of land filling for the development and construction of Piti power facilities, pipeline road, Dry Dock Island Road, and Rt. 1, the entire perimeter of the transect area has been artificially elevated, creating a shallow basin that frequently becomes flooded during periods of heavy rainfall. Except for depressions of standing water and reed grass marshes, the entire transect area is densely forested.

Within the overall transect area, Tracey et al. (1964) mapped the surface deposits as alluvium (Quaternary). Our observations along the transect revealed surface deposits of dark-colored, organic-rich muck where saturated with water, and a well-drained, black-to-brownish clayey muck that commonly forms a conspicuous hummocky topography where less saturated. Such hummocks are generally circular in outline, up to 40 cm high and <1 m in diameter, with the upper surface flattened to low convex, somewhat like the one shown in Text Figure 1816-1. At a several locations, low mounds of limestone base course material have been dumped on the surface near the Piti power facilities, and some scattered trash, consisting mostly of beverage cans and bottles and pieces of corrugated metal roofing, were also present. Although the substratum was not revealed within the transect area, the organic-rich soil surface is probably underlain by an unknown thickness of bioclastic beach and shallow water marine deposits. At higher elevations farther eastward, these bioclastic deposits probably pinch out into alluvial deposits derived from the adjacent eastern volcanic highland of the Tenjo Block.

Structurally, the low coastal alluvial land bordering the eastern side of Inner and Outer Apra Harbor is located within the north-south trending Cabras Fault zone, which separates the limestone Orote Block on the west from the volcanic mountainous Tenjo Block to the east. The overall downward tilt of the limestone Orote Block to the northeast indicates that movement along the fault took place after deposition of the Pleistocene Mariana Limestone Formation that makes up Orote Peninsula. It was this downward fault movement that created the marshy-swampy lowland presently found along the eastern part of the Orote Block. During the maximum Holocene +2-m sea stand 5,000 years ago, the Orote Block was most likely separated from the main island by a narrow shallow seaway, which then became slightly emergent when the relative sea level dropped to its present level about 3,000 years ago.

No rock or soil samples were collected within the transect area.

Soil Development Within the Survey Area

Soils within the transect area are a somewhat mosaic mixture of Inarajan Variant mucky clay No. 32 (0 to 3 percent slopes) along the southwestern two-thirds of the transect line, transitionally grading into Inarajan clay No. 30 (0 to 4 percent slopes) and Inarajan sandy clay loam No. 31(0 to 3 percent slopes) along the northeastern one-third of the transect line (Soil Survey of Territory of Guam, 1988). All of these soil types are close to the water table and subject to frequent flooding. Scattered depressions with permanent or ephemeral standing water were occupied by brown- to black-colored, organic-rich Inarajan Variant mucky clay No. 32, a soil of a plastic consistency that does not support ones' weight. Areas of higher elevation consist of a mixture of Inarajan clay No. 30 and Inarajan sandy clay loam No. 31, which, when wet, has a mucky consistency, but becomes quite firm and dissected with cracks and fissures upon drying out, commonly developing a hummocky topography (Text Figure 1816-1). Freshwater *Pomacea canaliculata* snails were found in a number of the larger pools of standing water, as well as their pink-colored egg cases on emergent stems of vegetation (Text Figure 1816-2).

Vegetation Within the Survey Area

The water table within the transect area is either at the surface or near enough to the surface to make the soil wet during much of the year, particularly during the wet season. During the dry season, the soil alternates between being wet during periods of rainfall to dry during extended periods of no rainfall. Scattered within the transect areas are local small depressions, some of which appear to be slightly below the water table and thus retain standing water throughout the year (Text Figures 1816-2 and 1816-4), while other shallower ones only have standing water during periods of heavy rainfall. During extended periods of heavy rainfall the region commonly becomes flooded. With such characteristics, the transect region can thus be considered a wetland, and since it is dominated by trees and shrubs (woody vegetation) can be considered a swamp, with scattered small patches of marshland.

Although the transect region can be characterized as swampland, it is rather unique in that it is dominated by vegetation unlike any of Guam's swamps described by Fosberg (1959, 1960). In the Piti transect region, the predominant swamp vegetation is dominated by introduced *Spathodea campanulata* trees (Text Figures 1816-8 and 1816-9) rather than the mangrove species *Nypa*, *Barringtonia*, *Hibiscus*, or *Hibiscus-Pandanus* species, as designated for swamps by Fosberg. Although the Piti transect region is dominated by *Spathodea campanulata* trees, many of the other swamp species occurring there, except mangroves species, are typical of those found in other Guam swamps.

Because of the presences of numerous *Spathodea campanulata* trees, the forest canopy is rather high, with a relatively even stature. Other conspicuous canopy species include scattered *Cocos nucifera* and a few *Pithecellobium dulce* trees. The second story trees form a more uneven layer, with common species that include *Hibiscus tiliaceus*, *Leucaena leucocephala*, and scattered clumps of *Bambusa vulgaris*. Some of the larger clumps of bamboo have canes extending into the canopy level (Text Figure 1816-3).

Understory tree species are of lower stature than the second story, commonly with a bushy tangled aspect that at some most places was difficult to pass through, particularly where intermingled with numerous *Flagellaria indica* vines. At several locations, these vines were so abundant that passage could only be made with the use of a machete (Text Figures 1816-5 and 1816-6). Common understory species include smaller trees and seedlings of the above canopy and second story species along with *Triphasia trifolia*, and vines of *Syngonium podophyllum* and *Flagellaria indica*.

Common large herbaceous groundcover species observed were *Nephrolepis hirsutula*, *Polypodium punctatum*, *Polypodium scolopendria*, *Asplenium nidus*, *Mikania scandens*, and *Chromolaena odorata*. Groundcover herbaceous plants add to the difficulty of making passage through the understory (Text Figures 1816-2 and 1816-5). Depressed areas with permanent or ephemeral standing water were commonly occupied by herbaceous marshland species that included *Phragmites karka*, *Acrostichum aureum*, *Scirpus littoralis*, and *Hymenocallis littoralis* (Text Figure 1816-7).

<u>Results of the Field Snail Survey</u>

Results of snail observations by both survey members are tabulated in Tables A-12 below. From a total of 77 mollusc shells observed, 68 were dead, bleached *Achatina fulica* snail shells found on the surface of bare exposed soil. Two of these shells were inhabited by living

Coenobita brevimanus hermit crabs. Five dead *Pomacea canaliculata* shells and two dead *Satsuma mercatoria* snails were found on the surface of bare exposed soil. Two living *Satsuma mercatoria* snails were observed on *Flagellaria indica* vines. Although some of the dead *Achatina fulica* shells appeared to be unweathered, none were observed alive. The five dead *Pomacea canaliculata* snails, being aquatic, were observed in the vicinity of depressions that appeared to have previously contained standing water.

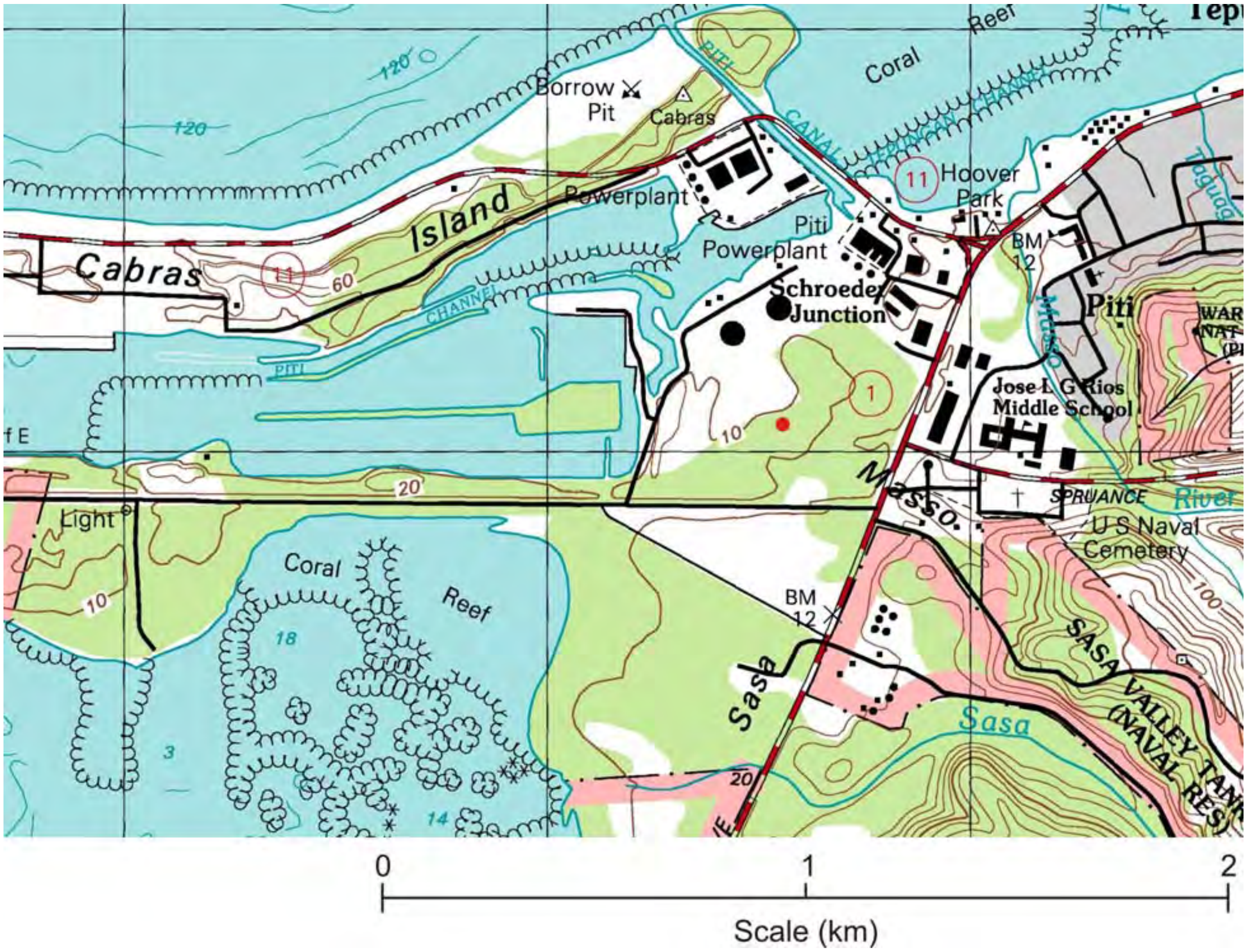
Table A-12. Land snails recorded by two observers surveying 10-m sectors of Piti Power Plant Transect 1.

Transect Sector	Species Observed	Number of Specimens	Habitat
0-10	*Achatina fulica*	4	Dead specimen on ground
10–20	*Achatina fulica*	1	Dead specimen on ground
	Satsuma mercatoria	2	Dead specimen on ground
20–30	*Achatina fulica*	3	Dead specimen on ground
30–40	*Achatina fulica*	4	Dead specimen on ground
40–50	*Achatina fulica*	5	Dead specimen on ground
50–60	*Achatina fulica*	1	Dead specimen on ground
60–70	*Achatina fulica*	2	Dead specimen on ground
	Satsuma mercatoria	1	Live specimen observed but not collected
70–80	*Satsuma mercatoria*	1	Live specimen observed but not collected
	Achatina fulica	1	Dead specimen on ground
80–90	None		
90-100	*Pomacea canaliculata*	3	Dead specimen on ground
100-110	*Achatina fulica*	2	Dead specimen on ground
110-120	*Achatina fulica*	2	Dead specimen on ground
	Pomacea canaliculata	1	Dead specimen on ground
120-130	*Achatina fulica*	1	Dead specimen; shell inhabited by *Coenobita brevimanus*)
130-140	None		
140-150	*Achatina fulica*	2	Dead specimen on ground
150-160	*Achatina fulica*	1	Dead specimen on ground
160-170	None		
170-180	None		
180-190	None		
190-200	*Achatina fulica*	1	Dead specimen on ground
200-210	None		
210-220	None		
220-230	None		
230-240	None		
240-250	None		
250-260	None		
260-270	None		
270-280	*Achatina fulica*	2	Dead specimen on ground
280-290	None		
290-300	None		
300-310	*Achatina fulica*	1	Dead specimen on ground
310-320	*Achatina fulica*	4	Dead specimen on ground
320-330	*Achatina fulica*	1	Dead specimen; shell inhabited by *Coenobita brevimanus*)
330-340	*Achatina fulica*	4	Dead specimen on ground
340-350	*Achatina fulica*	3	Dead specimen on ground
	Pomacea canaliculata	1	Dead specimen on ground
350-360	*Achatina fulica*	1	Dead specimen on ground
360-370	*Achatina fulica*	5	Dead specimen on ground
370-380	None		
380-390	None		
390-400	*Achatina fulica*	2	Dead specimen on ground
400-410	None		
410-420	None		
420-430	*Achatina fulica*	1	Dead specimen on ground
430-440	Achatina fulica	2	Dead specimen on ground
440-450	*Achatina fulica*	1	Dead specimen on ground
450-460	None		
460-470	*Achatina fulica*	3	Dead specimen on ground

Table A-12. Continued.

Transect Sector	Species Observed	Number of Specimens	Habitat
470-480	*Achatina fulica*	1	Dead specimen on ground
480-490	*Achatina fulica*	4	Dead specimen on ground
490-500	*Achatina fulica*	3	Dead specimen on ground

MAP FIGURES



Map Figure 1816-1. A section of the Apra Harbor USGS Quadrangle Map showing the mid part of Piti Power Plant Transect 1 (red dot), and other geographic areas mentioned in the text.

Map Figure 1816-2. A satellite image showing the location and track of Piti Power Plant Transect 1, within the 'Coastal Lowland' physiographic unit of the western central coastal area of Guam 'Uplands of Gently Sloping Foothills Cut by Major Streams' in southern Guam. Vegetation consists of a mosaic pattern of forested areas (dark green) and disturbed grass- weed areas (light green). Letter symbols: A = low coastal alluvial land bordered by Cabras Marina complex of boat docking facilities on the west, B = Piti power generating facilities on the north, C = Dry Dock Island Road on the south, and D = Rt. 1 Highway on the east.

TEXT PHOTOS

Text Figure 1816-1. Where the soil is less saturated and better drained, a black to brownish clayey muck commonly forms a conspicuous, hummocky topography. Such hummocks are generally circular in outline, up to 40 cm high and less than a meter in diameter, with the upper surface flattened to low convex, like those shown above. For scale, the geology hammer is 33 cm long.

Text Figure 1816-2. A standing pool of stagnant water located between Transect Stations 100 m and 110 m. This pool is about 10 m wide and is most likely at water table elevation, because the level changes with the tide. The pool has a decaying layer of dark colored organic material on the floor with an under-layer of black plastic muck. This is probably a permanent pool, because several aquatic *Pomacea canaliculata* snails were observed, as well as their subaerial pink-colored egg cases (pink spot in upper left). Throughout much of the transect ferns, such as those of *Nephrolepis hirsutula* and *Polypodium scolopendria* shown in the foreground, were common components of the herbaceous understory ground cover.

Text Figure 1816-3. Clumps of bamboo thickets between Transect Stations 180 m and 190 m. The most open understory region along the entire transect was here where a thick carpet of bamboo leaves seems to inhibit dense understory vegetation growth.

Text Figure 1816-4. Another pool of standing water located between Transect Stations 300 m and 310 m.

Text Figure 1816-5. Dense tangled vines of *Flagellaria indica* and understory ferns of *Nephrolepis hirsutula* in excess of 1 m in height between Transect Station 280 m and 290 m made progress difficult.

Text Figure 1816-6. A dense entangled growth of understory vines of *Flagellaria indica* located between Transect Station 310 m and 320 m.

Text Figure 1816-7. Depressed areas with permanent or ephemeral standing water, such as here between Transect Stations 400 m and 420 m, were commonly occupied by herbaceous marshland species that included *Phragmites karka* and *Hymenocallis littoralis*.

Text Figure 1816-8. A general view along the understory vegetation at Transect Station 440 m dominated by a dense stand of *Spathodea campanulata* trees, which is the principal canopy species along much of the transect as well. At this particular location a dense stand of medium-sized *Spathodea campanulata* trees provide so much shade that only a few of its seedling are found at ground level.

Text Figure 1816-9. A general view at Transect Station 500 m showing a small local opening dominated by saplings of *Spathodea campanulata* trees. Vines of *Syngonium podophyllum*, shown on tree trunks in the background, were quite common near the terminal end of the transect.

RHR 1817 FIELD NOTES
(Tolaeyuus River Transects No. 1, 2, and 3)

Date: July 7 and 9, 2009

Geographic Location: Guam, Tolaeyuus River area.

INTRODUCTION

All three Tolaeyuus River (often called Lost River) area transects are located in the immediate vicinity of the earthen dam gaging station and Maagas and Tolaeyuus Rivers, as shown in Map Figures 1817-1 and 1817-2. Transects 1 and 2 were conducted on July 7, and Transect 3 was conducted on July 9. The transect sites were accessed via the Fena Reservoir Road that leads to the pumping station at the base of the dam.

During both July 7 and 9 the weather was sunny with scattered clouds punctuated with a few very minor rain showers.

General Physiographic and Geologic Setting of the Survey Sites

Transect 1, which is 100 m long, is located along the immediate northwest side of the Tolaeyuus River, downstream from where it emerges from underground at a limestone scarp to its confluence with the Maagas River (Map Figures 1817-1 and 1817-2 and Text Figure 1817-1). A number of fish and aquatic snails were present in a pool at the base of the limestone scarp where the underground river exits (Text Figure 1817-2); a nest of honeybees on lobes of honeycomb was observed about 3 m directly above this pool, attached to the underside of a projecting limestone ledge (Text Figure 1817-3). Transect 1 Station 0 m is located at the base of a scarp of Bonya Limestone (Miocene), from whence the transect traverses downstream alongside the Tolaeyuus River. The transect was established on a riverside slope of alluvial deposits (Qal-Quaternary) intermixed with sand- to boulder-sized clasts of Bonya Limestone. Some of the cobble-to boulder-sized material appears to be fill and base-course material used for the roadbed and an old (now weed-covered) roadway that leads to a nearby borrow pit. Between Transect 1 Station 75 m to 85 m, the transect crosses the north side of a roadway bridge over the Tolaeyuus River, and it continues over riverside alluvial deposits to Transect 1 Station 100 m, near the confluence with the Maagas River. A sample of Bonya Limestone (Spec. No. 1817-1) was collected from the scarp wall at Transect 1 Station 0 m, at about 3 m elevation above the Tolaeyuus River level (Text Figure 1817-4) (see 'Collections' section for description).

Transect 2, which also is 100 m long, is located along the immediate southeast side of the Tolaeyuus River downstream from where it emerges from underground at a limestone scarp to its confluence with the Maagas River (Map Figures 1817-1 and 1817-2 and Text Figure 1817-5). Transect 2 Station 0 m is located at the base of a scarp of Bonya Limestone (Miocene), from whence it traverses downstream alongside the Tolaeyuus River upon a narrow riverside terrace of Bonya Limestone between Transect Stations 0 m to 20 m. From there, it continues upon a riverside slope of alluvial deposits (Qal-Quaternary) intermixed with sand- to boulder-sized clasts of Bonya Limestone. The transect crosses the south side of a roadway bridge over the Tolaeyuus River between Transect 2 Station 75 m to 85 m, and it continues over riverside alluvial deposits to Transect 2 Station 100 m. A sample of Bonya Limestone (Spec. No. 1817-2) was collected from the scarp wall at Transect Station 10 m, at about 3 m elevation above the Tolaeyuus River level (see ‘Collections’ section for description).

Transect 3, which is 630 m long, extends northeastward from the dam gaging station at the north side of the dam spillway to a borrow pit 100 m north of where the Tolaeyuus River emerges from underground at a limestone scarp (Map Figures 1817-1 and 1817-2). Transect 3 Station 0 m is located at the west side of an old barrow pit that displays several terraced layers excavated into Bonya Limestone deposits, (the type locality for the formation designated by Tracey et al., 1964). From the borrow pit, the transect extends southwestward downslope across forested disturbed Bonya limestone to where it grades into a flatted terrace at Transect 3 Station 129 m. The terrace contains disturbed fill material and alluvial deposits at a roadway that leads to Tolaeyuus Bridge. From Transect 3 Station 129 m, the transect traverses over a region dominated by weeds and woody brush growing on disturbed fill material and alluvial deposits to the forested north side of the Maagas River at Transect 3 Station 157 m. From Transect 3 Station 157, the transect traverses westward alongside the forested Maagas River on a steep slope of rugged fill material dominated by large boulders of Bonya limestone to the lower end of the Fena Reservoir spillway at Transect 3 Station 386 m. From the end of the spillway, the transect traverses over a gentle upward sloping, grassy mowed area on fill material of the earthen Fena Dam alongside a concrete revetment wall to Transect 3 Station 441 m. From Transect 3 Station 441 m, the transect follows more steeply upslope over forested artificial fill material of Fena Dam to the roadway at the top of the dam at Transect 3 Station 630 m.

Soil Development Within the Survey Sites

Soils within the Transect 1 area are classified as Ylig clay No. 54 (0 to 10 percent slopes) along the immediate river bank (Soil Survey of Territory of Guam, 1988), grading upslope from the river bank into disturbed fill material that consists of sand- to boulder-sized clasts of Bonya Limestone intermixed with some cobbly, dark-brown, clayey loam soil on the surface.

Soils within the Transect 2 area are classified as Ylig clay No. 54 (0 to 30 percent slopes) along the immediate river bank (Soil Survey of Territory of Guam, 1988), grading upslope into a low terrace of limestone talus intermixed with a thin surface layer of cobbly, dark-brown, clayey loam alongside a low scarp of Bonya Limestone.

At Transect 3, soils between Stations 0 m and 386 m, the transect traverses over disturbed Bonya Limestone that is classified as Ritidian-Rock outcrop complex, No. 44 (15 to 30 percent slopes) (Soil Survey of Territory of Guam, 1988). Between Transect 3 Stations 129 m and 157 m, the transect traverses over a graveled road bed region dominated by weeds and woody brush growing on disturbed fill material and alluvial deposits to the forested north side of the Maagas River that is classified as Urban land-Ustorthents complex, No. 53 (nearly level)

(Soil Survey of Territory of Guam, 1988). Between Transect 3 Stations 157 m and 386 m, the transect traverses over disturbed fill material and alluvial deposits along the forested north side of the Maagas River that is classified as Urban land-Ustorthents complex, No. 53 (nearly level) (Soil Survey of Territory of Guam, 1988). Between Transect 3 Stations 386 m and 630 m, the transect traverses over the Fena Dam artificial fill deposits that are classified as Urban land-Ustorthents complex, No. 53 (10 to 30 percent slopes) (Soil Survey of Territory of Guam, 1988).

During the construction of Fena Reservoir Dam and associated roadways, nearly all the original soil cover and underlying rock strata of the three transect areas was extensively disturbed by excavation and land filling.

Vegetation Within the Survey Sites

Extensive construction activities during construction of Fena Dam most likely removed all the vegetation within the three transect areas. Since then some regions that have not been maintained as grassy lawn areas have become forested either by deliberate planting, such as on the dam surface itself to control erosion, or have over time have become naturally reforested. The roadway that leads to the old limestone borrow pit has been abandoned and is now occupied by weed-brush type of vegetation that, if left undisturbed, will most likely become forest covered again.

Transect 1: Vegetation on the north side of the Tolaeyuus River bank consists of a narrow corridor of a mixed forest community along the immediate river bank that rapidly grades into a dense shrub-weed community a few meters inland from the bank. *Bambusa vulgaris* was the most conspicuous canopy species along the transect (Text Figures 1817-6 and 1817-7). Principal trees and shrubs species interspersed between the bamboo patches were seedlings and small trees of *Areca catechu* (betelnut), small saplings and shrubs of *Hibiscus tiliaceus*, and small clumps of *Pandanus tectorius*. Except for somewhat barren areas beneath bamboo patches, the understory and ground cover consisted of a rather dense growth grasses, ferns, and seedling trees up to several meters in height (Text Figures 1817-6 and 1817-7). Ferns were particularly abundant on the limestone scarp face where the Tolaeyuus River emerges from its underground course (Text Figures 1817-1 and 1817-4). Up-slope from the river bank, the forest community grades into dense weed-shrub community along the abandoned roadway to the old borrow pit and the present Tolaeyuus Bridge roadway. Conspicuous in this weed-shrub community are finger-sized stems of *Cassia alata*, vines of *Mikania scandens*, and dense patches of *Sida rhombifolia*.

Transect 2: The plant community along the south side of the Tolaeyuus River is much the same as that found on the north side along Transect 1 above (Text Figures 1817-5, 1817-6, and 1817-7), except for a lack of the dense weed-shrub community and a less dense groundcover of herbaceous vegetation. Patches of *Bambusa vulgaris* are common on the west side of the Tolaeyuus Bridge at the confluence of the Tolaeyuus and Maagas Rivers (Text Figure 1817-8).

Transect 3: Vegetation along this 630-m transect is much more varied than that along Transects 1 and 2, and it has not developed into any particular forest type of characteristic species. The vegetation between Station 0 m and the roadway at Station 129 m is dominated by dense tangled and fallen trunks and limbs of dead and living *Hibiscus tiliaceus* trees, *Areca catechu* (betelnut), and patches of *Bambusa vulgaris* (Text Figure 1817-9). Minor components of the vegetation along this sector not encountered on Transects 1 and 2 are trees of *Cananga odorata* (Text Figure 1817-10) and *Pimenta dioica* (allspice). A rather unusual bracket fungus was photographed on a dead log in a dense tangled stand of dead and living *Hibiscus tiliaceus* trees at Transect 3 Station 70 m (Text Figures 1817-11 and 1817-12).

Between Stations 129 m and 157 m the vegetation consists of a dense weed-shrub community along the present Tolaeyuus Bridge roadway, similar to that noted above at Transect 1. Vegetation between Stations 157 m and 386 m along this sector is more varied than along Transects 1 and 2, principally in the lack of bamboo patches, except for a few patches at the confluence of the Tolaeyuus and Maagas Rivers (Text Figure 1817-13). Common species along well-drained parts of this sector include trees of *Hibiscus tiliaceus*, *Pandanus tectorius*, and *Areca catechu* (Text Figure 1817-13). An occasional *Cocos nucifera* palm and *Casuarina equisetifolia* tree were also observed. Less well-drained regions have patches of *Bambusa vulgaris* along the Maagas River bank (Text Figure 1817-14). Stagnant water develops in the Maagas River channel near the Fena Dam spillway when no water is flowing over the spillway (Text Figure 1817-15).

Between Stations 386 m and 441 m the transect traverses over a mowed grassy lawn area (Text Figure 1817-16). Between Stations 441 m and 630 m, the transect traverses up a steep forested slope over forested fill material of Fena Dam to the roadway at the top of the dam at Transect Station 630 m. The forest here has a rather low, open stature dominated by trees and shrubs of *Hibiscus tiliaceus*, *Pandanus tectorius*, and *Vitex negundo*. On the lower part of the dam slope, the trees and shrubs are somewhat scattered, with a weedy ground cover dominated by various kinds of grasses. A few small fruiting trees of *Annona muricata* were also on the lower grassy slopes. As one progresses toward the dam crest, the trees become more closely set with a more open, weedy ground cover.

<u>Results of the Field Snail Survey</u>

Results of snail observations by both survey members are tabulated in Tables A-13–A-15 below. A single dead, bleached *Achatina fulica* snail shell was observed in each of Transects 1and 2 . One dead, bleached *Euglandina rosea* shell was observed on Transect 2. Each transect covered an area of 2,000 m^2. No living or dead endangered snails were observed.

Twenty dead, bleached *Achatina fulica* snails were observed along Transect 3, and 1 living and 6 dead *Satsuma mercatoria* snail shells were observed in 12,600 m^2 surveyed. No living or dead endangered snails were observed.

Table A-13. Land snails recorded by two observers surveying 10-m sectors of Tolaeyuus River Transect No. 1.

Transect Sector	Species Observed	Number of Specimens	Habitat
0–10	*Achatina fulica*	1	Dead specimen on ground
	Euglandina rosea	1	Dead specimen on ground
10–20	None		
20–30	None		
30–40	None		
40–50	None		
50–60	None		
60–70	None		
70–80	None		
80–90	None		
90–100	None		

Table A-14. Land snails recorded by two observers surveying 10-m sectors of Tolaeyuus River Transect No. 2.

Transect Sector	Species Observed	Number of Specimens	Habitat
0–10	None		
10–20	*Achatina fulica*	1	Dead specimen on ground
20–30	None		
30–40	None		
40–50	None		
50–60	None		
60–70	None		
70–80	None		
80–90	None		
90–100	None		

Table A-15. Land snails recorded by two observers surveying 10-m sectors of Tolaeyuus River-Fena Dam Spillway Transect No. 3.

Transect Sector	Species Observed	Number of Specimens	Habitat
0–10	*Achatina fulica*	2	Dead specimens on ground
10–20	None		
20–30	*Achatina fulica*	2	Dead specimens on ground
30–40	*Achatina fulica*	1	Dead specimen on ground
40–50	*Achatina fulica*	1	Dead specimen on ground
50–60	*Satsuma mercatoria*	2	Dead specimens on ground
60–70	*Achatina fulica*	1	Dead specimen on ground
70–80	None		
80–90	None		
90–100	*Satsuma mercatoria*	1	Dead specimen on ground
100–110	None		
110–120	None		
120–130	None		
130–140	None		
140–150	None		
150–160	None		
160–170	*Achatina fulica*	2	Dead specimens on ground
170–180	*Achatina fulica*	1	Dead specimen on ground
180–190	*Achatina fulica*	1	Dead specimen on ground
190–200	None		
200–210	None		
210–220	None		
220–230	*Achatina fulica*	3	Dead specimens on ground
230–240	None		
240–250	None		
250–260	None		
260–270	None		
270–280	None		
280–290	*Achatina fulica*	1	Dead specimen on ground
290–300	None		
300–310	None		
310–320	None		
320–330	None		
330–340	None		
340–350	None		
350–360	None		
360–370	None		
370–380	None		
380–390	None		
390–400	None		
400–410	None		
410–420	None		
420–430	None		
430–440	None		
440–450	None		
450–460	None		
460–470	*Achatina fulica*	1	Dead specimen on ground
470–480	None		
480–490	*Satsuma mercatoria*	1	Found living on ground
490–500	None		
500–510	None		

Table A-15. Continued.

Transect Sector	Species Observed	Number of Specimens	Habitat
510–520	None		
520–530	None		
530–540	*Achatina fulica*	1	Dead specimen on ground
	Satsuma mercatoria	2	Dead specimens on ground
540–550	None		
550–560	*Achatina fulica*	1	Dead specimen on ground
560–570	None		
570–580	*Achatina fulica*	2	Dead specimens on ground
580–590	None		
590–600	None		
600–610	None		
610–620	None		
620–630	None		

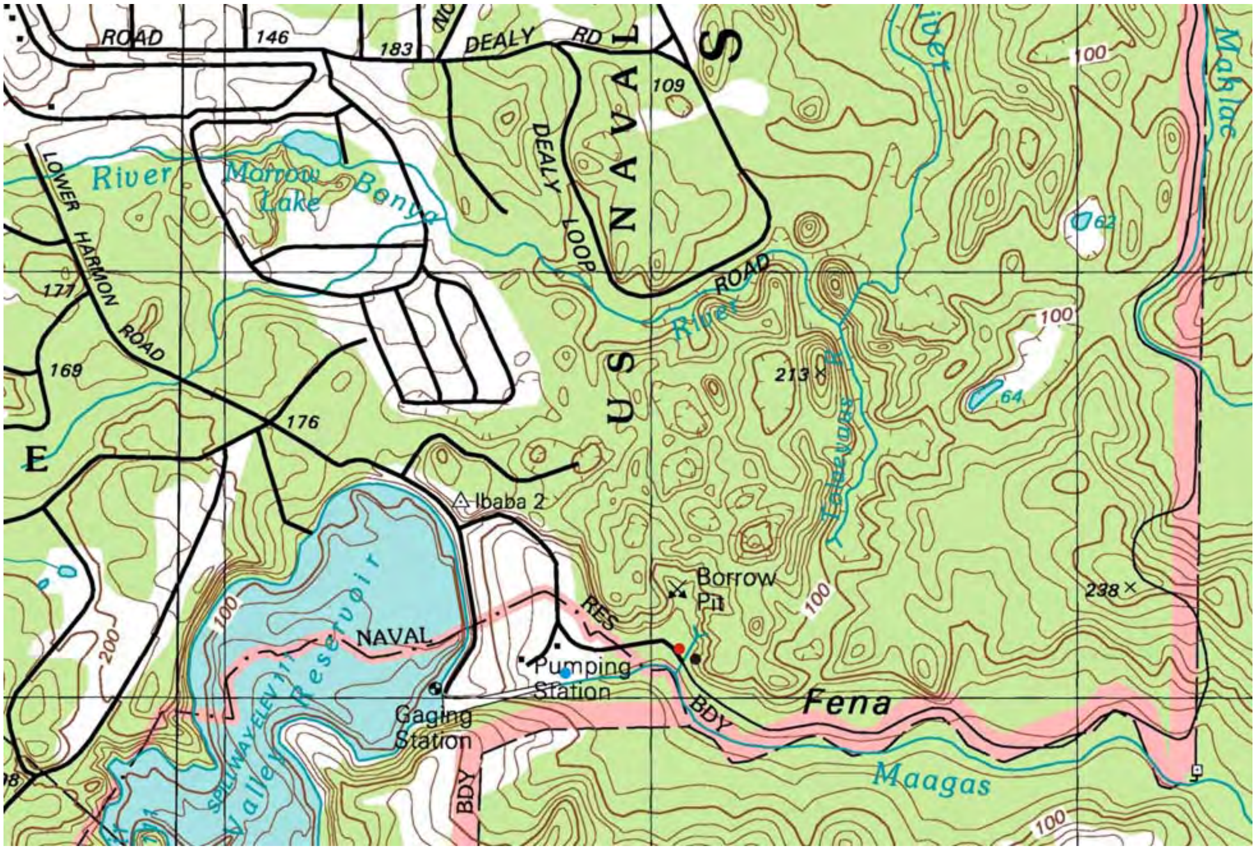
COLLECTIONS

Geologic Specimens:

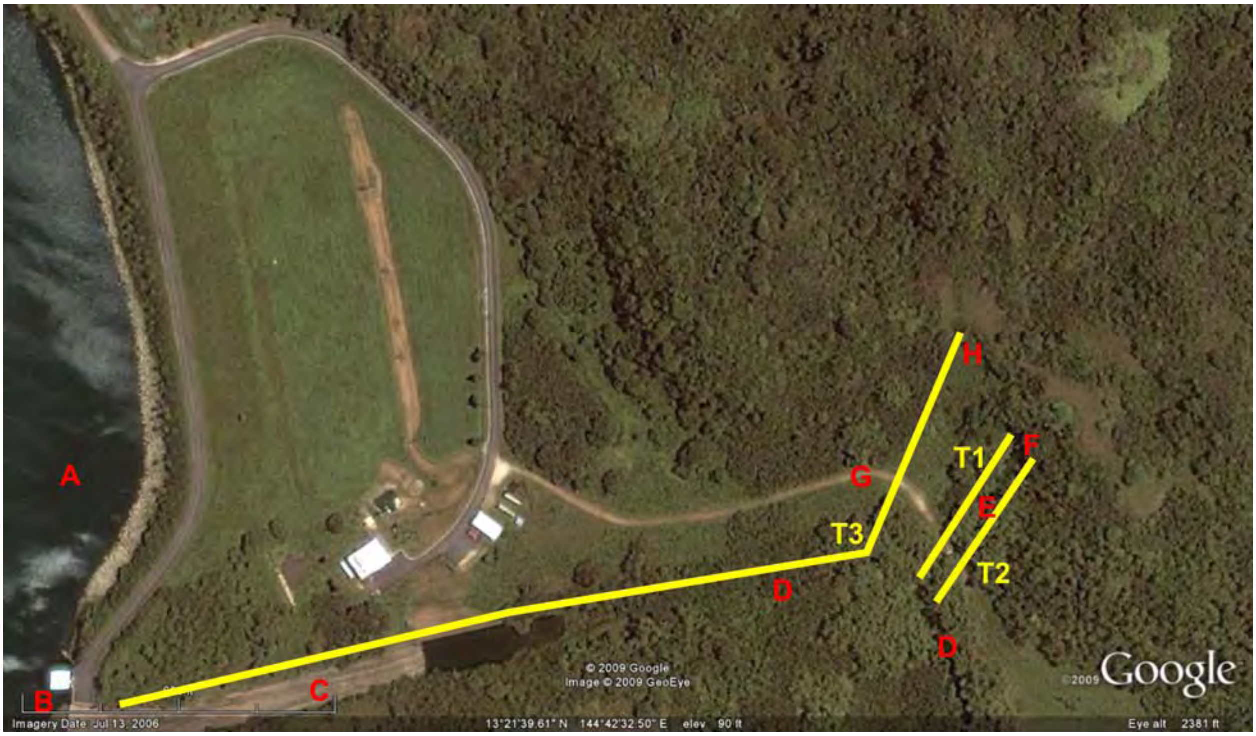
Specimen Number: Specimen 1817-1-T1
Number of Specimens Coll.: 1 piece
Specimen Name: A detrital limestone.
Geographic Location and Collecting Station: Guam, lower Tolaeyuus River. Collecting Station: RHR 1817-CS-1). The sample was collected from the scarp wall at Transect 1,Station 0 m, at about 3 m elevation above the Tolaeyuus River level.
Geologic Formation: Bonya Limestone Formation.
Elevation: 27 m
Notes: At the collecting station, the limestone is faintly bedded, off-white to buff in color, compact, and composed of poorly sorted clasts, some of which are beige in color.

Specimen Number: Specimen 1817-2-T1
Number of Specimens Coll.: 1 piece
Specimen Name: A detrital limestone.
Geographic Location and Collecting Station: Guam, lower Tolaeyuus River. Collecting Station: RHR 1817-CS-1). The sample was collected from the scarp wall at Transect 2, Station 0 m, at about 3 m elevation above the Tolaeyuus River level.
Geologic Formation: Bonya Limestone Formation.
Elevation: 27 m.
Notes: At the collecting station, the limestone is faintly bedded, off-white to buff in color, compact, and composed of poorly sorted clasts, some of which are beige in color.

MAP FIGURES



Map Figure 1817-1. A section of the Talofofo USGS Quadrangle Map showing the mid part of the Tolaeyuus River Transect 1 (red dot), 2(black dot), and 3 (Blue dot), and other geographic areas mentioned in the text.



Map Figure 1817-2. A satellite image showing the location and track of the Tolaeyuus River Transects 1, 2, and 3 within the 'Interior Basin Rolling Hills and Karst' physiographic unit of the central part of Guam. Vegetation consists of a mosaic pattern of forested areas (dark green) and disturbed grass-weed and landscaped areas (light green). Letter symbols: A = Fena Reservoir, B = Fena Dam, C = Dam Spillway, D = Maagas River, E = Tolaeyuus River, F = Limestone scarp where the Tolaeyuus River emerges from its underground course, G = Tolaeyuus Bridge Roadway, and H = Borrow pit. T1 is Transect 1, T2 is Transect 2, and T3 is Transect 3.

TEXT FIGURES

Text Figure 1817-1. A view of the Tolaeyuus River where it emerges from its underground course at the base of an overhanging scarp of Bonya limestone. Although not exposed, the underground course of the river most likely follows along a contact of basal volcanic rocks and overlying limestone deposits (upper white areas of the scarp). In the upper right is an out-wash bar of sand- to cobble-sized mater that consists of both volcanic as well as limestone clasts. Such cobble-sized out-wash material indicates that a considerable current must be present through the river's underground course during high-flow flood stage conditions. A submerged dark green clump of *Hydrilla verticillata* is present in the left center.

Text Figure 1817-2. Freshwater fish (*Kuhlia rupestris*) and snails (*Neritina pulligera*) in the pool of water where the underground Tolaeyuus River exits at the base of a limestone scarp. The range of this fish species was thought to be limited to waters downstream from where the Tolaeyuus River exits, but investigation of the river upstream of where the river flows underground revealed their presence there as well.

Text Figure 1817-3. A honeybee nest of exposed lobes of honeycomb attached to the ceiling of an overhanging limestone ledge directly above the pool where the underground Tolaeyuus River exits to the surface at Transect 1, Station 0 m.

Text Figure 1817-4. A view of the limestone scarp of Bonya Limestone at Transect No. 1, Station 0 m, showing one of the authors collecting a limestone sample (Spec. No. 1817-1). The sample collected revealed a rather compact, but porous, white to buff-colored detrital limestone, typical of the Bonya Formation. Water percolating down through the rock seeps out on the scarp face, and promotes a rich growth of ferns and other plants seen on its surface.

Text Figure 1817-5. A view of the Tolaeyuus River looking from the north side to the south side about 20 m downstream of where it emerges from the base of the limestone scarp. The exposed scarp face displays distinct beds that dip downward to the north. Differential weathering of alternating beds of different hardness form irregular projecting ledges up to 15 cm thick. Transect No. 2, Station 0 m begins at the base the scarp on the south side of the river bank (right side). In the foreground the water column is choked with a thick mat of floating aquatic vegetation of *Potamogeton mariannensis* and dead bamboo leaves.

Text Figure 1817-6. A downstream view of the Tolaeyuus River, showing the thick vegetation along the bank at Transect 1 on the right and Transect 2 on the left.

Text Figure 1817-7. An upstream view of the Tolaeyuus River from the bridge, showing a low sheet-piling dam. Such a dam could theoretically raise the water level within the underground aquifer, and thus increase its storage capacity to maintain supply during low-flow dry season periods. Patches of bamboo (foreground) and small *Pandanus tectorius* (background in vicinity of the sheet-piling dam) are quite common on both sides of the river along Transect 1 on the left and Transect 2 on the right.

Text Figure 1817-8. One of the authors (Randall) beside several patches of *Bambusa vulgaris* at the west end of Transect 2 near the confluence of the Tolaeyuus and Maagas Rivers.

Text Figure 1817-9. A patch of *Bambusa vulgaris* canes and several small trees of *Areca catechu* (betelnut) along Transect 3, between Stations 0 m and 129 m. Dead canes of bamboo that commonly accumulate around the periphery of a living patch are in the foreground.

Text Figure 1817-10. A view of the flowers (pale green clusters of petals) and clusters of fruit of a *Cananga odorata* tree growing along Transect 3, between Stations 0 m and 129 m. On the left are some pendant fronds of the fern *Nephrolepis acutifolia*.

Text Figure 1817-11. The dorsal surface of rather unusual bracket fungi growing on a dead log in a dense tangled stand of dead and living *Hibiscus tiliaceus* trees at Transect 3, Station 70 m. See Text Figure 1817-12 for a view of the ventral view of the bracket. At the bottom is a green vine of *Stictocardia tiliifolia*.

Text Figure 1817-12. A ventral view of bracket fungus shown in Text Figure 1817-11.

Text Figure 1817-13. A view along Transect 3, between Stations 210 m and 220 m, where the transect traverses along the base of a narrow, steep-sloped corridor of limestone fill alongside the Maagas River. Here the well-drained slope is dominated by *Areca catechu*, *Pandanus tectorius* trees, and a ground cover of tree seedlings and herbaceous vegetation.

Text Figure 1817-14. A view along Transect 3, between Stations 250 m and 260 m, where the transect traverses along the base of a narrow steep-sloped corridor of limestone fill alongside the Maagas River. Here the well-drained upper part of the slope is dominated by *Areca catechu* trees and *Hibiscus tiliaceus* seedlings in the foreground, which farther downslope grades into *Bambusa vulgaris* patches along the wetter bank of the Maagas River.

Text Figure 1817-15. A view of stagnant water in the Maagas River channel along Transect 3, between Stations 330 m and 340 m, near the lower end of the Fena Dam spillway, showing how the river appears when there is no water flowing over the dam spillway. When the reservoir is occasionally full and water is flowing over the spillway, there is a good flow of water in the Maagas River between the spillway and its confluence farther downstream with the Tolaeyuus River. Because of the prevalence of stagnant water conditions, a wetland swamp species of *Phragmites karka* is becoming established in the upper right.

Text Figure 1817-16. A grass lawn maintained in the area along Transect 3, between Stations 386 m and 441 m.

Text Figure 1817-17. A cave entrance where the Tolaeyuus River begins a 400-m underground passage to its cave exit at the base of the limestone scarp shown in Text Figure 1817-2. Flotsam debris at a higher elevation than the top of the cave entrance indicates that during periods of heavy rainfall the entire cave entrance can become flooded.

RHR 1818 FIELD NOTES
(Rt. 4 Option A)

Date: July 22, 2009

Geographic Location: Guam, Old Roadway to Inarajan from its Junction with Rt. 4 at Cetti Bay Overlook to the Mountain Ridge Top between Mt. Jumullong Manglo and Mt. Lamlam.

Introduction

Option A Survey is one of several proposed routes to construct a road to a remote part of the U. S. Naval Ordnance Annex within the Fena Valley Watershed area. Option A Transect follows along part of the former over-the-mountain roadway that led from Rt. 4 to Inarajan. More specifically, the transect survey route is located along this old roadway from where it junctions with Rt. 4 highway at the Cetti Bay Overlook site to the top of the southern mountain ridge between Mt. Jumullong Manglo and Mt. Lamlam, as shown in Map Figures 1818-1 and 1818-2. Although we were instructed to begin our transect at the roadside Mt. Lamlam trail marker at the Cetti Bay Overlook site, it should be noted that the original over-the-mountain roadway actually junctions with Rt. 4 about 220 m north of the overlook (see Map Figure 1818-1). The trail head from the Cetti Bay Overlook site thus junctions with the old roadway course several hundred meters farther up-slope to the mountain ridge top. As this transect was not previously marked, we used a hip chain meter (Chainman II®) to determine the 10-m intervals. Our transect route from the highway trail head (Sta. 0 m) to the mountain ridge crest is 1,126 m (Sta. 112 m) long and is shown on Map Figure 1818-2.

The Option A Transect was surveyed on July 22, 2009. During the survey the weather was sunny with scattered clouds and without any rain showers.

General Physiographic and Geologic Setting Within the Survey Area

Option A Transect traverses over the steep western rift-fault slope of a cuestal volcanic mountain ridge along the southwestern region of Guam (Text Figures 1818-1, 1818-2 and 1818-3). The volcanic deposits are deeply weathered into saprolite at most places and dissected into a ridge and valley topography by relatively short high-gradient rivers and streams. The transect region is bounded by the Sella River to the north and Cetti River to the south, with the intervening region eroded into numerous smaller ridges and valleys by secondary streams. In general the transect-roadway route meanders upward, following ridge tops to the southern mountain crest. Although badly rutted and eroded, the old roadway is fairly well marked by remnants of limestone base course material and foot trails where such base course has been eroded away (Text Figure 1818-3). Examination of the limestone base course material reveals a white detrital limestone that was most likely supplied by an un-mapped borrow pit of Alifan Limestone located on the mountain ridge crest between Mt. Lamlam and Mt. Jumullong Manglo. Lower valley slopes are generally forested, grading upward into savanna land vegetation on upper slopes and ridge tops. At about 213 m elevation, an east-west trending normal fault bisects the transect roadway, and several nearby faults are located to the north and south of the roadway. For exact location of these faults, see the Geologic Map of Agat Quadrangle, Guam, by Siegrist et al. (2007). Within the vicinity of our transect line, the entire volcanic mountain slope shows abundant evidence of mass downslope movement of saprolite, soil, and sheet-wash deposits. Numerous rotational slump scars are evident along steeper parts of the entire transect (Text Figure 1818-4). At many places of less gradient, downslope mass movement by soil creep has formed corrugated ridges and fissures over the slope surface. Grassland and shrubby savanna vegetation has very little effect in preventing such mass downslope movement, and even forested slopes are subject to slumping and creep as well.

From a trail head geologic survey benchmark at 193.2 m elevation alongside Rt. 4 highway to Station 100 m, the transect route traverses across extensively weathered volcanic rocks of the Facpi Formation (Eocene). Although weathered to saprolite, the structural and textural characteristics of volcanic rock are generally well preserved, except where overlain with sheet-wash deposits. Exposed saprolite reveals deposits mostly of breccias and conglomerates. Some of the less weathered clasts revealed vesicular basalt in which the cavities are secondarily in-filled with zeolite deposits. At an elevation of approximately 213 m, the Facpi volcanic deposits grade into volcanic deposits of the Bolanos Pyroclastic Member (Miocene) of the Umatac Formation, which extends up-slope to the transect terminus. The boundary between the Eocene Facpi deposits and Miocene Bolanos Pyroclastic deposits is occupied by intermittent interbedded lenses of limestone, sandy and tuffaceous limestones, and sandstones and conglomerates of the Geus River Member (Oligocene) of the Umatac Formation at many places along the southwest coast. Although a narrow band of these Oligocene deposits is mapped at the transect location, none were found exposed. The Bolanos pyroclastic deposits along the transect are composed of weathered breccias, conglomerates, and sandstones consisting mostly of fragmented andesite.

Two small limestone outcrops were intercepted along the transect route that consisted of interbedded lenses within the Bolanos Pyroclastic deposit; the lowermost one between Transect Stations 550 m and 580 m, and the uppermost one between Transect Stations 790 m and 900 m (Map Figure 1818-2). The transect passes adjacent to both of these outcrops within a few meters of vertical scarp exposures 6–8 m high (Text Figure 1818-5, 1818-6, and 1818-7). Rock samples from both of these limestone outcrops were collected (Sample No. RHR 1818-1 (4 pieces) from the upper outcrop, and Sample No. 1818-2 (3 pieces) from the lower outcrop). See ‘Collections’ section below for a more detailed description of the samples.

From 305 m (1000 ft.) elevation to the transect terminus at 367 m (1205 ft.) elevation, the transect intercepts a small elongate region mapped as the Talisay Member (Oligocene) of the Umatac Formation, which we failed to discriminate from the Bolanos Pyroclastic deposits. Possibly such Talisay deposits are present a bit farther west and north of our transect, along the basal contact of the southernmost part of the Alifan Limestone.

<u>Soils Developed Within the Transect Region</u>

Soils on the northern valley slope at the transect site are classified as Akina-Atate association, steep, No. 17 (Soil Survey of Territory of Guam, 1988), with the Akina component formed from residuum dominantly derived from tuff and tuff breccia and conglomerate, and the Atate component formed from residuum dominantly derived from tuff and tuff breccia. Such soils within the transect area appeared to be quite deep within flattened regions of low slope, and moderately deep to shallow within regions of increased slope. At most places along the transect, soil appeared to be moderately well-drained, particularly at the crests of valley slopes. In small swale-like depressions, the soils are more poorly drained, and at a few places contained small shallow areas of standing water, particularly in rotational slump basins. At most places along the transect, soil surface was covered with abundant organic litter, but where pig rooting occurred, the soil ranged from brownish yellow to brownish red. In general this transect is less disturbed by wild pigs than at Transect No. 1 along the Sadog Gaga River valley, particularly along regions dominated by coconut trees. A possible reason for this may be that such upland coconut forests here are drier, particularly during the dry season, than those on low riverside terraces.

Vegetation Within the Transect Site

The overall vegetation within the transect area can be broadly classified as a 'grassland-savanna type' with two small isolated forested patches of 'dissected volcanic mountainous upland ravine type forest' as defined by Fosberg (1959, 1960). Between Stations 0 m and 550 m, a grassy-scrub savanna vegetation dominated the transect region with a few scattered reforested *Acacia* sp. trees at several places. Between Stations 550 m and 630 m and Stations 790 m and 890 m, small forested patches were encountered on and around the peripheral area of the two small limestone outcrops. Species composition within the small forested patches was typical of a 'ravine forest of dissected volcanic land' that occupies the lower valley slopes and river bottomland found in nearby areas. Some conspicuous species within the immediate transect region include *Hibiscus tiliaceus*, *Leucaena leucocephala*, *Premna obtusifolia*, *Guettarda speciosa*, *Ficus tinctoria*, *Flagellaria indica*, *Triphasia trifolia*, *Bougainvillea spectabilis*, *Pandanus tectorius*, *Merrilliodendron megacarpum* (Text Figure 1818-8), *Elaeocarpus joga*, *Urena lobata*, *Discocalyx megacarpa* (Text Figure 1818-9), and *Glochidion marianum*. The small limestone outcrop between Stations 790 m and 890 m has a small religious shrine built into the base of the scarp at which patrons have planted a number of ornamental plants. As a result, many of these plants have become established in the region, particularly vines of *Syngonium podophyllum* and a large patch of *Heliconia bihai* shown in Text Figure 1818-10.

Snail Survey Results

Results of snail observations by both survey members are tabulated in Table A-16 below. No living or dead endangered tree snails were observed in 11,300 m^2 surveyed along the transect. The only living mollusc observed along the transect was the introduced slug *Veronicella cubensis* (Text Figure 1818-11). Four dead, bleached *Achatina fulica* snail shells were found on the surface of bare exposed soil.

Table A-16. Land snails recorded by two observers surveying 10-m sectors of Rt. 4 Option A Transect.

Transect Sector	Species Observed	Number of Specimens	Habitat
0–10	None		Savanna land
10–20	None		Savanna land
20–30	None		Savanna land
30–40	None		Savanna land
40–50	None		Savanna land
50–60	None		Savanna land
60–70	None		Savanna land
70–80	None		Savanna land
80–90	None		Savanna land
90–100	None		Savanna land
100–110	None		Savanna land
110–120	None		Savanna land
120–130	None		Savanna land
130–140	None		Savanna land
140–150	None		Savanna land
150–160	None		Savanna land
160–170	None		Savanna land
170–180	None		Savanna land
180–190	None		Savanna land
190–200	None		Savanna land
200–210	None		Savanna land
210–220	None		Savanna land
220–230	None		Savanna land
230–240	None		Savanna land
240–250	None		Savanna land
250–260	None		Savanna land
260–270	None		Savanna land
270–280	None		Savanna land
280–290	None		Savanna land
290–300	None		Savanna land
300–310	None		Savanna land
310–320	None		Savanna land
320–330	None		Savanna land
330–340	None		Savanna land
340–350	None		Savanna land
350–360	None		Savanna land
360–370	None		Savanna land
370–380	None		Savanna land
380–390	None		Savanna land
390–400	None		Savanna land
400–410	None		Savanna land
410–420	None		Savanna land
420–430	None		Savanna land
430–440	None		Savanna land
440–450	None		Savanna land
450–460	None		Savanna land
460–470	None		Savanna land
470–480	None		Savanna land
480–490	None		Savanna land
490–500	None		Savanna land
500–510	None		Savanna land
510–520	None		Savanna land
520–530	None		Ravine Forest
530–540	None		Ravine Forest
540–550	None		Ravine Forest

Table A-16. Continued.

Transect Sector	Species Observed	Number of Specimens	Habitat
550–560	None		Ravine Forest
560–570	None		Ravine Forest
570–580	None		Ravine Forest
580–590	None		Ravine Forest
590–600	None		Ravine Forest
600–610	None		Ravine Forest
610–620	*Veronicella cubensis*	1	Ravine Forest, on leaf litter
620–630	None		Ravine Forest
630–640	None		Savanna land
640–650	None		Savanna land
650–660	None		Savanna land
660–670	*Achatina fulica*	3	Savanna land, dead specimens on ground
670–680	None		Savanna land
680–690	None		Savanna land
690–700	None		Savanna land
700–710	*Achatina fulica*	1	Savanna land, dead specimen on ground
710–720	None		Savanna land
720–730	None		Savanna land
730–740	None		Savanna land
740–750	None		Savanna land
750–760	None		Savanna land
760–770	None		Savanna land
770–780	None		Savanna land
780–790	None		Savanna land
790–800	None		Ravine Forest
800–810	None		Ravine Forest
810–820	None		Ravine Forest
820–830	None		Ravine Forest
830–840	None		Ravine Forest
840–850	None		Ravine Forest
850–860	None		Ravine Forest
860–870	None		Ravine Forest
870–880	None		Ravine Forest
880–890	None		Ravine Forest
890–900	None		Savanna land
900–910	None		Savanna land
910–920	None		Savanna land
920–930	None		Savanna land
930–940	None		Savanna land
940–950	None		Savanna land
950–960	None		Savanna land
960–970	None		Savanna land
970–980	None		Savanna land
980–990	None		Savanna land
990–1000	None		Savanna land
1000–1010	None		Savanna land
1010–1020	None		Savanna land
1020–1030	None		Savanna land
1030–1040	None		Savanna land
1040–1050	None		Savanna land
1050–1060	None		Savanna land
1060–1070	None		Savanna land
1070–1080	None		Savanna land
1080–1090	None		Savanna land
1090–1100	None		Savanna land

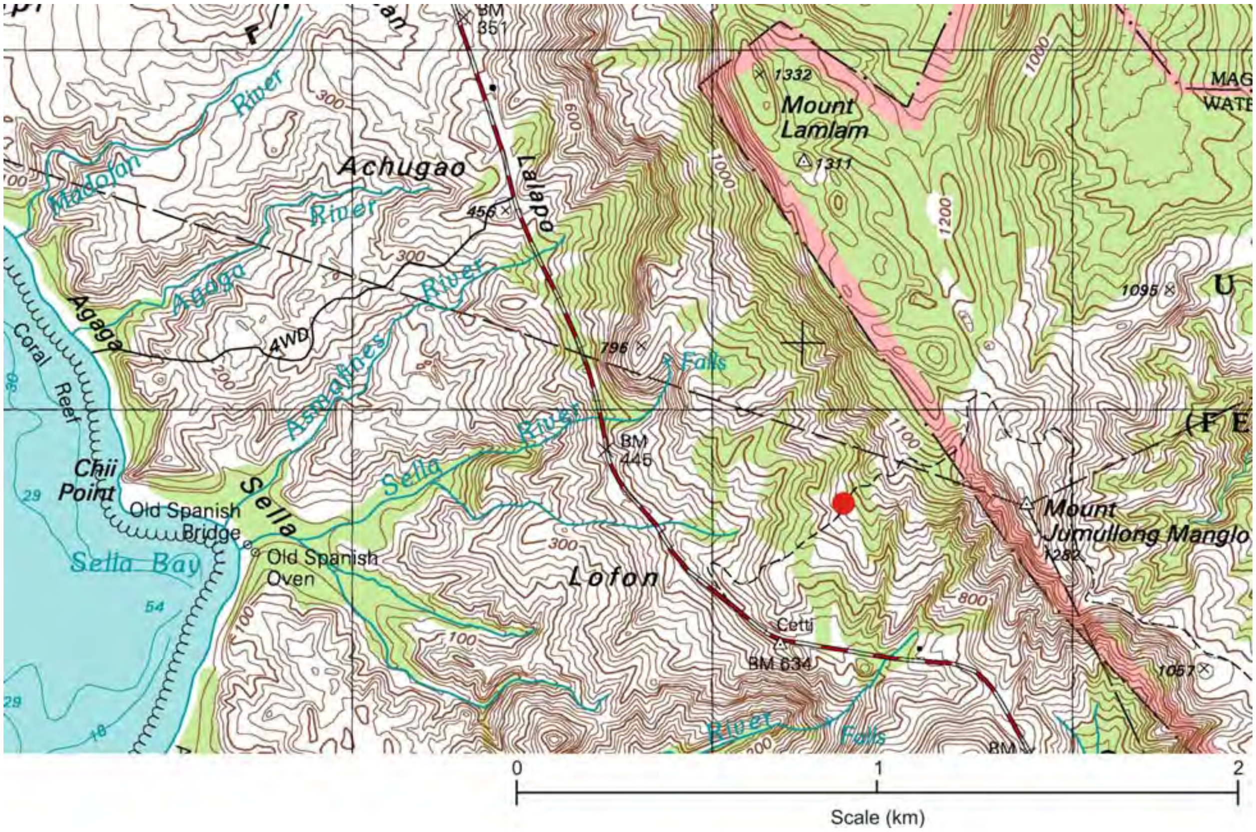
Table A-16. Continued.

Transect Sector	Species Observed	Number of Specimens	Habitat
1100–1110	None		Savanna land
1110–1120	None		Savanna land
1120–1130	None		Savanna land

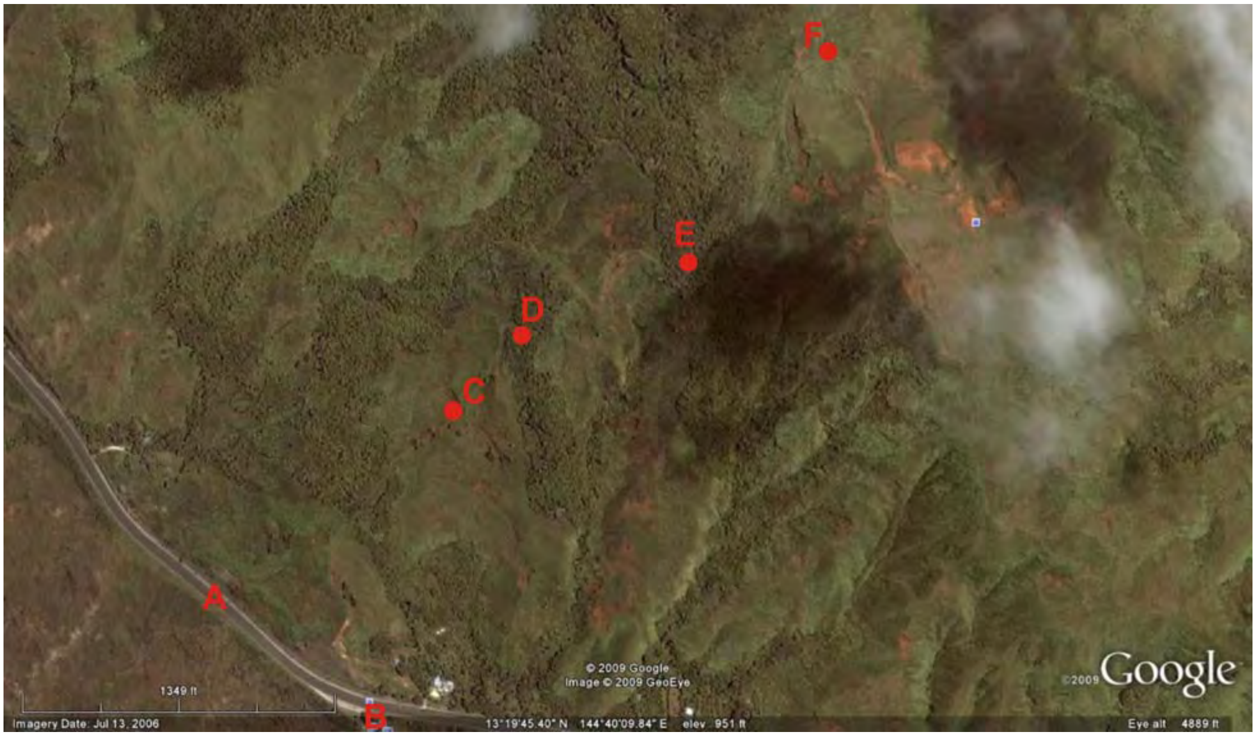
Remarks about the Snail Observations

Because this transect traversed mostly over savanna land that consists of open grassland and scrub vegetation that is lacking host tree species, we were not really surprised that land snails were not present. The two small isolated forested patches located rather high on the mountain slope support a rather dense dissected mountain ravine type forest that was considered as possibly favorable habitat for tree snails, but no living or dead native snails were observed.

MAP FIGURES



Map Figure 1818-1. A section of the Agat USGS Quadrangle Map showing the mid part of the Rt. 4 Option A Transect No. 1 (red dot), and other geographic areas mentioned in the text. For the most part the transect followed along the old roadway bed (dashed line) to the mountain crest.



Map Figure 1818-2. A satellite image showing the location and track of the Rt. 4 Option A, Transect 1 of the 'Volcanic Uplands, Steep Dissected Slopes of the West Cuestal Summit' physiographic unit in southeastern Guam. Vegetation consists of a mosaic pattern of forested areas (dark green), savanna grassland areas (light green), and exposed soil areas (reddish brown). Letter symbols: A = Route 4 Highway, B = Cetti Bay Highway Overlook, C = Transect 1, D = Lower forested limestone outcrop, E = Upper forested limestone outcrop, and F = Ridge Crest.

TEXT FIGURES

Text Figure 1818-1. A view from the mountain crest at the terminal end of Transect 1 looking toward Facpi Point. The typical dissected mountain slopes along the western cuestal slopes of the southern mountain range that are dominated by savanna type vegetation are pictured.

Text Figure 1818-2. A view from the mountain crest at the terminal end of Transect 1, looking toward the central interior lowland basin (right background), the central mountains of the Tenjo structural block (left background), and the summits of Alifan limestone peaks that cap the southern volcanic mountain range north of the transect (upper left). In the foreground is a dense growth of *Miscanthus floridulus* (sword grass).

Text Figure 1818-3. A view from lower edge of a limestone outcrop (not visible) between Transect Stations 550 m and 580 m, showing remnants of limestone base course (at lower left) on the old roadway along which the transect follows. Also in view is the coastal embayment of Cetti Bay, a river embayment drowned during the Holocene transgression 5,000 years ago.

Text Figure 1818-4. A fresh rotational slump in deeply weathered volcanic deposits along the lower one-third of the transect. The slip face of freshly exposed saprolite is about 25 m across and 10 m high. Commonly, the unstable slip face sets the stage for another rotational slump that results in the slump slip face zone migrating up-slope.

Text Figure 1818-5. A limestone scarp located between Transect Stations 790 m and 890 m. Limestone Specimens No. 1818-1 (a thru d, 4 pieces) were collected from along this scarp face. See Text Figure 1818-6 for a detail of the brown-stained scarp wall area to the right of Barry Smith, and Text Figure 1818-7 for a detail of the yellow algae on the scarp wall farther to the right of Barry Smith. For scale are Lauren Gutierrez (botanist), left, and Barry Smith (co-author of report), right.

Text Figure 1818-6. A detailed view of detail of the brown-stained scarp wall area shown in Text Figure 1818-5, which appears to be a living turf of a bryophyte moss that has been mineral-stained from evaporation of water seeping from the scarp wall.

Text Figure 1818-7. A detailed view of the yellow filamentous algae growing on the scarp wall shown in Text Figure 1818-5.

Text Figure 1818-8. A fruiting branch of a *Merrilliodendron megacarpum* tree located at the upper forested limestone outcrop between Transect Stations 790 m and 900 m.

Text Figure 1818-9. A fruiting *Discocalyx megacarpa* shrub located at the upper forested limestone outcrop between Transect Stations 790 m and 900 m.

Figure 1818-10. A patch of flowering *Heliconia bihai* that has become established near a limestone scarp located between Transect Stations 790 m and 890 m.

Text Figure 1818-11. The only living mollusc observed along the transect was the invasive slug *Veronicella cubensis*, observed at Transect Station 619 m.

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APPENDIX I
Mariana Fruit Bat Surveys

Mariana Fruit Bat Surveys in the Lumuna/Asdonlucas/Pagat Region Adjacent to Route 15 in Support of a Marine Corps Relocation Initiative to Various Locations on Guam SWCA Environmental Consultants, Inc. February, 2010

Mariana Fruit Bat Surveys on Navy Properties, Guam, 2008. NAVFAC Marianas Environmental, Guam

2010

MARIANA FRUIT BAT SURVEYS IN THE LUMUNA/ASDONLUCAS/PAGAT REGION ADJACENT TO ROUTE 15, IN SUPPORT OF A MARINE CORPS RELOCATION INITIATIVE TO VARIOUS LOCATIONS ON GUAM

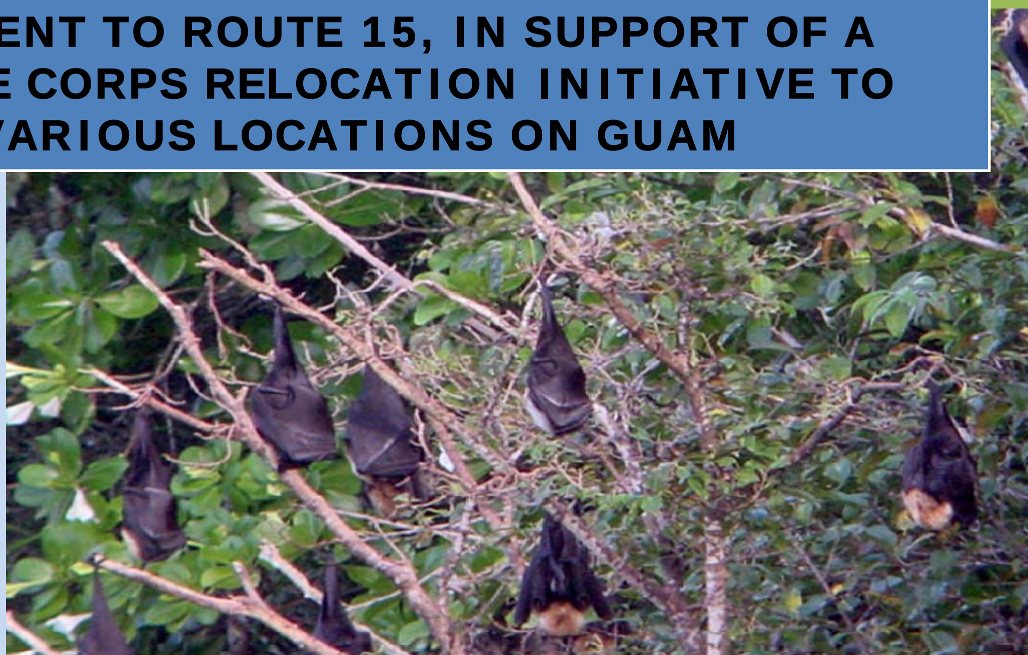

Photo: N. Johnson – SWCA

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17 February 2010

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1.0 INTRODUCTION

Surveys for the Mariana fruit bat, locally known as fanihi, (*Pteropus mariannus mariannus*) were carried out in October 2009 in the Lumuna/Asdonlucas/Pagat region (adjacent to Route 15), Guam. These surveys were part of the biological inventory for the Joint Guam Program Office (JGPO) Guam and Commonwealth of the Northern Mariana Islands (CNMI) Military Relocation Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS).

1.1 Mariana Fruit Bat: Species Description, Distribution, and Status

The Mariana fruit bat is a medium-sized colonial flying fox, averaging 7.7 to 9.8 inches (19.6 - 24.9 cm) in body length and 33.9 to 41.9 inch (86.1 - 106.4 cm) wingspan. Adult body weight varies from 11.6 to 20.4 oz (328.9 - 578.3 g) (USFWS 1990). In 1984, the Mariana fruit bat was listed as federally endangered on Guam by the U.S. Fish and Wildlife Service (USFWS) (USFWS 1984). However, in 2005 the USFWS determined that movement of fruit bats between all islands in the Mariana archipelago occurs, resulting in exchange of genetic material. Consequently, Mariana fruit bats on Guam and throughout the CNMI comprise one subspecies and are now listed as federally threatened throughout their entire range (USFWS 2005b). The Government of Guam included the fanihi in the Guam Comprehensive Wildlife Conservation Strategy (GCWCS) as a species of greatest conservation need (SOGCN) (GDAWR 2006). In the Mariana Islands, the Mariana fruit bat is known to occur on all islands extending northward from Guam to Maug (Wiles et al. 1989, Johnson 2001).

While solitary roosting Mariana fruit bats are somewhat common, the species is considered colonial and form colonies of a few to as many as 2,000 individuals (Wiles 1987, Wiles et al. 1989, Worthington and Taisacan 1995). Large colonies containing more than 1,000 fruit bats occur infrequently. Islands with low fruit bat numbers usually feature smaller roosts with fewer than 75 individuals (Wiles and Johnson 2004).

The Mariana fruit bat is typically found in association with a number of forest types, including primary and secondary limestone forest, *Cocos nucifera* forest, *Casuarina equisetifolia* groves, and ravine forest (Wiles et al. 1989, Johnson 2001, Worthington et al. 2001, Wiles and Johnson 2004). Tree species known to be used for roosting include *Barringtonia asiatica, C. equisetifolia*, *C. nucifera*, *Cordia subcordata, Elaeocarpus joga, Erythrina variegata, Ficus prolixa, Intsia bijuga, Macaranga thompsonii, Mammea odorata, Neisosperma oppositifolia, Ochrosia mariannensis, Premna obtusifolia, Pisonia grandis,* and *Terminalia catappa* (Johnson 2001, Janeke 2006, SWCA 2008a, b).

Thirty-nine species of plants have been documented as fruit bat food sources in the Mariana Islands; foods consist of fruits (29 species), flowers (15 species), and leaves (two species). Known food plants of the Mariana fruit bat include *Artocarpus altilis*, *A. mariannensis*, *B. asiatica*, *C. nucifera, Cycas micronesica*, *E. joga*, *E. variegata, F. prolixa, F. tinctoria, Freycinetia reineckei, M. odorata, N. oppositifolia, O. mariannensis, Pandanus tectorius,* and *T. catappa* (Wiles and Fujita 1992).

In 1931, W. Coultas (in USFWS 1990) reported that fruit bats on Guam were most abundant in the northern region of the island. However, in 1945, R. Baker (in USFWS 1990) determined that fruit bats were uncommon and primarily restricted to the forested cliff lines in northern Guam, and scarce in southern Guam. In 1958, D. Woodside (in USFWS 1990) estimated Guam's entire Mariana fruit bat population to be less than 3,000 individuals. Throughout the 1960s and 1970s, Guam's fruit bat population decreased considerably, plummeting to less than 50 animals in 1978 (Wiles et al. 1989). However, between 1980 and 1982, the population rapidly increased to approximately 850-1,000 individuals, potentially resulting from immigration of fruit bats due to illegal hunting activities on neighboring Rota (Wiles 1987, Wiles et al. 1989). Following a 1984 Guam fruit bat census, 425-500 individuals were recorded, indicating a population decline since the early 1980s (Wiles 1987).

From 1987 to 1995, Guam's fruit bat population fluctuated between 200 and 750 individuals that were primarily confined to the limestone forest near the cliff lines on Andersen Air Force Base (AFB) (Wiles et al. 1995). Throughout 1981-1994, Mariana fruit bat colonies were documented at 21 sites on Andersen AFB, 11 at Pati Point and 10 between Ritidian Point and the northern region of Tarague basin (Wiles et al. 1995). In 2006, Guam's population had decreased to less than 100 individuals, primarily restricted to a single colony and satellite individuals inhabiting the limestone forest on Andersen AFB (Janeke 2006). Between July 2007 and April 2008, multiple counts of the single remaining colonial roost on Andersen AFB tallied an average of 40 individuals (SWCA 2008a). Further counts of the same colony between July and August 2008 recorded an average of 32 fruit bats (SWCA 2008b). Illegal hunting appears to be the key reason for the fruit bat's dramatic decline on Guam, while habitat destruction and predation by introduced brown treesnakes (*Boiga irregularis*) may also be contributing factors (Wiles et al. 1989, Wiles et al. 1995, Morton and Wiles 2002, Brooke 2008)

2.0 METHODS

2.1 Survey Locations

Mariana fruit bat surveys were conducted from three locations positioned in forest areas containing known Mariana fruit bat roosting and foraging vegetation (Figure 1). The survey locations were situated on the east side of Route 15 in the northeast region of Guam, stretching from the Lumuna region through the Asdonlucas area south to Pagat Point. These locations were not associated with any of the designated transects used for vegetation, bird, tree snail, or herpetological surveys.

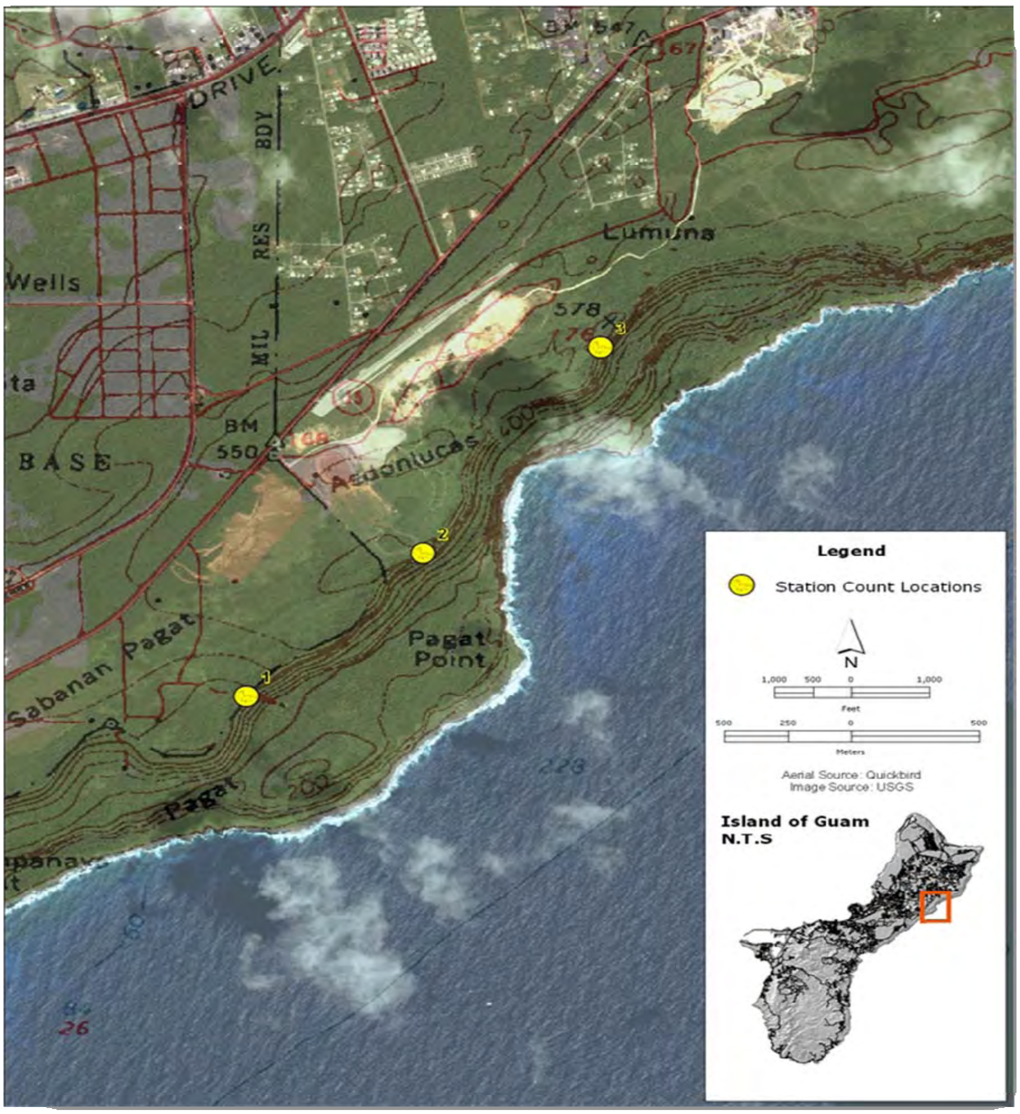

Figure 1.Mariana fruit bat station count locations in the Lumuna/Asdonlucas/Pagat region, Guam. Note the designated count location numbers: Transect 1 is furthest south, transect 3 is furthest north.

Essentially the entire survey area was described as “forest on elevated limestone” by H. I. Manner in 1995 (an update to F.R. Fosberg’s 1954 mapping efforts) (Mueller-Dombois and Fosberg 1998). This habitat community is typically a moist, broad-leaved forest with a variable canopy height that may reach up to 75 ft (23 m), dominated by *Artocarpus* spp. and *Ficus* spp., with some *Pandanus* spp. present (Mueller-Dombois and Fosberg 1998). A forest inventory and analysis of Guam by the U.S. Forest Service in 2002 described four vegetation types in the survey area: “urban cultivated” and “scrub forest” above the cliff line; below the cliff line, “limestone forest” was considered to be the dominant vegetation type, while “plantations” occupied a small portion (USFWS 2005a). General habitat descriptions of each of the survey locations are discussed below.

<u>Location 1 (UTMs = 0270725, 1493041)</u>
This count station was situated along the cliff line overlooking a forested basin below and mixed forest above. Vegetation below and along the cliff line was primarily *Bikkia tetrandra*, *Cocos nucifera*, *Ficus prolixa, Hibiscus tiliaceus, Macaranga thompsonii, Mammea odorata, Neisosperma oppositifolia, Pandanus tectorius,* and *Premna obtusifolia*. Flora above the cliff line included *Citrus* sp., *Eugenia reinwardtiana*, *H. tiliaceus*, *Musa* sp., *P. obtusifolia,* and *Vitex* sp. Other trees of interest recorded from this survey location were *Aglaia mariannensis, Barringtonia asiatica, Cycas micronesica, Cynometra ramiflora, Eugenia palumbis*, *Guamia mariannae, Guettarda speciosa*, *Intsia bijuga*, and *Maytenus thompsonii.*

<u>Location 2 (UTMs = 0271418, 1493715)</u>
Count station 2 was located along the cliff line and provided an unobstructed view of a forested basin below, as well as mixed forest above. Flora below and along the cliff line consisted mostly of *B. tetrandra, F. prolixa, H. tiliaceus, Macaranga thompsonii, M. odorata*, *N. oppositifolia, P. tectorius*, and *P. obtusifolia*. Vegetation above the cliff line was largely composed of *H. tiliaceus*, *Macaranga thompsonii, P. obtusifolia*, *Triphasia trifolia*, and *Vitex* sp. Other trees recorded from this survey location that may be of interest were *Aglaia mariannensis, Artocarpus altilis, B. asiatica, C. micronesica, C. ramiflora, G. mariannae*, and *G. speciosa.*

<u>Location 3 (UTMs = 0272113, 1494684)</u>
Count station 3 was situated along the cliff line and afforded a clear view of a forested basin below, and mixed forest and a cleared region above. Vegetation below and along the cliff line was comprised principally of *B. tetrandra, Casuarina equisetifolia, C. nucifera, F. prolixa, H. tiliaceus, Macaranga thompsonii, M. odorata, N. oppositifolia*, and *P. tectorius.* A large portion of forest above the cliff line had been cleared for unknown operations possibly associated with the racetrack, and the surrounding flora included *Carica papaya, H. tiliaceus, Macaranga thompsonii, P. obtusifolia*, and *Vitex* sp. Other trees recorded from this survey location that may be of interest were *Aglaia mariannensis, A. altilis, B. asiatica, C. micronesica, C. ramiflora, Erythrina variegata, I. bijuga, Ochrosia mariannesis,* and *Pisonia grandis*.

2.2 Mariana Fruit Bat Surveys

Station count surveys (Utzurrum et al. 2003) were conducted to 1) determine the presence of solitary Mariana fruit bats, 2) attempt to locate aggregations or colonies, and 3) assess the location of fruit bat flight paths. These surveys were carried out at the three locations mentioned above (Figure 1) between 0510 h and 0745 h. Each location was surveyed four times, twice each by two trained observers. The survey locations were chosen as vantage points that provided wide and unimpeded views of potential fruit bat habitat and flight paths. Binoculars and a spotting scope were used to detect and count fruit bats at each location.

2.3 Phenological Phases of Plants

While carrying out station count surveys for Mariana fruit bats, the observers collected anecdotal observational data on the phenological phases (flowering and fruiting) of plants, focusing on species that may be used as food sources by Mariana fruit bats.

2.4 Avian Species

During the station count surveys for Mariana fruit bats, observers also searched for federally endangered, and Government of Guam endangered and threatened Mariana swiftlets (*Aerodramus bartschi*). Searches were used to determine whether this species utilized the region for foraging, flights, and roosting or nesting purposes. All avian species heard or observed were recorded during station count surveys.

3.0 RESULTS

3.1 Mariana Fruit Bat Surveys

Between 6 and 22 October 2009, 12 station count surveys were completed at three locations in the Lumuna/Asdonlucas/Pagat region (Figure 1 and Table 1). No Mariana fruit bats were observed during any of the surveys.

Table 1. Mariana fruit bat station count results in the Lumuna/Asdonlucas/Pagat region, Guam.

Survey Date	Survey Location	Start Time	Stop Time	# of Bats Observed
6 October 2009	1	0545 h	0745 h	0
6 October 2009	2	0545 h	0745 h	0
13 October 2009	2	0525 h	0740 h	0
13 October 2009	3	0530 h	0740 h	0
14 October 2009	3	0515 h	0745 h	0
14 October 2009	1	0530 h	0740 h	0
20 October 2009	2	0510 h	0740 h	0
20 October 2009	1	0520 h	0740 h	0
21 October 2009	3	0510 h	0740 h	0
21 October 2009	2	0520 h	0740 h	0
22 October 2009	1	0520 h	0740 h	0
22 October 2009	3	0520 h	0740 h	0

3.2 Phenological Phases of Plants

Table 2 depicts the phenological phases of 18 plant species in the Route 15 survey area during Mariana fruit bat surveys. While not part of the contracted work, we considered this valuable information that may be of future use in terms of understanding movements and behaviors of Mariana fruit bats in relation to known and potential food sources.

Table 2. Phenological phases of plant species in the Lumuna/Asdonlucas/Pagat region, Guam: 6 - 22 October 2009. (F = flowering; S = fruiting).

Plant Species	Phenological Phase
Aglaia mariannensis[1]	S
Barringtonia asiatica[1]	F, S
Bikkia tetrandra	F
Carica papaya[1]	F, S
Citrus sp.	S
Cocos nucifera[1]	F, S
Eugenia palumbis	F
Ficus prolixa[1]	S
Guettarda speciosa[1]	F, S
Hibiscus tiliaceus	F
Intsia bijuga	F
Maytenus thompsonii	F
Musa sp.[1]	S
Neisosperma oppositifolia[1]	F, S
Ochrosia mariannensis[1]	S
Pandanus tectorius[1]	S
Premna obtusifolia[1]	F, S
Triphasia trifolia	F

[1] Known food plant of Mariana fruit bats (Wiles and Fujita 1992)

3.3 Avian Species

During the station count surveys, no endangered Mariana swiftlets were recorded. However, avian species that were identified in flight or vocalizing within habitat associated with the station count locations are shown in Table 3.

Table 3. Avian species detected during Mariana fruit bat station count surveys in the Lumuna/Asdonlucas/Pagat region, Guam: 6 - 22 October 2009. Status and nomenclature follow (Wiles 2005).

Avian Species	Status on Guam
Black francolin (*Francolinus francolinus*)	Introduced resident, breeding
Yellow bittern (*Ixobrychus sinensis*)	Native resident, breeding
Pacific reef heron (*Egretta sacra*)	Native resident, breeding
Pacific golden-plover (*Pluvialis fulva*)	Migratory or wintering species, non-breeding
White tern (*Gygis alba*)	Native resident, breeding
Island collared-dove (*Streptopelia bitorquata*)	Introduced resident, breeding

4.0 DISCUSSION

The survey method utilized during this project relies on observing fruit bats in low light and daytime conditions. Any fruit bats that were using the area prior to or after the survey period would not have been detected. No fruit bats were observed during the 12 station count surveys. However, the survey area is suitable for Mariana fruit bat to roost and forage because is situated away from dense human habitation and includes several known Mariana fruit bat roosting and food tree species. The survey area is also close (about 7.5 mile [12.1 km]) to the last remaining colonial roost location of fruit bats known on Guam. Therefore it would be prudent not to dismiss the possibility that fruit bats use the area for roosting and/or foraging as well as flight paths. When potential development projects arise in this area, consideration should be given to the suitability of the existing native and secondary forest habitat not only for Mariana fruit bats, but Mariana swiftlets, Micronesian starlings, yellow bitterns, white terns, and tree snails.

Noise associated with construction and rock-blasting activities on the property adjacent to survey location 3 was loud. The associated noise and possibility of hunting may prevent Mariana fruit bats from establishing permanent roosts in the area.

It is worth recognizing that three native, breeding resident and one migratory avian species were detected flying above habitat associated with the survey area.

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Mariana Fruit Bat Surveys on Navy Properties, Guam, 2008

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Introduction

Surveys of Mariana fruit bat or fanihi (*Pteropus mariannus mariannus*) were conducted on Navy properties on Guam in 2008 as part of the biological inventory for the Joint Guam Program Office (JGPO) Guam and Commonwealth of the Northern Marina Islands (CNMI) Military Relocation Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS) that is currently in preparation.

Once common throughout the Mariana archipelago, Mariana fruit bats have declined from overhunting, forest loss and predation by brown tree snakes (BTS) (reviewed in U.S. Fish and Wildlife Service [USFWS] 2005; Wiles and Brooke in press). Mariana fruit bats may be found during the day in large colonies, in small groups or solitarily (Wheeler and Augon 1978; Wiles et al 1989; Morton and Wiles 2002; Janeke 2006). Hunting pressure has pushed bats to roost in areas that are not frequented by people. This survey was designed to search for colonial roost sites and survey solitary bats on the Naval Munitions Site (NMS) (previously known as the Ordnance Annex), Waterfront Annex (or Navy Main Base), Naval Computer and Telecommunications Station Finegayan (NCTS), and Navy Barrigada.

At the time of this survey, less than 100 bats are believed to remain on Guam primarily in the northern forests of Andersen Air Force Base (AFB), the Guam National Wildlife Refuge, NCTS, and adjacent private lands (Janeke 2006). Surveys of the single remaining colonial roost at Pati Point have counted 19-40 bats since 2004 (N. Johnson, pers. com.). Small groups and solitary bats are known to be widely dispersed throughout Guam but are no longer commonly reported (Wheeler 1979; Wiles et al 1989; Johnson 2001; Morton and Wiles 2002; Janeke 2006).

Methods

Station count surveys were conducted at dawn as bats return to preferred roosting sites and at dusk as they disperse to forage (Utzurrum et al. 2003). Locations for station counts were selected for wide and unimpeded forest views. During each survey, a single observer actively scanned the area for bats in flight or roosting with Swarovski 10 x 40 binoculars. Surveys were conducted at dawn from ca. 0515 to 0630 and dusk from ca. 1730 to 1900. Between February and July 2008, 41 station counts were conducted at 15 locations on the NMS, 1 on the Waterfront Annex, 3 at NCTS, and 2 at Barrigada (Fig. 1). Replicate counts were done at most locations although three sites were surveyed only once. Seven of the sites on the NMS had been previously surveyed by Morton and Wiles (1996).

Results

Three solitary bats were sighted on Navy lands during 90 hours of observations at 14 different survey locations (Table 1). Two sightings were on NCTS, one below the cliff line in the northern section of the Haputo Ecological Reserve near Falcona, and the other was seen flying westward across Route 3A from Andersen AFB onto NCTS (Fig. 1). A single bat sighted on the NMS three times in the same location at ca 0540 each day is likely the same individual and not treated as separate sightings (Table 1).

Discussion

The survey method used in this study relies on seeing bats flying during daytime or in low light. Any bats that were present but not flying during the counts would not have been observed. A radio tracking study of bats on Andersen AFB found bats dispersed after nightfall and returned to the roost sites before dawn

(Janeke 2006). Consequently, the lack of bat sightings on Navy lands suggests few bats are present but is not an accurate indicator of the number.

The number of fruit bats on Guam has declined since the 1950s when potentially 3,000 bats were thought to be present (Woodside 1958). This time frame corresponds with post-World War II island development and spread of BTS. By 1972 the number of bats was estimated at less than 1,000 (Wiles 1987b) and by the late 1970s the estimated number had declined to less than 50 with no known colonies (Wheeler and Aguon 1978). In 1980, several hundred bats appeared at a Pati Point roost site and during the 1980s several colonies were present along the northern coast but after 1994, only the Pati Point site was used (Wiles 1987a; Janeke 2006).

The number of bats at the Pati Point colony has declined since the mid-1990s although there have been occasional increases thought to be bats coming from Rota (Wiles 1987b; Wiles and Glass 1990; Janeke 2006). In addition to colonies of roosting bats, small groups and solitary bats are known to be occur throughout Guam, however they are difficult to locate and monitor (Wheeler 1979; Wiles et al 1989; Johnson 2001; Morton and Wiles 2002; Janeke 2006). Because of the difficulty in monitoring solitary bats, the Pati Point colony is used as the indicator of the island-wide population.

The NMS and the Haputo Ecological Reserve at NCTS encompass some of the best remaining native forest on Guam and could support a large number of fruit bats. That only three bats were observed after extensive surveys is consistent with the steady decline in number of bats at the Pati Point colony and potentially indicates a very low number of bats remaining on Guam. Illegal hunting and predation from BTS are widely accepted as reasons for lack of fruit bat recovery on Guam (USFWS 2005; Wiles and Brooke in press).

Fruit bats continue to be a highly prized Chamorro delicacy and hunting is credited for the decline of bats in the southern Mariana Islands as well as on Guam (Wiles and Brooke in press). Between 1975 and 1989, over 200,000 fruit bats were sold in markets on Guam that had been hunted throughout the Pacific region (Wiles 1992). This international trade was stopped in 1999 with the local enforcement of Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). In 1984, fruit bats on Guam were listed as federally endangered but were downlisted to threatened in 2005 as fruit bats in the CNMI and Guam are considered a single population (USFWS 2005).

Consumer demand remains the driving force for illegal hunting and has prevented the recovery of fruit bats in the southern CNMI. Fruit bats are reported to sell for $50 on Tinian in 2008 and $140 on Saipan in 2006; the value of bats on Guam is beyond a monetary value with payment made by in-kind favors. The high value of bats to the Chamorro people makes recovery unlikely. Without support from leading government officials and law enforcement in the immediate future, the small number of remaining fruit bats will be gone.

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Table 1. Marina Fruit Bat Survey Results, Navy Properties, Guam (2008)

Date	*Map Number*	*Location*	*Latitude*	*Longitude*	*Start time*	*End time*	*Bats observed*
6/7	1	Almagosa Springs	13°20'45.42"N	144°40'39.07"E	0520	0630	
4/10	2	Almagosa Road	13°21'25.74" N	144°40'54.06"E	0550	0630	1 at 0553
4/29	2	Almagosa Road			0530	0630	1 at 0540
4/30	2	Almagosa Road			0515	0630	
5/5	2	Almagosa Road			0515	0630	1 at 0540
3/10	3	Breacher House	13°21'26.49"N	144°40'22.97"E	0600	0730	
3/12	3	Breacher House			0600	0730	
3/13	3	Breacher House			0600	0730	
5/6	3	Breacher House			0515	0630	
3/18	4	Bunker 21 @ 19	13°21'31.30"N	144°41'2.47"E	0600	0730	
5/1	5	EOD Road	13°20'44.98"N	144°41'26.50"E	0515	0630	
5/3	5	EOD Road			0515	0630	
5/9	5	EOD Road			0515	0630	
5/31	5	EOD Road			0500	0630	
7/14	6	Fena Dam	13°21'32.45"N	144°42'21.09"E	0510	0630	
2/19	7	High Rd forest	13°21'52.10"N	144°40'25.36"E	0545	0730	
2/20	7	High Rd forest			0545	0730	
2/22	7	High Rd forest			0545	0730	
5/7	7	High Rd forest			0515	0630	
7/6	7	High Rd forest			0550	0715	
3/6	8	Japanese overlook	13°22'37.81"N	144°40'14.41"E	0600	0730	
5/13	9	Maemong overlook	13°22'35.53"N	144°42'56.42"E	0500	0630	
5/14	9	Maemong overlook			0500	0630	
3/20	10	Haputo Bay	13°34'45.21"N	144°49'51.61"E	0600	0730	
3/29	10	Haputo Bay			0600	0730	
2/23	11	Double Reef overlook	13°35'4.03"N	144°50'3.25"E	0600	0745	
3/1	11	Double Reef overlook			0600	0800	1 at 0708
6/15	11	Double Reef overlook			1800	1910	
5/11	11	Double Reef overlook			0515	0630	
6/8	11	Double Reef overlook			0520	0630	
5/17	12	NCTS Rt 3A	13°35'33.66"N	144°51'47.21"E	0515	0630	1 at 0552
5/18	12	NCTS Rt 3A			0520	0630	
5/25	12	NCTS Rt 3A			0520	0630	
4/2	13	Orote Point	13°26'42.90"N	144°37'10.55"E	0550	0715	
4/3	13	Orote Point			0550	0715	
4/4	13	Orote Point			0550	0715	
4/7	13	Orote Point			1730	1900	
4/9	13	Orote Point			1730	1900	
5/19	14	Navy Barrigada	13°28'37.70"N	144°49'54.94"E	0515	0630	
5/23	14	Navy Barrigada			0515	0630	
6/11	15	Rt 15	13°26'56.57"N	144°49'8.66"E	0520	0630	

Figure 1. 2008 Mariana Fruit Bat Station Count Locations on Navy Properties, Guam: Waterfront Annex, NMS, Navy Barrigada, and NCTS Finegayan.