

2010

**OROTE PENINSULA ECOLOGICAL RESERVE AREA
GENERAL MANAGEMENT PLAN,
NAVAL BASE GUAM**



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ACRONYMS and KEY TERMS

AAFB	Andersen Air Force Base
ac	acre
ACE	Army Corps of Engineers
BTS	Brown treesnake
CA	Cooperative Agreements
CLEAN	Comprehensive Long-Term Environmental Action Navy program
CNO	Chief of Naval Operations
CO	carbon monoxide
CO ₂	carbon dioxide
COMNAVMAR	Commander, U.S. Naval Forces Marianas
CZMA	National Coastal Zone Management Act of 1972 (16 USC 1451 et seq.)
DLNR	Division of Land and Natural Resources
DoD	Department of Defense
ENSO	El Niño/Southern Oscillation
ERA	Ecological Reserve Area
ESA	Endangered Species Act of 1973, as amended, 16 USC 1531 et seq.
ft	feet
GCWCS	Guam Comprehensive Wildlife Conservation Strategy
GDAWR	Guam Division of Aquatic and Wildlife Resources
GEPA	Guam Environmental Protection Agency
GHG	greenhouse gases
GHPO	Guam Historic Preservation Officer
GIS	Geographic Information System
GMP	General management plan
GNWR	Guam National Wildlife Refuge
GovGuam	Government of Guam
ha	hectare
HERA	Haputo Ecological Reserve Area
in	inch
INRMP	Integrated Natural Resources Management Plan
IUCN	International Union for Conservation of Nature and Natural Resources
JRM	Joint Region Marianas
km	kilometer
km ²	square kilometer
kph	kilometer per hour
m	meter
m ²	square meters
Marianas	Mariana Islands
MBTA	Migratory Bird Treaty Act of 1918 [16 USC §§ 703-712]
MGD	Million gallons per day
mi	miles
mi ²	square miles
MLD	Million liters per day
MLLW	Mean lower low water (line)
MMPA	Marine Mammal Protection Act of 1972, as amended [16 USC 1361-1421]
MOU	Memorandum of Understanding
mph	Mile per hour
MSFCMA/SFA	Magnuson-Stevens Fishery Conservation and Management Act/Sustainable Fisheries Act
MSL	Mean Sea Level
MU	Marine Unit
NAVCAMS WESTPAC	Naval Communication Area Master Station, Western Pacific
NAVFACMAR	Naval Facilities Engineering Command Marianas
NBG	Naval Base Guam
NCTS	Naval Computer and Telecommunications Station

NEPA	National Environmental Policy Act
NGLA	Northern Guam Lens Aquifer
NMFS	National Oceanic and Atmospheric Administration, National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration Fisheries Service
OPERA	Orote Peninsula Ecological Reserve Area
OPNAVINST	Chief of Naval Operations Instruction
PACDIVNAVFACENGC	Pacific Division Naval Facilities Engineering Command
PTWC	Pacific Tsunami Warning Center
SCUBA	Self-contained Underwater Breathing Apparatus
SDZ	Surface Danger Zone
Sikes Act	Sikes Act of 1960, 16 USC §670a et seq. (1996)
SUV	Sport Utility Vehicle
T/E	Threatened and Endangered
TU	Terrestrial unit
USDA-WA	U.S. Department of Agriculture Wildlife Services
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
WPWP	Western Pacific Warm Pool

1.0 EXECUTIVE SUMMARY

The Orote Ecological Reserve Area (OPERA) was established by the Chief of Naval Operations (CNO) on March 15, 1984 under authority of Chapter 15, OPNAVINST 5090.1; Chapter 17 of the NAVFAC P-73 Real Estate Manual; 36 CFR 251.23; 40 FR 38; and HR 5602, The National Heritage Policy Act of 1979. The OPERA serves as one of several mitigation measures proposed by Federal and Government of Guam (GovGuam) resource agencies for the construction of Kilo Wharf at Adotgan Point in Outer Apra Harbor. The creation of the ERA is arguably the keystone mitigation that allowed Kilo Wharf to exist. The OPERA (total acreage: 163 acres) was also established to protect two biological units. The 30 acre (12 ha) terrestrial unit encompasses a remnant native limestone forest that provides habitat for native forest species. The 133 ac (54 ha) marine unit, provides a nursery for marine species of commercial and recreational fishery value.

Since its establishment, numerous concerns over potentially conflicted uses have arisen within the OPERA. These conflicts between military mission, recreational and visitor use in the marine unit and habitat preservation are expected to become more acute in light of the increased military build-up scheduled to take place over the next five years (JGPO 2009). The pending relocation of 8,000 US Marines and their dependents to new facilities being planned for the main navy base starting in 2010 provides the impetus to revise the OPERA management plan so that effective management guidance will be in place to protect the natural resources of the OPERA and uphold the original intent of the ERA.

The Naval Facilities Engineering Command Marianas (NAVFACMAR) has an overall objective to ensure that the natural resources within the OPERA is protected from physical, biological and human induced stressors that result in adverse changes to the ecological characteristics that made them eligible to be ERAs. Interest in the reserve's use for the protection of endangered species, mitigation requirements, urban encroachment and public relations interests has increased in recent times. In response, NAVFACMAR EV has instigated the creation of a General Management Plan (GMP) for OPERA. This GMP aims to:

1. provide a document that can be modified and updated regularly based on adaptive management outcomes;
2. practices provide direction for the preservation and management of the OPERA and its natural resources;
3. provide guidance to prioritize and seek opportunities for preservation and management;
4. identify stakeholders and public users;
5. describe potential threats or destructive activities; and

6. list activities and/or projects for the protection and maintenance of healthy ecological systems that integrate typical native flora and fauna over geologic, pedological and/or marine aquatic features and/or processes.

The GMP will also be in compliance with the terms of the Army Corps of Engineers (ACE) permit for allowing Kilo Wharf.

The OPERA contains a wealth of natural and cultural resources including federally listed and locally protected sea turtles, birds, reptiles, invertebrates, plants, and unique marine and terrestrial environments. These resources require carefully planned management to ensure they persist. The following management objectives are recommended to assist in achieving the goals of the OPERA GMP. These recommended management objectives apply to both the terrestrial and marine units of the OPERA and were developed given the physical and land use settings of the reserve, as well as the known condition of the OPERA.

Objective 1: Control and Eradicate Invasive Species

- Control and eradicate invasive flora and invertebrates
- Implementation of brown treesnake control
- Adopt adaptive management strategy for the control of crown of thorns starfish, and other harmful marine species
- Develop an early detection and rapid response plan
- Establish protocols for monitors and researchers

Objective 2: Prevent Harvest of Coconut Crabs

Objective 3: Maintain and Restore Valuable Habitat

- Prohibit all forms of fishing
- Implement ecological restoration
- Maintenance of habitat without restoration

Objective 4: Support Monitoring Surveys and Research

- Implement systematic baseline and regularly scheduled flora and fauna assessments and monitoring
- Monitor impacts of outdoor recreation and visitor use
- Execute long-term monitoring of Threatened or Endangered species

Objective 5: Develop an Outdoor Recreation and Visitor use Program

- Develop a visitor access policy for periods of range closure
- Signs for terrestrial and marine boundaries

- Develop natural resources educational programs
- Establish boat permit program
- Establish a no-drop-anchor policy requiring use of mooring buoys
- Develop a scuba dive permitting/reservation system
- Develop a tsunami warning and evacuation plan

Objective 6: Minimize Risks from Oil Spills and Hazardous Waste

Objective 7: Incorporate Adaptive Management

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2.0 INTRODUCTION

The Navy has jurisdiction over approximately 18,000 ac (7,300 ha) of land on Guam in addition to 36,000 ac (14,600 ha) of submerged lands (JGPO 2009). It is the policy of the Navy that the Natural Resources under its jurisdiction be managed to support and be consistent with the military mission, while protecting and enhancing those resources for biological integrity, sustainable yield and multiple use (OPININST 5090.1C). This is achieved by incorporating ecosystem management as the basis for planning and management of Navy installations. Furthermore, the Navy is responsible for complying with Federal environmental and natural resources laws and regulations that apply to the marine environment. This includes (but is not limited to) the National Environmental Policy Act (NEPA), the Marine Mammal Protection Act (MMPA), the Endangered Species Act (ESA), the Magnuson-Stevens Fishery Conservation and Management Act/Sustainable Fisheries Act (MSFCMA/SFA), the Sikes Act (10 U.S.C. 670), and Executive Order (EO) 13089 on Coral Reef Protection (Appendix 1).

Incorporated within Navy lands on Guam are Ecological Reserve Areas (ERA). An ERA is defined as an area dedicated primarily or exclusively to preserving examples of ecosystems and genetic diversity while providing opportunities for scientific research and education (OPININST 5090.1C; 24-5 § k (5)). Recognizing the national and international need to maintain areas in natural and near-natural conditions, and to have available such areas for baseline research and scientific manipulation, natural areas on Navy lands that warrant special conservation efforts may be identified as ERAs. These special natural areas should include characteristic or outstanding botanical, ecological, geological, and scenic features or processes.

There are currently two ERAs situated on Naval Base Guam (NBG) property; Orote Peninsula ERA (OPERA) and Haputo ERA (HERA) (Figure 1). This document focuses on the OPERA (see Appendix 2 for a legal description of OPERA).

The OPERA is located on the southern coast of the Orote Peninsula in the Santa Rita municipality, approximately 0.4 mi (0.6 km) north-northwest of Apunta Point (Figure 1 and 2). It is within the Apra Harbor Naval Complex. The 163 ac (64 ha) OPERA consists of a Terrestrial Unit (TU) area of 30 ac (12 ha) from the cliff boundary line to the mean lower low water (MLLW) line and the remaining 133 ac (54 ha) is the submerged Marine Unit (MU) from the MLLW seaward to the 20 fathom (36.6 m) contour line (Figure 3). The terrestrial portion of the OPERA, managed by the U.S. Navy, is an approximately 2 mi (3.4 km) stretch of coastline that lies within Navy Overlay. The MU of the ERA is listed as being part of the "U.S. Marine Managed Area".

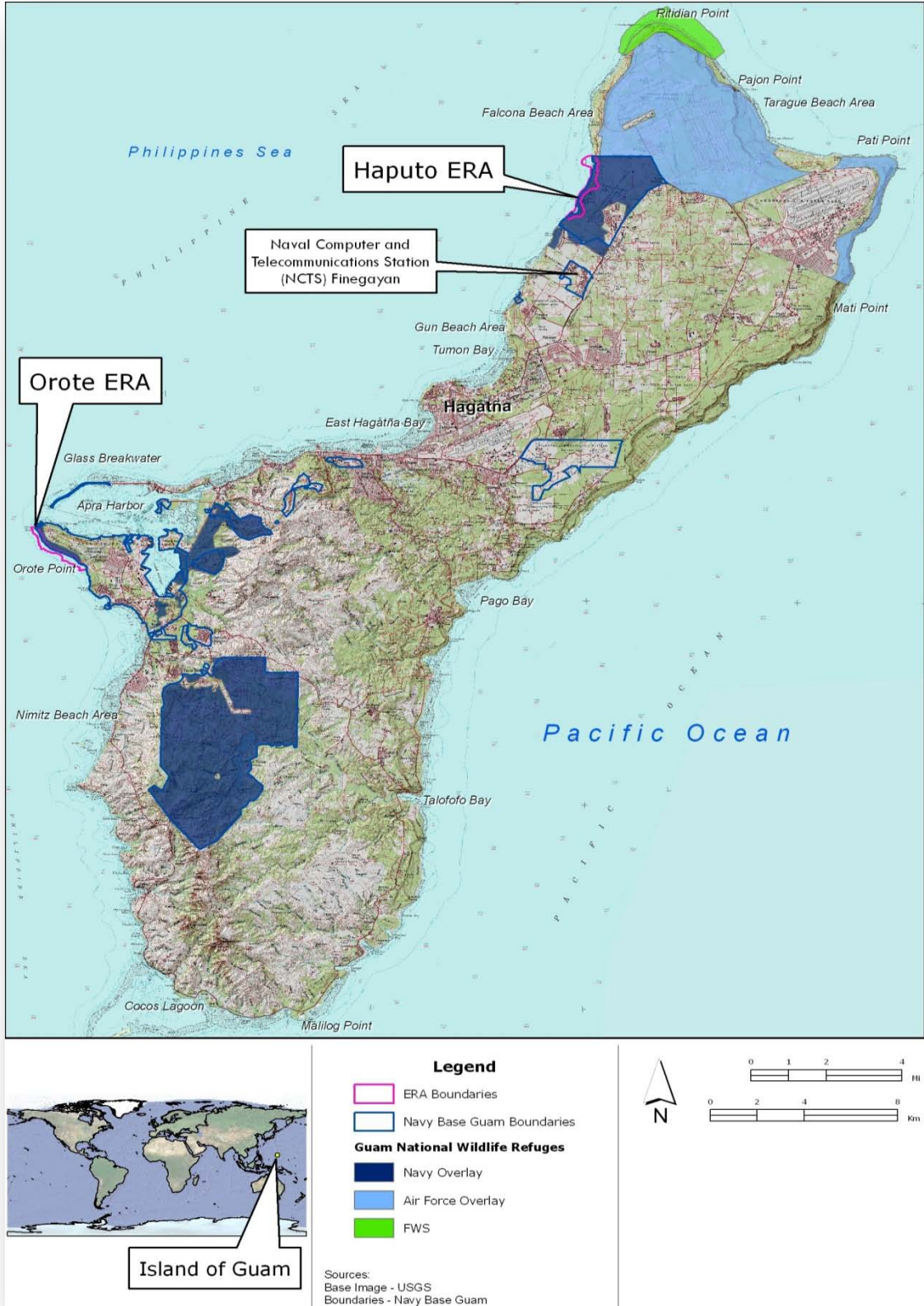


Figure 1. The island of Guam location of Orote Peninsula and Haputo Ecological Reserve Areas.

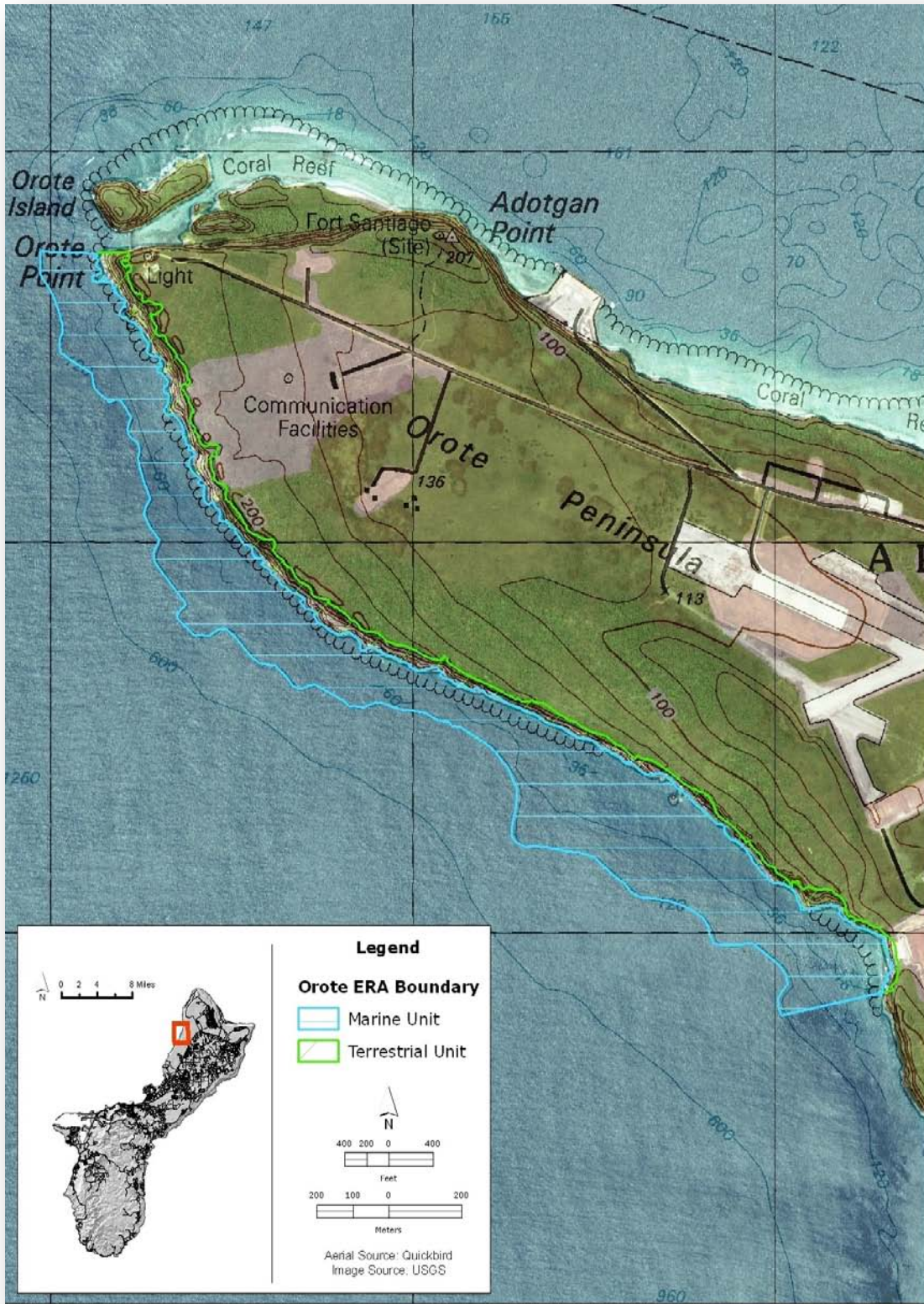


Figure 3. Marine and terrestrial boundaries of the Orote Peninsula Ecological Reserve Area, Guam.

The OPERA was established by the Chief of Naval Operations (CNO) on March 13, 1984 under authority of Chapter 15, OPNAVINST 5090.1; Chapter 17 of the NAVFAC P-73 Real Estate Manual; 36 CFR 251.23; 40 FR 38; and HR 5602, The National Heritage Policy Act of 1979. The reserve was initially created as mitigation and compensation allowing the construction of an ammunition wharf (Kilo Wharf) at Adotgan Point in Outer Apra Harbor (GDAWR 2006). The creation of the OPERA was key to gaining approval from various Federal and Government of Guam (GovGuam) entities for the wharf's construction (U.S. Navy 1986). Kilo Wharf would not exist without the creation and ongoing management of OPERA. The ERA is on the U.S. Marine Managed Area Inventory and has the potential to be designated as a Marine Protected Area under Executive Order 13158 in the future. Since its establishment, the OPERA has remained essentially unmodified.

The OPERA encompasses terrestrial and marine habitats and is intended for limited research, education, and recreational purposes. The first management plan for OPERA, prepared the Pacific Division, Naval Facilities Engineering Command in January 1986 (U.S. Navy 1986), allocated management responsibilities among the Commanding Officer NAVCAMS WESTPAC, PACDIVNAVFACENCOM, the U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), and GovGuam. It provided for natural resource surveys, boundary identification, control measures, habitat protection and improvement, and maintenance of the OPERA. The management plan also identified access procedures for permitted activities. Marine resource investigations funded by the Navy were conducted by the USFWS and NMFS in 1986 and 1988, Paulay et al. (2001), and SWCA (2009) to establish baseline conditions and monitor populations of fishes, corals, and macroinvertebrates within OPERA. A botanical survey and vegetation inventory was carried out on the OPERA in 2009-2010.

2.1 Purpose and Objectives

The overall management objectives of NBG are to ensure that the natural resources within each ERA are protected from physical, biological, and human induced stressors that result in adverse changes to the ecological characteristics that made them eligible to be an ERA. After 24 years, the 1986 Management Plan is in need of an update to reaffirm original management objectives while addressing current management needs in terms of the evaluation of impacts to the OPERA and the application of modern techniques. The OPERA continues to be of interest for the protection of endangered species, mitigation requirements, urban encroachment and public relations.

In response, NAVFACMAR EV has instigated the creation of a General Management Plan (GMP) for OPERA. This GMP is designed to:

1. provide a document that can be modified and updated regularly based on adaptive management outcomes;
2. provide direction for the preservation and management of the ERA and its natural resources;
3. provide guidance to prioritize and seek opportunities for preservation and management;
4. identify stakeholders and public users;
5. describe potential threats or destructive activities; and
6. list activities and/or projects for the protection and maintenance of healthy ecological systems that integrate typical native flora and fauna over geologic, pedological and/or marine aquatic features and/or processes.

This GMP will provide the tools for long-term compliance assurance with the ACE permit for the construction of Kilo Wharf at Adotgan Point in Apra Harbor by providing lasting management strategy options designed to allow opportunities for updating as management projects are completed or in need of reevaluation. Under adaptive management strategies, the GMP will provide a document that can be modified and updated as the need arises.

2.2 Management Responsibilities

Management of the OPERA calls for protection against activities that directly and/or indirectly impact normal ecological processes. Joint Region Marianas (JRM) has ultimate management jurisdiction for the ERA, with regulatory and/or programmatic authority or input from NAVFACMAR. Input can also be sought from:

1. U.S. Fish and Wildlife Service (USFWS)
2. National Oceanic and Atmospheric Administration Fisheries (NOAA)

Final approval for all actions within the ERA, including access, is determined at the discretion and guidance of JRM.

NAVFACMAR provides technical expertise to JRM on various management aspects of the ERA including resource management (cultural and natural) and development of maintenance, security and visitor use plans. Additional responsibilities of NAVFACMAR include future planning, advising, approving and/or monitoring research projects and serving as the point of contact for other Federal, Territorial, and private natural resource agencies desiring use of the OPERA. Within the OPERA, NAVFACMAR also provides technical assistance to JRM on all aspects of archaeological and historic site resource management.

The terrestrial unit of the OPERA is part of the Navy Overlay Unit (total area 4,855 ha; 12,000 ac). The overlay unit is managed in cooperation with the USFWS to protect federally threatened and endangered species and their habitat (USFWS memo dated March 25, 1994). The following purposes for the Overlay Units are specified in Cooperative Agreements (CA) with the U.S. Navy and U.S. Air Force, dated March 4, 1994, and March 10, 1994, respectively (see Appendix 3 for March 4, 1994 CA).

- a. "...to conserve (A) fish or wildlife which are listed as endangered species or threatened species...or (B) plants...(C) the ecosystems upon which endangered species and threatened species depend..." (Endangered Species Act of 1973, 16 U.S.C. 1534);
- b. "...shall be administered by him [Secretary of the Interior] directly or in accordance with cooperative agreements...and in accordance with such rules and regulations for the conservation, maintenance, and management of wildlife, resources thereof, and its habitat thereon..." (Fish and Wildlife Coordination Act, 16 U.S.C. 664);
- c. "...for the development, advancement, management, conservation, and protection of fish and wildlife resources" (Fish and Wildlife Act of 1956, 16 U.S.C. 742f(a)(4));
- d. "...for the benefit of the United States Fish and Wildlife Service, in performing its activities and services. Such acceptance may be subject to the terms of any restrictive or affirmative covenant, or condition of servitude, if such terms are deemed by the Secretary to be in accordance with law and compatible with the purposes for which acceptance is sought."
- e. (Fish and Wildlife Act of 1956, 16 U.S.C. 742f(b)(1));
- f. "...(1) incidental fish and wildlife-oriented recreational development, (2) the protection of natural resources, (3) the conservation of endangered species and threatened species" (Refuge Recreation Act, 16 U.S.C. 460k-1);
- g. "...the Secretary...may accept and use...donations of...real...property. Such acceptance may be accomplished under the terms and conditions of restrictive covenants imposed by the donors..." (Refuge Recreation Act, 16 U.S.C. 460k-2); and
- h. "To ensure that [Air Force and Navy] lands within the Guam National Wildlife Refuge remain available for the use of the [Air Force and Navy] to carry out its responsibilities to organize, supply, equip, train, service, mobilize, demobilize, administer, and maintain forces" (10 U.S.C. 8013).

The USFWS is responsible for implementing and enforcing some of our Nation's most important environmental laws, such as the Endangered Species Act, Migratory Bird Treaty Act, Marine Mammal Protection Act, North American Wetlands Conservation Act, and Lacey Act. The Service fulfills these and other statutory responsibilities through a diverse array of programs, activities, and offices that function to protect and recover threatened and endangered species, monitor and manage migratory birds, and restore nationally significant fisheries. USFWS is responsible for conservation and management programs for primarily terrestrial and freshwater threatened, endangered, or otherwise protected species. They ensure actions conducted on federal lands or waters do not jeopardize the continued existence of listed species. Implementation measures include issuing appropriate research permits, managing species, and providing technical review of projects potentially impacting protected wildlife. The USFWS may conduct flora and fauna surveys on a reimbursable basis. Although the principal area of responsibility for the USFWS is the TU, assistance in MU management may also be provided.

NOAA is dedicated to protecting and preserving the nation's living marine resources through scientific research, fisheries management, enforcement and habitat conservation. The organization works within the Magnuson-Stevens Act, the Marine Mammal Protection Act and the Endangered Species Act to fulfill its mission of promoting healthy ecosystems. NOAA is the lead federal agency responsible for the stewardship of the nation's offshore living marine resources and their habitat. They are specifically responsible for the stewardship of living marine resources within the United States' Exclusive Economic Zone (three to 200 mile offshore), including implementation and management of Marine Mammal Protection Act programs. NOAA works closely with other NOAA offices to protect and conserve marine resources. Specifically, NOAA's Office of Oceanic and Atmospheric Research explores and investigates ocean habitats and resources. NOAA's National Ocean Service provides maps and other data to help fishers and managers and also maintains a network of Marine Sanctuaries and Estuarine Research Reserves to help protect important resources. NOAA's Office of Marine and Aviation Operations provide a fleet of ships and boats to support the agency's fisheries operations. The primary area of responsibility for NOAA in the ERA is the MU.

The Guam Department of Agriculture's Division of Aquatic and Wildlife Resources (GDAWR) is the lead agency in the management of Guam's natural resources. They are involved in management activities associated with aquatic and terrestrial species, hunting and fishing programs, monitoring and assessment, and captive rearing and propagation programs for the recovery of endangered species. GDAWR is the primary Government of Guam agency responsible for local consultation in relation to the OPERA. This agency may provide fish and wildlife management recommendations or conduct monitoring surveys of the areas as funds permit. In 2006, GDAWR developed the Guam Comprehensive Wildlife Conservation Strategy

(GCWCS), the primary goal of which was to provide information for the effective management, preservation, protection, and restoration of the island's natural resources, especially those considered of greatest conservation need.

Although JRM employs a cultural resource specialist, the Guam Historic Preservation Officer (GHPO) can serve as the liaison for historic preservation matters. The GHPO may be consulted for proper management actions of known historic and pre-historic sites at the OPERA in the past and will be called upon where appropriate for any subsequent site discoveries during future archaeological work at OPERA.

2.3 ERA Access

Access to the OPERA is at the discretion and guidance of the Commanding Officer of NBG. Passes for NBG are issued at the NBG Pass and ID office. Access is for day use only (except cases of emergency or when approval is granted) and generally restricted to military personnel (active duty and retirees), their family members, sponsored guests and actively employed Department of Defense (DoD) civilian employees, and to other federal and territorial agency staff and their contractors having legitimate research or related business. At present, no permits are required for boat access to the ERA.

The OPERA TU is virtually inaccessible by foot because of the rugged terrain and thick vegetation. Access is unregulated with the exception of periodic closures when the Orote small arms range is open and special training events occur. As a result, commercial tour diving and fishing companies have almost complete and unfettered access to the OPERA MU. Navy management of OPERA has generally been passive and largely focused on protecting the ERA from encroachment and overuse. However, DoD has assimilated Government of Guam's fishing regulations and enforcement. Since its establishment in 1984, the Navy has permitted a range of scientific investigations.

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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 mi² (540 km²).

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 recorded in January, and the highest from June to November (Figure 4; <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. 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). 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 2°F (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 82.9°F (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).

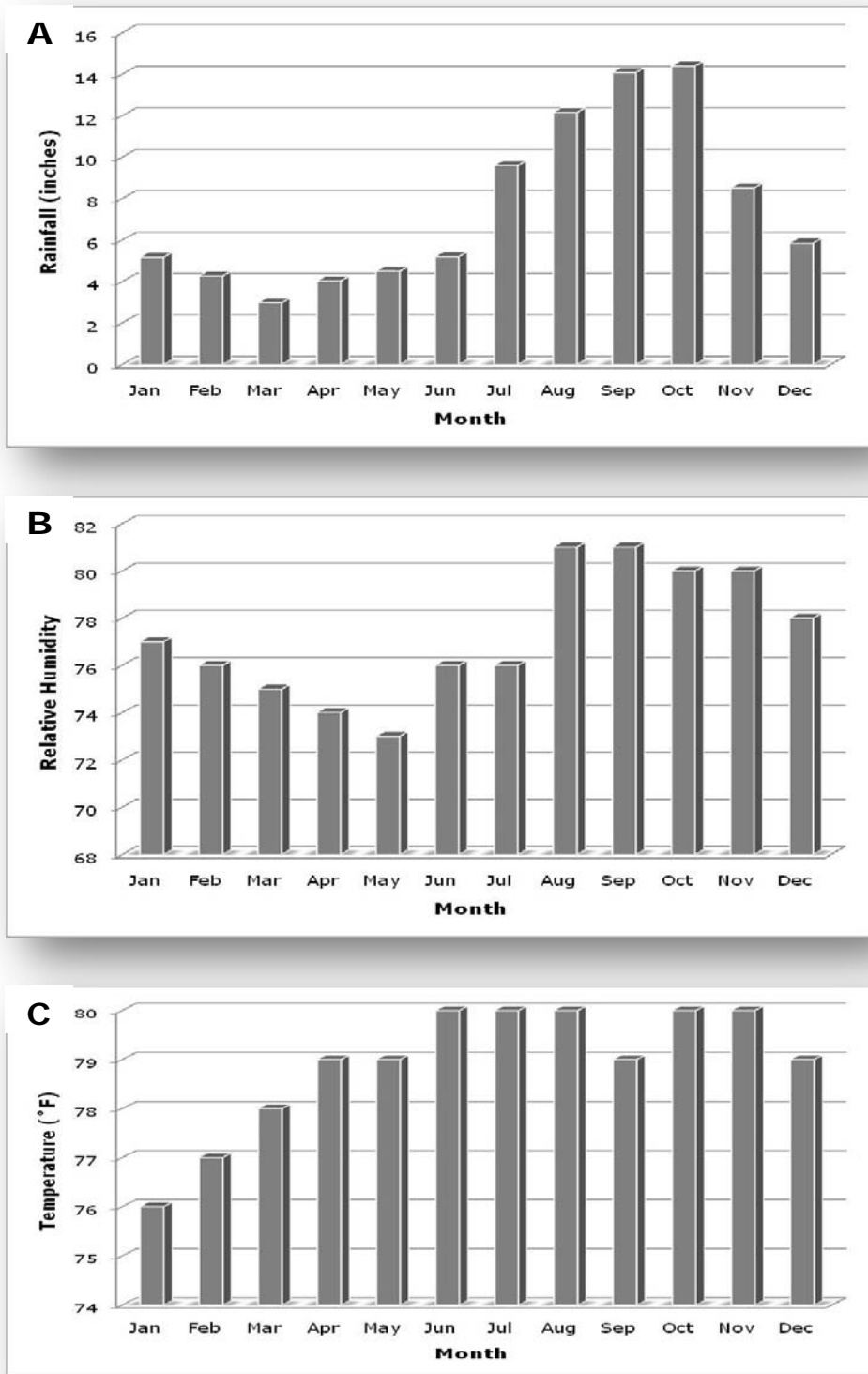


Figure 4. Graphs showing (A) average monthly rainfall (B); average monthly relative humidity (%), and C) average temperature (°F). Figures adapted from <http://www.climatetemp.info/mariana-islands>.

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 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 2001). Subsequent tectonic activity has caused uplift and emergence of the barrier reef and associated lagoon limestone deposits (Randall 1979). OPERA is completely comprised of Mariana limestone reef facies (Figure 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). OPERA is located on Rock outcrop-Ritidian complex, characterized by vertical cliffs and occasional ledges and benches (Young 1988). Cliff faces are almost devoid of soil which, when present, is very shallow and well drained. Very little of the OPERA is flat; most is situated on very steep sea cliffs 180 to 200 ft high (Figure 6). The cliff line is undercut near the shoreline, created by erosive wave action.

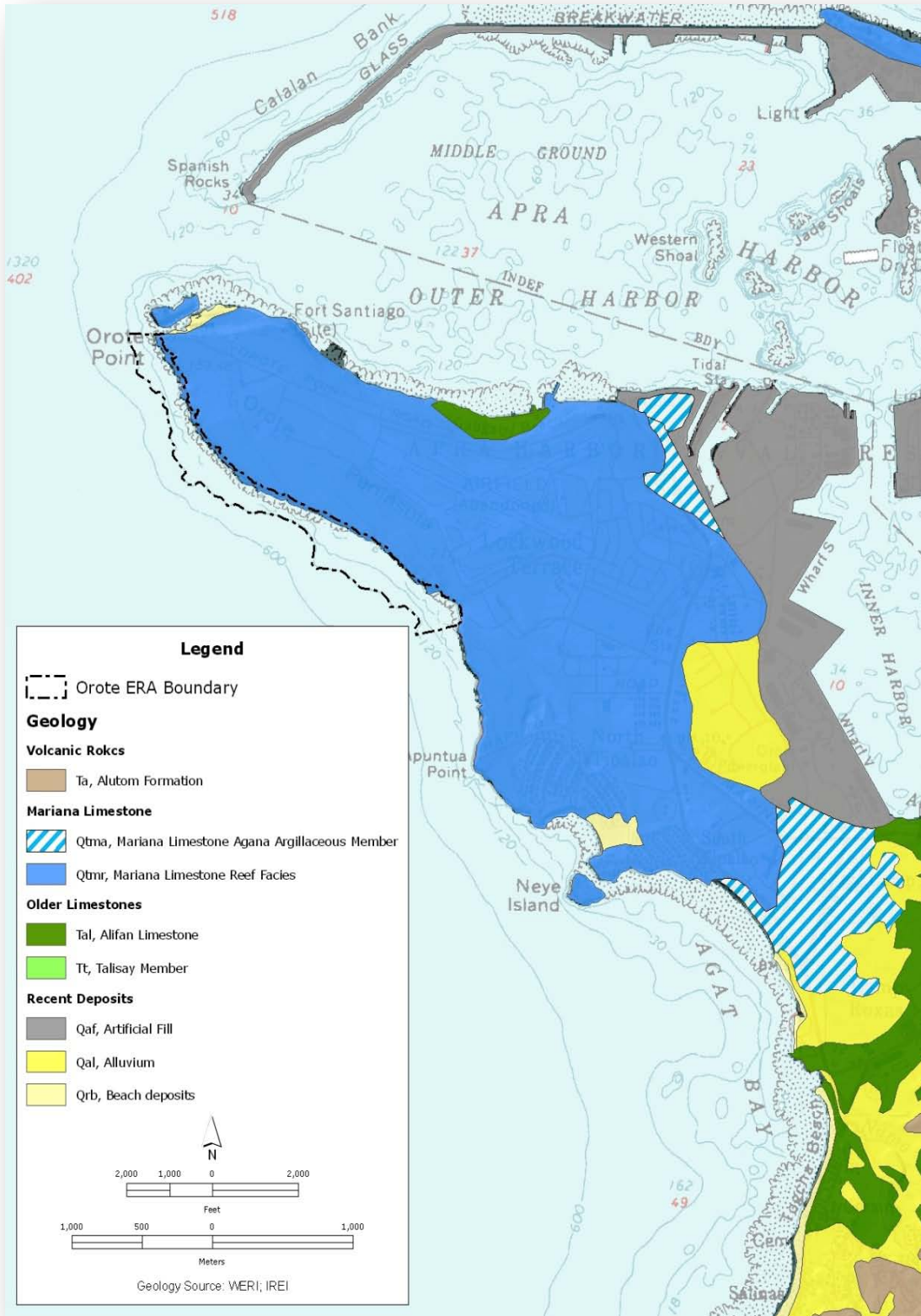


Figure 5. Geology of the Orote Peninsula Ecological Reserve Area.



Figure 6. The Orote Peninsula Ecological Reserve Area is characterized by vertical cliffs and occasional ledges and benches. Cliffs are eroded by wave action, resulting in undercuts at the base of the sea cliffs. 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 mi² 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 2001, Jocson et al. 2002, Gingerich 2003).

There are no areas of surface of ground water on the OPERA.

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 Anatahan and emissions of volcanic ash, gas, and steam continue. 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 OPERA is also influenced by emissions in the nearby main Navy base which originate from gasoline and diesel powered engines, sea vessels, 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 scenic coastal resources at the OPERA make the area a valuable natural sightseeing spot for locals and visitors to the island. The stunning sea cliffs, small strand of limestone forest, nearly pristine water quality

and clarity, and abundance of conspicuous corals, macroinvertebrates, and fishes all contribute to the aesthetic quality of the area. Although the size and terrain make access to the terrestrial area of the OPERA particularly difficult, its beauty can be readily seen from marine vessels or aircraft. The terrestrial area maintains 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 OPERA. The marine environment is particularly stunning because of the abundance of marine life and spectacular coral. Therefore, it is important that the OPERA 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 cliff line to ensure minimum disturbance.

3.1.6 Land Use

3.1.6.1 Pre-Historic and Historic Uses and Features

A number of researchers have conducted archaeological/historical investigations on Orote Peninsula (McCoy et al. 1978, Craib 1992, Craib and Yoklavich 1992a, b, Carucci 1993, DeFant et al. 1995, Fulmer et al. 1999). Identified sites span the range of Guam's history. Prehistoric sites have been identified on coastal strands on both the ocean side and harbor side of the peninsula, and on the plateau. Historic sites include the remains of forts, wells, stairs, and villages from the Spanish Period, maritime structures from the American and Japanese Periods, and extensive remains related to the massive development of the peninsula by U.S. Forces following the liberation of Guam in 1944.

Orote Peninsula sites either listed on or deemed eligible for nomination for the U.S. National Register of Historic Places include the Orote Historical Complex (Site 66-01-10009) which includes Fort Santiago, the Spanish Steps, a Spanish Well, and a prehistoric rock shelter site, The remnants of historic Sumay Village (Site 66-03-1041), the early 19th Century Spanish Fort Santa Cruz (Site 66-03-1010), the site of the Pan American Hotel (Site 66-03-1042), and the early 20th Century Cable Station (Site 66-03-1043) site (Guam Register of Historic Places).

3.1.6.2 Recent Land Uses

The OPERA 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.

The OPERA abuts an active naval installation and the Apra Harbor Naval Complex (Figure 2). Authorized military training activities periodically utilize the OPERA and surrounding areas. Most are training exercises (e.g., small arms and pistol range, bivouac, rappelling, helicopter flight and firebucket operations and field exercises (Helber Hastert and Fee 2005). In addition,

Assault Amphibian Vehicle (AAV) and Landing Craft Air Cushion (LCAC) landing sites have been identified at Tupalao and/or Dadi beaches, south of the ERA. Orote Peninsula also serves as the U.S. military's main Ordnance Port in the Western Pacific; the Kilo Wharf is Guam's only ordnance wharf. Improvement to ordnance handling on the peninsula with the expansion of Kilo wharf is planned to service a new class of ammunition ships (MILCON P-502).

The use of the OPERA is constrained by explosive safety quantity distance arcs that preclude inhabited buildings and place extreme limits on the types of allowable uses. Orote Peninsula small arms range, situated north of the OPERA on the plateau, is periodically used for security drills and weapons re-qualification activities. The two dimensional surface danger zone (SDZ) is oriented north-west over the OPERA and water (Figure 7); 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 NBG as a location for their infrastructural requirements, including buildings, housing, and training facilities. At this stage, the impacts of such a buildup on the OPERA are unknown; however, visitor use will likely increase as a result of the expected influx of military personnel, their dependants, contractors, and visitors to Guam.

Limited TU area means there is restricted terrestrial recreational activities for visitors to enjoy. Recreational activities must be compatible with the primary purpose of the ERAs. Currently there is no root or road access to the OPERA TU. Dive sites are generally accessible to civilians and military by boat. Popular dive sites on the OPERA and adjacent areas include Barracuda rock, Crevice, Blue Hole, The Wall and Spanish Steps (Figure 8 and 9). There is currently no data on frequency of TU or MU visitation at OPERA.

There are no improvements or other conveniences located on the OPERA.

The terrestrial and marine habitats at the OPERA support a variety of species and ecosystem functions. The OPERA 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 (Paulay et al. 2001, SWCA 2009), sea turtles (Grimm and Farley 2008). A vegetation survey was carried out on the OPERA in 2009-2010.

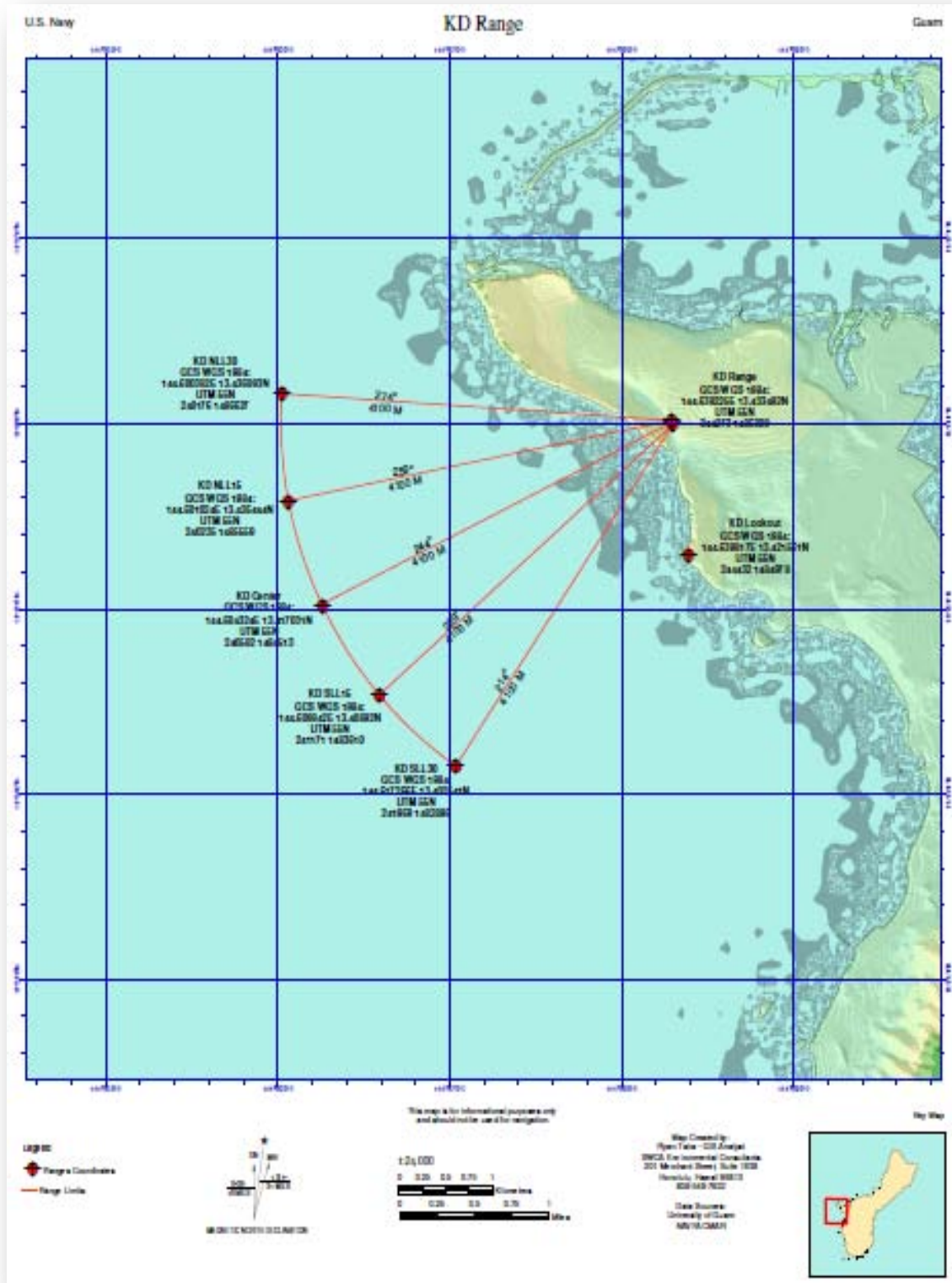


Figure 7. The Orote Peninsula Ecological Reserve Area and vicinity showing the reserve boundaries, Navy installation boundary, Navy submerged lands and safety danger zone (SDZ).

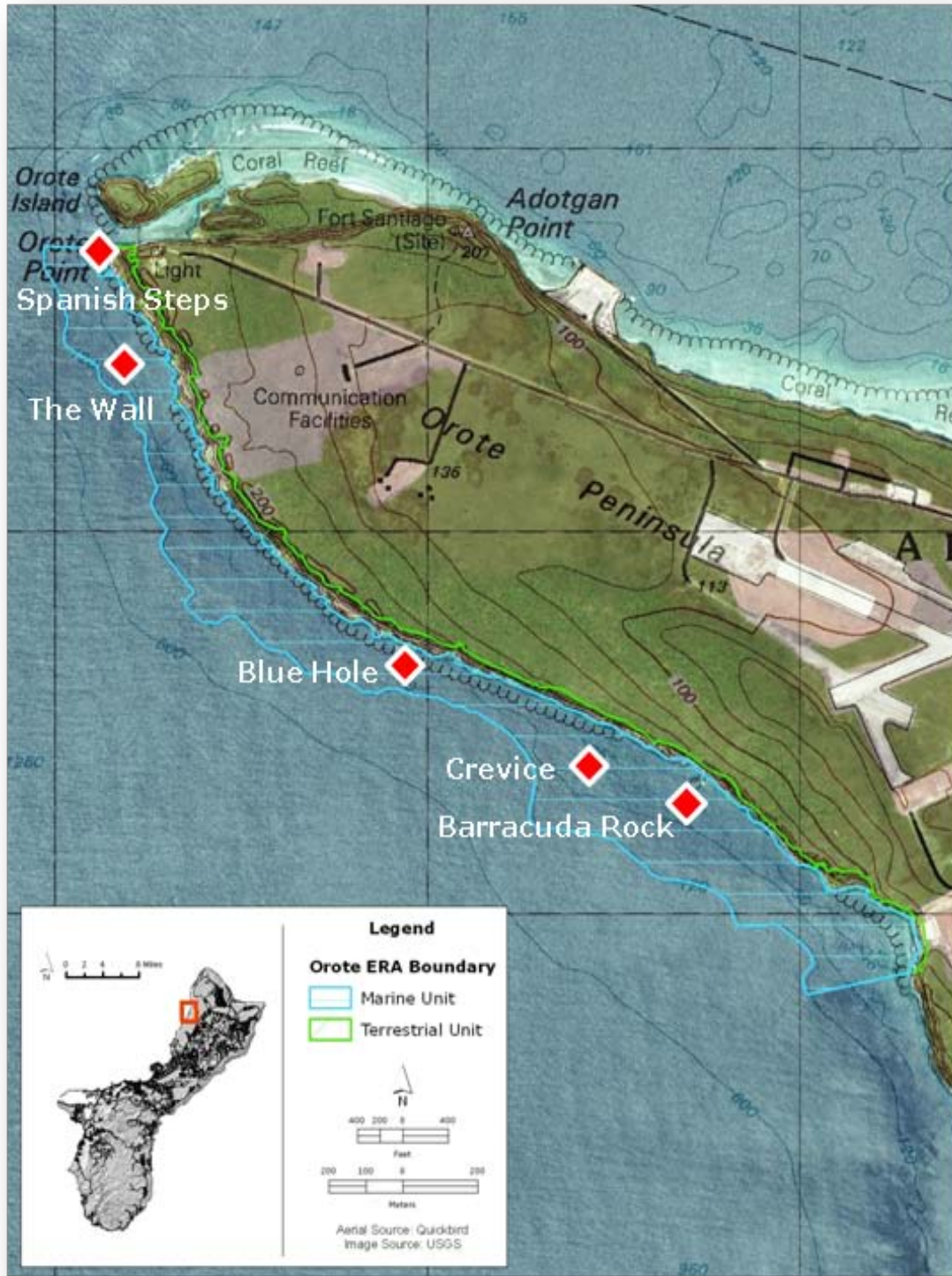


Figure 8. Areas within and adjacent to the Orote Peninsula Ecological Reserve Area are popular dive spots (indicated on figure as red diamond).

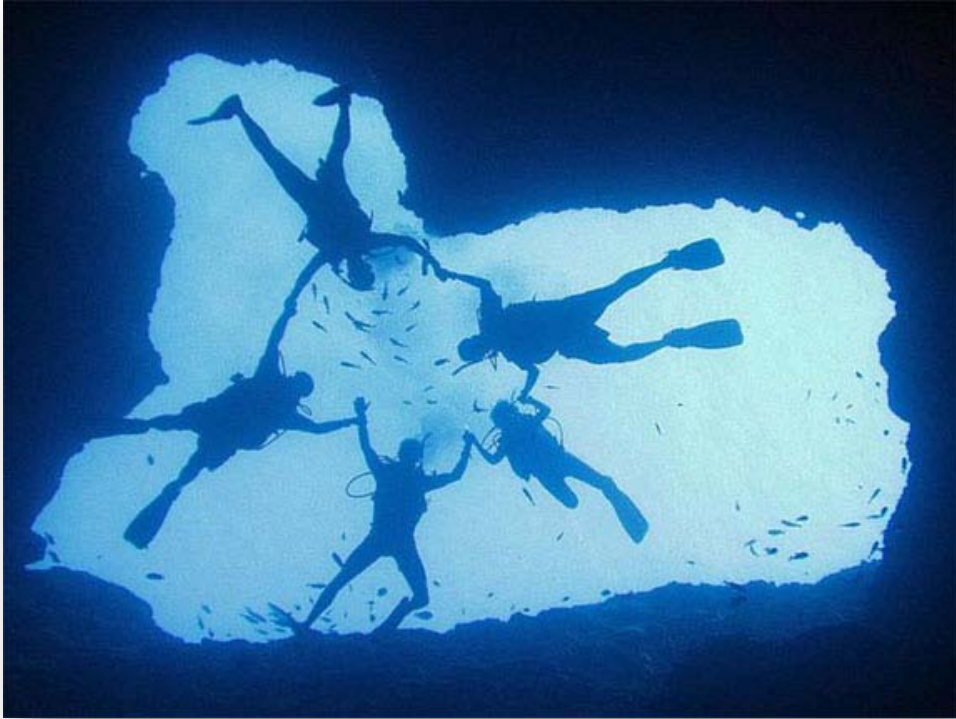


Figure 9. Blue Hole in the Orote Peninsula Ecological Reserve Area is arguably one of Guam's most popular dive spots.

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. The Guam's reefs are also integral to the island's economic status where tourism, enhanced by tropical waters and calm lagoons protected by barrier reefs, accounts for 60% of the government's annual revenues and provides for over 20,000 jobs (Porter, et al. 2005). 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, tropical 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).

The OPERA MU consists of three general macrohabitats: cliff reef, reef slope, and reef drop off (Paulay et al. 2001). It should be noted that Paulay et al. (2001) sampled in a larger area to the east of the Orote ERA, including North Agat Bay and vicinity. These areas are collectively referred to as OPERA in this report and in SWCA (2009). The reef slope represents a small, unique transitional habitat between the very different marine environments of Apra Harbor and south Orote, and strong currents often distinguish this macrohabitat (Paulay et al. 2001). All three macrohabitats characterize depth and physiographic zones present the length of Orote Peninsula, with reef drop off occurring near definite steep regions of the deep fore reef slope (Paulay et al. 2001).

3.2.1 Federally Listed and Candidate Endangered and Threatened Species

3.2.1.1 Sea Turtles

There are seven known species of sea turtles, of which three have been recorded inhabiting the waters off Guam: the federally threatened green sea turtle (*Chelonia mydas*), federally endangered hawksbill turtle (*Eretmochelys imbricata*), and federally endangered leatherback turtle (*Dermochelys coriacea*) (Eldredge 2003). Green sea turtles are considered to be common in the waters off Guam, hawksbill turtles are less numerous but not rare, and leatherback turtles have only been documented a few times (Wiles et al. 1995). The last sighting of a leatherback turtle around Guam was in 1985 (Cummings 2002).

Green sea and hawksbill turtles are known to frequent the waters of the OPERA. Green sea turtles (Figure 10) have been documented using all macrohabitats within the OPERA (Paulay et al. 2001), as well as the Navy estuaries of Sasa Bay and Inner Harbor (Geo-Marine Inc. 2008). Green sea turtle nesting activity has been documented at Waterfront Annex, NBG at Adotgan Dangkolo, Adotgan Dikiki, and Kilo Wharf (Grimm and Farley 2008). Hawksbills have been observed inside the Navy estuaries of Sasa Bay and Inner Harbor (Wiles et al. 1995, Helber Hastert and Fee 2005). Hawksbill turtles are known to nest on beaches in northern and central Guam, but it is unclear whether they utilize the beaches of the OPERA. However, four suspected hawksbill nest and/or crawls were observed at Adotgan Dikiki between 30 April and 20 June 2008 and a suspected nest was reported in 1997 on a beach near Sumay Cove (Grimm and Farley 2008). With precipitous cliffs present along the coast of the OPERA, it is unlikely that green sea or hawksbill turtles nest in this reserve.



Figure 10. Green sea turtle seen in the OPERA Marine Unit in November 2009. Photo: SWCA.

3.2.1.2 Other Species

Noteworthy resources present in the OPERA include two extraordinary sponge species, *Callyspongia subarmigera* and *C. aff. carens*; one of only two populations of the zooxanthellate soft coral, *Paramainabea goslineri*; a small, undescribed *Leptoseris* coral species; and the endemic yellow-crowned butterflyfish (*Chaetodon flavocoronatus*), which is only known from Guam, Tinian, and Anatahan (Paulay et al. 2001).

3.2.2 Marine Species of Interest

A remarkable 1,252 species of marine macrofauna (taxa usually > 1 cm in size) have been recorded in the waters off the southern part of Orote Peninsula and north Agat Bay, encompassing the OPERA, including 339 species of fish and 156 species of coral (Paulay et al. 2001). (Paulay et al. 2001) and SWCA (2009) found the coral communities in the ERA are unusually diverse and healthy. Within these waters, approximately 28 percent of Guam's known marine fauna, 37 percent of the Guam's known fish fauna and 60 percent of Guam's coral fauna have been documented (Paulay et al. 2001).

3.2.2.1 Algae and Corals

Fifty-two genera of marine algae were recorded at OPERA (SWCA 2009). New species records for Guam include: *Amphiroa tribulus*, *Dictyosphaeria intermedia*, *Galaxaura cohaerens*, *Gracilaria* cf. *millardetii*, *Haloplegma duperreyi*, *Hypnea saidana*, *Phyllocladion anastomosans*, and *Tricleocarpa cylindrica*. *Pseudocodium okinawense* was an intriguing find. *Pseudocodium okinawense* species has been recently described (Faye et al. 2008) from a deep site at Orote (250 ft), based on photographs taken before the specimen was lost. *Pseudocodium okinawense* appears to be the species with the largest geographical range within the genus. A high crustose coralline algae (CCA) cover, rich *Halimeda* stands and little turf algae cover, was observed along the tip of Orote Peninsula. Shallow sites at OPERA also had high CCA cover while the remaining stations were typified by high cover percentages of turf algae and *Padina* (the dominant brown alga within the Ochrophyta).

An assessment of coral colony size recruitment at OPERA suggests that recruitment is occurring and corals are replacing themselves. One hundred seventy one species of stony corals were recorded in 2008, up from 156 species recorded in 2001 in the biodiversity surveys. In quantitative coral surveys, 52 species were recorded in 2008, up from 37 species in 2001. The mean number of coral species at each quantitative transect station in OPERA was 15.1 in 2008, up from 12.1 in 2001. OPERA coral diversity is lower than that of HERA primarily due to the limited number and spatial heterogeneity of macrohabitats: cliff reef, reef slope, and reef drop off (Paulay et al. 2001). Only 350 species of macroinvertebrates were recorded from biodiversity studies at OPERA in 2008, down from 757 species in 2001. Surprisingly, quantitative surveys of macroinvertebrates in 2008 (SWCA 2009) found 42 species, up from 28 species in 2001 (Paulay et al. 2001). However, none of these differences are statistically significant and can be explained by observer interest, bias, experience, and sampling error.

3.2.2.2 Macroinvertebrates

The most common macroinvertebrates currently inhabiting the OPERA comprise high densities of the sea urchin (*Echinostrephus aciculatus*) followed by the edible sea cucumber (*Holothuria edulis*), and the rock boring sea urchin (*Echinometra mathaei*) (SWCA 2009). Only 350 species of macroinvertebrates were recorded from biodiversity studies at OPERA in 2008, down from 757 species in 2001. Surprisingly, quantitative surveys of macroinvertebrates in 2008 (SWCA 2009) found 42 species, up from 28 species in 2001 (Paulay et al. 2001). However, none of these differences are statistically significant and can be explained by observer interest, bias, experience, and sampling error.

The crown of thorns starfish (*Acanthaster planci*) has been an indigenous but periodically invasive species of concern in Guam in recent times. The species was not common until 1967

when the species became abundant on reefs on the northwestern side of the island. Within two years, more than 90 percent of corals between Ritidian Point in the north and Orote Peninsular in the south were destroyed by the starfish (Chesher 1969). The starfish preys on a variety of stony corals by feeding on the polyps. There have been several outbreaks of the crown of thorns starfish on Guam over the past four decades (Birkeland 1997). Control methods at the time resulted in the destruction of over 12,000 star fish (Randall 1972). It has been reported in large concentrations in the Indo-Pacific region in recent years. Although infestations occur naturally, they are considered very rare, estimated to occur naturally once every 400 years (Randall 1972). Despite not being mentioned in the final report documenting findings of a 2001 marine diversity survey of the OPERA and surrounding waters, it is unknown whether *A. plani* occurs in the OPERA (Paulay et al. 2001).

3.2.2.3 Fish

USFWS recorded 227 marine fish species at OPERA in (USFWS 1986). However, only 116 fish species were found two years later (USFWS 1988). Paulay et al. (2001) found 339 species of marine fishes at OPERA through biodiversity surveys. SWCA (2009) recorded 427 species of fishes at OPERA, some not found elsewhere on Guam. This difference may have been due to a number of factors such as observer expertise and interest, misidentification of species, natural variation in abundance, differences in sampling design, and sampling error. In spite of the difference between years, little qualitative change in the health of the fish community has been observed. The families of wrasses (Labridae) and damselfishes (Pomacentridae) were the best represented with 12 species, respectively (USFWS 1986, 1988). Other well represented families included triggerfish (Balistidae), surgeonfish (Acanthuridae), squirrelfish (Holocentridae), butterflyfish (Chaetodontidae), jack (Carangidae), and goatfish (Mullidae). The most abundant species in both surveys were damselfish (*Chrysiptera leucopomus*) and (*Pomachromis guamensis*) and goby (*Pogonoculius zebra*) (USFWS 1988).

Two species of sharks (Carcharhinidae), the blacktip (*Carcharhinus melanopterus*), and the reef whitetip (*Triaenodon obesus*), have been recorded in the OPERA (SWCA 2009).

Burdick, et al. (2008) reported that large parrotfishes, groupers, and wrasses are being targeted by spearfishers as the rise of 'trophy' fishing has become more popular in the 1990s. The main families fished targeted by boat and shore fishermen on Guam from 2004 to 2006 include fish in the families Acanthuridae, Carangidae, Lutjanidae, Lethrinidae, Mullidae, Siganidae, Kyphosidae, Scaridae, Scombridae and Sphyraenidae (Burdick et al. 2008). Large-sized species tended to be rare at Orote and were limited to emperors (*Lethrinus olivaceus*), parrotfishes (*Chlorurus microrhinos*, mostly juveniles or young immature-phase females, and *Scarus rubrioviolaceus*) and surgeonfishes (*Naso brachycentron*, primarily juveniles).

3.2.2.4 Marine Mammals

Anecdotal information suggests that a pod of spinner dolphins (*Stenella longirostris*) moves up and down the west coast of Guam between Double Reef and Agat (Eldredge 2003). In recent marine surveys, marine mammals were detected in the OPERA (SWCA 2009). While no marine cetaceans were observed underwater, they were observed directly on the surface or indirectly, by detection of audible signals underwater. Most observations were small groups of spinner dolphins (*Stenella longirostris*, Delphinidae) but larger aggregations of the short-finned pilot whale (*Globicephala macrorhynchus*, Delphinidae) were infrequently observed.

A single record of a sperm whale (*Physeter macrocephalus*, Physteridae) on the surface off Orote Peninsula was obtained as a radio report from a reliable observer in 2008 (SWCA 2009). Because these species are highly mobile, they likely utilize the entire coastlines off Orote.

3.2.3 Introduced and Invasive Species

A non-native invasive marine species that has been recorded at Apra Harbor is the Atlantic barnacle (*Chthamalus proteus*). This species threatens natural substrates through dense colonization (IUCN/SSG 2007). Despite not being mentioned in the final reports documenting findings of 2001 marine diversity surveys of the OPERA and surrounding waters, it is unknown whether the Atlantic barnacle occurs in this ERA (Paulay et al. 2001).

Crown of thorns starfish (see section 3.2.2.2 for discussion) is indigenous but has the potential to be invasive and therefore harmful to the OPERA MU. It has been reported in large concentrations in the Indo-Pacific region in recent years. Although infestations occur naturally, they are considered very rare, estimated to occur naturally once every 400 years (Randall 1972). Outbreaks of crown of thorns starfish have caused serious harm to coral reefs in Guam (Wilkinson 2008). Increased nutrient levels in the water as a result of agriculture or other land use practices that enhance soil erosion are considered the major cause (GDAWR 2006). Since crown of thorns are attracted to the metabolites released by damaged or broken corals, walking on, anchoring, mining or storm damage to reefs could trigger a bloom. There are very few natural predators of the crown of thorns starfish. Triton (Genus *Charonia*) is one such predator but because of their highly desirable shell, these animals are over-collected in most Pacific areas.

3.3 Terrestrial Environment

The OPERA TU includes steep limestone cliffs, below which narrow limestone shoreline benches occur (USFWS 1986). Very little land mass occurs within the OPERA boundaries. The majority of the terrestrial unit of the OPERA 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). The “forest on elevated limestone” habitat community is typically a moist, broad-leaved forest with a variable canopy height that may reach up to 75 ft (23 m), and mainly dominated by *Artocarpus mariannensis* and *Ficus prolixa*, with some *Pandanus dubius* present (Mueller-Dombois and Fosberg 1998). U.S. Navy (1986) referred to the reserve as containing marginal strands of native limestone forest, with sparse to dense vegetative cover. The vegetation along the cliff line retains functional components of native limestone forest (Figure 11), which is suitable habitat for threatened and endangered bird species although none are presently known to inhabit the area.

The 1986 OPERA Management Plan mentioned that the reserve contained a decent stand of remnant native limestone forest (U.S. Navy 1986). A 2005 draft feasibility study for potential expansion of the OPERA outlined five vegetation types that occur on Orote Peninsula: limestone forest, halophytic-xerophytic forest (scrub), strand, tangantangan (*Leucaena leucocephala*) forest, and wetland (Vogt and Williams 2004, Helber Hastert and Fee 2005). Of these, limestone forest and halophytic-xerophytic forest (scrub) exist within the boundaries of the OPERA (Helber



Figure 11. The Orote Peninsula Ecological Reserve Area is primarily steep sea cliffs covered with marginal strands of native limestone forest. Photo: SWCA.

Hastert and Fee 2005). Limestone forest in this area was dominated by *Heritiera longipetiolata*, *Tristiropsis obtusangula*, *Neisosperma oppositifolia*, *Ficus prolixa*, *Guamia mariannae*, *Dendrocnide latifolia*, *Guettarda speciosa* and *Eugenia reinwardtiana* (BioSystems 1990, Helber Hastert and Fee 2005). Trees of interest present within the terrestrial unit of the OPERA include *Pisonia grandis*, *Cycas circinalis [micronesica]*, and the Guam-endangered *Heritiera longipetiolata* (Helber Hastert and Fee 2005).

USFWS (1986) listed at least 50 plant species in the OPERA found during the 1986 survey. Of these, the majority were found in the limestone cliff vegetation and included *Scaevola taccada*, *Pemphis acidula* and *Bikkia tetrandia*. Components of limestone forest were less

common but considered important (e.g. *Pandanus sp.*, *Cycas circinalis [micronesica]*, *Melanolepis multiglandulosa*, *Hibiscus tiliaceus*, *Colubrina asiatica* and *Pipturus argenteus*).

3.3.1 Federally Listed and Candidate Endangered and Threatened Species

3.3.1.1 Plants

The only federally endangered plant species on Guam is the fire tree (*Serianthes nelsonii*). Of the six mature fire trees ever found on Guam, the majority were located in the north, on or near the GNWR (Wiles et al. 1996). Currently, only one mature, naturally occurring fire tree is present on Guam, and not within the OPERA (USFWS 1994b, Wiles et al. 1995).

Six plants on Guam are considered by USFWS to be species of concern: *Coelogyne guamensis*, *Lycopodium phlegmaria* var., *Nervilia jacksoniae*, *Tabernaemontana rotensis*, *Thelypteris warburgii*, and *Tinosperma homosepala* (USFWS 2005) (Appendix 4). There are more than 200 *T. rotensis* trees found in various regions of northern and southern Guam (GDAWR 2006). It is unknown whether *T. rotensis* or the five other species of concern are present in the OPERA; none were noted by USFWS (1986) have thus far been observed in recent ongoing vegetation surveys (SWCA, unpublished data).

3.3.1.2 Invertebrates

Although none of Guam's native partulid tree snails are currently federally listed as threatened or endangered, all are drastically declining or extirpated. As a consequence, three species are candidates for federal listing; the Mariana Islands tree snail (*Partula gibba*), Pacific tree snail (*P. radiolata*), and Mariana Islands fragile tree snail (*Samoana fragilis*). The Guam tree snail (*Partula salifana*) is considered

a species of concern; however, this species is possibly extirpated from Guam (USFWS 2005), B. Smith UOG, personal communication). Hopper and Smith (1992) found 24 adult Pacific tree snails during a timed count at a survey station on the western tip of Orote Point. In the same study, Mariana Islands tree snail and Mariana Islands fragile tree snail were not detected at Orote Point (Hopper



Figure 12. *Maytenus thompsonii*, the only known host tree for the Marianas wandering butterfly, is present on the Orote Peninsula and may be present in the Ecological Reserve Area. Photo: SWCA.

and Smith 1992). A more recent survey conducted in 2008 did not specifically survey the OPERA for tree snails, but did discover two previously unknown colonies of the Pacific tree snail in nearby Naval Munitions Site on Navy overlay (Figure 1) (Smith et al. 2008).

Two Guam butterfly species are candidates for federal listing (Appendix 4): Marianas eight spot butterfly (*Hypolymnus octicula*) and Marianas wandering butterfly (*Vagrans egestina*). The Marianas eight spot butterfly, endemic to Guam and Saipan, is known to occupy karst limestone forest habitats and its larvae have been reared on *Procris pedunculata* and Tupon Ayayu (*Elatostema calcareum*) (Schreiner and Nafus 1997). Despite native limestone habitat occurring in the OPERA, the presence of *P. pedunculata*, *E. calcareum* or Marianas eight spot butterfly in the reserve remains unknown. The Marianas wandering butterfly, endemic to Guam and Rota, has not been detected on Guam recently, but several were collected in the early 1970s (Schreiner and Nafus 1997). The only known host tree for the butterfly, *Maytenus thompsonii* (Figure 12), is located on Orote Peninsula (Helber Hastert and Fee 2005), and likely within the ERA.

3.3.1.3 Herpetofauna

There are currently no terrestrial reptiles or amphibians federally listed as threatened, endangered, or species of concern on Guam.

3.3.1.4 Birds

Historically, the Orote Peninsula likely supported at least five of the eight currently federally endangered avian species: the Micronesian kingfisher (*Halcyon cinnamomina cinnamomina*), Guam rail (*Rallus owstoni*), bridled white-eye (*Zosterops conspicillatus*), Mariana crow (*Corvus kubaryi*), and Guam broadbill (*Myiagra freycineti*) (Jenkins 1983, Engbring and Ramsey 1984) (Appendix 4). The Micronesian kingfisher and Guam rail are now extirpated from the wild, but are maintained in captivity (Wiles 2005). While the bridled white-eye is considered possibly extirpated from Guam (USFWS 2005), the Guam broadbill is officially extinct (USFWS 2004).

Although suitable habitat for Mariana crows exists in the OPERA and the peninsula in general, it is unlikely the species currently utilizes the reserve for foraging and nesting activities. If the Micronesian kingfisher and Guam rail were to be successfully reintroduced on Guam, they may utilize appropriate areas of the OPERA. The OPERA does contain *Pisonia grandis*, a soft-wooded tree that may be appropriate for cavity-nesting Micronesian kingfishers.

The Mariana common moorhen (*Gallinula chloropus guami*) and Mariana swiftlet (*Aerodramus bartschi*) are Guam's only other federally endangered avian species present in the wild. Currently, there are three known Mariana swiftlet colonies on Guam and all are located within limestone caves on Navy property (Grimm 2008). The OPERA is not likely to support

appropriate roosting and nesting caves for the swiftlet; however, foraging activities may occur throughout the ERA and the peninsula. On Guam, the Mariana common moorhen inhabits emergent vegetation within freshwater habitats including marshes, swamps, ponds, and calm rivers (Marshall 1949, Baker 1951, Jenkins 1983, USFWS 1991, Takano and Haig 2004). Although there is no freshwater habitat present in the OPERA, San Luis and Sumay ponds are present on the north side of Orote Peninsula (USFWS 1991) and could support the moorhen. Despite being designated as low quality habitat for moorhen (USFWS 1991), three adult moorhen were observed in San Luis Pond in May 2001 (Takano and Haig 2004) and the Sasa Bay Marine Preserve has been designated a moorhen foraging site (GDAWR 2006).

3.3.1.5 Mammals

The only federally listed terrestrial mammal documented in and perhaps still occasionally occurring in the OPERA is the threatened Mariana fruit bat (*Pteropus mariannus mariannus*; Figure 13). Before the construction of the Kilo Wharf, a fruit bat roost site was present in the



Figure 13. Mariana fruit bat (*Pteropus mariannus mariannus*) may occasionally utilize the Orote Peninsula Ecological Reserve Area for foraging or roosting. Photo: N. Johnson, SWCA.

OPERA. Surveys of Mariana fruit bats in 1966 and 1967 resulted in 103 and 332 bats respectively, all within the forested area of Orote Peninsula, just north of the OPERA (Helber Hastert and Fee 2005). However, the last sighting of the species on the peninsula was in the early 1980's (USFWS 1986). Although the Mariana fruit bat has been previously observed near Naval Munitions Site, Navy Overlay (Morton and Wiles 2002), more than 13 km (8 mi) southwest of the reserve's southern border (SWCA 2008a) there are currently no known roost sites

present on in the OPERA. However, there are suitable native canopy and understory trees present in the OPERA, critical for fruit bat foraging and roosting activities.

3.3.2 Other Species of Interest

3.3.2.1 Plants

Along with the fire tree, the Government of Guam lists two other plant species as endangered and threatened: Ufa-halomtano (*Heritiera longipetiolata*) and tree fern (*Cyathea lunulata*) (GDAWR 2006). Ufa-halomtano is primarily found in northern Guam, restricted to limestone cliffs and plateaus, almost always within 330 to 660 ft (100 to 200 m) of coastal limestone cliffs. The species is also present in several locations within halophytic-xerophytic scrub forest habitat on Orote Peninsula, including the ERA (Helber Hastert and Fee 2005, Geo-Marine Inc. 2008). Tree ferns are considered rare and have only been found in the southern hills of Guam, including the hilly banks of Fena Lake (Navy Overlay) and a wet ravine at Mt. Tenjo (Stone 1970). It is unknown whether *C. lunulata* is present in the OPERA; none were noted by USFWS in 1986 or have thus far been observed in recent ongoing vegetation surveys (SWCA, unpublished data).

Two plant species, Faniok (*Merrilliodendron megacarpum*) and Fadang (*Cycas micronesica*), are locally considered as species of greatest conservation need (GDAWR 2006). Faniok is found in limestone forest habitat and is considered rare (Stone 1970). The species has been documented in southern Guam (e.g., Mt. Lam Lam, Mt. Tenjo, the Agana Spring area, Naval Munitions Site) (GDWAR 2006) and may be present in OPERA. The species was not recorded in the OPERA 1986 (USFWS 1986) and has thus far not been noted during recent ongoing vegetation surveys (SWCA, unpublished data).

The University of Guam determined that Fadang (Figure 14) is a major component of ecosystem processes (T. Marler, University of Guam, personal communication). Historically, Fadang was common throughout Guam's undisturbed limestone forests and coastal regions, but since the introduction of the cycad scale (*Aulacaspis*



Figure 14. Fadang (*Cycas micronesica*) can be found on the Orote Peninsula. Photo: SWCA.

yasumatsu) in 2003, significant mortality has occurred in the population (GDAWR 2006). Although Fadang occurs on the Orote Peninsula and likely the ERA, the impact of cycad scale on those plants is largely unknown.

3.3.2.2 Invertebrates

With limestone forest habitat present in the OPERA, it is possible that coconut crabs (*Birgus latro*) exist in this reserve (Figure 15). During unrelated nocturnal surveys, biologists discovered coconut crab traps in areas adjacent to the OPERA (Helber Hastert and Fee 2005, SWCA, personal observation). Although coconut crabs are not locally or federally listed, they are culturally important to the people of Guam.



Figure 15. Coconut crabs (*Birgus latro*) may be present in the Orote Peninsula Ecological Reserve Area. Photo: SWCA.

3.3.2.3 Herpetofauna

There are presently 11 native reptile species in Guam (Rodda et al. 1991). These include six skinks: oceanic snake-eyed skink (*Cryptoblepharis poecilopleurus*), littoral skink (*Emoia atrocostata*), azure-tailed skink (*Emoia cyanura*), Mariana skink (*Emoia slevini*), moth skink (*Lipinia noctua*), Pacific blue-tailed skink (*Emoia caeruleocauda*); and five geckos: oceanic gecko (*Gehyra oceanica*), Pacific slender-toed gecko (*Nactus pelagicus*), Micronesian gecko (*Perochirus ateles*), mutilating gecko (*Gehyra mutilata*), and mourning gecko (*Lepidodactylus lugubris*). Although none are federally listed, eight (five skinks and three geckos) are locally considered species of greatest conservation need (GDAWR 2006, Appendix 5). These include the oceanic snake-eyed skink, littoral skink, azure-tailed skink, Mariana skink, oceanic gecko, moth skink, Pacific slender-toed gecko, and Micronesian gecko.

The Pacific blue-tailed skink, mourning gecko, and mutilating gecko were found in the OPERA in 1986 (USFWS 1986) and on at least one of three small islets adjacent to Orote Peninsula (Perry et al. 1998). During 2008 surveys on Orote Peninsula, the same three species were captured or observed (SWCA 2010). Monitor lizards (*Varanus indicus*) have also been found in the OPERA (USFWS 1986). No other native reptile or amphibian is known to occur in the ERA.

3.3.2.4 Birds

The Micronesian starling (*Aplonis opaca*), although not federally listed, is considered a species of conservation need by the Government of Guam (GDAWR 2006, Appendix 5). Micronesian starlings are currently found in the housing area of AAFB, Mount Santa Rosa, and Cocos Island (GDAWR 2006). Jenkins (1983) reported starlings as rare on Orote Peninsula (and presumably the OPERA) in the late 1970s. The species is not likely to presently inhabit the OPERA.

Two resident breeding waterbirds, the yellow bittern (*Ixobrychus sinensis*) and Pacific reef heron (*Egretta sacra*) are usually detected in forest edge and exposed coral reef habitats (Pratt et al. 1987). The yellow bittern is the only native land bird still common on Guam. Jenkins (1983) considered yellow bitterns common on Orote Peninsula (and presumably the OPERA) in the 1970s. The species was detected in the OPERA in 1986 (USFWS 1986) and on Orote Peninsula in 2005 (Helber Hastert and Fee 2005). Pacific reef herons may periodically utilize parts of the OPERA.

Marine waters near the OPERA likely serve as important flyways for breeding and non-breeding seabirds. The brown noddy (*Anous stolidus*) and white tern (*Gygis alba*) are Guam's only resident breeding seabirds. Brown boobies were observed in great numbers off the coast of Orote Peninsula around the turn of the 20th century (Safford 1905). Brown noddies have been recorded in the OPERA (USFWS 1986) and are common on the Orote Peninsula. USFWS (1986) recorded 159 noddies in 1986, 150 of them in a single colony on an offshore rock within the OPERA boundary. Nesting by brown noddies also occurs on Adotgan Rock, just off the north coast of Orote Peninsula.

Some seabirds may not breed on Guam but use the island to roost. Species that are frequently detected in Guam's near-shore waters including those in or near the OPERA, include the wedge-tailed shearwater (*Puffinus pacificus*), white-tailed tropicbird (*Phaethon lepturus*), red-tailed tropicbird (*Phaethon rubricauda*), brown booby (*Sula leucogaster*), red-footed booby (*Sula sula*), great frigatebird (*Fregata minor*), black noddy (*Anous minutus*), black-naped tern (*Sterna sumatrana*), short-tailed shearwater (*Puffinus tenuirostris*) and sooty tern (*Sterna fuscata*) (Wiles 2005). Brown boobies (Jenkins 1983), great frigate birds (USFWS 1986), short-tailed shearwaters (USFWS 1986), and red-footed boobies (Safford 1905) have all been observed in or adjacent to the OPERA.

Guam serves as an important stop-over location for migratory shorebirds during the non-breeding season, and more than 80 migratory birds have been recorded on Guam (Wiles 2005). Frequent sightings during the fall migration have been recorded on Guam for the following species: Pacific golden plover (*Pluvialis fulva*), wandering tattler (*Heteroscelus incanus*), gray-tailed tattler (*Heteroscelus brevipes*), whimbrel (*Numenius phaeopus*), ruddy

turnstone (*Arenaria interpres*), and common sandpiper (*Actitis hypoleucos*) (National Audubon Society 1989-2006). Wandering tattlers, whimbrel and Pacific golden plover have been observed above the OPEA but are not likely to utilize the OPERA TU to any great extent (USFWS 1986).

3.3.2.5 Mammals

There are currently no additional mammal species of special interest on Guam.

3.3.3 Introduced and Invasive Species

3.3.3.1 Plants

Numerous invasive plant species are present on Guam and possibly in the OPERA. Mile-a-minute (*Mikania micrantha*), chain-of-love (*Antigonon leptopus*), tangantangan (*Leucaena leucocephala*), and small-leaved vitex (*Vitex parviflora*) have greatly altered the composition of native habitats on Navy lands. Mile-a-minute and chain-of-love are known to dominate flora communities by smothering plants and trees and obstructing light penetration to the forest floor (GDAWR 2006). Both tangantangan and small-leaved vitex rapidly establish in disturbed areas and displace native flora (IUCN/SSG 2006a).

Additional plant species that are known to negatively affect native habitats on Guam's Navy lands include jack in the bush (*Chromolaena odorata*), giant sensitive plant (*Mimosa diplotricha*), Indian snakeweed (*Stachytarpheta indica*), burr marigold (*Bidens alba*), and the African tulip tree (*Spathodea campanulata*). Jack in the bush, tangantangan, papaya (*Carica papaya*) and stinking passion flower (*Passiflora foetida*) were notable among introduced species within the OPERA in 1986 (USFWS 1986). Again, the extent to which these and other invasive species impact the OPERA is currently unquantified.

3.3.3.2 Invertebrates

There are a number of non-native invertebrates that are present and considered invasive. The cycad scale (*Aulacaspis yasumatsui*) is a serious threat to the survival of the native cycad tree, fadang. Two species of scarab beetle (*Protaetia pryeri* and *P. orientalis*) are known to feed on flowering native ifit tree (*Intsia bijuga*), reducing the seed set by as much as 98 percent. The *Erythrina* gall wasp (*Quadrastichus erythrinae*) produces galls on the leaves and young shoots of native *Erythrina variegata* trees (GDAWR 2006, IUCN/SSG 2006b). *Erythrina* trees have allegedly not flowered or set seed in some areas since gall wasps were introduced to Guam in 2005. The coconut rhinoceros beetle (*Oryctes rhinoceros*), accidentally introduced to Guam and first documented in the Tumon Bay area in September 2007, has the potential to spread to the OPERA, causing serious problems to coconut (*Cocos nucifera*) and native *Pandanus* trees if not controlled. Additionally, introduced African land snails (*Achatina fulica*)

are present throughout Guam including the OPERA (SWCA, personal observation) and impact native snail populations by competing for resources (GDAWR 2006).

It is unknown to what extent any of these invasive invertebrates are present in the OPERA, although recent vegetation surveys have reported cycads infected with cycad scale (SWCA, unpublished data 2010, Figure 16). No evidence of *Erythrina* gall wasp, scarab beetles, and coconut rhinoceros beetle have been observed in the OPERA, but host plants like *Erythrina*, coconut, and *Pandanus* will certainly suffer negative effects by these invertebrate pests.



Figure 16. Cycad scale (*Aulacaspis yasumatsui*) is a serious threat to the native cycad tree, fadang.

Other invasive invertebrate species that are known or likely to be present in the OPERA and pose threats to native wildlife and the ecosystem include at least 26 species of ants, including the African big-headed ant (*Pheidole megacephala*) and yellow crazy ant (*Anoplolepis gracilipes*), and 17 non-native mosquito species,

representing six genera (*Anopheles*, *Aedes*, *Culex*, *Armigeres*, *Mansonia*, and *Aedeomyia*). Non-native ants can affect native ecosystems by feeding on, parasitizing, or hybridizing with a native species. Ants can compete with native species for food or limited resources or interrupt pollination (Kenis et al. 2009).

3.3.3.3 Herpetofauna

There are several introduced reptiles and amphibians present on Guam that threaten the survival of the native fauna. Perhaps the most notorious is the brown treesnake (*Boiga irregularis*; BTS). This snake has indirectly affected forest composition and structure by eliminating many native bird and herpetofauna species (Savidge 1987, Wiles et al. 2003). Marine toads (*Rhinella marina*, formally *Bufo marinus*) have substantially impacted

ecosystems via direct and indirect mechanisms (Crossland 2000) and are likely a threat to native invertebrate and herpetofauna in the OPERA. This toad is a voracious, opportunistic feeder (Hinkley 1962), possessing large parotoid glands that excrete poison that can kill most predators (Crossland 2000).

Other introduced reptiles and amphibians that have the potential to negatively impact the native fauna in the OPERA include, but are not limited to the curious skink (*Carlia ailanpilai*, formerly *Carlia fusca*), house geckos (*Hemidactylus frenatus*), eastern dwarf frogs (*Litoria fallax*), greenhouse frogs (*Eleutherodactylus planirostris*), crab-eating frogs (*Fejervarya cancrivora*), Hong Kong whipping frogs (*Polypedates megacephalus*), and Gunther's Amoy frogs (*Sylvirana guentheri*). These species can displace native species and provide food for other introduced species (Christy et al. 2007). During surveys in 2008, four introduced herpetofauna (BTS, curious skink, house gecko and marine toad) were found in the OPERA (SWCA 2010). The BTS is known to inhabit the OPERA (U.S. Navy 1986). Perry et al. (1998) found snakes on islets adjacent to OPERA. Other introduced reptiles that have been previously detected on Orote Peninsula area include curious skinks, house geckos, and marine toads (Perry et al. 1998).

3.3.3.4 Birds

Six introduced avian species occur on Guam and include the island collared-dove (*Streptopelia bitorquata*), Eurasian tree-sparrow (*Passer montanus*), black francolin (*Francolinus francolinus*), blue-breasted quail (*Coturnix chinensis*), black drongo (*Dicrurus macrocercus*), and rock pigeon (*Columba livia*) (Wiles 2005). The island collared-dove was introduced to Guam by the Spanish from the Philippines in the 1700s (Baker 1951) and is present in the OPERA (U.S. Navy 1986, Paine 1991). One island collared-dove was detected near the Spanish Steps trail on Orote Peninsula in 2005 (Helber Hastert and Fee 2005) and three on the OPERA in 1986 (USFWS 1986). Introduced between 1945 and 1960 (King 1962), the Eurasian tree-sparrow is now very common in urban areas throughout Guam and occurs in the OPERA (Paine 1991). Also observed in the OPERA (Paine 1991), the black francolin was introduced to Guam from Southeast Asia in the 1960s as a game animal (Jenkins 1983). Black francolins were detected in a field adjacent to the OPERA in 1986 and 2005 (USFWS 1986, Helber Hastert and Fee 2005).

The black drongo was introduced by the Japanese to Rota from Taiwan in 1935 (Baker 1951) and is presumed to have colonized Guam on its own (Jenkins 1983). It is considered to be strongly territorial and aggressive, and known to displace smaller birds that might otherwise nest within their territories (Fritts and Rodda 1998). Drongos have been documented within the OPERA (U.S. Navy 1986, Paine 1991) and adjacent plateau (USFWS 1986).

The blue-breasted quail was introduced to Guam from the Philippines in 1894 and is known to inhabit grassy areas (Seale 1901). Rock pigeons on Guam are believed to be the progeny of escaped carrier pigeons previously utilized by the U.S. Navy and Marine Corps (Jenkins 1983). It is unknown if blue-breasted quail or rock pigeons occur in the OPERA.

3.3.3.5 Mammals

Non-native mammals present on Guam that are likely detrimental to the native wildlife and vegetation include the Asiatic water buffalo or carabao (*Bubalus bubalis*), feral pigs (*Sus scrofa*), Philippine deer (*Cervus mariannus*), feral cats (*Felis catus*), feral dogs (*Canis familiaris*), house shrews (*Suncus murinus*), three species of rats (*Rattus diardi*, *R. exulans* and *R. norvegicus*), and house mice (*Mus musculus*) (Wiewel et al. 2009).

Carabao are not present in the OPERA. Orote Peninsula is not known for supporting Philippine deer (Wiles et al. 1999) and the precipitous cliff face of the OPERA is thought to prevent feral pigs and Philippine deer from utilizing the habitat (U.S. Navy 1986). Neither species were detected during surveys in the OPERA in 1986 (USFWS 1986) or on the Orote Peninsula in 2005 (Helber Hastert and Fee 2005).

Rodents, particularly rats, have been implicated in 40 to 60 percent of recorded bird and reptile extinctions (Wanless et al. 2007). Introduced rodents also contribute to the decline of native vegetation by consuming native seed or seedlings (DeMattia et al. 2004). Rodents are predators of nesting birds, land invertebrates, and plants, as well as a reservoir of disease and disperser of invasive plant seeds (Amori and Clout 2003). At high densities, musk shrews can negatively impact plant, invertebrate, and vertebrate species through competition or predation (Varnham and IUCN/SSG 2006). Feral cats have the ability to prey on reptiles and ground birds (Dickman 1996). On Guam, a barking dog in pursuit of a Philippine deer caused one Mariana fruit bat to flush from its roost (SWCA 2008b). Rats, feral cats, musk shrews, house mice, and feral dogs are presumably present on the OPERA, but information on exact numbers are lacking.

4.0 PERMITTED AND PROHIBITED USES IN THE ERA

Visitation to the OPERA has been permitted but not monitored or regulated. Almost all visits are to the MU and are passive recreation for the purposes of enjoying nature and activities such as subsistence fishing, SCUBA diving, snorkeling and swimming. Population growth and development of military facilities and support infrastructure in light of the transfer of military forces and their dependants from Japan to Guam, is expected to occur. An increase of Guam's base population of 178,000 by about 20 percent within the next 10 years will not only impact visitor use of the OPERA, but may create encroachment issues caused by facility expansion.

A visitor use survey is recommended to determine the current uses and impacts that currently occur in the OPERA, as well establish an appropriate daily use limits of each permitted activity.

The 1986 OPERA Management Plan (U.S. Navy 1986) outlined a set of permitted and prohibited uses for the OPERA. In light of the amount of time that has passed since the publication of the 1986 document, potential natural and anthropologic changes to the environment and the impending military buildup, these lists require modification and updating to reflect the current situation. The prohibited and permitted uses described below (also see Table 1) were developed by examining a broad range of activities and evaluating these activities in terms of whether they are compatible with the purpose of the ERA. Many were also included in the 1986 Management Plan (U.S. Navy 1986).

4.1 Permitted Activities

Access to the OPERA TU and MU is subject to closure at any time due to firing range and military training activities. All activities must be in accordance with standing naval security regulations which require users of the ERA to register with NBG Security prior to entry and upon leaving the OPERA. Recreational use is limited to the MU and is not permitted in the TU as a result of the rugged terrain and lack of safe trails. Following are revised permitted use policies for the OPERA.

- a) Swimming, snorkeling, and associated activities on a day-use basis for all accessible areas.
- b) SCUBA diving, on a day-use basis only.
- c) Use of boat or kayak within the MU, on a day use basis only.

- d) Scientific studies involving defined objectives and scopes of study. All non DoD entities require prior approval for the use of OPERA for scientific study purposes prior to the onset of any study. This includes procedure for the purposes of conducting routine, ongoing fish and wildlife surveys, natural and cultural resource surveys, and other routine scientific investigations and emergency actions which are deemed necessary for the survival of a species or for the preservation of the ERA. All agencies shall submit an annual schedule of proposed ERA visits to the NAVFACMAR EV. NAVFACMAR EV has final approval authority for all studies involving the ERA. The Study Approval Procedure and Study Approval Policy are provided in Appendix 6.

4.2 Prohibited Activities

- a) Jet skiing, water skiing and other motorized craft within the OPERA. However, authorized use of motorized craft will be permitted for the purposes of research, search and rescue and other emergency situations.
- b) All forms of fishing (i.e., recreational, commercial, traditional, or subsistence). Prohibited means include, but are not limited to: pole and line, net, spear, hooks, electrical, and chemical (natural extract and manufactured). Authorized exceptions will be permitted as defined in 4.1(d). Exclusion of fishing within the OPERA is also supported by the NBG Instruction on fishing expected to be approved in 2010.
- c) Removing, damaging, injuring, trapping, killing or possessing any form of or parts of any minerals, vegetation, wildlife or fish except as authorized in 4.1(d). This includes but is not limited to trees, wood, medicinal plants, rocks, soil, fish, crustaceans, and animals. Removing, damaging or otherwise altering any vegetation includes the creation and marking of trails.
- d) Feeding fish, except as authorized in 4.1(d).
- e) Shell collecting, except as authorized in 4.1(d).
- f) Damaging, destroying or harvesting for any purpose any coralline structure or fossil within the ERA. Harvesting of coral includes broken and dead pieces found on the beach and in the water.
- g) Introduction of any form of non-indigenous plant or animal life into the ERA except as authorized in 4.1(d).
- h) Operation of any land or air vehicle, or other mode of transportation within the ERA including buses, sedans, SUVs, off-road vehicles, All Terrain Vehicles (ATV), bicycles,

and gliders. Use of approved vehicle permitted by authorization user for emergency purposes only. Registration with Station Security upon entry and exit is required. Large vehicles (e.g., buses) are prohibited.

- i) Possession or use of any firearm, bow and arrow, or any other weapon, trap, snare, poison or any device designed to take, capture, or kill wildlife or to possess or use any explosives, poison or any other chemical to kill or capture fish or other marine life except as authorized in 4.1(d).
- j) Dogs, cats, or other animals not considered being part of the natural fauna of the ERA are not permitted within the ERA.
- k) Vendors prohibited within the ERA to sell or distribute food or drinks, or any other commercial product or venture.
- l) Start or maintain an open fire.
- m) Overnight camping, except if authorized in 4.1 (d).
- n) Dump, drain or leave any litter, toxic material, or other waste material in the ERA or to otherwise violate any federal or Guam law regarding land, water, or air pollution.
- o) Remove, alter, deface or otherwise damage historical or cultural sites or artifacts found within the ERA in accordance with the National Historic Preservation Act of 1966, as amended, as well as 32 CFR Part 229 and other historic preservation statutes and regulations.
- p) Remove, damage or disturb of any notice, sign, marker, fence, or structure delineating the boundary or located within the ERA.
- q) The use of an anchor for mooring boats. All boats or any other type of vessel within the MU must be moored to designated buoys.

Table 1. Summary table of permitted and prohibited activities in the Orote Peninsula ERA. Activities either listed as permitted or prohibited in the 1986 OPERA Management Plan (U.S. Navy 1986) are listed in the last column.

Activity	Description	Permitted in 1986 MP
Permitted Uses		
Swimming	Day-use basis only	X
Picnicking	Day-use basis only	X
Flora and Fauna Observation	Bird watching and similar activities in designated areas only. Day-use basis only	X
Snorkeling	Day-use basis only	X
SCUBA Diving	Day-use basis only	X
Boating	Day-use basis only	X
Kayaking	Day-use basis only	X
Research/Scientific Studies	By application via the Study Approval Procedure and Study Approval Policy (Appendix 6)	X
Prohibited Uses		
Jet Skiing/Water Skiing	Only for authorized emergency use	
Fishing	Fishing defined as the act of capturing, harvesting, or collecting fish, crustaceans, mollusks, echinoderms, and other marine organisms. All forms are fishing are prohibited (<i>including</i> traditional, recreational, and subsistence fishing). Exception includes authorized collection for scientific/mitigation purposes	X
Plant Harvesting/Collection	Unless authorized for scientific/mitigation purposes	
Hunting	Unless authorized for scientific/mitigation purposes	X
Terrestrial Crab Trapping	Unless authorized for scientific/mitigation purposes	
Feeding Fish/wildlife	Providing fish or any other wildlife with food, except as authorized for scientific purposes	
Shell Collecting	The collection of shells is prohibited, except as authorized for scientific purposes	X
Coral Collecting	Dead or living coralline structures and fossils.	

Activity	Description	Permitted in 1986 MP
	Exception includes authorized collection for scientific purposes	
Introducing Non-Native Plants or Animals	Unless authorized for mitigation	
Vehicle Use	Only for authorized emergency use. Buses are not allowed	
Possession/Use of Firearms	Including firearms, weapons, explosives, except for training or emergencies	
Domestic Animals	Dogs, cats, or other animals	
Commercial Activities	Selling food, drinks, souvenirs, etc.	
Open Fire	Fires are not to be started or maintained in the ERA	
Camping	Overnight camping is not permitted with in the ERA, unless authorized for scientific purposes	
Dumping and Littering	Including litter, toxic material, or other waste material	
Damaging Cultural Resources	Including removing, altering, defacing historical items, cultural sites or artifacts	
Disturb Signage or Fencing	Including removing, damaging or defacing	
Mooring with Anchor	Vessels are only permitted to moor at designated buoys	

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5.0 MANAGEMENT ISSUES - THREATS AND STRESSORS

Environments throughout the world are susceptible to various types of impacts, which typically influence the components therein. Degradation to coral reefs has been noted worldwide due to both anthropogenic and natural impacts (NOAA 2001). A 2.5 month survey of over 300 coral reefs in 31 countries and territories found few of these ecosystems remained unaffected by man (Hodson 1999).

Both the marine and the terrestrial units of the ERA can be adversely affected in numerous ways. Threats and stressors that are adversely affecting or have the potential to affect the marine and terrestrial environments at the OPERA are described below. Both threats that are directly and indirectly related to human activities, as well as threats from natural events, are included. A general summary of the relative impact of natural and human-related threats to the overall marine ecosystem in Guam is provided in Table 2.

Table 2. Extent of natural and human-related threats to the marine ecosystem in Guam. Based on the National Coral Reef Action Strategy (Goldberg et al. 2008).

Threat	Threat Level on Guam
Coastal development and runoff	High
Storm Activity	High
Coastal pollution	High
Tourism and Recreation	Medium
Fishing	Medium
Ships, boats, and groundings	Medium
Global warming and bleaching	Medium/Low
Trade in coral and live reef species	Low
Marine debris	Low
Alien species	Low
Security training activities	Low
Offshore oil and gas exploration	Low
Disease	Low

5.1 Human-Related Impacts

Many of the impacts to ecosystems on Guam originate from the island's residents, as well as visiting tourists. The marine environment within the OPERA provides different types of

recreation such as diving, snorkeling, fishing, and boating, which are popular activities for residents, tourists, and military personnel stationed on the island. However, when anthropogenic use of the area is high and unregulated, negative effects such as coral damage or overfishing can occur (Hodson 1999). Other non-recreational human activities, such as urban development, can also indirectly impact the OPERA through sedimentation, increased runoff, pollution etc. There is currently no documentation of the human usage of the marine environment at OPERA or its impacts. However, the popularity of this region is likely to increase in light of the planned military buildup of Guam to be completed by 2012 (JGPO 2009). It is important that potential impacts be address and measures to prevent and reduce impact be emplaced.

5.1.1 Fishing

Fishing is popular in Guam and has long been a part of the local Chamorro community's life (Puglise and Kelty 2007). However recent estimates demonstrate that Guam's fishery catches have declined over the last few decades (Burdick et al. 2008). Further, enforcement of existing laws and environmental regulations is a major problem on Guam, leaving the marine environment susceptible to overfishing (Richmond and Davis 2008). Although the exact impact of recreational and subsistence fishing is difficult to quantify since fisherman are not required to be licensed or report their catch, fishing is expected to have contributed to this decline (Burdick et al. 2008).

Likewise, the fishing activities at OPERA and catch composition from the area have not been documented. However, fish surveys from 1986, 2001 and 2008 have indicated that overfishing at OPERA is likely to be occurring (see section 3.2). Currently, fishing with in OPERA is not restricted, although it falls under Guam fishing laws and regulations which permits the use of most, but not all, fishing methods. SCUBA spear fishing and gill netting are still permissible in Guam, which is contrary to the prevailing conservation ethic (Richmond and Davis 2008). Hook and line fishing generally results in an under-represented assemblage of predatory fish. The absence of other species such as large herbivorous fish, which are not susceptible to hook and line fishing methods, are indications that other types of fishing - cast net (talaya), spear fishing with snorkel and SCUBA, gill net (tekken), surround net, trolling, drag net (chenchulu), hooks and gaffs, jigging, spincasting, and bottom fishing - are occurring in the OPERA. Whether or not fish are harvested for the aquarium trade is currently unknown.

Fishing can result in depletion of numbers and reproductive capacity of fish, and invertebrates. Changes in the abundance, composition, and demography of targeted reef fish populations can cause a wide range of trophic levels impacts. Typically fisherman target dominant high end food chain predators and visual surveys have indicated that large reef fish are conspicuously absent from many reefs (Paulay et al. 2001, Burdick et al. 2008). The removal of predatory

fishes may result in accelerated bioerosion of corals due to increased population levels of the invertebrate prey that these fishes formerly held in check. Furthermore, overfishing of herbivorous fishes can allow an overgrowth of coral reefs by algae (Burdick et al. 2008). Fortunately, the benthic assemblage of OPERA's reef is diverse and coral recruitment is still occurring (SWCA 2009). Good management practices coupled with enforcement of existing laws and environmental regulations, will likely reduce damage to OPERA reef community caused by fishing.

Certain fishing techniques, such as gill nets, cause physical damage to the reef environment. GDAWR regularly removes abandoned nets from nearshore reefs. Discarded fishing nets can cause coral mortality due to abrasion and smothering (Burdick et al. 2008). Fishing can also adversely affect endangered marine species as a result of by-catch. In Hawai'i, green sea turtles have been documented to suffer from hook-and-line and gillnet fishing gear-induced trauma (Chaloupka et al. 2008). It is not known if this is occurring at OPERA.

5.1.2 Recreational Diving and Snorkeling

Guam offers diving opportunities for people of all experience levels, and for those new to the sport, there are many dive companies that offer training. Diving and snorkeling are two popular recreational activities at the OPERA. Commercial ventures offer diving opportunities at many locations, particularly Blue Hole, the Wall, and Spanish Steps.

Damage to coral reef as a result of diving has been well documented worldwide (e.g., (Tabata 1992, Roupheal and Inglis 2001, Tratalos and Austin 2001). Divers and snorkelers can physically damage reef corals, invertebrates, and algae by standing on the reef, accidentally kicking, crushing and breaking coral with their fins, or stirring up silt that increases turbidity and suffocates coral (Burdick et al. 2008). Physical damage to coral species can be long lasting due to generally slow tissue regeneration (Davenport and Davenport 2006). In addition, many divers on Guam are either newly certified or inexperienced and may not fully understand their impact on the marine environment (Porter et al. 2005). Since OPERA is a popular area for snorkeling and diving, it is likely that at least some coral damage is occurring due to these activities. Recreational usage of OPERA's waters needs to be documented and diving/snorkeling related coral impacts should be recorded to determine the extent of the problem.

Some divers and snorkelers also feed fish in order to attract large schools. It is not known if this is occurring at OPERA. However, measures should be emplaced to ensure that this does not occur. Feeding fish can disrupt typical distribution and abundance patterns and alter normal reproductive output of marine species (Sweatman 1996, SPC Fisheries 2004). Fish-feeding may modify natural feeding cycles of fish (Roberts 2006) and have negative effects on

prey populations by minimizing feeding on algae (Hollier 2009). Feeding large fish can attract predators that scare off smaller fish, thereby reducing local biodiversity (Davenport and Davenport 2006). This activity has been shown to interfere with natural instincts and behaviors essential for fish survival (Roberts 2006, Burdick et al. 2008). Studies have shown that feeding alters fish behavior towards humans. Fish can become conditioned to associate humans with food, often causing them to become aggressive to humans and inducing attacks (SPC Fisheries 2004, Roberts 2006, Hollier 2009). Alternatively, feeding decreases wariness of fish to humans, rendering them more susceptible to capture.

Although the use of sunscreen by divers and snorkelers seems trivial, it can have an impact on marine life at the OPERA. Certain chemicals contained in commercial sunscreens have the potential to adversely impact coral reefs by promoting viral infections of endosymbiotic zooxanthellae, which are essential for the survival of coral species. The chemical compounds in sunscreen can cause dormant viruses present in zooxanthellae to continually replicate until the zooxanthellae are expelled and the coral is bleached (Buddemeier et al. 2004, Danovaro et al. 2008). Sunscreens may also decrease the penetration of UV radiation, impacting marine organisms that depend on light for various functions (Eichenseher 2006, Blitz and Norton 2008). The extent and specificity of impact of sunscreen on the coral reef environment at the OPERA has not been studied and remains unknown.

5.1.3 Motorized Personal Watercraft Use

Motor-boating and jet skiing cause noise pollution, leak fuel, and can also cause damage to sea grass and corals (Porter et al. 2005, Burdick et al. 2008). Some negative impacts caused by marine vehicles are unintentional, such as vessel groundings as a result of typhoons or navigation error (Burdick et al. 2008). During the process of removing grounded vessels, ballast water can be discharged, facilitating the introduction of non-native species (NOAA 2001). The most serious impact of motorized personal watercraft is probably the coral damage that results from anchoring despite the presence of mooring buoys located at OPERA. Incidental observations of anchor damage have been recorded at OPERA, but have not quantified (SWCA 2009). Vessels in the ERA will only permitted to moor at designated buoys. In addition, discarded food, plastics, and other items that are discarded into the ocean from boats at or adjacent to the OPERA can be ingested or entangle wildlife within the marine unit of the reserve.

Recreational and commercial boats also can create point source pollution in the offshore waters. Point-source pollution is pollution from any confined or discrete conveyance such as pipes, ditches, channels, wells, or vessels. The amount of point source pollution from these sources is unknown and likely varies during the year depending on the number of boats.

5.1.4 Hunting and Trapping

Since foot access to the OPERA is limited and introduced Philippine deer, feral pigs, and black francolins are relatively uncommon, illegal hunting is not likely to be a major issue on the ERA. If hunting or trapping on the periphery of the ERA were to occur, litter would be a concern. Discarded food, plastics, shot gun shells and other items can lead to the death of terrestrial wildlife through ingestion or becoming entangled. Debris not properly disposed of can also be carried to the marine environment during storms or floods.

Although baiting coconut crabs occurs in the area immediately adjacent the OPERA (e.g., Figure 17), the collection of coconut crabs is not permitted in the OPERA.



Figure 17. An example of a coconut crab trap used on the Orote Peninsula. Harvesting of coconut crabs may also be occurring in the Orote Peninsula Ecological Reserve Area. Photo: SWCA.

5.1.5 Non-Indigenous Species

Remote island ecosystems are typically vulnerable to the establishment of non-native species (Loope and Mueller-Dombois 1989, Clements and Daehler 2007). Invasive species impact island ecosystems in a variety of ways and are recognized as a major threat to native ecosystems and to the survival of threatened and endangered species (Pimental 2005). Marine invasive species can be introduced to an environment through marine debris, ship groundings, ballast water, scientific research, and poor management strategies (NOAA 2001).

Although there is currently almost no land component to OPERA, introduced or invasive species occupying adjacent areas can impact the reserve. Feral pigs and Philippine deer uproot and browse on vegetation, prohibiting growth of native seedlings. Ungulates and rodents are known to cause erosion, strip vegetation cover and facilitate invasive plant encroachment. Introduced rodents also contribute to the decline of native vegetation by consuming native seed or seedlings (DeMattia et al. 2004), predated on nesting birds and land invertebrates, and spreading disease (Amori and Clout 2003). Other non-native mammals (cats and dogs) prey on reptiles and ground-nesting birds (Dickman 1996) and may cause Mariana frit bats to flush (SWCA 2008b). Invasive herpetofauna displace native species and provide food for other

introduced species (Christy et al. 2007). Ants, mosquitoes, and other invertebrates also threaten the resources at the OPERA. Numerous invasive plants have rapidly established in disturbed areas of the reserve, displacing native flora.

A colony of Atlantic barnacle (*Chthamalus proteus*) was recorded from the OPERA in early 2000's (Paulay et al. 2002, Paulay and Ross 2003). No invasive species were reported in the marine environment in recent 2008 surveys (SWCA 2009), although Atlantic barnacles were not specifically targeted. Other invasive such as Japanese seastar (*Asterias amurensis*), zebra mussels (*Dreissena polymorpha*) and kelp (*Undaria pinnatifida*) may easily find their way to Guam as hitchhikers on the ever increasing maritime transportation network and establish on the OPERA, particularly considering the short distance between Guam's military and commercial ports and the OPERA.

5.1.6 Scientific Research

Limited scientific research has occurred in the OPERA since its creation. Research that has occurred includes marine monitoring (e.g., USFWS 1986, Paulay et al. 2001, SWCA 2009) and terrestrial flora and fauna inventories (e.g., USFWS 1986, SWCA 2010, SWCA unpublished data). Although scientific research is essential to properly manage a reserve, unregulated or inappropriate research has the potential to negatively impact the natural environment in a number of ways. Over-collection of rare species; transect cutting that opens up pathways for ungulates, invasive plant establishment and erosion; habitat enhancement/revegetation utilizing inappropriate or harmful species, or placement of semi-permanent objects in or on fragile substrates are examples of inadvertent but detrimental impacts to the ecosystem. Researchers conducting studies in areas of low human-impact can also serve as vectors for invasive species when preventive measures are not observed (D. Gulko, HDAR, personal communication).

The impacts of scientific collection and research at OPERA are regulated by a permitting process required by OPNAVINST 5090.1c. The study approval procedure and policy for OPERA research is outlined in the 1986 OPERA Management Plan (U.S. Navy 1986) and amended in Appendix 6. In addition to Navy requirements, scientific research involving any Federal endangered or threatened species shall require a permit from the USFWS and GDAWR if Guam endangered or threatened species are involved. Applications for archaeological research must be in accordance with 36 CFR Part 229 and other Federal and Guam historic preservation statutes and regulations.

5.1.7 Oil Spills and Hazardous Waste

Oil spills and hazardous waste can have extremely negative effects on marine and terrestrial ecosystems. Guam's coral reefs (including the OPERA) are particularly vulnerable to oil spills. The Guam EPA administers permits to regulate discharges into the marine environment; several active permits allow discharges that may contain minor amounts of oil or other toxic materials (Burdick et al. 2008). However, according to Burdick et al. (2008), there are currently no oil or gas prospects identified near Guam, which decreases the potential for spills.

Oil spills have the potential to destroy coral, depending on the species, life stage, and magnitude of exposure (NOAA 2001, 2009). According to NOAA, there are three primary modes by which coral reefs are exposed to oil spills: 1) direct oil contact, which can happen when surface oil is deposited on intertidal corals; 2) oil entering the water column (happens during rough seas and lighter, more soluble products are involved) exposes coral to harmful oil constituents; and 3) subsurface oiling coral is potentially smothered due to heavy oils weathering, or mixing with sediment material, and increase in density to the point they sink. The first type of exposure, direct oil contact, is likely to have the most significant impact (NOAA 2001).

Oil spills can impact coral reefs in a variety of ways and over varying time frames. NOAA (2001) lists the following responses shown by corals exposed to oil and oil fractions: tissue death, impaired feeding response, impaired polyp retraction, increased mucus production, change in calcification rate, gonad damage, premature extrusion of planulae, larval death, impaired larval settlement, expulsion of zooxanthellae, change in zooxanthellae primary production, and muscle atrophy. In addition to coral, other species in the coral reef community, such as associated fish, invertebrates, and plants, can also be adversely affected by oil spills through direct contact or bioaccumulation in coral tissues (NOAA 2001).

Hazardous waste (i.e. batteries, pesticides, gasoline, paint, motor oil, and products contain mercury) from domestic or industrial sources can also be discharged into the marine environment through street gutters and storm drains or direct dumping. These toxic pollutants have been shown to prevent coral gametes fecundation, cause coral bleaching, and inhibit photosynthesis. The impact of hazardous waste on coral and coral reef communities has not been as intensively investigated as oil spills (Ramade and Roche 2006). Hazardous waste is a known problem on Guam due to illegal dumping. Areas have become illegal dumping grounds for all types of waste including abandoned vehicles, batteries, tires, and household trash.

5.1.7.1 Contaminants at OPERA and North Agat Bay

The Orote Landfill, used from 1944 to 1969 for the disposal of industrial, commercial, and residential waste, is located within the Apra Harbor Naval Complex on Guam. Waste metals

and related materials were dumped along the south shore of Orote Peninsula at the Orote Landfill in 1986, prior to its remediation (USFWS 1986). Rusted and congealed iron and steel scrap and waste concrete was found along shore and within the shallow waters offshore (Figure 18).

In 1997, the Comprehensive Long-Term Environmental Action Navy program (CLEAN) confirmed the presence of contaminated materials within and adjacent to the landfill as the seaward edge of the landfill had been eroding since 1990 allowing waste to accumulate on the beach. Concern was raised over the potential introduction of contaminants into the OPERA. The Navy subsequently initiated a project to: 1) prevent future erosion of landfill materials to the beach and marine environment; and 2) prevent human and ecological receptors from coming in contact with the landfill surface soil or waste materials (Boudreau et al. 2002).



Figure 18. Shoreline adjacent to Orote Landfill in 1986 illustrating congealed iron and steel scrap and concrete waste. Photo: J. Ford, USFWS.

By April 2000, the Navy had constructed a seawall consisting of ten toe-wall sections, several layers of aggregate, filter fabric, high density polyethylene liner, and concrete armoring at the Orote Landfill site to protect it from erosion by the sea. Following the removal of the metallic waste material from the debris field, Guam Environmental Protection Agency (GEPA) divers discovered additional pockets of debris scattered across the reef pavement in approximately ten feet of water, which were later removed.

In September 2001, the Navy, in conjunction with the GEPA and the Guam Department of Public Health and Social Services (Guam DPHSS) issued a Seafood Advisory to the residents of

Guam that seafood harvested from Agat Bay between Orote Point and Nimitz Beach may not be safe to eat. The Advisory cautioned that residents against eating any seafood harvested from these areas until further studies are complete. The environmental studies that the Seafood Advisory is based on involved a limited number of whole fish samples. The fish sampled were Sergeant Major fish and Hexagon Grouper (Gadao) fish taken in June of 2001. Fish tissue samples were found to have elevated concentrations of polychlorinated biphenyls, or PCBs, and other chemicals rendering unfit for human consumption. The Navy subsequently posted warning signs along the Orote beaches and implemented an island-wide public outreach program to advise islanders of the risks involved (Navy Environmental Health Center, 2002; <http://www.atsdr.cdc.gov/news/displaynews.asp?PRid=2124>).

5.1.8 Sedimentation

Discharge of sediments into marine ecosystems is one of the most significant threats to Guam's reef community (Burdick et al. 2008). Rainstorms and wind can carry sediments from the steep upland areas to the marine environment. Suspended sediment loads in the ocean, as a result of eroding soil, can smother corals, decreasing light penetration and inhibiting photosynthesis. Eroded soil can bury coral and other substrates, which abrades coral tissue. In turn, this can lead to a reduction in recruitment of a variety of species due to loss of habitat and spawning sites (Burdick et al. 2008). Sediment from run-off can also block gills and filter feeder apparatus. Furthermore, corals can be forced to expend valuable energy removing sediment, further inhibiting survival (stress response). In addition to corals, other organisms in the marine ecosystem (sedentary aquatic plants, animals, and their eggs) are affected by smothered eroded sediments. All of these factors can lead to altered species composition or lower species diversification, shallower depth distribution limits, and a loss of biodiversity in coastal marine ecosystems. On Guam, accelerated rates of sedimentation are attributed to illegally set wildfires, clearing and grading of forested land, inappropriate road construction methods, recreational off-road vehicle use, and grazing by feral ungulates (Burdick et al. 2008).

With increased urbanizations, the risk of sediment damage to OPERA may likely increase. Development of areas adjacent to the OPERA is slated to begin in 2010 (JGPO 2009); if water runoff, drainage and erosion are not properly addressed, the impact to the OPERA would be severe.

5.1.9 Coastal Development and Non-Point Source Runoff

Several coastal developments associated with the anticipated military buildup are planned in the vicinity of the OPERA. These developments have the potential to negatively impact water quality within the OPERA by increasing the amount of non-point source pollution. Non-point

source pollution is “water pollution that comes from many diffuse sources rather than from a specific point, such as an outfall pipe; often the result of unintended human activities” (USEPA; <http://www.epa.gov/nps/success/glossary.htm>). Pollutants (e.g. fertilizers, herbicides, insecticides, oil, grease, sediment, and pathogens) are carried by rainwater on the surface or through the ground to the coastal zone. Non-point source pollution is positively related to the amount of impervious surfaces in an area (e.g. roads, parking lots, sidewalks, and roofs). Impervious surfaces prevent water and pollutants from passing through the ground and percolating into the soil (Schueler 1994). Again, the planned expansion of military facilities in the vicinity of OPERA will likely increase the risk of non-point source pollution.

5.1.10 Global Climate Change

While the concept of global warming is widely accepted, the exact source of this phenomenon (natural or human induced), remains a debate. Emerging consensus contends that increasing quantities of greenhouse gases (GHGs) in the atmosphere, especially carbon dioxide (CO₂), are impacting climate and may be the dominant force driving recent warming trends. Greenhouse gases are largely derived from human activities, primarily fossil fuel use (Solomon et al. 2007). Global climate change has the potential to impact a wide range of ecological conditions. Projected impacts that may have a significant effect on the OPERA are coral bleaching, oceanic chemical composition change, sea level rise, water resources, and ecological responses. Disruption to the El Niño / La Niña oscillation is likely to increase the frequency and/or intensity of typhoons in the region.

5.1.10.1 Coral Bleaching

Coral bleaching, the expulsion of symbiotic zooxanthellae from coral polyps and subsequent loss of photosynthetic pigments is the result of both natural and anthropogenic stresses. Although corals may pale in response to seasonal increases in sea surface temperature, there has been a higher frequency of large-scale bleaching events since the 1980s (Nicholls et al. 2007). The most severe global bleaching event ever recorded occurred in 1997-98 when over 50 countries showed signs of bleaching (Grimsditch and Salm 2005). Many species of coral currently exist in the upper limits of their specific temperature range; thus, an increase in average sea surface temperatures (even by 1.8 or 3.6°F) over a sustained period has been shown to cause mass bleaching, especially in shallow water habitats (Grimsditch and Salm 2005). Other variables contributing to bleaching episodes include extended periods of high temperatures, freshwater flooding, ultraviolet radiation, precipitation changes, salinity changes, light changes, sedimentation, and marine pollution.

Large-scale coral bleaching events are not common on Guam (Porter et al. 2005). Only two large-scale bleaching events have been recorded on Guam and none of the reported cases have been accompanied by mass mortality. The bleaching event observed in 1994, which is

not believed to be caused by increased seawater temperatures, affected roughly 68 percent of surveyed taxa. Minimal mortality was observed and inter-species response to bleaching was highly variable (Paulay and Benayahu 1999). Similarly, a 1996 bleaching event resulted in approximately half of the *Acropora* species showing moderate to heavy bleaching. Little mortality was seen during this event.

Preliminary information on more recent bleaching events has been documented. In June 2004, an event was recorded in Pago Bay, possibly due to the freshwater influx from Tropical Storm Tingting (Porter et al. 2005). On July 21, 2007, during a survey of the reef flat in the area of the Guam National Wildlife Refuge Ritidian Unit that is closed to visitor use, coral bleaching was noticed. Further surveys to determine the extent of the bleaching have been conducted, but additional research is pending (C. Bandy, USFWS, personal communication). Scientists at the University of Guam Marine Laboratory have reported annual cases of coral bleaching on Guam that did not result in mass mortality; however, the threat of climate change-related bleaching events have increased due to rapid development and deforestation that could intensify atmospheric and sea surface temperature rises (Prasad and Manner 1994, Porter et al. 2005), making coral communities in the OPERA vulnerable.

5.1.10.2 Changes in Seawater Chemistry

A higher concentration of CO₂ in the atmosphere means that a greater amount of CO₂ is dissolved in the surface ocean. Higher dissolved CO₂ increases ocean acidity and the concentration of carbonic acid and bicarbonate ions, while decreasing the concentration of carbonate ions, which corals and other marine organisms use to build their skeletons. Many marine organisms use calcium (Ca²⁺) and carbonate (CO₃²⁻) ions from seawater to secrete CaCO₃ skeletons (Buddemeier et al. 2004). A lowered calcification rate means calcifying organisms (corals) may grow skeletons at a slower rate, lower density, and/or lessened strength. Thus, changes in global seawater chemistry reduce the ability of corals to compete for space and increase their susceptibility to breakage (Grimsditch and Salm 2005).

5.1.10.3 Sea Level Rise

Climate change induced thermal expansion of the sea is the main factor contributing to global sea level rise (Solomon et al. 2007). Predicted sea level rises as a result of climate change will increase the volume of water that covers reef habitats, causing some coral species to “drown” due to decreased light availability. It is expected, however, that growth rates of most coral reefs will match predicted sea level rises (Buddemeier et al. 2004). Cliff erosion rates and patterns at the OPERA have the potential to be influenced by changes in sea level. As the ocean rises, wave activity amplifies erosion. Cliffs formed in softer lithologies are more likely to retreat (Nicholls et al. 2007). Accelerated erosion and enhanced sedimentation could further smother and stress corals (Porter et al. 2005) and create deeper undercuts that could break

off and further damage corals.

5.1.10.4 Water Resources

Changes to freshwater resources as a result of variations in precipitation, evaporation, and ENSO patterns are variable depending on location and therefore difficult to predict. However, decreased salinity in both the mid- and high latitude waters suggest that precipitation and evaporation rates are changing over the oceans (Solomon et al. 2007). Recent studies demonstrate that precipitation amounts are “very likely” to increase in the tropical Pacific and high latitude areas, while precipitation is “likely” to decrease in most subtropical regions (Solomon et al. 2007). Conversely, more intense and prolonged droughts have been observed in the tropics and subtropics since the 1970s (Solomon et al. 2007). Changes in precipitation could adversely impact the terrestrial flora at OPERA but because of its size, impacts will likely be minimal.

5.1.10.5 Ecological Responses

Evidence suggests that recent climatic changes have affected a broad range of individual species and populations in both the marine and terrestrial environment. Individuals and populations have responded by altering (1) range and distribution, (2) phenology (timing of seasonal activities) and physiology, (3) community composition and interaction, and (4) ecosystem structure and dynamics (Walther et al. 2002).

Plant and animal range boundaries are often determined by tolerances to certain temperatures, precipitation amounts, and other climatic factors. Changes in these factors can produce range shifts, or changes in the geographical distribution of species. Globally, climate shifts have already caused species to migrate to new areas, particularly towards higher altitudes (Dow and Downing 2006, Parmesan and Matthews 2006).

The reproductive physiology and population dynamics of insects, amphibians, reptiles, seabirds, and waterbirds are highly influenced by environmental conditions such as temperature and humidity (Duffy 1993, Baker et al. 2006). Global climate change can alter species gender ratios (Baker et al. 2006) or change the timing of biological events, such as breeding and flower blooming (Parmesan and Matthews 2006).

Changes in climatic conditions can alter community composition and competition. Increases in nitrogen availability, CO₂ levels, and temperatures can impact plant photosynthetic rates, alter plant species composition, decrease nutrient levels, lower herbivore weights (Vitousek 1994, Ehleringer et al. 2002) and increase the dispersal ability of non-native flora or fauna (Walther et al. 2002). In the marine environment, variable atmospheric circulation has been shown to influence fish recruitment (Walther et al. 2002). The responses of individual plants and

animals will also have substantial implications for ecosystem composition, structure, and dynamics.

5.2 Natural Disasters

5.2.1 Tsunamis

Historically, seismic ocean waves have been incorrectly termed "tidal waves," but these events are not at all related to tides. Seismic ocean waves are now commonly referred to as tsunamis (Japanese for "harbor waves"), and are traditionally defined as a series of ocean waves with very long wavelengths that can travel great distances. Tsunamis are usually generated by an underwater earthquake or landslide, but are occasionally caused by volcanic eruptions or major landslides into the ocean (Morrissey 2005). Tsunamis can have catastrophic effects, including massive infrastructure destruction and human mortality (UNEP 2006).

The severity of the damage depends on the magnitude of the event buffered by the resilience of the society and the environment impacted (Kohl et al. 2005). Tsunamis have the potential to adversely impact the OPERA MU. Coral reefs are particularly susceptible to damage because severe wave action can break, overturn, crush, or dislodge corals (Scheffer et al. 2009). Sedimentation produced by tsunamis can smother coral colonies and large vegetation can cause damage as it washes across the reef (Foster et al. 2006). Due to the height of the sea cliffs of the OPERA, damage to the TU is likely to be minimal. However, wave action on these cliffs may accelerate erosion and cause chunks of the cliff to break off.

5.2.2 Storms and Typhoons

Guam lies in the western Pacific typhoon trough near the center of the cyclonic-storm basin (Kerr 2000); thus, Guam often experiences typhoons [tropical storms with winds between 75 and 150 mph (120 and 241 km/h)] and super typhoons [tropical storms with winds greater than 150 mph (241 km/h)] (USFWS and USAF 2001). Nearly 200 tropical storms and typhoons passed near the island between 1950 and 2000 (Guard et al. 1999). Four severe storms have hit Guam over the past ten years, causing extreme waves and 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 storms may occur throughout the year, the probability increases from July through September (Prasad and Manner 1994).

Typhoons bring violent winds and heavy rain and often inundate low-lying coastal areas (USFWS 1992). Coral and marine communities in the OPERA are susceptible to damage by typhoons. Extreme wave action associated with storms and typhoons can physically damage the reef, creating coral debris and fragments (Scheffer et al. 2009). Storm surge, wave

inundation, and heavy rains can also down corals by increasing sea levels and bring sediments and other debris to the marine ecosystem (Burdick et al. 2008). Unlike tsunamis, the continual wave action results in abrasion of corals or coral fragments (Scheffer et al. 2009). Recovery from storms and typhoons can be suppressed by other stressors on the reef, such as bleaching, coastal development, or ship groundings (NOAA 2001).

The flora in the terrestrial unit of OPERA is also at risk from the high winds produced by typhoons. The high winds produced by typhoons can knock down plants and snap branches. Typhoons can damage and destroy healthy trees, including rare and endangered species. At least two endangered *Serianthes nelsonii* trees on Guam have ultimately been killed by typhoons (Northwest Field, Typhoon Omar 1992 and Typhoon Russ 1990). Marine communities in the OPERA are also susceptible to damage by typhoons; these communities at Ritidian Point were stated to be vulnerable to typhoons by Donaldson and Rongo (2006). Even moderate storms can cause substantial wind-driven salt spray onshore that can be detrimental to exposed vegetation and soil. Salt spray can suppress plant growth by causing water stress (Goldstein et al. 1996), disrupting plant physiology (Morris 1992), and inhibiting the uptake of nutrients such as potassium and calcium (Munns 1993). Salt spray has also been found to be an important ecological factor influencing species distributions in coastal environments (Griffiths and Orians 2004).

On the other hand, typhoons can have positive impacts on the coral reefs and terrestrial vegetation on Guam. Coral reefs along protected areas of Guam's coast are not usually substantially affected by heavy wave action generated by typhoons because they are constantly conditioned to withstand such wave action (Birkeland 1997). There is also evidence that frequent typhoons can offer some protection against coral bleaching in Guam's lagoons and shallow reef flats because the heavy wave action can sweep out the warm, shallow water and replace it with deeper, cooler oceanic waters.

In limestone forest, winds have blown down clusters of trees, opening gaps in the forest canopy where understory vegetation proliferate (Quinata 1994). Typhoons can enhance forest regeneration by inhibiting shade tolerant invasive plants and increasing vegetative reproduction (Craig 1992). Regenerating typhoon-modified limestone forest is composed of dense understory vegetation, including ferns, herbaceous vegetation, and small shrubby species (Quinata 1994), which support native bird and animal species.

5.2.3 Earthquakes

Guam, located in close proximity to the Mariana Trench, is prone to frequent earthquakes (Gvirtzman and Stern 2004). On average, Guam experiences approximately two earthquakes (magnitude 5.0 and greater) per year (USGS 2008). One of the strongest earthquakes on

Guam in recent history was on 8 August 1993, when an 8.1 magnitude disturbance shook the island for at least 30 seconds (EERI 1993).

Earthquakes can result in considerable structural damage to man-made structures, and damage to terrestrial and marine ecosystems. Coral reefs and sloping coastal forest communities are particularly vulnerable to strong earthquake activity, as observed following the two earthquakes in the waters offshore of Aceh, Indonesia in 2004 and 2005 (Foster et al. 2006). Marine ecosystem damage after these powerful seismic events include uplifted coral reefs, shattered beds of coral, and overturned coral colonies (Foster et al. 2006).

On land, earthquakes can trigger slope failures (landslides) and subsequent removal of vegetation. Landslides and denuded slopes can affect soil characteristics and result in increased erosion, sediment transport, and discharge during rainy periods (Foster et al. 2006). The impacts of sedimentation on the reef are described in Section 5.1.9. Landslides can also disrupt soil seed banks and may favor the establishment of non-native species (Restrepo and Vitousek 2001). Terrestrial and marine ecosystems in the OPERA are susceptible to the negative impacts caused by future significant earthquakes on Guam.

5.2.4 Volcanoes

There are presently nine active volcanic islands in the Mariana archipelago (Nakada et al. 2005). Anatahan, the closest of these volcanic islands to Guam (200 mi or 320 km north), exhibited its first historical eruption on 10 May 2003 (de Moor et al. 2005). Threats to terrestrial and marine communities on Guam (including the OPERA) in the form of ash fall may be a possibility if atypical wind direction occurs during future eruptions. On 23-24 May 2005, wind direction changed from easterly to northerly due to the approach of Typhoon Chan-hom, resulting in reports of ash on Guam (de Moor et al. 2005). Volcano activity is not likely to be a major threat to the OPERA.

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6.0 MANAGEMENT GOALS

The overall goal for NBG in management of the OPERA is to ensure that its natural resources are protected from physical, biological, and human induced threats and stressors that result in adverse changes to the ecological characteristics. These include flora collection (e.g., Ifit wood, medicinal plants); fauna trapping (e.g., coconut crab, coral and shells) unregulated diving, boating and jet skiing; anchor damage to corals; and a host of public safety issues including trash, sanitation, and access.

The approach of the existing 1986 OPERA Management Plan consisted of relatively passive management, primarily highlighting the protection of the ERA from overuse and intrusion. The Management Actions of the 1986 Management Plan focused upon six main areas:

1. Responsibilities
2. Surveys
3. Boundary Identification
4. Control Measures
5. Habitat
6. Maintenance

However, the only form of substantial natural resources protection outlined in the 1986 Management Plan is habitat protection. The 1986 OPERA Management Plan states: "The primary purpose of an ERA is to preserve an identified physical or biological unit. The entire focus of this plan will be to protect the OPERA ecological community from change. No actions will be taken or allowed which have a detrimental effect on either the terrestrial or marine habitat." Protection appears to be provided in paper form, but specific details on exact management actions are lacking.

Since the 1986 plan, interest in the reserves' use for the protection of endangered species, mitigation requirements, urban encroachment and public relations interests have increased. It is assumed that the popularity of the OPERA may increase in the near future considering the planned military buildup of the island. Thus, in order to preserve the goal of the ERA, a more active management approach will be adopted. Management objectives, strategies, and tasks designed to reach the ERA goal are discussed below.

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7.0 MANAGEMENT OBJECTIVES, STRATEGIES, AND PROPOSED TASKS

The following management objectives are recommended to assist in achieving the goals of the OPERA GMP. These recommended management objectives apply to both the terrestrial and marine units of the OPERA and were developed given the physical and land use settings of the reserve, as well as the known condition of the OPERA.

7.1 Objective 1: Control and Eradicate Invasive Species

Recommended control and eradication measures for exotic species that are found to be negatively impacting existing habitats or species within the TU and MU of the OPERA are outlined below. For the purpose of management, control is the reduction of a species in a given area, usually through prevention of immigration, creation of unsuitable habitat conditions or eradication. Eradication is the physical removal (death) of individuals from the area.

7.1.1 Control and Eradicate Invasive Flora and Invertebrates

Eradication or at least control of invasive flora and invertebrate species within the OPERA is critical to permitting the growth of native flora species. If found to occur, invasive flora such as chain-of-love, tangantangan, mile-a-minute, jack in the bush, giant sensitive plant, Indian snakeweed, burr marigold, African tulip tree, and small-leaved vitex should be controlled and/or eradicated. Although removal methods are highly dependent on species, control of invasive flora should generally involve both chemical and manual removal techniques. Invasive invertebrates detected in the OPERA should also be considered for control and/or eradication. These include, but are not limited to, cycad scale, scarab beetles, *Erythrina* gall wasp, and coconut rhinoceros beetle.

Control and eradication of invasive plants and invertebrates should include on-going monitoring and maintenance to assure low densities of harmful species. If an invasive species is totally removed from an area, follow-up monitoring should continue for a minimum of five years for verification that removal was successful. Monitoring should also include documentation of any new invasives to the ERA and the subsequent incorporation of those species into on-going management strategies.

Target species and eradication methods shall be determined by NAVFACMAR EV in cooperation with experts in the relevant field.

7.1.2 Implementation of Brown Treesnake Control

As a result of the detrimental impacts caused by the BTS, some BTS control in the TU should be considered. The effectiveness of aerial drops of acetaminophen-laced neonatal mice known to be toxic to BTS is currently undergoing testing for use in BTS removal. Although abundance of BTS in the OPERA is currently not known, reduction in the number of BTS within the reserve could increase the chance of successful nesting by birds and potentially increase abundance of native reptiles that inhabit the OPERA.

7.1.3 Adopt Adaptive Management Strategy for the Control of Crown of Thorns Starfish, and Other Harmful Marine Species

Although the crown of thorns starfish is native to Guam, colonies can experience severe outbreaks that result in long-term damage to Guam's coral reefs. Controlling the crown of thorns starfish in the OPERA MU during periods when large concentrations of individuals appear on the reef is highly recommended. A precedent for periodic removal of crown of thorns has been set by GDAWR by the issuance of a permit to remove the starfish from their Tumon Bay Marine Preserve Area. Such control will maintain growth and recruitment of many of the host stony coral species that may otherwise decrease in abundance. Management would include on-going periodic removal of individuals from the MU as a means of lowering the potential for an outbreak. Removal effort would be increased if it became apparent that numbers of crown of thorns were increasing. In the event of an outbreak, a previously prepared plan of action, in the form of an adaptive management plan, should be instigated. An adaptive management strategy will detail how to assess and respond to the immediate situation and the appropriate agencies to consult (such as NOAA, NAVFAC, USFWS, GDAWR and Guam Coastal Management Program). Appropriate management actions can be adapted to the present situation but must be based on a sound understanding of current scientific and local knowledge and recommendations proffered by the stakeholder agencies. Recommendations would include courses of action from no intervention, to action strategies, the identification of funding sources, and post-action follow-up measures.

If invasive invertebrates such as the Atlantic barnacle are found in the OPERA, control and/or eradication must be considered. As with a crown of thorns starfish outbreak, an adaptive management plan or strategy would be activated.

7.1.4 Develop an Early Detection and Rapid Response Plan for Invasive Species

Typically, there is a "lag period" between when an incipient organism is introduced into an environment and when they begin to have dramatically harmful effects. An early detection and rapid response plan is designed to capitalize on this time period and respond in a timely manner to improve the effectiveness and reduce the cost of ongoing control (FICM-NEW 2003,

WA-ANSC 2005). Components of the plan include the creation and development of:

1. A list of known invasive and deleterious species on or likely to arrive Guam that could adversely affect the OPERA;
2. An outreach and monitoring program to improve early detection of each species on the list of known invasive and deleterious species so that new introductions can be detected in a timely manner;
3. A centralized reporting system and set of procedures for reporting suspicious species and confirming reported sightings; and
4. Appropriate actions for situations requiring response.

An early detection or rapid response plan will reflect the recommendations provided within the Micronesia Biosecurity Plan and will be coordinated with the Micronesia Regional Invasive Species Council (RISC).

7.1.5 Establish Protocols for Minimizing/Preventing Non-native Species Invasions into the ERA

Develop an ERA specific plan for minimizing introductions or transfers of invasive species by researchers and other users of the ERA. The plan should be based on RISC recommendations, and protocols outlined in the Guam Integrated Natural Resources Management Plan (INRMP) (2011) and the Micronesia Biosecurity Plan (2010).

7.2 Objective 2: Prevent Harvest of Coconut Crabs

Coconut crabs are an important consumptive and cultural resource to the indigenous people of Guam. Harvesting of coconut crabs is allowed by GovGuam during a set annual permitted take season. However, these crabs are often collected outside the legal harvesting season and surveys in the Marianas have indicated that over harvesting is occurring (Kessler 2006, Vogt 2008). A study on coconut crabs within the HERA found that only 11 percent of crabs were of legal harvestable size and that the population was highly skewed towards young, small crabs (USFWS 2001). Harvesting coconut crabs is not permitted in the ERAs or NBG. Whether trapping is occurring within the OPERA is unknown, although traps have commonly been seen in areas adjacent to the reserve (SWCA personal observation 2010). The ban on harvesting coconut crabs within the OPERA should be enforced through monitoring of the reserve and the regular removal of crab traps. Coconut crabs in the OPERA can also be surveyed every six months to assess demographical changes over time.

7.3 Objective 3: Maintain and Restore Valuable Habitat

7.3.1 Prohibit All Forms of Fishing

Inshore and offshore fishing has been a tradition and a tourist attraction on Guam for many years. Fishing has been divided into activities. Inshore fishing typically involves casting, netting, and spearfishing, and offshore fishing is usually by boats that troll and bottomfish (GDAWR 2000-2008a). Due to damages caused to the coral reefs and overfishing, restrictions have been implemented, which have amended Guam's fishing regulations. On May 16, 1997, Public Law 24-21 created five marine preserves: the Pati Point Preserve, the Tumon Bay Preserve, the Piti Bomb Holes Preserve, the Sasa Bay Preserve, and the Achang Reef Flat Preserve (GDAWR 2000-2008b). The reef tourism industry requires healthy coral reef ecosystems, but fishing is generally considered to be damaging to them and the biodiversity that makes them attractive to tourists (Craig 2008).

Since the focus of the 1986 and this OPERA MP is to protect the OPERA ecological community from change and to allow no actions which have a detrimental effect to take place on either the terrestrial or marine habitat, all forms of fishing and shell collecting should be banned within the OPERA, as they are within Sasa Bay Marine Preserve to OPERA. The prohibition of fishing within the OPERA is expected to become Navy policy after the approval of a NBG Instruction expected to be released in 2010.

7.3.2 Implement Ecological Restoration

Following the removal of invasive flora, fauna and invertebrates from the OPERA, ecological restoration should be initiated. The ultimate purpose of ecological restoration is to assist the recovery of a degraded ecosystem with respect to its health, integrity and sustainability (SER 2004).

At the OPERA, re-introducing native plants is one potential method to restore damaged ecosystems. Suggested native plant species to be planted include, such as *Heritiera longipetiolata* and *Cycas micronesica*, as well as known Mariana fruit bat roosting and food trees (e.g., *Mammea odorata*, *Pisonia grandis*, *Cordia subcordata*, *Ficus prolix* and *F. tinctoria*). Where applicable, erosion control should augment native plantings. This may include the use of berms, revetments, straw wattles, or erosion control mats/ blankets (composed of straw, coconut, or jute).

The exact location of specific restoration areas will be identified once adequate baseline surveys are conducted. However, vegetation restoration should focus in areas with remnant native forest components or in adjacent buffer zones.

Prior to beginning a restoration project at OPERA it is important to identify the specific goals and objectives of the project; develop an explicit plan, schedule, and budget; and outline performance standards with monitoring protocols to determine the success of the project (SER 2004). These will be overseen by JRM or NAVFACMAR EV depending on the project and funding source.

7.3.3 Maintenance of Habitat without Restoration

Not all areas of the ERA require intense management or restoration actions. Karst limestone forests and steep cliffs, constituting ostensibly the entire OPERA TU, are largely inaccessible to visitors and likely do not require active management protocols. Since these karst limestone forests are rarely if ever accessed, maintaining these good quality habitats may require little or no management or restoration. Exceptions may be in place to provide access and maintenance to these areas for approved management and research.

7.4 Objective 4: Support Monitoring Surveys, Research and Protocols

Unique and federally or locally threatened/endangered flora and fauna species inhabit the terrestrial and marine unit of the OPERA. For this reason, important baseline assessments, long-term monitoring efforts, established protocols and additional research are recommended below.

7.4.1 Implement Systematic Baseline and Regularly Scheduled Flora and Fauna Assessments and Monitoring

Systematic Baseline Surveys

- Conduct systematic baseline assessments to determine the distribution and abundance of native and protected birds, fruit bats, tree snails, coconut crabs, reptiles, fishes, sea turtles, and other marine organisms within the terrestrial and marine units of the OPERA.
- Conduct baseline monitoring of the effects of increased human use on federally or locally threatened/endangered species that use the OPERA.
- Undertake detailed habitat mapping exercises of the terrestrial and marine habitats to prioritize (e.g., high, medium, low) habitats for native and protected terrestrial and marine species. Previous vegetation and habitat mapping exercises should be used as a template for future work.
- Frequency of baseline surveys should occur at five to 10 year intervals.
- Surveys should be detailed and aim to collect the most thorough dataset possible.

- Methods should mimic as closely as possible those of previous surveys so they can be compared over time. If previous surveys are unavailable, the most current accepted literature should be used to determine best data collection, analysis and reporting methods.
- Utilize this information to assist adaptive management decisions aimed at sustaining ecosystem within the physical, chemical, and biological components of the OPERA.
- Archive all data and reports at JRM and produce yearly summaries of activities and important findings.

Regularly Scheduled Flora and Fauna Surveys

- Conduct mammal, herpetofauna and invertebrate surveys as needed at regularly scheduled intervals. Survey frequency is dependent on outcome of baseline surveys and available funding.
- Consider the collection of yearly data on the presence of native and protected birds, via the annual National Audubon Society Christmas Bird Count.
- Methods should replicate previous surveys or utilize the most current accepted techniques established in the literature.
- Utilize regular surveys to augment information obtained from systematic baseline surveys.
- Archive all data and reports at JRM and produce yearly summaries of activities and important findings.

7.4.2 Monitor Impacts from the Outdoor Recreation and Visitor Use

Because visitor use of the OPERA is expected to increase dramatically, Navy resource managers will benefit from information concerning visitation and recreational use trends in the OPERA. This would include both current (baseline) and future conditions of natural resources, so that the effects of human use can be monitored over time and ideally linked to the events that bring about change to visitor use. If various resource-condition thresholds such as carrying capacity are exceeded, then the implementation of an adaptive management strategy to modify management of a particular resource or area would be necessary. Due to access issues, visitor use of the TU (except where access is from maritime vessel) is not necessary. Monitoring of visitor use within the OPERA may be established as a project that is annually or periodically funded and contracted to appropriate service providers.

Information to be gathered from a visitor use program includes:

- Number and types of users (e.g., military, civilian, family, tour group);
- Group size;
- Type of vehicle (including boat, kayak, canoe, jetski, etc.);
- Commercial or private vessel;
- Vehicle use while in OPERA (anchored, drifting, underway, multiple anchor sites);
- Location within the OPERA;
- Time of visit;
- Duration of visit;
- Primary activities (e.g., fishing, diving, snorkeling); and
- Place of origin and other demographic characteristics.

7.4.3 Execute Long-term Monitoring of Threatened or Endangered Species

In order to understand the life history and extent of use within the terrestrial and marine units of the OPERA, establishing and maintaining a consistent long-term monitoring program for federally or locally threatened/endangered species is highly recommended. Protected species that are known to and or have the potential to inhabit the ERA, along with suggested objectives are presented below.

Green sea and hawksbill turtles

- Carry out regularly-scheduled surveys, in addition to monitoring of historic and current nesting sites.
- Implement long-term monitoring of the effects of increased human use.
- Determine habitats used by sea turtles for foraging.
- Monitor sea turtle movement and migration patterns.
- Establish sea turtle population estimates and analyze trends in abundance.

Mariana fruit bat

- Conduct surveys to establish whether suitable habitat is available and/or used by the Mariana fruit bat.
- If found, colony/activity counts will be conducted on a regular basis (no less than quarterly).
- If roosting occurs, carry out monthly direct colony counts to monitor numbers and trends.
- Implement long-term monitoring of the effects of increased human use if the bat consistently uses the OPERA.

Tree snails

- Conduct surveys to establish whether the Mariana Islands tree snail, Pacific tree snail, or fragile tree snail is present.
- If found, carry out regularly-scheduled monitoring surveys (no less than quarterly).
- If consistently found, implement long-term monitoring of the effects of increased human use (e.g., planned military buildup) on the tree snails.

7.5 Objective 5: Develop an Outdoor Recreation and Visitor Use Plan

7.5.1 Develop a Visitor Access Policy for Periods of Range Closure

Access to the OPERA TU and MU is restricted during all military training activities and ordnance functions. However, unfettered and unrestricted access even when the range is closed is not fully compatible with the guidelines for the establishment of an ERA and may not be in the best interest of the ERA's natural resources. A visitor's use study should be conducted to determine current and projected use (as a result of the increased military presence on Guam) and the associated impacts to the OPERA. From this study, a revised visitor access policy will be formulated to properly address the management objective to minimize human impacts to the reserve. A visitor use study would determine management needs in regards to open trail access for the public. As a result, an access policy for times when the range is closed would be implemented.

7.5.2 Develop Training for NBG Security Force Conservation Law Enforcement

Presently, NBG security personnel are unclear on their jurisdiction or acceptable visitor or research use within the OPERA. Therefore, providing expertise to train existing NBG Security Forces on conservation law enforcement techniques is necessary.

7.5.3 Signs for Terrestrial and Marine Boundaries

At present, signage to indicate the boundaries of the OPERA is inadequate. Interpretive signs should be erected and maintained along accessible boundaries of the OPERA TU and MU where appropriate (e.g., frequent visitation and high educational value areas). Signs should be in three languages (English, Chamorro, and Japanese) and clarify the objectives and allowed uses in each of the units, ERA boundaries, as well as promote recycling and litter removal. Regular maintenance of signage should be scheduled and implemented.

7.5.4 Develop Natural Resources Educational Programs

Developing educational programs that promote the natural resources of the OPERA TU and MU without compromising environmental protection is crucial for visitors to understand and appreciate the important ecological roles native and endangered/threatened flora and fauna play.

Educational programs in the MU could be a joint venture between DoD and commercial tour agencies, providing visitation frequency can be maintained at a level that does not result in adverse impacts to the resources. Combining efforts with commercial tour agencies within a structured system of guided boat tours would likely increase visitor appreciation for the OPERA while controlling visitor numbers. A limited number of boats with prior authorization would be authorized to enter the MU each day. Educational material such as brochures, maps, displays, photographs, and other informational packets would be provided to participants. Prior to entering the waters of the reserve, a mandatory pre-dive presentation should be presented by all dive tour operators to instruct visitors on safety measures, gear cleaning, general conduct and familiarization with unique marine species they may encounter. A film dedicated to the ERA could also be shown as a component of SCUBA classes.

Educational material for visitors should also include information on importance of the coconut crab as resource, its protected status within the OPERA, and threats to the crab from harvesting. The information should also include notification that illegal traps will be removed for the ERA

A further aspect of the educational program for the OPERA could be to raise awareness about invasive species and their detrimental impacts to the TU and MU ecosystems. This program could educate audiences about pathways through which introduced species may enter the ERA, as well as prevention methods.

Education for tour operators should also be considered in order to decrease their impact on the ERA. Some measures recommended for inclusion in this program are to:

- Clarify the objectives and permitted uses in the OPERA;
- Promote trash removal and recycling;
- Increase awareness of impacts to coral caused by diving and snorkeling;
- Identify walking on coral as a prohibited activity;
- Encouragement safe diving and snorkeling activities;
- Ensure safety guidelines are adhered to at all times;

- Emphasize effects on marine wildlife such as anchoring on coral;
- Promote awareness of permitted boating activities;
- Require education of tour operators using boat as a component of a permitting/reservation system; and
- Require visitors to sign an affidavit affirming that they have read and understand educational material regarding permitted and prohibited uses of the ERA prior to entry.

7.5.5 Establish Boat Permit Program

The establishment of a boat permit system for certain types of watercraft entering the OPERA MU. Types of craft requiring a license would include all boats with motors and sailboats longer than 12 feet. Boats would be provided a decal as proof of permit. Fees could be on a sliding scale, depending on whether they are for commercial or recreational use. Monthly permits may also be made available for those visiting briefly.

The impetus for the permit system is two-fold. First, it is a way in which DoD can keep track of the volume of traffic visiting the MU. Second, funds collected may be a way of generating revenue to support activities or research within the ERAs, such as the establishment of signage or additional mooring buoys or prevent the introduction of invasive species.

7.5.6 Establish a No-Drop-Anchor Policy Requiring Use of Mooring Buoy

Additional mooring buoys should be established to limit damage to the reef and other marine life. All recreational boats in OPERA must attach to the mooring buoys; no other form of anchoring is to be permitted. The time limit for use of a mooring buoy by any one vessel would be limited (recommended not exceed two (2) hours). Limitations on how many dive boats and divers are permitted in the OPERA each day will be set. Overnight mooring should be prohibited, except in case of an emergency. If necessary, additional mooring buoys will be deployed to meet levels of use.

7.5.7 Develop a Scuba Dive Permitting/Reservation System

As mentioned in Section 5.1.2, scuba diving is popular for both tourists and residents on Guam. If diving is included in the recreation and visitor use program at the OPERA (see section 7.5.1), divers and dive companies need to be educated on the potential human impacts to coral reefs, legal protection afforded to marine wildlife and habitat, and how to minimize impacts to these ecosystems. This includes all recreational divers and commercial dive boats that enter the waters of the OPERA. Boats operators who receive proper education should be included in a permitting/reservation system and only boats within this system

should be allowed within the waters of the OPERA. The permitting/reservation system would also allow boats to use mooring buoys.

7.5.8 Develop a Tsunami Warning and Evacuation Plan

It is unlikely that a tsunami with the force comparable to the December 2004 incident in Aceh, Indonesia will occur on Guam because of the depth of the Mariana Trench and the protection provided by the surrounding coral reefs (Limtiaco 2004). However, planning for such an event is necessary since unusual events can still occur. Monitoring tsunamis on Guam is an ongoing process carried out by the Pacific Tsunami Warning Center (PTWC). PTWC is responsible for all American interests in the Pacific, including Hawai'i and Guam. Procedures for a tsunami warning received by Guam Homeland Security, Office of Civil Defense from the PTWC validate the warning and notify the appropriate officials and groups to ensure island preparedness.

The OPERA requires procedures specific to its particular needs. The TU of the reserve will likely not be impacted because the majority of the area is atop a 180 200 ft sea cliff that is unlikely to suffer inundation. However, as a marine recreational area, this reserve requires alarm systems to warn of possible tsunamis. With a procedure currently in place for Guam, including already existing tourist areas and hotels, procedures and technologies compatible with the existing emergency plan are recommended (e.g., Appendix 7). Such procedures include efficient assignment of responsibilities, safe evacuation procedures for humans and essential equipment, effective use of public announcement, and emergency communication equipment systems.

7.6 Objective 6: Minimize Risks from Oil Spills and Hazardous Waste

The USEPA works with other federal agencies, state and local agencies, and industries to prevent accidents, as well as to maintain superior response capabilities (USEPA 2008). The EPA provides national leadership for managing environmental emergencies, which can include developing and implementing prevention programs to reduce the risk of releases of oil and hazardous substances in to the environment, building preparedness capacity for oil and hazardous substance emergencies, and responding to emergency events and releases of hazardous materials (USEPA 2008). The Guam Environmental Protection Agency has different divisions to protect the environment. The Recreational Waters Pollution Report Guam (GEPA 2008a) is of importance to the OPERA, since the waters are utilized for a variety of activities and the ERA is located very close to the Navy's harbor and commercial port. The Monitoring Program of the Environmental Monitoring and Analytical Services Division takes water samples at 44 recreational beaches and analyzes samples for concentrations of enterococcus bacteria (GEPA 2008a). The Water Programs Division aims to preserve and protect Guam's surface, marine, and ground and drinking waters from contamination (GEPA 2008b). The Water Pollution Control Program has two sections, the Community Wastewater Program, which deals

with sewage treatment and related facilities for Guam, and the Individual Wastewater Program for domestic wastewater (GEPA 2008b).

Precautions such as mobilizing absorbent booms and positioning clean up materials at a location close to OPERA for prompt deployment in case of an oil spill should ensure that the OPERA TU and MU are not affected by oil spills and hazardous waste. Potential clean-up methods in the marine environment include: physical containment and collection using booms and skimmers; collection via vacuum pumps; in-situ burning; and the use of dispersants, which reduce surface tension of the oil and promote dispersal throughout the water column. These techniques have advantages and disadvantages depending on the spill site. Thus, response options generally need to be developed on a case-by-case basis.

Care should be taken to ensure that spill response efforts do not further impact coral reefs due to physical contact with coral structures, especially in shallow waters. Using floating lines rather than heavy lines can prevent dragging on the coral reef. Furthermore, a disposal waste plan should be developed to properly dispose of collected waste oil and other waste products (NOAA 2001).

7.7 Objective 7: Incorporate Adaptive Management

Adaptive management is defined as a formal, structured approach to dealing with uncertainty in natural resources management, using the experience of management and the results of research as an on-going feedback loop for continuous improvement (65 Fed. Reg. 35242). Integrating ecological knowledge into adaptive management of protected areas is a fundamental component of successful conservation, restoration, and long-term management. In an active adaptive management approach, information that is gathered during monitoring and research (see Management Objective 4) will influence future management practices if the goal of the OPERA is not being achieved.

8.0 CONSTRAINTS AND OPPORTUNITIES

8.1 Potential Conflicts between Programs

The U.S. Pacific Command is implementing the Asia-Pacific Defense Strategy and the island of Guam is a key component. Elements of the initiative include relocating a Marine Expeditionary Force from Okinawa to Guam, improving NBG to serve as a forward operational and logistics support hub, and development at AAFB to serve new forward-based and rotational mission requirements. Any development associated with the military buildup, and training exercises or other military operations within or in close proximity to the OPERA should require that avoidance and minimization of impacts and species recovery goals are met.

8.2 Potential Expansion of the ERA

Considering the expansion of the Kilo ammunition wharf at Apra Harbor (Helber Hastert and Fee 2005), the construction and expansion at Polaris Point for a new aircraft carrier berthing wharf, and the forthcoming urbanization and development of the Orote Peninsula (JGPO 2009), strategies should be in place to protect natural and cultural resources. A number of proactive and ameliorative measures are recommended and outlined below.

1. Expand the MU and TUs of the ERAs. Helber, Hastert & Fee (2005) conducted a feasibility study and outlined several options for expanding the marine and terrestrial units. These options appear to encompass sizeable portions of the terrestrial and marine habitats adjacent to the ERAs. In particular, the inclusion of the limestone forest patch to the east of the TU, Udall Island and/or the area around Spanish Steps is recommended. For a more detailed description of possible expansion scenarios and regions, see Helber, Hastert & Fee (2005).
2. Protect ERAs with a buffer zone. If expansion of the OPERA is not possible, a buffer zone around the ERA should be established. The total buffer area should be 300 ft wide with the first 100 ft (closest to the ERA) designated a no-disturbance zone where no clearing, lighting or other disturbance is permitted. The remaining 200 ft zone should be designated a no-build zone where clearing or landscaping is permissible but construction of buildings or any other structure is prohibited.
3. Development of artificial reefs (Randall 1963, Ogden and Ebersole 1981) could be used to create additional coral reef habitat, alleviate damage to the natural reefs and eventually provide additional dive spots for recreational use. If artificial reefs are to be developed, positioning and composition of materials to be used will require further development.

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