3.0 AFFECTED ENVIRONMENT

Guam is the largest and southernmost island in the Marianas Archipelago, a chain of volcanic islands in Micronesia (GDAWR 2006). It is situated in the western Pacific Ocean, approximately 5,950 km (3,700 miles) west of Honolulu and 2,415 km (1,500 miles) south of Tokyo. The unincorporated U.S. Territory of Guam has a total landmass of approximately 209 mi^2 (540 km^2).

3.1 Physical Environment

3.1.1 Climate

The climate of Guam is characterized by year-long warm temperatures with high relative humidity, much like other tropical islands in the Western Pacific that fall within the tropical and torrid zones. Yearly variations in climate are generally modest and are explained by differences between Guam's wet season and dry season as well as El Niño/Southern Oscillation (ENSO) and storm activity. The wet season occurs between July and November. Guam has an average annual temperature of 81°F (27°C) at sea level, with lowest temperatures in January, and the highest between June and November (Figure 3; http://ns.gov.gu/climate.html). Average humidity ranges between 65 to 80 percent during the day and 85 to 100 percent at night (Khosrowpanah and Jocson 2005) and is highest from July to December.

Annual rainfall across the island ranges between 80 and 110 in (2-2.8 m), and varies depending on the season (Figure 3). During the dry season, rainfall averages 4.6 in (12 cm) per month, and 11.8 in (30 cm) during the wet season (Lander and Guard 2003). Elevation and site location effect rainfall patterns which generally follow the northeast-southwest orientation of the island. Rainfall is highest in central-northern Guam and along the western and southern mountains due to the rain shadow effect from the prevailing north-east trade winds. The coastal lowlands typically receive less rainfall (Lander and Guard 2003). The least amount of rain falls on the areas southwest of Mount Santa Rosa, south of Ritidian Point, and along the southern coast. At Andersen Air Force Base (AAFB) close to HERA, mean monthly rainfall from 1950 to 2000 ranged between 4.1 and 13.4 in (10-34 cm) (Lander and Guard 2003). Strong rainfall gradients are produced along the major mountain ranges and by the rain shadows of Mount Santa Rosa and Mount Barrigada (Lander and Guard 2003). As a result, the HERA received slightly higher rainfall than the island average. Prolonged drought periods occur almost every four years during El Niño/Southern Oscillation (ENSO) events (Gingerich 2003).

Tropical storms, typhoons, and squalls are common weather phenomena on Guam. The Mariana Islands lie in the western Pacific monsoon circulation path; thus, Guam experiences typhoons, with winds between 75 and 150 mph (120-241 km/hour) and supertyphoons, with winds in excess of 150 mph (USFWS and USAF 2003). Typhoons bring destructive winds, generally heavy rain causing inundation of low-lying coastal areas and typically occur on average once or twice a year (USFWS 1992). These storms can precipitate almost 20 in (50 cm) of rain in a single event (Mylroie et al. 1999). In 1976, supertyphoon Pamela brought winds of 160 mph (260 km/hour) (USFWS 1992). Over the past ten years, four severe typhoons have hit Guam, bringing winds greater than 150 mph (Guard et al. 2003). During 2002, Guam experienced the eye passage of two typhoons that produced high short-term rainfall and stream flows (Lander and Guard 2003). Although tropical depressions may form throughout the year, the probability increases from July through September (Prasad and Manner 1994).

Prevailing ocean currents surrounding the island can further influence weather patterns by moderating the surrounding surface air temperature. Guam is situated in the north-westward-flowing North Equatorial Current. This current, most prevalent from June to December generates eddies in the leeward (western side) of the island. The speed of this current is rapid, varying from 4 to 8 in per second (10 - 20 cm/s) (Wolanski et al. 2003). Sea surface temperatures surrounding Guam range from 81 to 86°F (27 - 30°C); however, water temperatures can be roughly 2ºF (1°C) higher close to shore, in lagoons, and over reef flats during daylight hours as thermal heat absorption and transition take place over the reef flat (Jones et al. 1976, Paulay 2003). On the reef flat and fore reef off Ritidian Point (northern tip of Guam; Figure 1), mean water temperature was 82.9ºF (28.3°C), with higher records during summer months and low tides (Donaldson and Rongo 2006). The mean seawater density around Guam is approximately 25.7‰ (Eldredge 1983), a little less than the overall ocean average (34‰).

There are both annual and cyclical variations in the oceanographic climate of the waters surrounding the Marianas Islands due to the influence of El Niño Southern Oscillation events where the Western Pacific Warm Pool (WPWP) migrates in response to large scale climatic factors. During ENSO warm phase events, the easterly winds diminish and the WPWP moves eastward. In ENSO cool phases, the trades keep the warm water in a more westerly location (Asami et al. 2004).

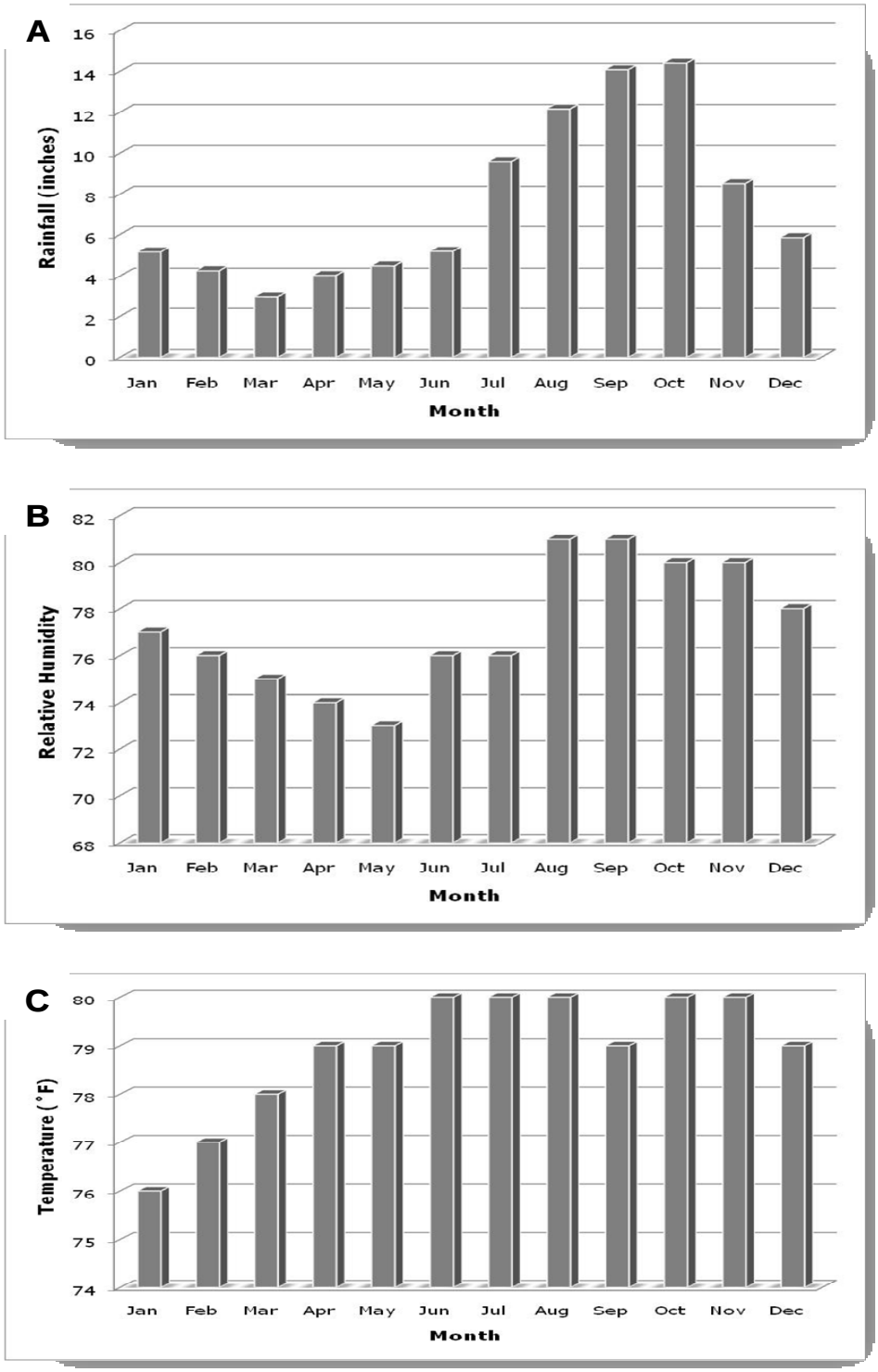

Figure 3. Graphs showing (A) average temperature (°F); (B) average monthly rainfall; and C) average monthly relative humidity (%). Figures adapted from http://www.climatetemp.info/mariana-islands/.

3.1.2 Geology and Soils

Guam is situated on the Mariana Ridge at the boundary of the Philippine and Pacific Plates, a tectonically active region. Interactions between these plates created the deep Mariana Trench that lies 97 to 160 km (60 to 100 mi) east of Guam (Khosrowpanah and Jocson 2005) and an archipelago island arc system. Because Guam is surrounded by tropical seas, coral reef formation is an important factor in the development and structure of the island. Thus, Guam's geology is a complex result of the tectonic movements of the plates causing frequent and sometimes substantial earthquakes, volcanic activity typical of island arc systems, and the production of limestone by reef growth. Limestone is uplifted in subduction zones, with volcanic activity protruding through.

The volcanics that formed the basement rocks of Guam probably emerged in the early Cenozoic, which began 65 million years ago (Prasad and Manner 1994). The geological surface features have been classified into three major regions: the northern limestone plateau, the central volcanics, and the southern volcanics.

The Alutom formation, which forms the central part of the island, contains the oldest exposed rocks. These volcanics are of Eocene (54.8 to 33.7 million years ago) to Oligocene (33.7 to 23.8 million years ago) age and were laid down by a volcano which was located to the west of the modern island (Tracey et al. 1964, Gingerich 2003). The southern half of Guam is mostly composed of the Umatac formation. These volcanics were derived from a younger, Miocene age (23.8 to 5.3 million years ago) volcano that was situated to the southwest of Guam. Neither of the volcanoes that formed these regions is above sea level today. The older volcanics contain limestone fragments and are capped by younger limestone in some locations (Mylroie et al. 2001). The northern limestone plateau was probably formed by a barrier reef lagoonal complex. The plateau is separated from the primarily volcanic terrain in the south by the northwest-southeast trending Pago-Adelup Fault (Mylroie et al. 2001). Subsequent tectonic activity has caused uplift and emergence of the barrier reef and associated lagoon limestone deposits (Randall 1979). HERA is primarily comprised of Mariana limestone detrital facies and Marian limestone reef facies with recent sandy beach deposits (Figure 4 and 5).

Similar to the geology of the island, the soils of Guam are diverse. There are five types of soils on the island: laterite, or volcanic; riverine mud; coral rock; coral sand; and argillaceous soils, or mixtures of coral and laterite (JGPO 2009). The northern coastal soils of Guam have been classified as "Ritidian-Rock outcrop" (Young 1988).

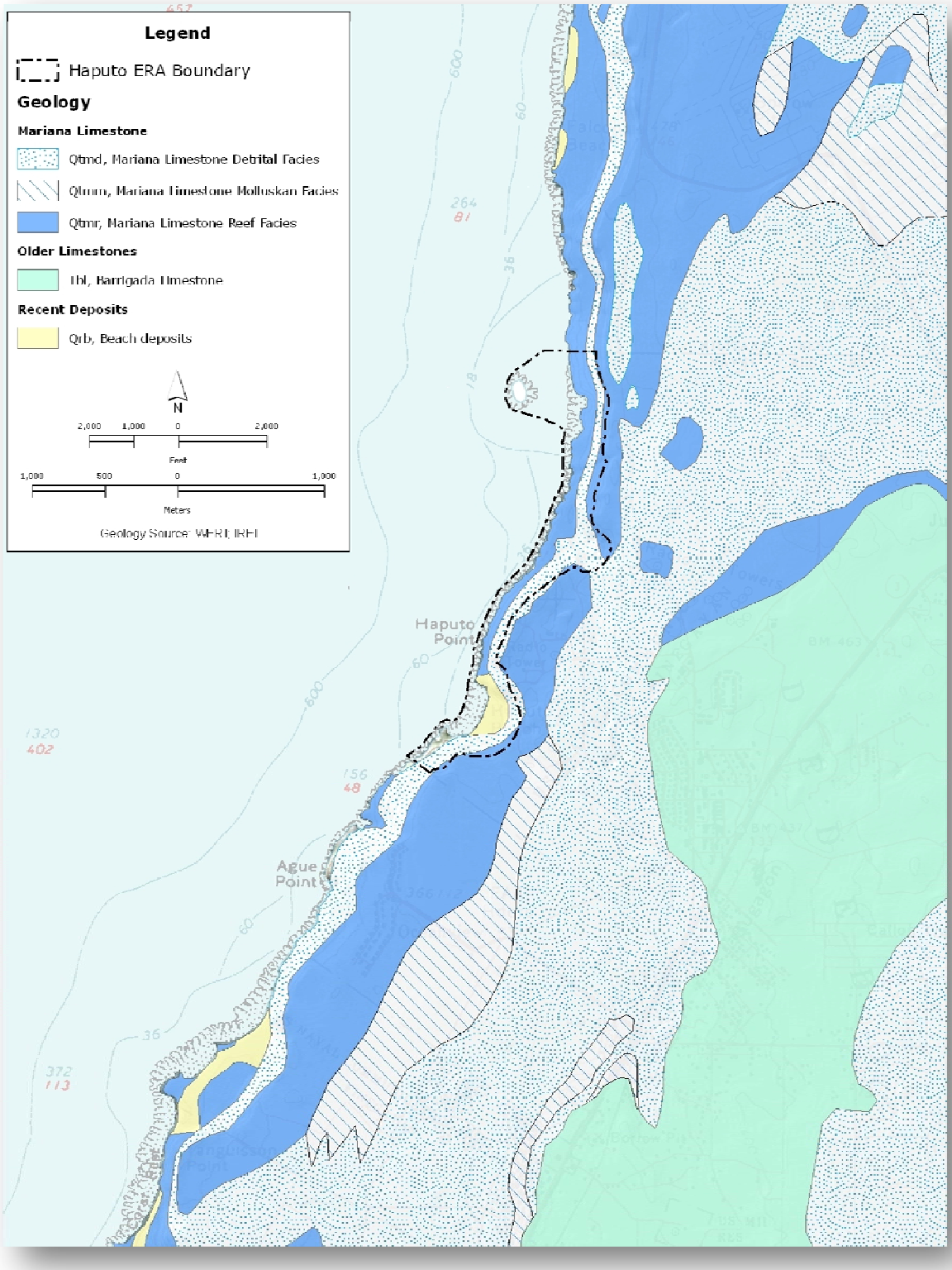

Figure 4. Geology of the Haputo Ecological Reserve Area.

Figure 5. The Haputo Ecological Reserve Area has many areas of limestone karst outcrops. Photo: SWCA.

3.1.3 Hydrology and Water Features

Guam is divided into two hydrogeological areas: the northern limestone province and the southern volcanic highlands. Northern Guam consists of six watershed sub-basins. The main source of fresh water in the south is from surface water, with reservoirs providing an average of 9.9 million gallons per day (MGD) (37 million liters per day (MLD) (Gingerich 2003). The primary source of domestic drinking water in the south is from Fena reservoir, supplying both U.S. Navy and local residential water. Fena reservoir was built after World War II and drains a 5.9 mi^2 area in southern Guam (Gingerich 2003, Neill and Rea 2004, GDAWR 2006). The Fena reservoir provides between 10 and 12 MGD (37 - 45 MLD) during the wet season and only 6 to 8 MGD (23 - 30 MLD) in the dry season (SWCA and TNWRE 2007).

There are no permanent streams or lakes in the northern portion of the island due to the porous limestone substrate that allows rainwater infiltration (USFWS 1992, Gingerich 2003); however, there is a considerable amount of groundwater in this region. The Northern Guam Lens Aquifer (NGLA), the principle groundwater source for the island, is a karst aquifer

comprised of uplifted limestone units (GEPA 1998, Jocson et al. 2002). The aquifer is a freshwater lens that floats on denser seawater. A transitional or brackish zone exists between these layers due to mixing during tidal and pumping fluctuations. The fresh and brackish water tends to move seaward from the aquifer (Mylroie et al. 2001, Jocson et al. 2002, Gingerich 2003).

3.1.4 Air Quality

Air pollution is derived from a variety of sources and has many harmful effects on the health and welfare of humans, plants, animals, and other living organisms. The Guam EPA is responsible for implementation and enforcement of the Air Pollution Control Program, which regulates air pollution and control standards and regulations on island (GDAWR 2006).

Ambient air quality data has not collected on Guam since 1991, therefore no recent data is available. However, the air quality on Guam is typically very good, but can vary depending on wind and weather conditions (GEPA 2007). On Guam, north-east trade winds are prevalent throughout the year, with an average annual wind speed between 4 to 12 mph (2.5 - 7.5 kph) (Lander and Guard 2003). This helps to keep the air from becoming stagnant on the island. Sulfurous gases can affect Guam's air (GEPA 2007). Sulfurous gases are caused by sulfur dioxide mixing with sunlight and other compounds to create hydrogen sulfide, sulfuric acid, and particulates, and can smell like rotten eggs, or have a pungent, acidic odor (GEPA 2007). These gases can be released by the power plants if offshore winds carry the emissions over Guam (GEPA 2007). Another source of these gases is likely an active volcano on Anatahan, 200 mi (320 km) north of Guam. The most recent eruptions commenced in May 2003 with emissions of volcanic ash, gas, and steam continuing. These emissions periodically affect Guam when low level winds blow from the north-northeast. Air pollution can also be caused by grass fires, cars or dust storms (GEPA 2007). Occasionally emissions such as carbon monoxide (CO) affect Guam, generally during late summer and fall, from either East Asia or Southeast Asia (Jaffe et al. 1997). This does not rule out pollution during winter months, as enhanced CO levels were found from Hawaii to Guam originating from an Asian outflow plume in February, 2001 (Heald et al. 2003)

The air quality of the HERA is also influenced by emissions in the nearby Finegayan area and more distant Andersen AFB which originate from gasoline and diesel powered engines, jet engines, generators, incinerators, fires, and related sources. Potential air quality effects on Guam would occur from both construction and operational activities associated with the impending military build-up (JGPO 2009).

3.1.5 Aesthetic and Visual Resources

Guam is an island that offers a diversity of naturally beauty. The coral reefs at the HERA, with over a hundred species of coral (Porter et al. 2005), are important visual features that are important to both visitors and residents alike. The undisturbed limestone forest, clean white beach, nearly pristine water quality and clarity, and abundance of conspicuous corals, macroinvertebrates, and fishes all contribute to the aesthetic quality of the area. The scenic coastal and shoreline resources at the HERA make the area a valuable nature sightseeing spot for locals and visitors to the island. The terrestrial areas also maintain habitats for different flora and fauna that may not be seen in other parts of the island, further influencing the visual quality and uniqueness of the HERA. Therefore, it is important that the HERA is properly maintained to ensure that the aesthetic and scenic qualities of are not degraded. This would include monitoring diving to protect the coral reef, and patrolling the beaches to keep the environment free of unwanted debris and ensure minimum disturbance.

3.1.6 Land Use

3.1.6.1 Pre-Historic and Historic Uses and Features

Archaeological investigations in the HERA have identified large prehistoric coastal habitation settlements, as well as, less intensively occupied sites on the adjoining plateau (Thompson 1932, Osborne 1947, Reinman 1977, Aguon 1985, Craib and Yoklavich 1996, Olmo et al. 2000). The archaeological sites situated along the coastline have not been significantly disturbed by modern activities; whereas, sites located on the interior plateau have received significant impacts due to 20th Century development of this area.

Notable archaeological sites located within the HERA include the Haputo site (66-08-0007), the Pugua Point Site (66-08-0008), the Hila'an Complex (66-08-0005), the Hila'an Cave/Rockshelter (66-08,0168); and Tweed's Cave (66-08-1051). The Haputo and Latte Stone Park sites are listed on the U.S. Register of Historic Places, Haputo since November 1974 (National Park Service 2008). Archaeological investigations conducted to-date has associated prehistoric occupation of the HERA with the Latte Period (AD 1000 to AD 1521) of Marianas Prehistory. Several sites located in both the coastal and interior plateau portions of the HERA exhibit intact Latte stone structures.

The Haputo site is of particular value as it is arguably the best preserved prehistoric coastal village on Guam. The site contains the remains of at least 20 Latte structures with almost complete spatial integrity (Osborne 1947). The soil is rich with lusongs, pottery, artifacts, and food remains. Until 2009, the site was most recently surveyed in 1998 (Olmo et al. 2000). Preliminary mapping indicated that most cultural features were undisturbed. In 2009, the Haputo Village Project was initiated by UOG (Olmo and Kataoka 2009). The project is designed

to develop accurate and detailed maps showing the surface distribution of the Latte Period features and artifacts associated with the site.

The HERA contains at least four well-known caves: Haputo Cave, Tweed's Cave, Coconut Crab Cave, and Frankie's Cave (Taborosi 2004), in which significant historical resources are present. Tweed's Cave is historical in that it served as a WWII hideout for U.S. Navy radioman, George Tweed, from October 1942 until July 1944 (Taborosi 2004).

3.1.6.2 Recent Land Uses

The HERA was initially established in 1984 as mitigation and compensation for the 1989 construction of the Kilo ammunition wharf at Adotgan Point in the Outer Apra Harbor, Guam. Since its establishment, the ERA has remained essentially unmodified. However, in the late 1980's, USFWS biologists observed evidence that some construction debris may have been bulldozed over the cliff just north of Haputo Beach (J. Ford, SWCA, personal observation).

The HERA abuts the active Finegayan NCTS facility where continuous global communications to fleet services, shore activities and joint forces operations take place. Authorized military training activities periodically utilize the HERA and surrounding areas. Since 2008, the only Area Training activity in the HERA authorized and scheduled is small craft landing over reef beach insertions. When possible, training activities are scheduled in other areas to avoid possible impact to the HERA (L. Johnson, NBG Area Training, personal communication).

In addition the Haputo small arms range, situated east of the HERA on the plateau above the cliffs, is periodically used for security drills and weapons re-qualification activities. The two dimensional surface danger zone (SDZ) is oriented north-west over the water between Haputo and Pugua Patch Reef beaches (Figure 6); however, extensive dirt berms on both sides and behind the targets significantly decrease the risk of stray bullets overshooting the range. As part of the relocation of the Marine Corps from Okinawa to Guam, the Marines are proposing NCTS Finegayan as a location for their infrastructural requirements, including buildings, housing, and training facilities. At this stage, the impacts of such a buildup on the HERA are unknown; however, however, visitor use will likely increase as a result of the expected influx of military personnel, their dependants, contractors, and visitors to Guam.

HERA is used for recreational activities, such as hiking, swimming, snorkeling, sunbathing, and cave exploration. Recreational activities must be compatible with the primary purpose of the ERAs defined in U.S. Navy's (1986) Management Plan. Access to Haputo Beach requires hiking down 212 narrow steps which descend through the limestone forest to the beach from a small (up to five vehicles) parking area at the top. Currently, the area is not open to the general public and is accessible by land only to those with access to NCTS Finegayan. However access

to special groups (e.g., Guam Boonie Stompers) is allowed by request to the NBG Commander via the Public Affairs Officer. Dive sites are generally accessible to civilian and military by boat. Popular dive sites and beaches include in the HERA are Haputo Beach (Figure 7), the Pinnacle (Figure 8), and Pugua Patch Reef (Figure 9). There is currently no data on frequency of TU or MU visitation at HERA.

There are no improvements or other conveniences located at the beach.

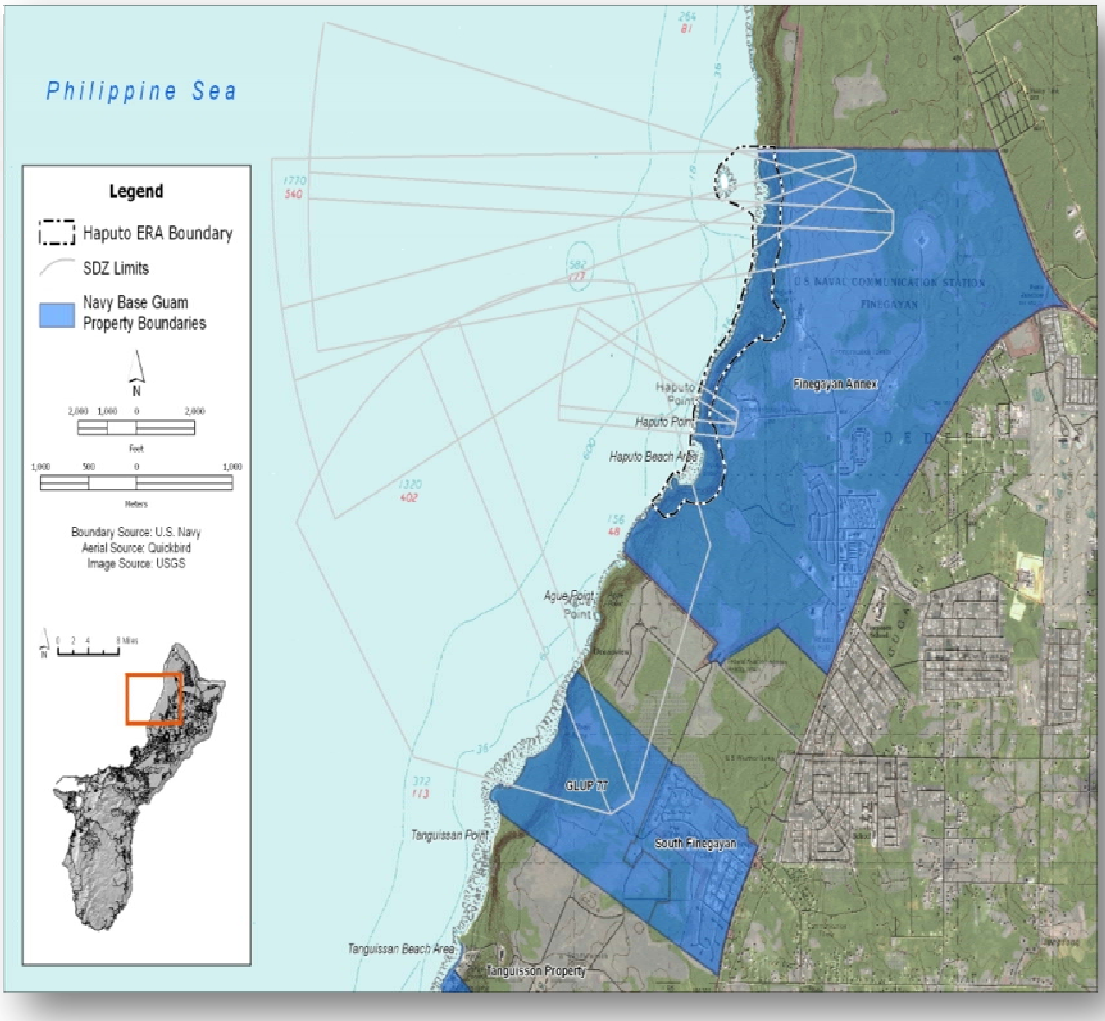

Figure 6. The Haputo Ecological Reserve Area and vicinity showing the reserve boundaries, Navy installation boundary, Navy submerged lands, safety danger zone (SDZ).

Figure 7. A shallow reef flat fronts Haputo Beach. The coconut forest and strand community give the lush, secluded tropical feel popular among visitors. Photo: SWCA.

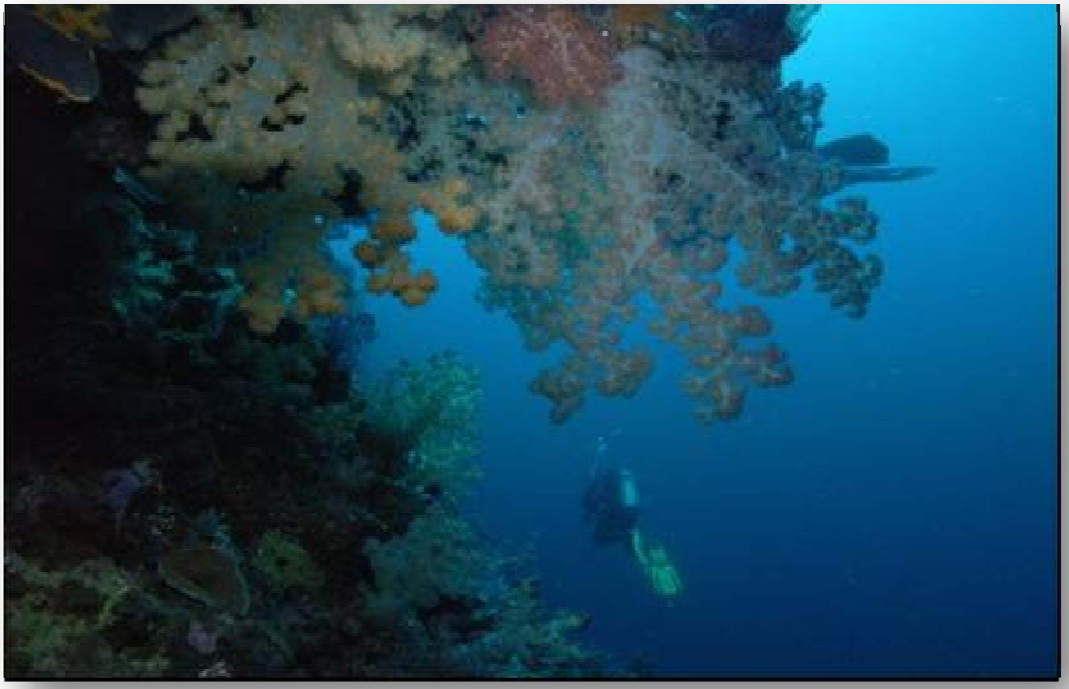

Figure 8. The Pinnacle is a popular dive spot in the Haputo Ecological Reserve Area. Photo: Myron Haynes.

The terrestrial and marine habitats at the HERA support a variety of species and ecosystem functions. The HERA is intended to protect ecosystems, but can be used for research, education, and limited recreational purposes. Following its establishment and in accordance with Section II.A.3.a of the Management Plan (U.S. Navy 1986), USFWS conducted quantitative biological surveys of terrestrial and marine resources in 1986 (U.S. Navy 1986). Since then, a number of natural resource inventories and assessments have been completed, including fish, coral, and macroinvertebrate inventory (Amesbury et al. 2001, SWCA 2009), coconut crab survey (USFWS 2001), Mariana fruit bat station counts (Brooke 2008) and tree snail surveys (Smith et al. 2008). A vegetation survey was undertaken in the HERA in 2009-2010.

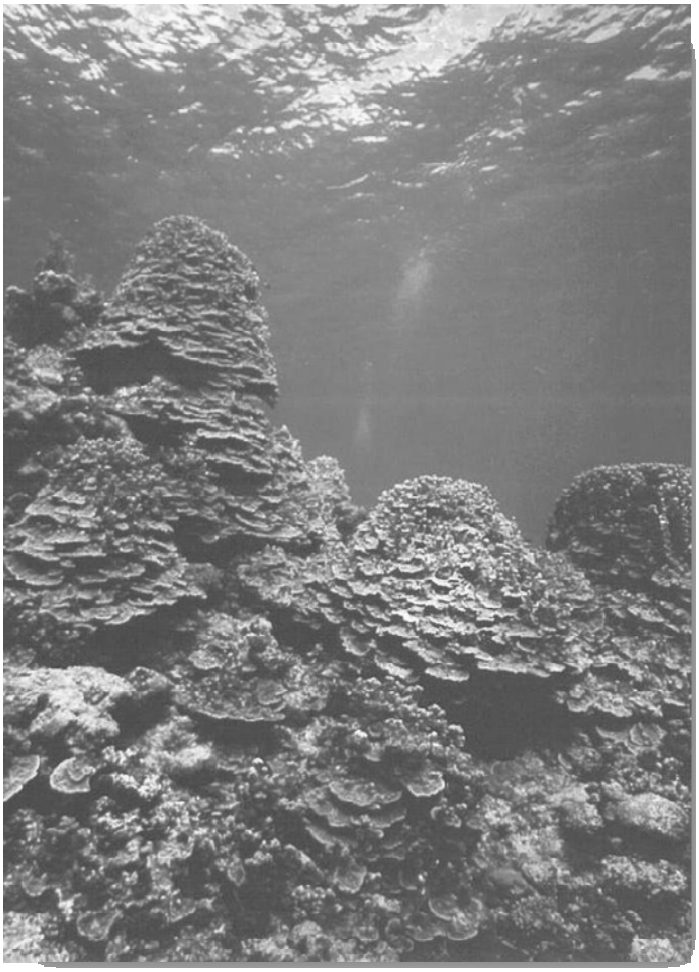

Figure 9. Diving Pugua Patch Reef (often called Double Reef) in the Haputo Ecological Reserve Area is advertized on almost every dive company website that services Guam. Dramatic stony coral colonies dominate portions of the shallow fore reef habitat in the lee of Double Reef. Photo: John Ford (circa 1986).

3.2 Marine Environment

Marine habitats are vitally important to the economy of Guam, particularly the fisheries and recreation and tourism industries. In addition, Guam's marine environments hold strong cultural, educational, and research value, while providing coastal protection. Van Beukering et al. (2007) estimated that the total economic value of Guam's reefs is $127 million per year. Despite its importance, marine ecosystems on Guam are threatened by a variety of factors including: habitat destruction, invasive species, development, resources exploitation, climate change, marine pollution and debris, siltation, and typhoons (USFWS 1994a, Kelty and Kuartei 2004, Porter et al. 2005, Burdick et al. 2008). As a result, marine reserves have been established throughout Guam and an array of monitoring and research activities are being conducted.

Coralline algae and reef corals are central to coral reef structure and function. They provide the physical framework of the reef itself, their productivity is at the base of the marine food web, and they provide complex structure used by other reef organisms for shelter and habitat. There has been much concern expressed in recent years about declines in coral reefs due to the synergistic effects of local fishing practices, disease, topical storms, habitat alteration and loss, sedimentation, water pollution, recreational uses, ship groundings, marine debris, invasive species, and global climate change (Porter et al. 2005, Richmond et al. 2007). Corals also provide an important feature of the ecosystem to monitor changes in condition since, unlike fishes and motile invertebrates, corals are sedentary and remain in place once established. Declines in coral communities can be detected by a decrease in total coral cover, loss of species, and changes in percent cover or size structure. A reef with a range of colony sizes probably had good recruitment, while a reef with only large size classes may indicate that, while adults are surviving, there is little or no recruitment of new corals.

Various coral reef ecosystems are present on Guam including fringing reefs, patch reefs, submerged reefs, offshore banks, and barrier reefs (van Beukering et al. 2007). Compared to other islands in Micronesia, Guam is considered to have the best-documented marine biota (Paulay 2003). Over 5,100 species of marine fauna have been recorded on Guam (Burdick et al. 2008). This includes approximately 1,000 near-shore fish, 300 scleractinian coral, 59 flatworms, 1,722 mollusks, 104 polychaetes, 840 arthropods, and 196 echinoderm species (Kelty and Kuartei 2004, Burdick et al. 2008).

Guam's northwest coast is dominated by steep limestone cliffs and is relatively sheltered in terms of wave action and currents due to its location leeward of the prevailing northwest trade winds. It has limited marginal reef development (Amesbury et al. 2001), and is characterized by relatively narrow reef flats to the north; narrow, supra-tidal benches or rock faces to the

south; and largely devoid of reef flats in between. The HERA includes only two small, localized reef flats (Haputo Beach and inshore of Double Reef). Double Reef is an incipient barrier reef that lies on a shelf that extends seaward from the adjacent areas of fore-reef. The region around Double Reef is highly heterogeneous, due to erosion caused by a sizeable freshwater aquifer that discharges into the area, the topographic variation created by reef growth, and the shelter in its lee that affords a thriving and distinctive back-reef community. In contrast, the northwest Guam fore-reef exhibits little variation in macrohabitat, although fine-scale variation in benthic communities is considered widespread (Amesbury et al. 2001).

The HERA MU can be divided into six macro-habitats (Amesbury et al. 2001) which include exposed benches; protected reef flats; Double Reef top; a back reef; a shallow forereef; and a deep forereef. The first three macrohabitats lie in the shallowest zone (supra-tidal to 3 ft (1 m)), back-reef and shallow fore-reef at intermediate depths (3–27 ft or1-9 m), and deep fore-reefs at 27 to 54 ft (9-18 m) deep.

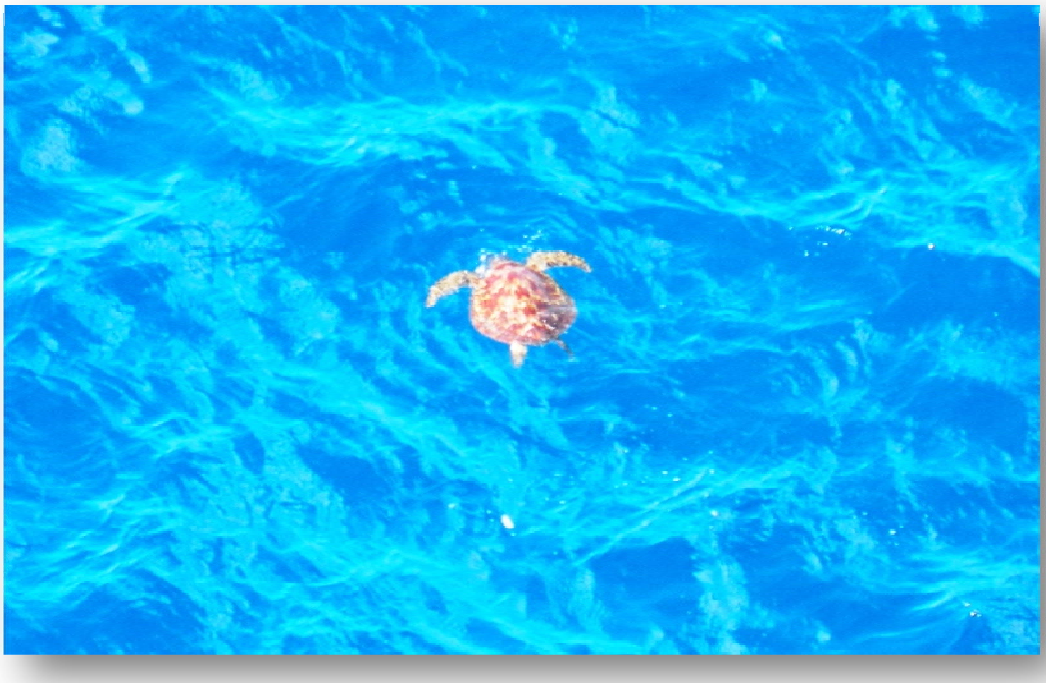

Figure 10. Green sea turtles are often seen in the Haputo Ecological Reserve Area. Photo: SWCA.

3.2.1.2 Other Species

The now rare Napoleon humphead wrasse, (*Cheilinus undulatus*), listed as Endangered on the International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened and Endangered Species (Russell 2004), was found at only at five biodiversity survey sites at HERA in a recent survey (SWCA 2009). Of these, most were juveniles or smaller females. The giant bumphead parrotfish (*Bolbometopon muricatum*), listed as Vulnerable on the IUCN Red List (Chan et al. 2007), was absent from all stations. The lack of adult sized individuals of these commonly harvested species at HERA indicates that overfishing may be occurring.

Noteworthy resources present in the HERA include the sponge *Neofibularia hartmani*, which has only been recorded in the HERA on Guam; *Dendrophyllia gracilis*, which represents just the second known species of coral of this type on Guam; the rare, striking xanthid crab, *Atergatis granulates*, which is known only from a few specimens from Japan, Mauritius, and the Red Sea; and spinner dolphins (*Stenella longirostris*), which sometimes gather together at the Double Reef area (Amesbury et al. 2001).