NAVFAC Atlantic Biological Resource Services

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Final Marine Resource Assessment for the Japan and Mariana Archipelagos Volume II: Chapters 6-15

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LIST OF ACRONYMS AND ABBREVIATIONS

°	degrees
%	percent
°C	degrees Celsius
°F	degrees Fahrenheit
µm	micron
µmol	micromole
µPa	micropascal
AAFB	Anderson Air Force Base
AM	amplitude modulated
BMUS	Bottomfish Management Unit Species
BOEM	Bureau of Ocean Energy Management
C.F.R.	Code of Federal Regulations
CBD	Convention on Biological Diversity
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CHCRT	Currently Harvested Coral Reef taxa
chl *a*	chlorophyll *a*
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
cm	centimeter
CMS	Convention on the Conservation of Migratory Species of Wild Animals
CMUS	Crustacean Management Unit species
CNMI	Commonwealth of the Northern Mariana Islands
COMPACFLT	U.S. Commander Pacific Fleet Activities
COTS	crown-of-thorns starfish
CRCA	Coral Reef Conservation Act
CRE	Coral Reef Ecosystem
CRT	Critical Risk Threshold
CV	coefficient of variation
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
DA	domoic acid
DAWR	Division of Aquatic and Wildlife Resources
dB	decibel
dB re 1 µPa-m	decibels with a reference pressure of one micropascal at 1 meter
DCM	deep chlorophyll maximum
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DNA	deoxyribonucleic acid
DoD	Department of Defense
DPS	distinct population segment
DSL	deep scattering level
EEZ	Exclusive Economic Zone
EFH	essential fish habitat
EIMS	Environmental Information Management System
EIS	Environmental Impact Statement
ENSO	El Niño/La Niña-Southern Oscillation

EO	Executive Order
ERA	Ecological Reserve Area
ESA	Endangered Species Act
ESRI	Environmental Systems Research Institute, Inc.
ETP	eastern tropical Pacific
EUC	Equatorial Undercurrent
FAD	fish aggregation device
FAO	Food and Agriculture Organization of the United Nations
FCA	Fisheries Cooperative Association
FDM	Farallon de Medinilla
FEIS	Final Environmental Impact Statement
FGDC	Federal Geographic Data Committee
FM	frequency modulated
FMC	Fishery Management Council
FMP	Fishery Management Plan
FR	Federal Register
FSM	Federated States of Micronesia
ft.	feet
ft./s.	feet per second
FWPCA	Federal Water Pollution Control Act
g	gram
GIS	Geographic Information System
GPS	Global Positioning System
Guam	U.S. Territory of Guam
ha	hectare
HAB	harmful algal bloom
HABHRCA	Harmful Algal Bloom and Hypoxia Research and Control Act
HAPC	habitat area of particular concern
Hz	hertz
IMDCC	Interagency Marine Debris Coordinating Committee
IMO	International Maritime Organization
INRMP	Integrated Natural Resources Management Plan
IPCC	Intergovernmental Panel on Climate Change
ISA	International Seabed Authority
ISI	Institute for Scientific Information
IUCN	International Union for Conservation of Nature
IWC	International Whaling Commission
kg	kilogram
kHz	kilohertz
km	kilometer
km^2	square kilometers
km/hr	kilometers per hour
lbs.	pounds
LME	Large Marine Ecosystem
LMMA	Locally-Managed Marine Area
m	meter
m/s.	meters per second
m^2	square meter
m^3	cubic meter

MARPOL	The International Convention for the Prevention of Pollution from Ships
MBTA	Migratory Bird Treaty Act
MDRPRA	Marine Debris Research, Prevention, and Reduction Act
mg	milligram
mi.	miles
mi.^{2}	square miles
min	minute
MISTCS	Mariana Islands Sea Turtle and Cetacean Survey
MITT	Mariana Islands Training Testing and Training Testing Area
MLW	mean low water
mm	millimeter
MMA	marine managed area
MMPA	Marine Mammal Protection Act
MOU	Memorandum of Understanding
MPA	Marine Protected Area
mph	miles per hour
MPPRCA	Marine Plastic Pollution Research and Control Act
MPRSA	Marine Protection, Research, and Sanctuaries Act
MRA	Marine Resource Assessment
ms	millisecond
MSC	Micronesian Shipping Commission
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
MSL	mean sea level
MtDNA	mitochondrial DNA
MUS	Management Unit Species
NARP	National Artificial Reef Plan
Navy	U.S. Department of the Navy
NDAA	National Defense Authorization Act
NDM	Navy Data Model
NEC	North Equatorial Current
NECC	North Equatorial Counter Current
NEPA	National Environmental Policy Act
NFEA	National Fishing Enhancement Act
NGO	non-governmental organization
nm	nautical mile
NMFS	National Marine Fisheries Service
NMSA	National Marine Sanctuaries Act
NOAA	National Oceanic and Atmospheric Administration
NPIW	North Pacific Intermediate Water
NPS	nonpoint source
NPSG	North Pacific Subtropical Gyre
NRFCC	National Recreational Fisheries Coordination Council
NWRS	National Wildlife Refuge System
OCP	organochlorine pesticide
OCSLA	Outer Continental Shelf Lands Act
OCSLAA	OCSLA Amendments
OPAREA	Japan/Okinawa Complexes Operating Area
P.L.	Public Law
Palau	Republic of Palau

PBDE	polybrominated diphenyl ether
PCB	polychlorinated biphenyl
PCE	primary constituent element
PDO	Pacific Decadal Oscillation
PFC	perfluorinated compound
PHCRT	Potentially Harvested Coral Reef Taxa
PIFSC	Pacific Islands Fisheries Science Center
POP	persistent organic pollutant
ppt	parts per thousand
psu	practical salinity unit
RFRCP	Recreational Fishery Resources Conservation Plan
RMI	Republic Marshall Islands
ROV	remotely operated vehicle
S.D.	standard deviation
SCUBA	self contained underwater breathing apparatus
s.	second
SEC	South Equatorial Current
sec^2	square second
SECDEF	Secretary of Defense
SFA	Sustainable Fisheries Act
SLA	Submerged Lands Act
SSH	sea surface height
SST	sea surface temperature
Sv	Sverdrup
SWOT	State of the World's Sea Turtles
the MRA Study Area	MRA Study Area for the Japan and Mariana Archipelagos
TTS	temporary threshold shift
TU	terrestrial unit
U.S.	United States
U.S.C.	U.S. Code
UK	United Kingdom
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UNFSA	United Nations Fisheries Stock Agreement
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USCRTF	U.S. Coral Reef Task Force
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
WGS	World Geodetic System
WHOI	Woods Hole Oceanographic Institution
WPacFIN	Western Pacific Fisheries Information Network
WPRFMC	Western Pacific Regional Fishery Management Council
WWII	World War II
yr	year

6.0 REPTILES

6.1 INTRODUCTION

There are six reptiles listed under the Endangered Species Act (ESA) that occur within the MRA Study Area for the Japan and Mariana Archipelagos (the MRA Study Area), five sea turtles and one crocodile. The crocodile (*Crocodylus porosus*) is widespread throughout the Indo-Pacific, but only occurs in the Republic of Palau (Palau) within the Study Area. The sea turtle species are more oceanic and all could occur throughout the Study Area, but are generally limited to specific regions described in the profiles.

Sea turtles are long-lived reptiles that occur throughout the world's tropical, subtropical, and temperate seas. The seven living species of sea turtles are in two distinct families—the Dermochelyidae (leatherback sea turtle), and the Cheloniidae (hard-shelled sea turtles)—distinguished from one another based on their carapace (i.e., top shell) structure. The black sea turtle (*Chelonia agassizii*) is occasionally recognized as an eighth species, yet studies of deoxyribonucleic acid and morphology suggest more accurate classification of this as a subspecies of green sea turtle (Karl and Bowen 1999).

Ranges of five sea turtle species overlap the waters of the MRA Study Area (see Figures 6-1, 6-7, 6-9, 6-11, and 6-12). Four of these species — green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), leatherback (*Dermochelys coriacea*), and olive ridley (*Lepidochelys olivacea*) turtles — have been reported in the waters around U.S. Territory of Guam (Guam) and the Commonwealth of the Northern Mariana Islands (CNMI) (Kolinski, Ilo, and Manglona 2004; National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998b, c, d, f; Pritchard and Plotkin 1995). Both green and hawksbill sea turtles nest on Guam and the CNMI (Maison, Kelly, and Frutchey 2010). The only nesting population of loggerhead turtles (*Caretta caretta*) in the North Pacific occurs in Japan, but this species has never been reported in the Mariana Archipelago (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998e). Of these species, the threatened green sea turtle is the most common in the Marianas, while the endangered loggerhead is the most common in Japan. A relatively large nesting population of green sea turtles also occurs in Palau (Maison, Kelly, and Frutchey 2010).

6.1.1 Global Distribution and Preferred Habitat

Sea turtles nest on all continents, offshore islands, and throughout Oceania, as far north as 40°N (loggerhead rookeries in Japan) and as far south as 30°S (leatherback rookeries in South Africa). Most data regarding sea turtle distribution comes from nesting beach studies, which identify the important coastal habitats. However, satellite telemetry, tagging studies, fisheries information, and other observational data demonstrate that all sea turtle species migrate hundreds of miles along coastlines and thousands of miles across ocean basins between nesting beaches, mating areas, nursery habitats, developmental habitats, and adult feeding grounds (Meylan 1995).

Although nesting occurs in relatively warm climates, at-sea range often depends on water temperature (Coles and Musick 2000; Davenport 1997; Epperly et al. 1995), with most sea turtles becoming lethargic at temperatures below 10 degrees Celsius (°C) and above 40°C (Spotila, O'Connor, and Paladino 1997). Olive ridleys appear to require a more constant temperature, as they commonly migrate thousands of kilometers (km) within the 20°C isotherms (Abreu-Grobois and Plotkin 2008). Conversely, the leatherback turtle can remain active across a wider range of water temperatures because of its ability to maintain a warm body temperature in temperate waters and avoid overheating in tropical waters (Southwood et al. 2005; Spotila, O'Connor, and Paladino 1997; Wallace et al. 2005). Leatherback turtles

have been observed actively swimming in water as cold as 0.4°C (James et al. 2006). While water temperature is a controlling factor, accurate determinations of distribution and migratory routes are also determined by locations of nesting beaches, breeding grounds, foraging grounds, and the prevailing currents that intersect these key habitats. Moreover, habitat use varies among species and between the life stages of individual species.

Recent research related to genetics, satellite telemetry, and tagging has increased understanding of population structures of all sea turtle species. This research supplements long-term data sets of oceanographic features, sightings, thermal tolerance, fishery bycatch data, and mark-recapture studies. In 2011, the loggerhead turtle was determined to consist of nine distinct population segments to be managed as unique and discrete stocks, including the North Pacific Stock, which nests solely on Japanese beaches (National Marine Fisheries Service 2011). The same analysis has been recommended for all of the other turtle species, to improve management and recovery efforts (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007a, b, c, d, e). In the following sections, presentations of species profiles of the sea turtles within the MRA Study Area include results of these respective analyses.

6.1.2 Biology, Life History, and Behavior

Sea turtles are highly migratory and are present in coastal and open ocean waters of the MRA Study Area. Most sea turtles prefer to live in warm waters because they are cold-blooded reptiles. Leatherbacks are the exception, and are more likely to be found in colder waters at higher latitudes due to their unique physiology.

All sea turtles use a variety of mechanisms to guide their movements on land and at sea (Lohmann et al. 1997). Hatchlings are strongly attracted to light (Witherington and Bjorndal 1991) and use light wavelengths and shape patterns to find the ocean after emerging from the nest (Lohmann et al. 1997; Witherington 1992). Once in the ocean, hatchlings use wave energy to navigate offshore (Lohmann and Lohmann 1992). Nesting beaches may be evolutionarily selected for based upon favorable eddys and coastal currents that transport hatchlings quickly away from predation and into productive foraging grounds, increasing probability of survival (Shillinger et al. 2012). In the open ocean, post-hatchlings appear to rely on convergence zones, where downwelling concentrates buoyant material that would otherwise be dispersed across the ocean (Carr 1987). These conditions provide both food and refuge for turtles, as well as increase the possibility of interaction with marine debris and other pollutants. In the open ocean, turtles orient themselves based on the earth's magnetic field at a given location, which allows them to navigate transoceanic migrations from their natal beach to foraging grounds, as well as to return to the beaches where they were born in order to nest (Fuxjager, Eastwood, and Lohmann 2011; Lohmann et al. 2001; Lohmann and Lohmann 1996; Lohmann et al. 1997).

Information on sea turtle hearing and vocalization is limited. The ecological role of hearing has not been well studied in the wild for sea turtles. No scientific accounts have been published of marine turtles using sounds underwater for communication (Pilcher and Siow 2010). Reception of sound is through bone conduction, with the skull and shell acting as receiving structures (Lenhardt et al. 1983). Sea turtles appear to be low-frequency specialists (Bartol and Ketten 2006), with a frequency range from 30 to 2,000 hertz (Hz) and a maximum sensitivity between 100 and 800 Hz (Bartol and Ketten 2006; Bartol, Musick, and Lenhardt 1999; Lenhardt 1994, 2002; Ridgway et al. 1969). All sea turtles respond to sounds in the low frequency range, from at least 100 Hz to no greater than 900 Hz (Pilcher and Siow 2010). Experiments testing turtle reaction to sounds, similar to seismic surveys, indicate an attempt to swim

away from the source of the sound (Lenhardt 1994; McCauley et al. 2000; O'Hara and Wilcox 1990), although whether impacts to hearing occur or are permanent remains unknown (Pilcher and Siow 2010). Eckert (2002) proposed a summary of the most plausible, potentially damaging impacts to turtles in response to seismic survey impulses:

- Significant changes in normal behavior patterns (increased swimming activity, erratic swimming patterns, agitated behavior, abrupt body movements, startle responses)
- Increased energetic expenditures resulting from avoidance
- Inappropriate behavioral responses (fleeing or extended surface periods)
- Failure to respond to biologically important signals because of noise masking or attention difficulties.

Sea turtles produce large numbers of offspring as a biological response to high levels of egg and hatchling death. Mortality rates are presumed highest during these stages of life due to predation on eggs and hatchlings, and ocean currents that sweep hatchlings into waters too cold for survival (Conant et al. 2009). Open ocean juveniles spend 2 to 14 years drifting, foraging, and developing; a general lack of knowledge regarding this period has led to labeling it “the lost years”(Witham 1980). This lack of knowledge has impeded efforts at management during this life phase, and has challenged scientists to pose questions in novel ways. One study identified the diets of post-hatchling Atlantic green sea turtles through stable isotope analysis to better understand location and preferred habitats during this period (Reich, Bjorndal, and Bolten 2007). Green sea turtles spend 3–5 years foraging for jellyfish in the open ocean, occupying similar habitats and foraging at the same trophic levels as early juvenile loggerheads, before shifting suddenly to neritic habitats. Loggerheads, however, remain in this life phase for 10 years (Bjorndal et al. 2003; Bolten 2003; Bolten et al. 1998). Because juvenile turtles can protect themselves more effectively from predators, are generally too small to interact with commercial fisheries, can better maintain their position within a marm water mass, and are not at risk from land-based and nearshore sources of mortality, survival rates are believed highest during this phase (Conant et al. 2009). After this juvenile pelagic phase, hawksbill, loggerhead, and green sea turtles settle into coastal habitats as subadults, dedicated to a specific home range until adulthood. Leatherback and olive ridley turtles remain primarily in the open ocean throughout their lives, except for possibly mating in coastal waters and when females come ashore to lay eggs. Breeding age adults of all species are known to migrate long distances across large expanses of the open ocean, primarily between nesting and feeding grounds. Given the variety of human-caused threats, estimates of natural deaths during the subadult and adult stages increase slightly (Conant et al. 2009).

6.1.3 Global Threats and Management

While all sea turtles have unique life histories, threats are common among all species. On beaches, wild dogs, pigs, and other animals ravage sea turtle nests. Humans harvest eggs and nesting females, threatening some turtle populations. Human consumption has been the main factor in the global decline of most turtle species (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007a, b, c, d, e; The SWoT Team 2011). Coastal development can cause beach erosion and loss of nesting habitat. It can also create or increase the intensity of artificial light, which can disrupt female nesting activities and attract hatchlings away from the water. Habitat degredation and loss from coastal development can impact both nesting and foraging grounds of sea turtles. Lowered water quality and introduced species can alter ecosystems which may limit food availability and no longer provide the habitat needed by the turtles. Other threats within the foraging grounds include fishing pressures, as turtles may get caught, injured, or drowned in fishing gear, or boat strikes, which may cause damage to their shell, spine, or

head, and result in injury or death (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007a, b, c, d, e). These impacts to important turtle habitats reduce reproductive rates and carrying capacities.

Threats in the offshore environment include bycatch in commercial fisheries, primarily longline fishing that kills an estimated 447,000 turtles every year worldwide (Wallace et al. 2010), and entanglement in abandoned nets and other fishing gear (Carr 1987), which can drown turtles of all life stages. Sea turtles often mistake floating plastic for food, such as plastic bags resembling jellyfish, which are eaten by many turtle species in early life phases, and exclusively by leatherback turtles throughout their lives. One study found plastic in 37 percent (%) of dead leatherbacks (Mrosovsky, Ryan, and James 2009).

Climate change, with predictions of increased ocean and air temperatures, increased storm frequency and intensity, and sea level rise, may adversely impact turtles in all life stages, from egg to adult (Chaloupka, Kamezaki, and Limpus 2008; Mrosovsky, Ryan, and James 2009; Schofield et al. 2010; Witt et al. 2010). Effects from increased temperatures include embryo mortality, skewed sex ratios, loss of nesting habitat resulting from sea level rise and increased beach erosion, and coastal habitat degradation (e.g., coral bleaching). Climate change may impact other organisms, which may alter marine food webs. A change in the marine food web may impact turtles if there is a decline in prey species.

Many questions regarding potential impacts remain unanswered, including how climate change would affect hatchling dispersal and migration, how foraging ecology would change, and how turtles would find new beaches if current beaches become unsuitable for nesting (The SWoT Team 2011). Fibropapillomatosis is a debilitating, tumor forming disease in marine turtles, primarily green sea turtles, that may be related to environmental degradation (Santos et al. 2010). This affliction, first noted in the 1930s, peaked in the 1980s and 1990s, and recently has shown signs of decrease across global populations (The SWoT Team 2011). Each sea turtle recovery plan includes detailed descriptions of threats in the nesting and marine environment, ranking the seriousness of threats within each of the U.S. Pacific states and territories (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998a, b, c, d, e, f).

6.2 SPECIES LIST AND STATUS

The status of sea turtle populations is determined primarily from assessments of the adult female nesting population. Much less is known about other life stages of these species. The National Research Council recently reviewed the current state of sea turtle research and concluded that relying too much on nesting beach data slows a more complete understanding of sea turtles and limits evaluation of options for managing their overall health and recovery (National Research Council 2010). The five sea turtles found in the MRA Study Area are listed as endangered or threatened. The status, presence, and nesting occurrence of sea turtles in the MRA Study Area are listed by region in Table 6-1.

Table 6-1: Status of Sea Turtles in the MRA Study Area

Species Name and Regulatory Status			Ecoregional Presence[4,5]						
Common Name	Scientific Name	ESA Listing	Open Ocean				Coastal Waters		
			NCP	KU	ECS	PS	JA	MA	CI
Family Cheloniidae (hard-shelled sea turtles)									
Green Sea turtle	*Chelonia mydas*	Threatened, Endangered[1]	X	X	X	X	X^n	X^n	X^n
Hawksbill Sea turtle	*Eretmochelys imbricata*	Endangered	X	X	X	X	X	X^n	X
Loggerhead Sea turtle	*Caretta caretta*	Threatened[2], Endangered	X	X	X	X	X^n	X	X
Olive ridley Sea turtle	*Lepidochelys olivacea*	Threatened[3], Endangered	X	X	X	X	X	X	X
Family Dermochelyidae (leatherback sea turtle)									
Leatherback Sea turtle	*Dermochelys coriacea*	Endangered	X	X	X	X	X	X	X

Notes:
[1]As a species, the green sea turtle is listed as threatened. However, the Florida and Mexican Pacific Coast nesting populations are listed as endangered. Note that some green sea turtles found in the MRA Study Area may belong to the endangered Mexican Pacific Coast population, although genetic studies indicate a distinct western Pacific population.
[2]The status of the loggerhead turtle was revised by the National Marine Fisheries Service (NMFS) in 2011: The species is now managed as nine distinct population segments. Only the North Pacific Ocean distinct population segment occurs in the MRA Study Area and it is listed as endangered.
[3]There are two listed populations of olive ridleys: the "Mexican Pacific Coast Breeding Colonies" is listed as endangered and "All Other Areas" is listed as threatened.
[4]Ecoregional presence relates to open ocean and coastal waters of the MRA Study Area. Ecoregional presence in open ocean waters include: the North Central Pacific Gyre (NCP); the Kuroshio Current (KU), East China Sea (ECS) and the Philippine Sea (PS).
[5]Ecoregional presence in coastal waters includes nearshore waters of the Japan Archipelago (JA), the Mariana Archipelago (MA), which includes the Commonwealth of the Northern Mariana Islands (CNMI) and U.S. Territory of Guam (Guam), and the Caroline Islands (CI) which includes Palau and Yap. Areas where nesting occurs are indicated as X^n
ESA = Endangered Species Act

6.3 GREEN SEA TURTLE (CHELONIA MYDAS)

6.3.1 Description

The green sea turtle is the largest of the hard-shelled marine turtles (chelonids), but has a comparatively small head. A typical green sea turtle reach can exceed 3.3 feet (ft.) (1 meter [m]) in carapace length and can weigh from 200 to 500 pounds (lbs.) (90 to 225 kilograms [kg]). The largest individual collected was 4.9 ft. (1.5 m) long and weighed 871 lbs. (395 kg). Hatchlings average about 4.7 to 5.4 centimeters (cm) in carapace length, and 22 to 31 grams (g) in weight (Eckert 1993). The carapace is smooth and has mottled, dark brown color, while the bottom shell (plastron) is creamy white in color. While algal growth on the turtle can give it a green hue, the green sea turtle is named for the color of its body fat, known as calipee. The green sea turtle has five vertebral scutes running down the middle of its shell, and four costal scutes on each side.

6.3.2 Status and Management

The green sea turtle was listed under the ESA in July 1978 due to excessive commercial harvest, lack of effective protection, evidence of declining numbers, and habitat degradation and loss (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007a). Under the ESA, recovery plans have been prepared for Atlantic, Pacific, and east Pacific green sea turtle populations (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998a, b). The breeding populations off Florida and the Pacific coast of Mexico listed as endangered, and all other populations classified as threatened. Critical habitat was designated in 1998 for green sea turtles in coastal waters around Culebra Island, Puerto Rico. Critical habitat has not been designated in the Pacific.

Recent analysis of genetic data indicates presence of as many as 34 distinct stocks across the world. Two genetically distinct breeding populations are within the MRA Study Area—a Northwest Pacific population that nests in Japan and a Western Central Pacific population that nests in Micronesia, the Mariana Archipelago, and Palau (The SWoT Team 2011). The Hawaiian stock (North Central Pacific) and two east Pacific stocks may occasionally occur in waters within and near the MRA Study Area. These distinct stocks may require independent management (Dutton, Balazs, and Dizon 1998; Dutton et al. 2008). For management purposes, the threatened Pacific green sea turtle is the population most likely to occur in the MRA Study Area.

A 5-year review completed in 2007 (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007a) includes updated information on biology and habitat, as well as an analysis of threats to and conservation measures for the species.

6.3.3 Population and Abundance

Based on data from 46 nesting sites around the world, 108,761–150,521 female green sea turtles nest each year (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007a), which is a 48–65% decline in the number of females nesting annually over the past 100–150 years (Seminoff and Marine Turtle Specialist Group Green Turtle Task Force 2004). Of nine major nesting sites in the Pacific, four appear to be increasing (Hawai‘i, Mexico, Japan, Heron Island), three appear to be stable (Galapagos, Guam, Mexico), and the trend is unknown for two (Central American Coast and Raine Island). In addition to these nine nesting sites, at least 166 smaller nesting sites are scattered across the western Pacific, with an estimated 22,800–42,580 females nesting in the Pacific each year, including the Western Central Pacific stock that nests in Micronesia, Marianas, and Palau (Maison, Kelly, and Frutchey 2010; National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007a). The Raine Island, Australia nesting population is the largest in the world, and accounts for 90% of the total Pacific population (Maison, Kelly, and Frutchey 2010).

Within the MRA Study Area, low levels of nesting occur in the CNMI, Guam, Palau, and Japan, as well as nearby oceanic islands. The largest concentration, with 400 to 500 females nesting annually, is at a single site in the Ogasawara Islands of Japan. In Palau, 250–400 females nest across 13 known nesting sites. Less than 20 females nest across the Mariana Archipelago from Guam to Agrigan Island. Nesting numbers have increased in recent years for the Japan population, while the trend is unknown for Guam, CNMI, and Palau (Maison, Kelly, and Frutchey 2010).

The green turtle nests in the Ryukyu (also known as Nansei) and Ogasawara Islands. In the Ogasawara Islands, mating occurs from March through May, and nesting follows from May through early September, with a peak in nesting activity between June and July (Suganuma et al. 1996). The Chichi-

jima rookery in the Ogasawara Islands is one of the major nesting sites in Japan, despite undergoing decades of harvest that decimated the population in the 20th century(Chaloupka et al. 2007). Remigration intervals (the number of years between successive nesting seasons) for green sea turtles nesting at the Ogasawara Islands range from 2 to 9 years, with a mode of 4 years (Tachikawa et al. 1994). From 1991 through 1994, green sea turtles laid an average of four clutches per nesting season at the Ogasawara Islands; the average clutch size for these nests was slightly over 100 eggs (Suganuma et al. 1996). Since the late 1970s, the population of green sea turtles nesting at Japan's Ogasawara Islands has experienced a strong recovery from serious depletion due to past commercial exploitation, with an annual population growth rate of 6.8% (Chaloupka et al. 2007). Since Japan is home to the northernmost nesting sites for green sea turtles in the entire Pacific, the green sea turtle population residing there is estimated to be small (Uchida 1994).

Sea turtles in the Mariana Archipelago are protected under the U.S. federal ESA and local Guam and CNMI laws. The Guam Department of Agriculture Division of Aquatic and Wildlife Resources and the CNMI Department of Land and Natural Resources, Division of Fish and Wildlife have monitored nesting activity since 1999. In the Mariana Archipelago, green sea turtles typically nest from March through August, with some year round activity documented on the islands of Guam, Saipan, Tinian, and Rota (Maison, Kelly, and Frutchey 2010).

Genetic samples analyzed to date indicate that nesting green sea turtles in CNMI and Guam are indistinguishable and should be treated as a single management unit (Maison, Kelly, and Frutchey 2010). However, sample sizes are small, and additional sampling may reveal other haplotypes. Sufficient information on nesting trend is not available for green sea turtles in the Mariana Archipelago, although anecdotal information from residents suggests that nesting (Chaloupka et al. 2007) activity has decreased over time, likely as a result of direct harvest, coastal development, and World War II impacts. Illegal harvest and degradation of terrestrial and nearshore habitats continue to be the primary threats to turtles of the Mariana Archipelago.

6.3.4 Biology, Ecology, and Behavior

Predator/Prey Interactions. The green sea turtle is the most herbivourous of the sea turtles, especially in their coastal life phase (Mortimer 1995), although the diet changes throughout its life. While at the surface, hatchlings feed on floating patches of seaweed, and at shallow depths on comb jellies and gelatinous eggs, appearing to ignore large jellyfish (Salmon, Jones, and Horch 2004). While in the open ocean, juveniles smaller than 8–10 inches (in.) (20–25 cm) eat worms, small crustaceans, aquatic insects, grasses, and algae (Bjorndal 1997). After settling into a coastal habitat, juveniles eat mostly seagrass or algae (Balazs et al. 1994; Mortimer 1995). Preferred algae include species of the genera Codium, Amansia, Ptercladia, Ulva, Gelidium, Acanthophera, and Hypnea (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998b). Juveniles and adults that remain in the open ocean, and even some residing in coastal waters, also consume jellyfish, sponges, and sea pens (Blumenthal et al. 2009; Godley et al. 1998; Hatase et al. 2006; Heithaus et al. 2002; National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007a; Parker and Balazs 2005).

Predators of green sea turtles vary according to turtle location and size. Land-based predators on eggs and hatchlings include ants, crabs, birds, reptiles and mammals, such as dogs, raccoons, and feral pigs. Aquatic predators, mostly fish and sharks, impact hatchlings most heavily in nearshore areas. Sharks are the primary predators of juvenile and adult turtles (Stancyk 1982).

Life History. Green sea turtle eggs incubate in the sand for approximately 48–70 days. When hatchlings leave the nesting beach, they begin an oceanic phase (Carr 1987), initially using a three-day supply of energy from their yolk sac to swim out to sea, before floating passively in current systems (gyres), where they develop (Carr and Meylan 1980). Post-hatchlings live at the surface in the open ocean for approximately 1 to 3 years (Hirth 1997). Once reaching the juvenile stage (estimated at 5 to 6 years and shell length of 8 to 10 in. [20–25 cm]), they move to lagoons and coastal areas rich in seagrass and algae (Bresette, Singewald, and De Maye 2006; Musick and Limpus 1997). The optimal habitats for late juveniles and adults are warm, quiet, and shallow (10–33 ft. [3–10 m] deep) waters, with seagrasses and algae, that are near reefs or rocky areas used for resting (Makowski, Seminoff, and Salmon 2006). This is where they will spend most of their lives (Bjorndal and Bolten 1988; Makowski, Seminoff, and Salmon 2006; National Marine Fisheries Service and U.S. Fish and Wildlife Service 1991). A small number of green sea turtles appear to remain in the open ocean for extended periods, perhaps never moving to coastal feeding sites (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007a; Pelletier, Roos, and Ciccione 2003).

Green sea turtles are estimated to reach sexual maturity at between 20 and 50 years. This prolonged time to maturity has been attributed to their low energy plant diet (Bjorndal 1995) and may be the highest age for maturity of all sea turtle species (Chaloupka and Musick 1997; Hirth 1997; National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007a).

Once mature, at around 90 cm straight carapace length for Pacific populations (Hirth 1997), green sea turtles may reproduce for 17–23 years (Carr, Carr, and Meylan 1978). They return to their birth beaches to nest every 2 to 5 years (Hirth 1997). This irregular pattern can cause wide year-to-year changes in numbers of nesting females at a given nesting beach. Each female lays between three to five clutches (nests) per season, laying an average of 115 eggs each time. Based on an average of three clutches per season and 100 eggs per nest, a single adult female may deposit 9–33 clutches (900–3,300 eggs) during her lifetime (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007a). While survivorship at specific life stages is not well known and differs across populations, fewer than one in 250 hatchlings survives to breeding age (Bjorndal 1980; Hirth 1997). Nesting peaks between March and August in Guam and the CNMI, and from April to August in Micronesia, with evidence of year-round nesting for these stocks (Maison, Kelly, and Frutchey 2010). Nesting occurs between mid-May and mid-July in Japan (Kikukawa, Kamezaki, and Ota 1999), and occurs year round at sites closer to the equator, such as Palau (Maison, Kelly, and Frutchey 2010).

When green sea turtles are not breeding, adults live at coastal feeding areas that they sometimes share with juveniles (Seminoff and Marine Turtle Specialist Group Green Turtle Task Force 2004). The green sea turtle at all ages has a dedicated home range within which it repeatedly visits the same feeding and breeding areas (Bresette, Gorham, and Peery 1998; Makowski, Seminoff, and Salmon 2006).

Migration. Green sea turtles are highly migratory throughout their lives. They may travel thousands of km between their juvenile developmental grounds and adult breeding and nesting grounds (Mortimer and Portier 1989). When they reach sexual maturity, green sea turtles begin migrating regularly between feeding grounds and nesting areas every few years (Hirth 1997). Both males and females migrate, typically along coastal routes from breeding areas to feeding grounds, although some populations migrate thousands of km across entire oceans (Carr 1986, 1987; Mortimer and Portier 1989). Following nesting migrations,green sea turtles often return to the same feeding areas (Godley et al. 2002; National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007a) where they have specific home ranges and movement patterns (Seminoff, Resendiz, and Nichols 2002).

Hearing/Vocalization. As research into turtle hearing and vocalization is limited, a general description of hearing and vocalization is provided in Section 6.1.2, Biology, Life History and Behavior [all turtles].

Diving. Four Pacific studies (Brill et al. 1995; Hatase et al. 2006; I-Jiunn 2009; Rice and Balazs 2008) and one Atlantic study (Hays, Metcalfe, and Walne 2004) assessed green sea turtle diving ability. In the open ocean, Hatase (2006) observed that green sea turtles dive to a maximum of 265 ft. (80 m), although typically no greater than 131 ft. (40 m). Green sea turtles migrating between the northwestern and main Hawaiian Islands reached a maximum depth greater than 445 ft. (135 m) at night (the deepest dives ever recorded for a green sea turtle), but only 13 ft. (4 m) during the day (Rice and Balazs 2008). In their coastal habitat, green sea turtles typically make dives shallower than 100 ft. (30 m) (Godley et al. 2002; Hatase et al. 2006; Hays et al. 2000; Hochscheid, Bentivegna, and Hays 2005), and do not often exceed 55 ft. (18 m) (Hays, Metcalfe, and Walne 2004; Rice and Balazs 2008), although they are known to feed and rest at depths of 65–165 ft. (20–50 m) (Balazs 1980; Brill et al. 1995).

Green sea turtle resting dives (i.e., more than 90% of dive time spent at maximum depth) can exceed 3.5 hours (Rice and Balazs 2008), but are generally less than 1 hour (I-Jiunn 2009). Feeding dives are shorter, with maximum durations of just over an hour, and average durations up to 30 minutes (Brill et al. 1995; I-Jiunn 2009).

6.3.5 Habitat and Distribution

The green sea turtle is the most widespread of the seven species of sea turtle, occurring in the tropical and subtropical coastal and open ocean waters, and nesting on beaches of all oceans primarily between 30°N and 30°S. Major nesting beaches occur throughout the western and eastern Atlantic, Indian, and western Pacific Oceans, and are found in more than 80 countries (Hirth 1997) and 1,167 sites (The SWoT Team 2011) worldwide.

Two nesting populations of green sea turtles in the North Pacific Ocean occur outside of the MRA Study Area—a Hawaiian population and an East Pacific population. Both populations feed and migrate throughout all waters of the tropical and subtropical Pacific, rendering possible their presence in the waters of the MRA Study Area. Few reports have been received of turtles from South Pacific populations occurring in the North Pacific Ocean (Limpus, Bell, and Miller 2009).

Figure 6-1 shows green sea turtle nesting sites throughout the Pacific, as provided by turtle research groups to the State of the World's Sea Turtles (SWOT) database. Figure 6-2 shows green sea turtle nesting sites and beach-specific nesting densities in the MRA Study Area, while Figures 6-3, 6-4, 6-5, and 6-6, respectively, provide detailed maps of nesting sites and densities for Saipan, Tinian, Rota and Guam.

Open Ocean Waters of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. Open ocean distribution data are sparse for the green sea turtle. Available satellite telemetry data for green sea turtles nesting in Hawaiʻi, Oceania, and Asia (63 individual data sets) do not show any migrations through the North Central Pacific Gyre (The SWoT Team 2011). The only available information is from bycatch data for the Hawaiʻi-based longline tuna fishery, that operates between 15° N to 35° N and 150° W to 180° W, and the Hawaiʻi-based longline tuna fishery, that operates in the area northeast of the Hawaiian Islands, on the high seas in the North Pacific Transition Zone (Gilman et al. 2007). Overall interaction rates with the Hawaiʻi-based fishery are low, with fewer than five green sea turtles caught and one mortality on average between 2005 and 2010, while an estimated 93 green sea turtles were caught by foreign longline fleets operating in the

North Pacific in 2009 (National Marine Fisheries Service 2012a). Of these, about 57% of green sea turtles captured in longline fisheries in the North Central Pacific Gyre and North Pacific Transition Zone come from the endangered Mexican nesting population, while 43% are from the threatened Hawaiian nesting populations. Therefore, these findings suggest that green sea turtles on the high seas within these areas of the western and central Pacific are from these two populations.

KUROSHIO CURRENT. The green sea turtle, known as "aoumigame" in Japanese, is the second most common of the two turtle species regularly found in the waters off the four main islands of Japan (Uchida and Nishiwaki 1995). Although green sea turtles are common residents of the coastal bays and estuaries of East and South Japan, they are rarely found in the waters of the Inland Sea between Honshū, Shikoku, and Kyūshū. Green sea turtles are not expected to occur north of the Kuroshio Current deflection off the coast of Honshū, as they are a predominantly tropical species.

Satellite tracks of post-nesting females of the Ogasawara Islands indicates that these turtles migrate quickly back to neritic feeding grounds on the Japanese mainland, feeding in nearshore waters from the Izu Islands to Kyūshū and the Ōsumi Islands (Hatase et al. 2006). Time-depth recorders also indicate that post-nesting green sea turtles also forage in oceanic waters between the nesting and foraging grounds (Hatase et al. 2006). Other satellite tracks, in addition to stable isotope analysis of green sea turtle eggs laid in Ogasawara, Japan, strongly implied that a few of the mature females feed on animals in the oceanic habitat, indicating adult use of both coastal and pelagic habitats (Hatase et al. 2006).

EAST CHINA SEA. Feeding grounds in Japan are located in shallow waters along the Pacific coast of the archipelago from 26°N to 38°N, and may extend west into the East China Sea and waters near Taiwan (Suganuma 1989; Tachikawa et al. 1994). Late juvenile and adult green sea turtles are frequently captured in coastal gillnet and setnet fisheries off the east coast of Taiwan, where rocky shores provide a suitable feeding ground (Cheng and Chen 1997).

PHILIPPINE SEA. Green sea turtles that nest throughout Oceania likely migrate through the Philippine Sea to foraging grounds in the coastal waters of the Philippines(Maison, Kelly, and Frutchey 2010; Suganuma 1989).

Of nesting females on Saipan during summer 2011, three were outfitted with satellite transmitters. One turtle migrated to the Philippines and the second to Japan. The third turtle's transmission failed shortly after she began her migration, but her route appeared to follow an initial trajectory similar to that of the turtle which headed to the Philippines. In 2000 and 2007, two post-nesting green sea turtles were satellite-tagged on Guam, and they also traveled to the Philippines and Japan, respectively (Maison, Kelly, and Frutchey 2010). Additional satellite tracking activities between 2005 and 2007 from other Western Pacific Island nations, including the FSM, Republic of the Marshall Islands, and Palau, also suggest regional connectivity between the Pacific Islands and the Region, as some post-nesting females migrated to foraging habitats of Japan, Philippine, and Indonesian waters (Maison, Kelly, and Frutchey 2010).

Coastal Waters of the MRA Study Area

Scattered and small nesting populations occur across Oceania in the western Pacific, including low-level nesting throughout Micronesia, including on Guam and the CNMI (Maison, Kelly, and Frutchey 2010). While the two largest nesting sites in Australia account for approximately 82% of the total nesting populationin Oceania, there are seven sites where between 100 and 2,000 green turtles nest annually.

The largest nesting aggregations within the MRA Study Area are in Palau, Yap, and Japan's Bonin Islands (Maison, Kelly, and Frutchey 2010). Figure 6-2 shows locations and relative nesting aggregation sizes of these populations.

JAPAN ARCHIPELAGO. Small aggregations of green sea turtles nest throughout the Ryukyu Islands from Taiwan to approximately 31°N on the southern tip of Kyūshū, including the Okinawan and Ōsumi Islands (Sea Turtle Association of Japan 2005b). Nesting season runs from May through August (Kikukawa, Kamezaki, and Ota 1999). The largest aggregation occurs in the Ogasawara Islands, outside of the MRA Study Area, where 500 clutches were counted in the 2003 breeding season on Chichi-jima (Chaloupka et al. 2008). This is one of the most northern rookeries for green sea turtles in the Pacific Ocean (Suganuma 1989).

Bōsō Peninsula, Izu Peninsula, and Izu Islands. Green sea turtles that breed in the Ogasawara Islands make regular reproductive migrations from their foraging grounds along the Pacific coast of Japan (e.g., the Izu Islands, mainland Japan, and the Ryukyu Islands), and may even come from areas as far west as the East China Sea or the coast of Taiwan, based on mark-recapture studies on headstarted early juveniles, subadults, and nesting and foraging adults (Hatase et al. 2006; Suganuma 1989).

Kyūshū Island, Ōsumi Islands, and Tokara Archipelago. Green sea turtles have been documented foraging in the coastal waters of Kyūshū and nearby islands (Suganuma 1989).

Okinawa Island, Kerama Island, Kume Island, and Daitō Islands. Green sea turtles nest in May on the beaches of the Okinawa island group, and are frequently encountered foraging on seagrasses in the coastal waters surrounding these islands (Tetra Tech EM Inc. 2010). A green sea turtle tagged on June 7, 2007, in Palau was recaptured in Okinawa on October 15, 2007, migrating a distance of 1,562 miles (mi.) (2,515 km) (Maison, Kelly, and Frutchey 2010).

MARIANA ARCHIPELAGO. The green sea turtle is the most common sea turtle occurring in the nearshore waters of the CNMI, found predominantly in the waters of the southern islands (Farallon de Medinilla [FDM] to Guam) (Kolinski 2001). An estimated 1,000 to 2,000 green sea turtles live on reefs of the southern islands (Kolinski 2001), with 54% off Tinian, 38% off Saipan, and 6% off Rota (Kolinski et al. 2006). Surveys indicate that most of the green sea turtles in these waters are juveniles (69%), with 17% and 11% sub-adults and adults, respectively (Kolinski 2001; Kolinski et al. 2006). The waters of the southern islands are considered a primary resident green sea turtle habitat with a minor nesting component (Kolinski 2001). Prior to 2009, Division of Fish and Wildlife documented 4 to 18 green sea turtle nests laid per year (Division of Fish and Wildlife unpublished reports), including nests on Bird Island Beach, Laulau Beach, Obyan Beach, Tank Beach, and Wing Beach on Saipan and Okgok Beach, and on Tatgua Beach on Rota (The SWoT Team 2011). In 2010, scattered nests were observed on 12 beaches on Rota, as well as on Tinian Island (The SWoT Team 2011). During the 2011 nesting season, 31 nests were documented and 4 individual green sea turtles were observed on beaches of Saipan, and no nests were observed on Rota and Tinian, although some beaches were not accessible during the time of a rapid assessment. In the nearshore environment, green sea turtles prefer resting under ledges and within shallow grottos (Smith and Marx Jr. 2006).

Pagan. Three resident green sea turtles were observed on the south side entrance of Bandeera bay, in an area where healthy coral reef resources are abundant (Sukhraj et al. 2010).

Farallon de Medinilla. An estimated 10 green sea turtles occur in the waters around FDM (Kolinski 2001; Smith and Marx Jr. 2009), although total counts during surveys conducted between 2000 and 2007 are as high as 20 per year (Vogt 2008).

Saipan. An estimated 574 green sea turtles occur in the waters around Saipan (Kolinski 2001).

Tinian. In 2001, 351 green sea turtles were observed during surveys of 59% of Tinian's reefs (Kolinski 2001). Tinian appears to have the highest density of green sea turtles in the CNMI, despite a lack of seagrass habitat, the primary forage of the turtle (Kolinski 2001). Densities at Tinian, estimated at 15.2 turtles per km of shoreline, are two times greater than on Saipan, nine times that of Rota, and 44 times greater of Aguijan (Minton et al. 2009). Few turtles (7%) were observed along the reefs north of the island, while the east and west coasts locations each accounted for 38% of all sightings. Based on these surveys, an estimated 833 green sea turtles occur in the waters off Tinian (Kolinski, Ilo, and Manglona 2004).Green turtles have been observed in waters within and nearby Tinian harbor, and green turtle nesting was reported prior to 1994 at Kammer Beach, just east of Tinian Harbor (Minton et al. 2009).

Aguijan. In 2001, 14 green sea turtles were observed during surveys of 95% of Aguijan's reefs (Kolinski 2001). Based on these surveys, an estimated 19 green sea turtles occur in the waters off Aguijan (Kolinski, Ilo, and Manglona 2004).

Rota. A 2003 in-water survey observed 73 individual green sea turtles along 51 km of Rota's outer reef, with the majority of turtles (55%) found on the east and south (26%) sides of the island (Kolinski et al. 2006). Concentrations were highest on the northeastern, eastern, and southeastern shorelines, although the survey did not identify ecological reasons for the differences in densities across the island. The population was dominated by juveniles, with only eight identified as adults. Based on these data, 118 turtles occur on Rota's nearshore reefs.

Guam. In Guam, nesting activity is currently documented opportunistically by Haggan-watch, a community-based volunteer network administered by Division of Aquatic and Wildlife Resources. Green sea turtle nesting on Guam is most prevalent at the northern and southern ends of the island (Gutierrez 2004). During the 2011 nesting season, at least 20 green sea turtle nests were documented.

Aerial surveys conducted by the Guam Division of Aquatic and Wildlife Resources indicate presence of a year-round resident population in Guam's nearshore waters (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998b). Aggregations of foraging and resting green sea turtles are often seen in close proximity to Guam's well-developed seagrass beds and reef flats, which are found in Cocos Lagoon, Apra Harbor, along Tarague Beach and Hilaan, in deeper waters south of Falcona Beach, and at several other locations throughout the island's shelf (Abraham et al. 2004; Davis n.d.; U.S. Department of the Navy 2003; Wiles et al. 1995). Recreational self contained underwater breathing apparatus (SCUBA) divers regularly see green sea turtles at the following sites off Guam: Boulder Alley, Ane Caverns, Napoleon Cut, Gab Gab I, and the Wall (Franko Maps Ltd. 2005).

In a 2011 extensive vessel-based survey of the western waters of Guam, six green turtles were sighted, all in waters less than 100 m deep and within one km of shore. Two were sighted in Tumon Bay, three in Agat Bay, and one in Agana Bay (HDR 2011). The average number of turtles was calculated at 0.011 turtles per nautical mile (nm) of transect, although most of the survey occurred in deep waters as far as 10 nm from shore.

Haputo Ecological Reserve Area – Green sea turtles are commonly sighted in the marine waters around the Haputo Ecological Reserve Area (Helber Hastert & Fee 2007b).

Orote Peninsula Ecological Reserve Area – As many as 21 green turtles have been sighted during underwater surveys along the Orote Peninsula (HDR 2011), including three within the nearshore waters of Agat Bay. The area has reefs with healthy algal assemblages that should support resident green sea turtles (Helber Hastert & Fee 2007a; Smith et al. 2009; Smith 2006), although the predominant species are not considered preferred forage of green turtles (Smith and Marx Jr. 2006).

Apra Harbor – Green tutles have been relatively common in Apra Outer Harbor (Smith 2006, 2007; Smith and Marx Jr. 2006), although generally swimming, as the harbor is generally not condusive to support resident turtles (Smith 2006). One location, Big Blue Reef W does include substantial algal forage, although turtles have not been observed feeding on the reef (Smith 2006, 2007).

CAROLINE ISLANDS. The nesting populations of green turtles in the Caroline Islands, primarily Yap and Palau, are among the largest in the North Pacific (Maison, Kelly, and Frutchey 2010). Data from satellite tracked Yap turtles indicate that Yap turtles spend five to six weeks post-nesting in the waters near these beaches before migrating to foraging grounds in the Philippines (Cruce 2009). Post-nesting Palau turtles from Merir and Helen Islands, conversely, have been tracked migrating south past West Papua and on to the Aru Islands, Indonesia in the Banda Sea (Klain et al. 2007). Other satellite data indicate that the green turtles from Yap and Palua migrate widely throughout the Western Pacific and Southeast Asia(Klain et al. 2007).

Yap. Green sea turtles are the most common turtle species nesting in Yap. Genetic analysis suggests nesting green sea turtles in Yap are of one genetic stock distinguishable from other Pacific nesting populations (Maison, Kelly, and Frutchey 2010). Ulithi Atolll, 115 miles northeast of Yap proper, is the location of five significant green turtle nesting populations (Cruce 2009). Green sea turtle nesting peaks between April and August, with some evidence of year-round nesting. Nest counts have been ongoing since 2005 (Cruce 2009). In 2010, 396 and 87 nesting females were counted on Gielop Island and Loosiep Island (Ulithi Atoll), respectively (The SWoT Team 2011). Monitoring data from 2000 and earlier reported 124 nesting females on Iar Island (Ulithi Atoll), 12 nesting females on Oroluk Atoll, 30–40 nesting females on Elato Atoll, 70–75 nesting females on Ngulu Atoll, and 27 nesting females on Olimarao Atoll (The SWoT Team 2011).

Commercial sale of sea turtle meat and eggs is prohibited in Yap, and traditional harvest is managed through cultural limitations dictated by leaders on the chief island, Mogmog (Cruce 2009). Turtle take may have increased in recent years, although this has not been quantified (Maison, Kelly, and Frutchey 2010).

Palau. In 2005, the Palau Bureau of Marine Resources established the Palau Sea Turtle Conservation and Management Program to monitor beaches and obtain data in 10 of Palau's 16 states. Green sea turtle nesting has been documented at Helen Reef in Hatohobei State and Merir Island in Sonsorol State, with additional low-level nesting in Ngarchelong, Kayangel, and Melekeok States (Maison, Kelly, and Frutchey 2010). During the 2005 monitoring season, 301 green sea turtles nests were counted, and 47 individual turtles were tagged on Helen Reef, with nesting turtles emerging almost every night between April and August. On Merir Island, 331 nests were counted, and 36 individual turtles were tagged, with peak nesting in May. Over a 9-month period in 2007–2008, 739 turtle nests were counted at Pulo Ana Island in Sonsorol State. Peak nesting was also in May (Maison, Kelly, and Frutchey 2010).

Harvest of sea turtles is permitted in Palau, although it is regulated by minimum size limits and closed seasons. Green sea turtles must be 34 in. carapace length, and the closed seasons occur from June 1 to August 31, and December 1 to January 31 (Maison, Kelly, and Frutchey 2010).

6.3.6 Species-specific Threats

Most threats to sea turtles are similar across species. These include egg harvest, intentional take of juveniles and adults, bycatch in fisheries, and loss of nesting habitat to development and sea level rise (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007a). The primary threat specific to green sea turtles is the loss of nearshore seagrass beds, as seagrass is the primary diet of green sea turtles (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007a). Seagrass habitats are among the most susceptible to degradation, as they occur in sheltered coastal areas many of which are targeted for port development and human settlements (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007a). Invasive algae, many of these toxic to turtles, can also overtake seagrass habitat.

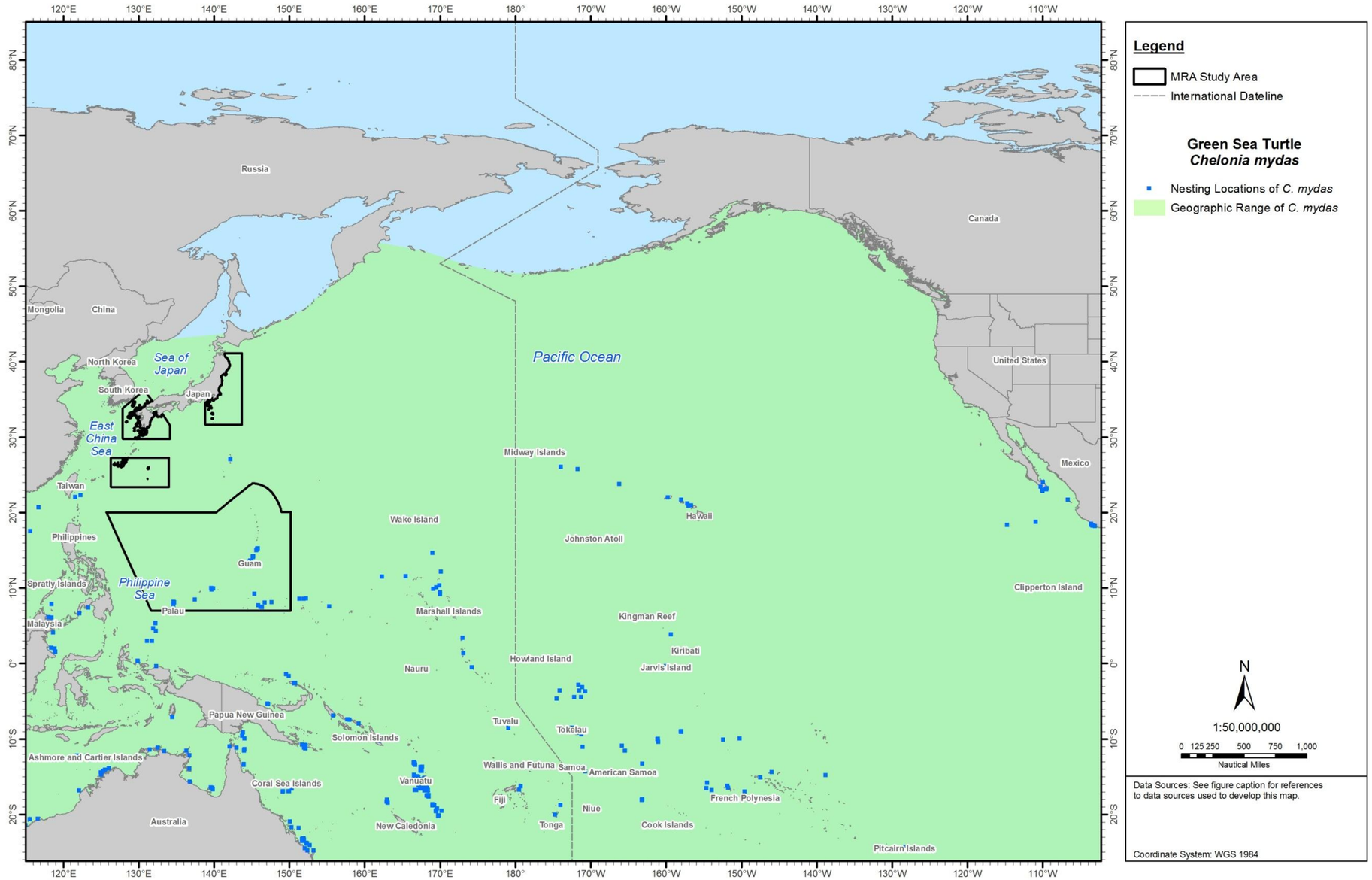

Figure 6-1: Geographic Range and Location of Nesting Beaches of the Green Sea Turtle in the North Pacific Ocean
Source: Márquez (1990). Nesting locations obtained by permission from the SWOT database.

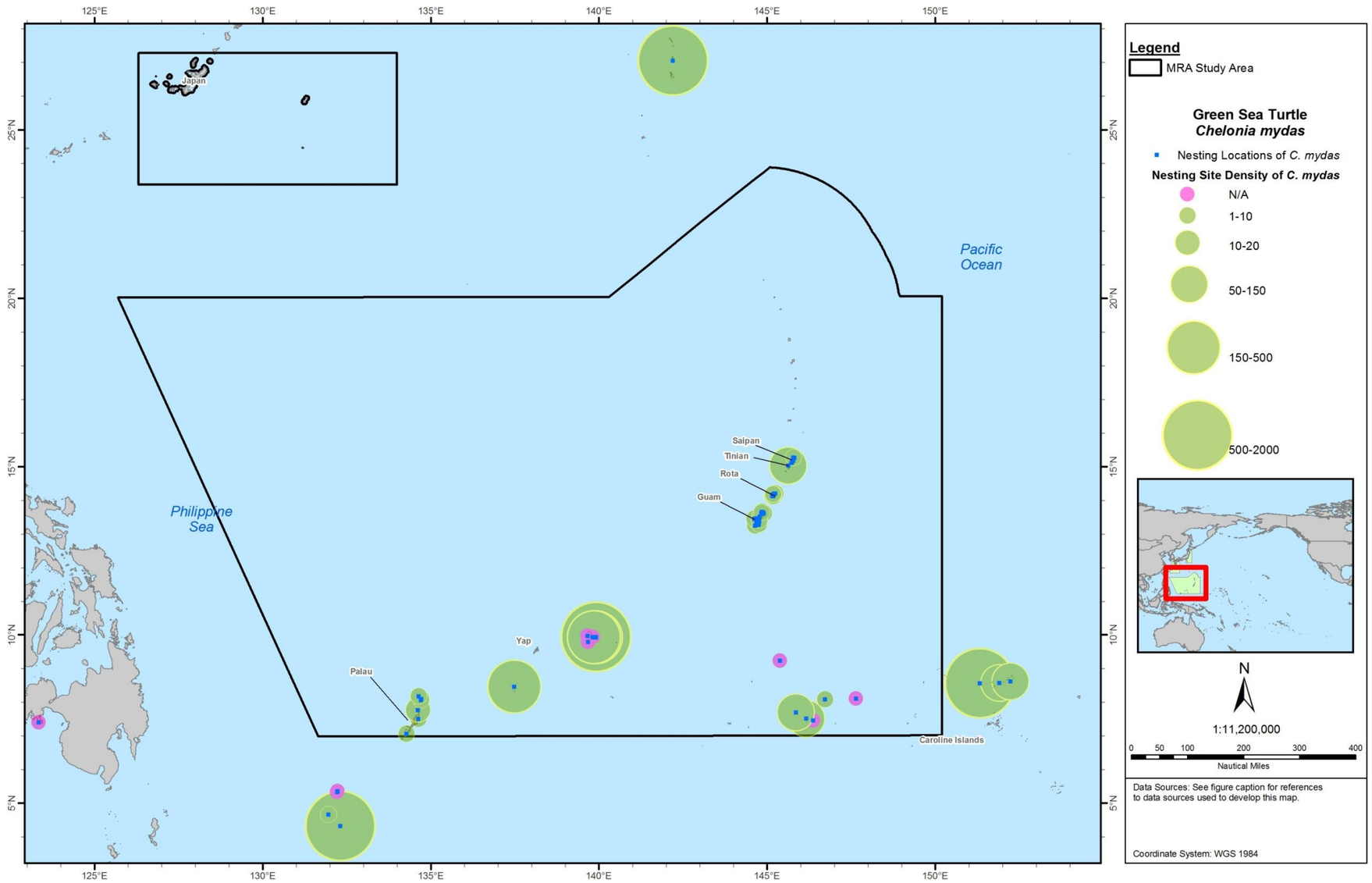

Figure 6-2: Locations and Density of the Green Sea Turtle Nesting Beaches in the MRA Study Area

Sources: Nesting locations obtained by permission from the SWOT database.

Densities obtained from Barr (2006); Bowen (1992); Chaloupka et al. (2007); Cruce (2008); Kolinski (1993); Hachiglou, Kolinski, and Smith (1991); Maison, Kelly, and Frutchey (2010); Pritchard and Plotkin (1995); The SWoT Team (2011); and Wenninger (2010, 2011, 2012).

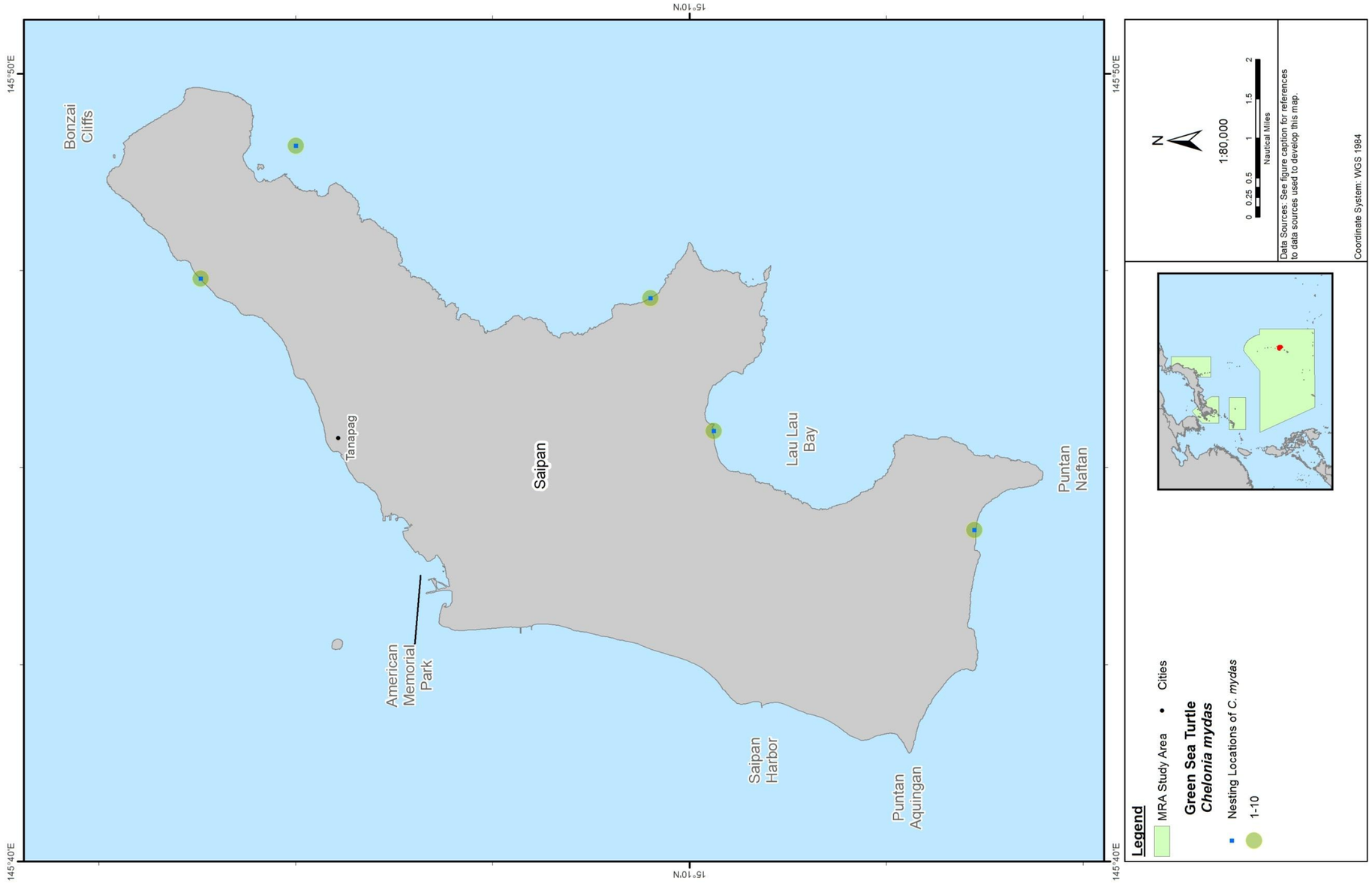

Figure 6-3: Locations and Density of the Green Sea Turtle Nesting Beaches in Saipan
Source: Nesting locations obtained by permission from the SWOT database for Saipan, nesting locations not available from the SWOT database for Tinian. Densities obtained from Maison, Kelly, and Frutchey (2010).

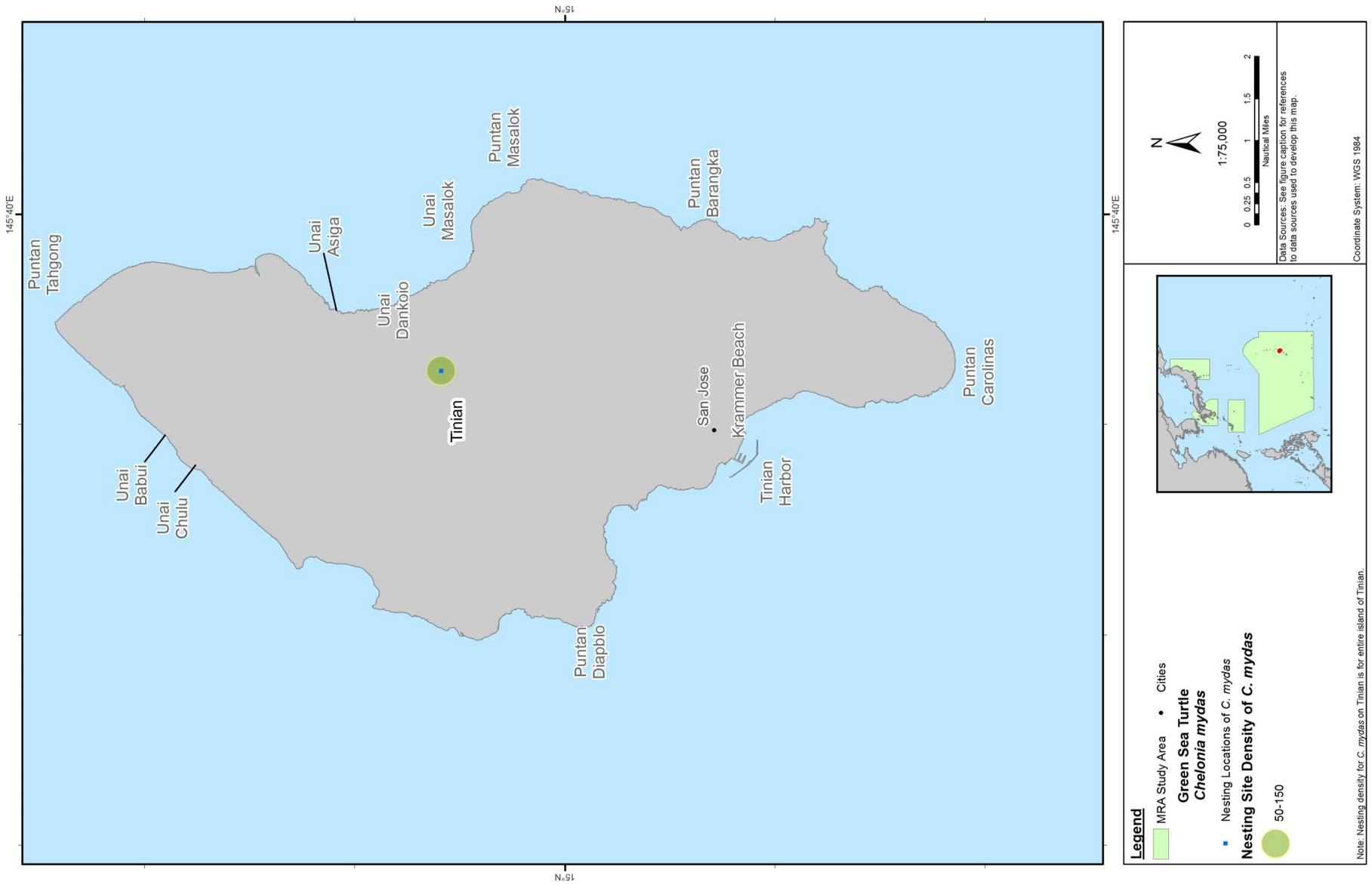

Figure 6-4: Locations and Density of the Green Sea Turtle Nesting Beaches in Tinian

Source: Nesting locations not available from SWOT database. Aggregate number of annual turtle nesting estimated from Maison, Kelly, and Frutchey (2010) and Wenninger (2010, 2011, 2012).

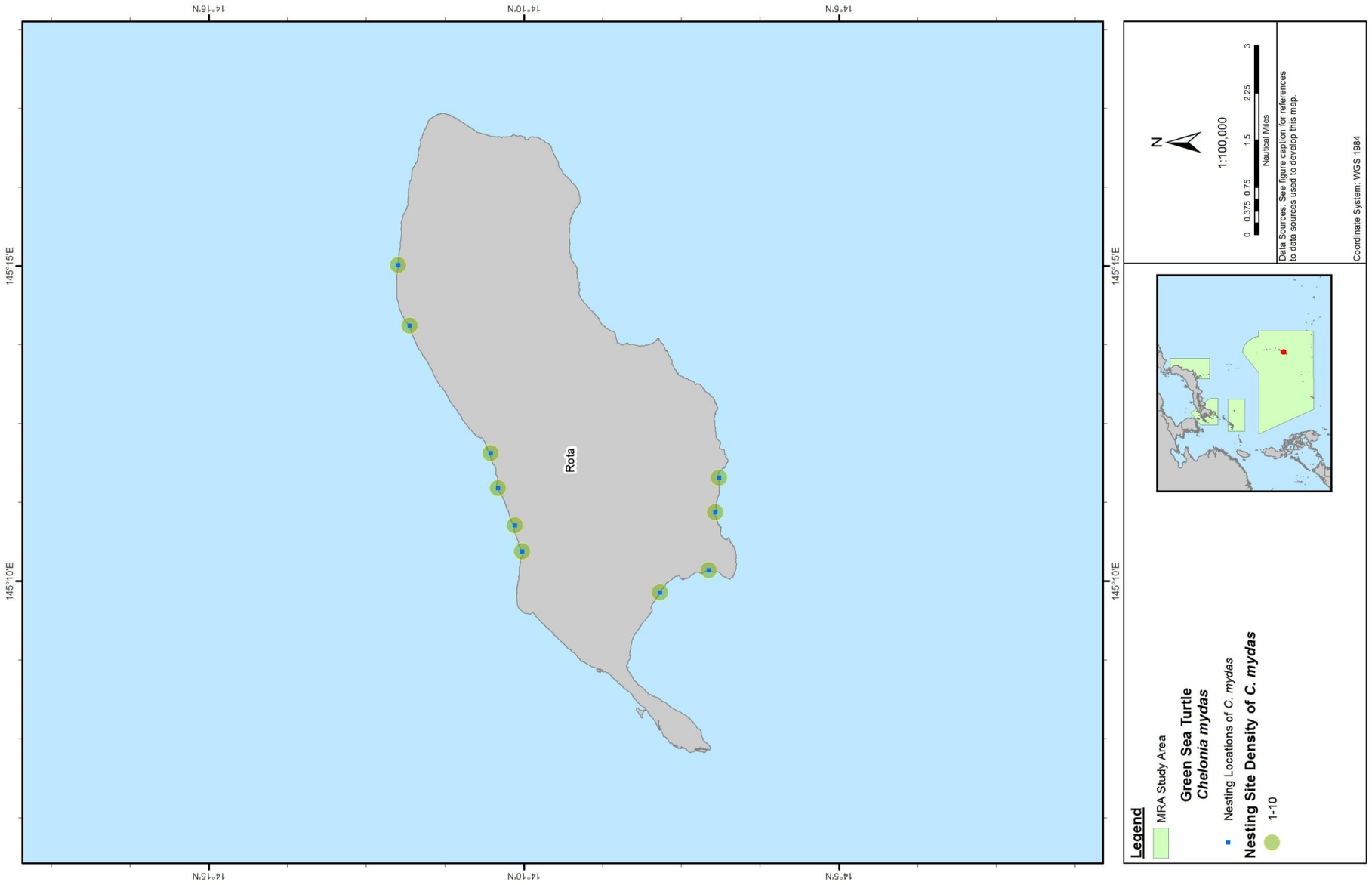

Figure 6-5: Locations and Density of the Green Sea Turtle Nesting Beaches in Rota

Source: Nesting locations obtained by permission from the SWOT database. Densities obtained from Maison, Kelly, and Frutchey (2010).

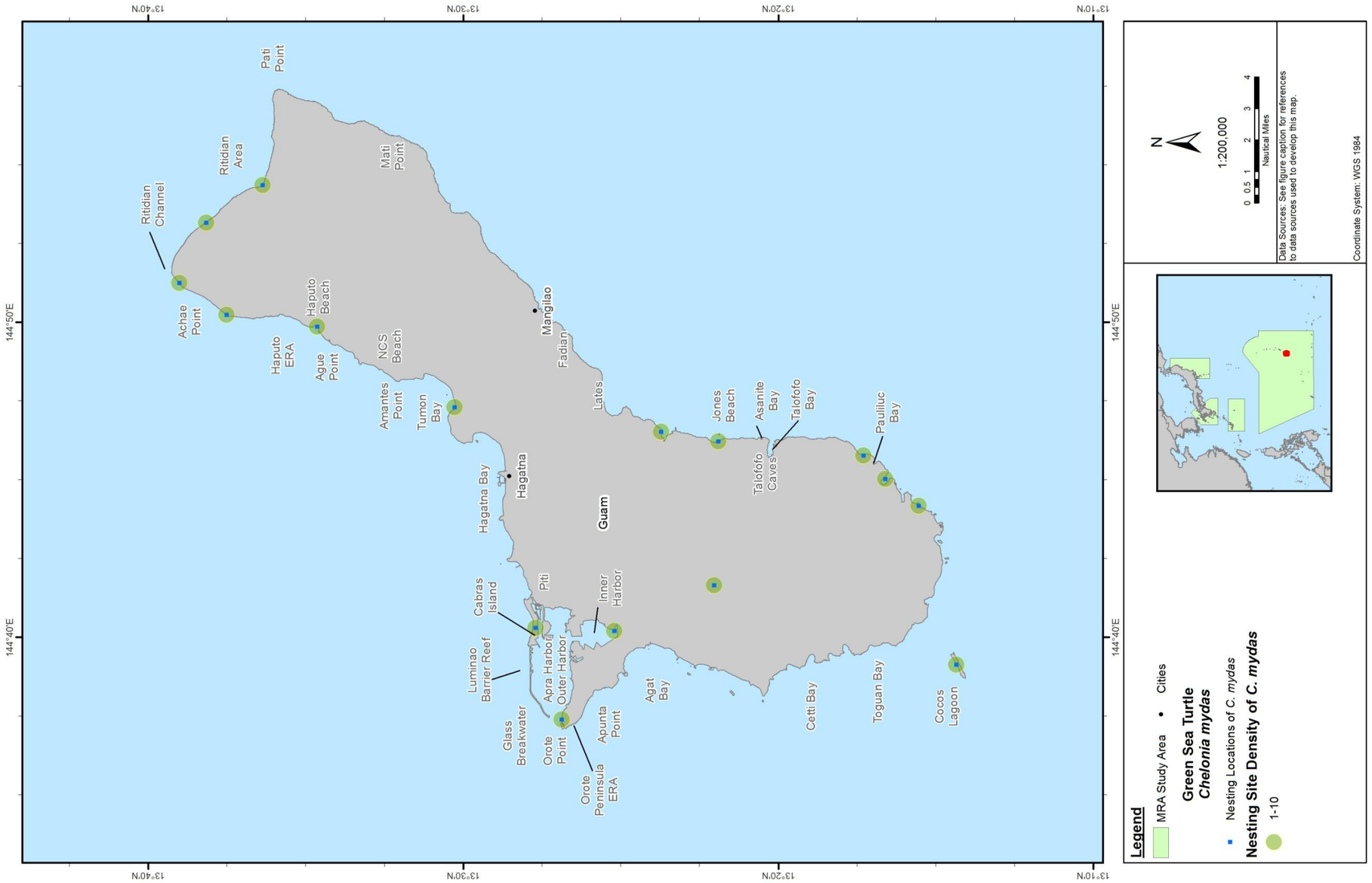

Figure 6-6: Locations and Density of the Green Sea Turtle Nesting Beaches in Guam

Source: Nesting locations obtained by permission from the SWOT database. Densities obtained from Maison, Kelly, and Frutchey (2010).

6.4 HAWKSBILL SEA TURTLE (ERETMOCHELYS IMBRICATA)

6.4.1 Description

The hawksbill sea turtle is a medium-sized, hard-shelled sea turtle, with adults weighing 100–150 lbs. (45–70 kg) and 2–3 ft. (65–90 cm) long (National Marine Fisheries Service 2012c). The head is narrow with a sharp, hawk-like beak that allows the turtle to reach into crevices of coral reefs looking for food. The carapace has overlapping, sharp scutes, colored dark to golden-brown with highlights of red, orange, and black.

6.4.2 Status and Management

The hawksbill sea turtle is listed as endangered under the ESA (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998c). While the current listing as a single global population remains valid, data may support separating populations at least by ocean basin under the distinct population segment policy (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007b), which would lead to specific management plans for each designated population. Hawksbills in the Eastern Pacific are probably the most endangered sea turtle population in the world (Gaos and Yañez 2008). The hawksbill shell has been prized for centuries by artisans and their patrons for jewelry and other adornments. This trade, prohibited under the Convention on International Trade in Endangered Species, remains a critical threat to the species (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007b). Critical habitat has not been designated for the hawksbill in the Pacific.

In the Yaeyama Islands of Japan, in the Okinawa prefecture, scientists at a stock enhancement research station have been studying propagation of the hawksbill sea turtle for stock recovery since 1999 (Kobayashi et al. 2010), although the program remains in the research stage with recent experiments on the behavior of captive-reared turtles (Okuyama et al. 2010).

6.4.3 Population and Abundance

A lack of nesting beach surveys for hawksbill sea turtles in the Pacific Ocean and a poor understanding of this species' nesting have made it difficult for scientists to assess the population status of hawksbills in the Pacific (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998c; Seminoff et al. 2003). An assessment of 25 sites around the world indicates that hawksbill nesting has declined by at least 80% over the last three generations (105 years in the Atlantic and 135 years in the Indo-Pacific) (Meylan and Donnelly 1999). Only five regional populations with more than 1,000 females nesting annually remain worldwide – two in Australia, and one each in Indonesia, the Seychelles, and Atlantic Mexico (Meylan and Donnelly 1999). The largest of these is in the South Pacific, where 6,000–8,000 hawksbills nest off the Great Barrier Reef (Limpus 1992).

The 2007 *5-Year Review* (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007b) assessed nesting abundance and nesting trends in all regions that the hawksbill sea turtles inhabit (Table 6-2). Of the 19 populations assessed in the Pacific, all showed historic (20–100 year trend) population declines. Recent trends (within past 20 years) were not much better, with only one (Hawai'i population) exhibiting an increasing population trend.

Table 6-2: Summary of Worldwide Hawksbill Nesting Trends

Ocean Basin	Number of Sites								
	Total Sites	Recent Trends (within past 20 years)				Historic Trends (over 20 to 100 years)			
		▲	▬	▼	?	▲	▬	▼	?
Atlantic	33	9	0	11	13	0	0	25	8
Indian	31	0	2	5	24	0	0	17	14
Pacific	19	1	1	13	4	0	0	16	3
Total	83	10	3	29	41	0	0	58	25

Key: ▲ = increasing population; ▬ = stable population; ▼ = decreasing population; **?** = unknown trend.
Source: (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007b).

Hawksbills in the U.S. Pacific nest only on main island beaches in Hawai‘i (5–10 nesting females annually), primarily along the east coast of the Island of Hawai‘i (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007b).

6.4.4 Biology, Ecology, and Behavior

Predator/Prey Interactions. Hawksbills eat both animals and plants during the early juvenile stage, feeding on such prey as sponges, algae, mollusks, crustaceans, and jellyfish (Bjorndal 1997). Older juveniles and adults feed primarily on sponges, which comprise as much as 95% of their diet in some locations, although the diet of adult hawksbills in the Indo-Pacific includes other invertebrates and algae (Meylan 1988; Witzell 1983). The shape of the hawksbill’s mouth allows it to reach into holes and crevices of coral reefs to find sponges and other invertebrates.

Predators of hawksbills vary according to turtle location and size. Land predators on eggs and hatchlings include ants, crabs, birds, and mammals, such as dogs, raccoons, and feral pigs. Aquatic predators, mostly fish and sharks, impact hatchlings most heavily in nearshore areas. Sharks are the primary predators of juvenile and adult turtles (Stancyk 1982).

Life History. As with all other turtle species, hawksbill hatchlings enter an oceanic phase and may be carried great distances by surface currents. Although little is known about their open ocean stage, younger juvenile hawksbills have been found in association with sargassum in the Pacific Ocean (Musick and Limpus 1997; Parker 1995; Witherington and Hirama 2006; Witzell 1983) before settling into nearshore habitats as older juveniles. Preferred habitat is coral reefs, but hawksbills also inhabit seagrass, algal beds, mangrove bays, creeks, and mud flats (Mortimer and Donnelly 2008). Some juveniles may associate with the same feeding grounds for a decade or more (Meylan 1999), while others appear to migrate among multiple sites as they age (Musick and Limpus 1997). Indo-Pacific hawksbills are estimated to mature between 30 and 38 years old (Mortimer and Donnelly 2008).

Once sexually mature, they undertake breeding migrations between foraging grounds and breeding areas at intervals of several years (Dobbs et al. 1999; Mortimer and Bresson 1999; Witzell 1983). Although females tend to return to breed where they were born (Bowen and Karl 1997), as juveniles they may have foraged hundreds or thousands of km from their birth beaches.

Hawksbills are solitary nesters on beaches throughout the tropics and subtropics. During the nesting season, female hawksbills return to their natal beaches every 2 to 3 years at night. A female hawksbill lays between three and five clutches during a single nesting season, which contain an average of 130 eggs per clutch (Mortimer and Bresson 1999; Richardson, Bell, and Richardson 1999). In the Ryukyu archipelago, the nesting seasons runs approximately from mid-May through July (Kikukawa, Kamezaki, and Ota 1999).

Migration. Hawksbills were originally thought to be a non-migratory species as a result of the close proximity of suitable nesting beaches to coral reef feeding habitats and the high rates of local recapture, including hawksbills tagged in the Yaeyama Islands of Japan (Kamezaki and Hirate 1992). Other tagging studies have shown wide-ranging migrations. A sub-adult tagged in Brazil was captured in Gabon, with a straight-line migration distance of 4,669 km (Bellini, Sanches, and Formia 2000). In the Indo-Pacific, a post-nesting female travelled 1,600 km between the Solomon Islands and Papua New Guinea (Meylan 1995). A female tagged at Buck Island Reef National Monument in the U.S.Virgin Islands traveled 1,160 miles (1,866 km) to the Miskito Cays in Nicaragua (Spotila 2004). This research indicates that adult hawksbill sea turtles are capable of migrating distances comparable to green and loggerhead turtles.

Hearing/Vocalization. As research into turtle hearing and vocalization is limited, a general description of hearing and vocalization is provided in Section 6.1.2, Biology, Life History and Behavior [all turtles].

Diving. Foraging dive durations are often a function of turtle size, with larger turtles diving deeper and longer. Shorter and more active foraging dives occur predominantly during the day, while longer resting dives occur at night (Blumenthal et al. 2009; Storch et al. 2005; van Dam and Diez 1996). Lutcavage and Lutz (1997) cited a maximum dive duration of 73.5 minutes for a female hawksbill in the U.S. Virgin Islands. Van Dam and Diez (2000) reported foraging dives at a study site in the northern Caribbean ranged from 19 to 26 minutes at depths of 26.3 to 32.8 ft. (8 to 10 m), with resting night dives from 35 to 47 minutes. Foraging dives of immature hawksbills are shorter, ranging from 8.6 to 14.0 minutes, with a mean and maximum depth of 16.4 ft. and 65.6 ft. (5 m and 20 m), respectively (van Dam and Diez 1996). (Blumenthal et al. 2009) reported consistent diving characteristics for juvenile hawksbills in the Cayman Islands, with an average daytime dive depth of 25 ft. (8 m), a maximum depth of 140 ft. (43 m), and a mean nighttime dive depth of 15 ft. (5 m). A change in water temperature affects dive duration; cooler water temperatures in the winter result in increased nighttime dive durations (Storch et al. 2005).

6.4.5 Habitat and Distribution

The hawksbill rarely occurs in latitudes higher than 30°N or 30°S in the Atlantic, Pacific, and Indian Oceans (Lazell 1980; The SWoT Team 2008; Witzell 1983). It inhabits coastal waters in more than 108 countries (Groombridge and Luxmoore 1989) and nests in at least 70 countries. The major regional rookeries in the western Pacific are the Northern Australian stock, the Solomon stock, the Sabah stock, and the peninsular Malaysian stock (Chaloupka, Dutton, and Nakano 2004). Within the Central Pacific, nesting is widely distributed, though scattered and in very low numbers. In the U.S. Pacific, hawksbills nest only on main island beaches in Hawai‘i, American Samoa, and Guam (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007b). Hawksbills also nest in Japan and the Philippines (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007b).

Hawksbills generally occur closer to shore than the other marine turtles, with juveniles and adults preferring coral reef habitats (National Marine Fisheries Service 2012c). Reefs provide shelter for resting hawksbills day and night, and they are known to visit the same resting spot repeatedly. Hawksbills are

also found around rocky outcrops and high-energy shoals—optimum sites for sponge growth—as well as in mangrove-lined bays, estuaries, and saltwater mangrove forests (Gaos et al. 2012; National Marine Fisheries Service 2012c).

Figure 6-7 shows hawksbill sea turtle nesting sites throughout the Pacific, as provided by turtle research groups to the State of the World's Sea Turtles (SWOT) database. Figure 6-8 shows hawksbill sea turtle nesting sites and beach-specific nesting densities in Palau, the only location within the the MRA Study Area where there is appreciable hawksbill nesting.

Open Ocean Water of the MRA Study Area

Hawksbills are known to occasionally migrate large distances, possibly in the open ocean. Hatchling and early juvenile hawksbills have been found in the open ocean, in association with floating mats of seaweed (Maison, Kelly, and Frutchey 2010; Musick and Limpus 1997). Although information regarding foraging areas is largely unavailable due to research limitations, juvenile and adult hawksbills may also be present in open ocean environments (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007b).

NORTH CENTRAL PACIFIC GYRE. While sub-adult and adult hawksbills have been observed in the pelagic environment, and post-hatchlings and juveniles remain in the pelagic zone for years, the pelagic habitat in the Pacific is unknown (National Marine Fisheries Service 2012c).

KUROSHIO CURRENT. Because the hawksbill is a highly tropical species, it is not expected to occur in waters north of where the Kuroshio Current deflects off the coast of Honshū. South of the Kuroshio deflection, hawksbills may occur off the Japanese mainland, as evidenced by a few sightings and strandings of juvenile turtles off southern Honshū, Shikoku, and Kyūshū (Uchida and Nishiwaki 1995).

Coastal Waters of the MRA Study Area.

Foraging hawksbills have been reported from virtually all of the island groups of Oceania and from the Galapagos Islands in the eastern Pacific to Palau in the western Pacific (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007b; Witzell 1983).

JAPAN ARCHIPELAGO. There is little information on the abundance of hawksbills in Japanese waters, although the population is believed to be very small (Eckert 1993; Ishikawa and Osawa 2002). They are expected to occur year round in shelf waters surrounding all islands of the Ryukyu Archipelago south of 30°N based on their preference for nearshore habitats and their known nesting range in these islands (Sea Turtle Association of Japan 2005b). Hawksbills are known to occur in areas south of the Izu Peninsula on the Pacific side and Noto Peninsula on the Japan Sea side (Uchida and Nishiwaki 1995). In-water occurrence is not concentrated in the coastal areas of the northern and central Ryukyu Islands (i.e., the Ōsumi, Amami, and Okinawa islands) as the extreme scarcity of nesting in these areas limit the need for migration or residence in the Ryukyu Islands (Kikukawa, Kamezaki, and Ota 1999).

Hawksbill sea turtle nests have been reported on Kakeroma Island of the Amami group (Uchida 1994), on Okinawa Island (Eckert 1993; Kikukawa, Kamezaki, and Ota 1999), and in the Kerama group (Tetra Tech EM Inc. 2010), Miyako group (Tetra Tech EM Inc. 2010), and Yaeyama group (Kamezaki 1989; The SWoT Team 2008). The northern limit of nesting occurs in the Nansei Islands (Uchida and Nishiwaki 1995). The most recent nesting data available is for 2006 on Ishigaki island in the Yaeyama group (The

SWoT Team 2008) , and 2008 on Okinawa Island (Tetra Tech EM Inc. 2010), where fewer than 10 nests were reported at each location.

The coral waters of the Yaeyama group are important foraging grounds for the hawksbill in Japan (Kamezaki and Hirate 1992; Kamezaki et al. 2003; Nishizawa et al. 2010). The relatively slow growth rate of hawksbills in Yaeyama waters suggests that the turtles may be food-limited (Tetra Tech EM Inc. 2010). In addition, the average size of hawksbills in Yaeyama waters (18 in. [46 cm]) indicates that most are juveniles (Tetra Tech EM Inc. 2010). Hawksbills sometimes occur both on the Pacific coast of Honshū and on the Japan Sea coast of Honshū (Tetra Tech EM Inc. 2010).

MARIANA ARCHIPELAGO. Hawksbills are rare in the Mariana Archipelago, with only a single record of a nesting event, which occurred in 1991 on Guam, and no nests reported in the Northern Mariana Islands. While hawksbills were last reported to be nesting in Guam in 1995, recent monitoring efforts have found no evidence of hawksbill nesting (The SWoT Team 2008). A small population of foraging hawksbills occurs in Guam waters. Two hawksbills were sighted during underwater surveys at FDM in 2005 and 2006 (Smith and Marx Jr. 2009) and one in 2010 (Smith and Marx Jr. 2010). A single hawksbill turtle was sited more than 100 nm west of FDM during the 2007 MICTCS cruise (U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007).

Sasa Bay within Apra Harbor, and Orote Peninsula to the south of the harbor, are considered feeding grounds of the hawksbill turtle (Helber Hastert & Fee 2007a, b). An area known as Big Blue Reef West within Apra Harbor has a healthy sponge population, the primary forage of hawksbills, although no hawksbills have been observed and no bite marks on the sponges were seen during the surveys (Smith 2007). Two underwater sightings of hawksbills were made in November 2003 near Kilo Wharf and one in October 2004 (Smith 2006). One hawksbill was seen swimming off St. Louis Beach in 2005 in a large and diverse area of sponges. Although no bite marks were observed on sponges, the sighting and abundance of prey suggest this may be a hawksbill foraging site (Smith 2006).

CAROLINE ISLANDS. Hawksbills nest at low levels in Palau and Yap (The SWoT Team 2008), with a single hawksbill nest reported in Yap in 2005 (Maison, Kelly, and Frutchey 2010). A hawksbill tagged in Palau was caught in a fishing net 950 km to the west in the Philippines, indicating extensive migrations in the region (Klain et al. 2007).

Yap. A marine turtle nesting beach monitoring project on Gielop and Iar Islands, Ulithi Atoll, Yap State, Federated States of Micronesia in 2005 (June to August) included tagging, measurements, health assessments, and tissue sample collection of nesting sea turtles. This project was repeated in summer 2006 and focused on Gielop Island alone for logistical reasons including issues of boat and staff availability. In 2005, a single nesting hawksbill was observed and tagged while nesting on Gielop Island, and no hawksbills were observed in 2006 (The SWoT Team 2006).

Palau. Palau has one of the largest nesting populations of hawksbills in Micronesia (Klain et al. 2007), where they nest primarily in the Rock Islands Southern Lagoon area of Koror State. There are 13 known nesting sites and an estimated 250-400 nesting females every year in Palau (Maison, Kelly, and Frutchey 2010). The hawksbill sea turtle population is declining in Palau, despite a head-start program in Koror since 1982 that reared and released 2,364 6–12 month old turtles between 1982 and 1990 (Sato and Madriasau 1991). Because that undertaking was not successful, new management techniques, including nest protection, have been attempted.

In 2006, 79 hawksbill sea turtle nests were found in Palau within the States of Melekeok (1), Peleliu (6), Koror (47), Ngaraard (8), Ngarchelong (7), and Kayangel (10). Nesting season in Palau is from May to August (The SWoT Team 2006).

6.4.6 Species-specific Threats

Hawksbills appear to be rarely caught in pelagic fisheries (McCracken 2000; Plotkin 1995), although artisanal fisheries bycatch in foraging areas of the western Pacific is listed as a serious to extreme threat to the population (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007b). Nevertheless, the main hazards for hawksbills are commercial harvesting for bekko (tortoiseshell), egg harvesting, and nesting habitat destruction (Meylan and Donnelly 1999; National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998c).

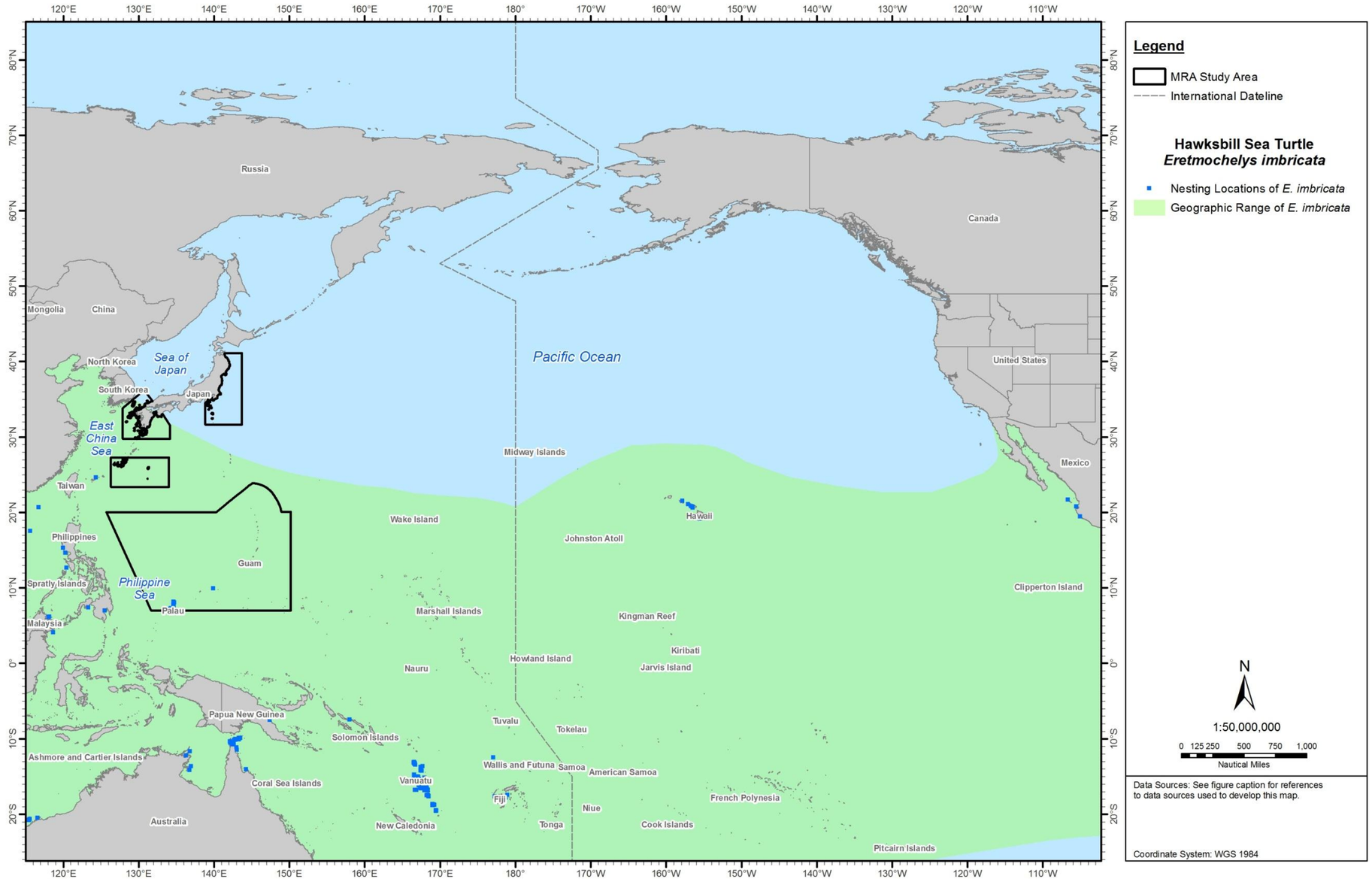

Figure 6-7: Geographic Range and Location of Nesting Beaches of the Hawksbill Sea Turtle in the North Pacific Ocean
Source: Márquez (1990). Nesting locations obtained by permission from the SWOT database.

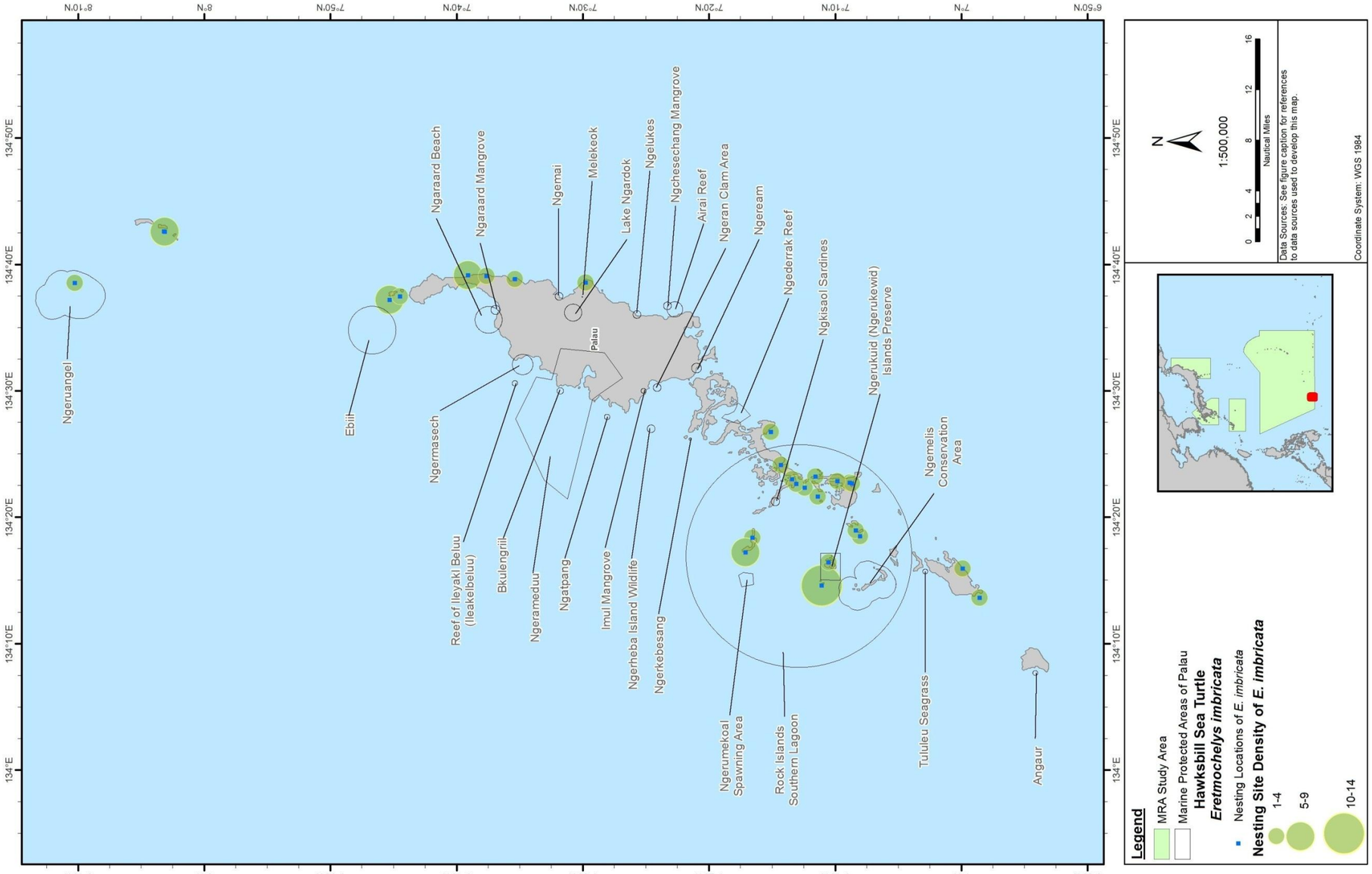

Figure 6-8: Locations and Density of the Hawksbill Sea Turtle Nesting Beaches in Palau
Source: Nesting locations obtained by permission from the SWOT database. Densities obtained from Klain et al. (2007).

6.5 LOGGERHEAD SEA TURTLE (CARETTA CARETTA)

6.5.1 Description

Loggerhead sea turtles are one of the larger species of turtle, named for their large blocky heads that support powerful jaws used to feed on hard-shelled prey. Adult loggerheads weigh an average of 250 lbs. (113 kg) and are 3 ft. (1 m) in length. They have a reddish-brown carapace with a pale yellow plastron. The loggerhead is found in temperate to tropical regions of the Atlantic, Pacific, and Indian Oceans, and in the Mediterranean Sea (National Marine Fisheries Service 2012c).

6.5.2 Status and Management

A complete stock analysis was conducted for the loggerhead turtle to identify distinct population segments within the global population (Conant et al. 2009). Three distinct population segments occur in the Pacific: North Pacific, South Pacific, and Southeast Indo-Pacific Ocean. Genetic data (Bowen et al. 1995; Resendiz et al. 1998) and tagging data (Conant et al. 2009) indicate that the South Pacific and Southeast Indo-Pacific Ocean nesting populations rarely, if ever, are found in North Pacific waters. North Pacific loggerheads nest exclusively in Japan. Based on a review of census data obtained from most of the Japanese beaches from the 1950s through the 1990s, Kamezaki et al. (2003) concluded that the annual loggerhead nesting population in Japan declined 50–90% in recent decades. This drop in numbers was primarily the result of fishery bycatch from the coastal pound net fisheries off Japan, coastal fisheries that affect juvenile foraging populations off Baja California, and undescribed fisheries that likely affect loggerheads in the South China Sea and the north Pacific Ocean (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007d). More recently, loggerhead nest numbers across Japan have increased from 2,064 in 1997 to 11,000 nests in 2008. While nesting numbers have gradually increased in recent years, current nesting represents a fraction of historical nesting levels (Kamezaki et al. 2003). In September 2011, National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) designated the North and South Pacific distinct population segments as endangered (National Marine Fisheries Service 2011). Although two petitions to designate critical habitat have been submitted to NMFS (Turtle Island Restoration Network [16 July 2007] and the Center for Biological Diversity [November 16, 2007]), critical habitat has yet to be designated for Pacific loggerheads.

6.5.3 Population and Abundance

The global population of loggerhead turtles is estimated at 43,320–44,560 nesting females (Spotila et al. 2000). The largest nesting populations occur in the subtropics on the western rims of the Atlantic and Indian Oceans. Although recent efforts have provided a much more detailed picture of nesting populations worldwide, no data are currently available on population size in the oceanic habitat. The North Pacific loggerhead distinct population segment, which is the segment that occurs in the MRA Study Area, nests primarily in Japan (Kamezaki et al. 2003), although low-level nesting may occur on beaches surrounding the South China Sea (Conant et al. 2009). The largest Pacific nesting aggregation is between 1,000 and 10,000 females nesting per year in Japan and eastern Australia, and approximately 10 to 100 females nesting in New Caledonia. The Australia and New Caledonia aggregations are part of the South Pacific distinct population segment, and are not expected to occutr in the MRA Study Area.

In 2003, fewer than 1,000 females were estimated to breed annually in Japan (Kamezaki et al. 2003). In recent years, Japan beach nest counts have increased from a low of 2,064 nests in 1997 to a high of 11,082 in 2008. The most recent nest counts for 2009, 2010, and 2011 are 7,495, 10,121, and 9,011,

respectively (National Marine Fisheries Service 2012a). Based on these nesting numbers, the adult female population in the North Pacific for 2008–2012 is estimated at 7,138 (Van Houtan and Halley 2011).

Recent studies indicate that fewer than 1,000 females nest annually in Japan (Kamezaki et al. 2003). Long-term counts of loggerheads in all parts of southern Japan have shown that the number of loggerheads breeding there has decreased by more than half since 1990 (Hatase, Kinoshita, et al. 2002; Sato et al. 1997; Sea Turtle Association of Japan 2005a).

6.5.4 Biology, Ecology, and Behavior

Predator/Prey Interactions. In both open ocean and nearshore habitats, loggerheads are primarily carnivorous, although they also consume some plant matter (Bjorndal 1997; Dodd 1988). Both juveniles and adults forage in coastal habitats, where they feed primarily on the bottom, although they also capture prey throughout the water column (Bjorndal 2003). Adult loggerheads feed on a variety of bottom-dwelling animals, such as crabs, shrimp, sea urchins, sponges, and fish. They have powerful jaws that enable them to feed on hard-shelled prey, such as whelks and conch. During migration through the open sea, they eat jellyfish, mollusks, flying fish, and squid.

Polovina et al. (2006) found that juvenile loggerheads in the western North Pacific Ocean at times swim against weak prevailing currents due to the attraction of areas of high productivity. Similar observations have been made in the Atlantic (Hawkes et al. 2006). These results suggest that locations of currents and associated frontal eddies are important to the loggerhead's foraging during its open ocean stage (McClellan and Read 2007).

Predators of loggerheads vary according to turtle location and size. Land predators on eggs and hatchlings include ants, crabs, birds, and mammals, such as dogs, raccoons, and feral pigs. Aquatic predators, mostly fish and sharks, impact hatchlings most heavily in nearshore areas. Sharks are the primary predators of juvenile and adult turtles (Stancyk 1982).

Life History. Females lay three to five nests, and sometimes more, during a single nesting season (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007d). Mean clutch size is approximately 100 to 130 eggs per clutch (Dodd 1988). The temperature of a viable nest ranges between 79 and 90 degrees Fahrenheit (°F) (26 - 32°C). Eggs incubate approximately 2 months before they hatch (Mrosovsky 1980). As with all sea turtles, incubation temperature near the upper end of the viable range (32°C) produces all females, and temperature near the lower end (26°C) produces all male hatchlings (Mrosovsky 1980).

Hatchlings travel to oceanic habitats and often are found in seaweed drift lines (Carr 1986, 1987; Witherington and Hirama 2006). Loggerheads spend the first 7–11.5 years of their lives in the open ocean (Bolten 2003). In the North Pacific, foraging juvenile loggerheads congregate along the Kuroshio Extension Bifurcation Region (or Transition Zone Chlorophyll Front), where warm, low-chlorophyll water meets cool, high chlorophyll water (Howell et al. 2010; Kobayashi et al. 2008; Polovina et al. 2006). At about 14 years old, some juveniles move to nearshore habitats close to their birth area, while others remain in the oceanic habitat or move back and forth between the two (Laurent et al. 1998; Musick and Limpus 1997). Turtles may use the same nearshore developmental habitat all through maturation or may move among different areas, finally settling in an adult foraging habitat. Loggerheads reach sexual maturity at around 35 years of age and move from subadult to adult coastal foraging habitats (Godley et al. 2003; Musick and Limpus 1997). Data from Japan (Hatase, Matsuzawa, et al. 2002), Cape Verde

(Hawkes et al. 2006), and Florida (Reich et al. 2007) indicate that at least some of the adult population forage in the open ocean.

Migration. The loggerhead embarks on transoceanic migrations, and has been reported as far north as Alaska and as far south as Chile. Loggerheads foraging in and around Baja California originate from breeding areas in Japan (Conant et al. 2009), while Australian stocks appear to migrate to foraging grounds off the coasts of Peru and Chile (Alfaro-Shigueto et al. 2004).

Hearing/Vocalization. As research into turtle hearing and vocalization is limited, a general description of hearing and vocalization is provided in Section 6.1.2, Biology, Life History and Behavior [all turtles].

Diving. Loggerheads do not dive particularly deep in the open ocean (about 80 ft. [25 m]), although they will forage to bottom depths of at least 490 ft. (150 m) in coastal habitats (Hatase, Omuta, and Tsukamoto 2007; Polovina et al. 2003; Soma 1985). Diving profiles in open ocean and nearshore habitats appear to be based on location of the food source, with turtles foraging in the nearshore habitat diving to the seafloor (average depth 165–330 ft. [50–150 m]) and those in the open ocean habitat diving exclusively in the 0–80 ft. (0–25 m) depth range (Hatase, Omuta, and Tsukamoto 2007). Dive duration increases in warmer waters. The average foraging dive duration is 25 minutes, although night resting dives at depths of 45 ft. (14 m) longer than 300 minutes have been recorded. Resting appears to be the main function of night dives (Hatase, Omuta, and Tsukamoto 2007).

A study in the Central North Pacific Ocean, using two longline-caught loggerheads, showed that the turtles spent about 40% of their time in the top 3 ft. (1 m), 70% of the dives were no deeper than 15 ft. (5 m), and virtually all of their time was spent in water shallower than 330 ft. (100 m) (Polovina et al. 2003).

6.5.5 Habitat and Distribution

Loggerheads occur throughout the temperate and tropical regions of the Atlantic, Pacific, and Indian Oceans, in habitats ranging from coastal estuaries to the open ocean (Dodd 1988). Loggerheads spend much of their lives in the open ocean (Kobayashi et al. 2008). Recent studies have attempted to correlate at-sea distribution with environmental variables to help understand how loggerheads utilize pelagic habitats (Carr 1987; Luschi, Hays, and Papi 2003; Polovina et al. 2004; Polovina et al. 2000; Polovina et al. 2006). Studies of satellite-tracked north Pacific loggerheads indicate that five variables influence their pelagic distribution: sea surface temperature, chlorophyll a concentration, earth magnetic force, earth magnetic declination, and earth magnetic inclination (Kobayashi et al. 2008). Of these, temperature and chlorophyll concentration are temporal features of the pelagic environment identifiable through remote sensing data, and confirm the importance of the 8,000-km long Transition Zone Chlorophyll Front of the north Pacific (Kobayashi et al. 2008; Polovina et al. 2001).

Similar to the leatherback, the loggerhead embarks on transocean migrations. Migratory routes can be coastal or involve crossing deep ocean waters (Schroeder, Foley, and Bagley 2003). The species can be found hundreds of km out to sea, as well as in inshore areas, such as bays, lagoons, salt marshes, creeks, ship channels, and the mouths of large rivers. Coral reefs, rocky places, and shipwrecks are often used as feeding areas. The nearshore zone provides crucial foraging habitat, as well as internesting and overwintering habitat. In the eastern Pacific, loggerheads have been reported as far north as Alaska and as far south as Chile, with most records of juveniles off the coast of California. Loggerheads that mate and nest in Japan cross the Pacific to feed in waters off the west coast of Mexico, including the Baja Peninsula, a critically important developmental habitat for juvenile loggerheads.

Loggerheads typically nest on beaches close to reef formations and adjacent to warm-temperature currents (Dodd 1988). They prefer nesting beaches facing the open ocean or along narrow bays (Conant et al. 2009). Nesting beaches tend to be wide and sandy, backed by low dunes and fronted by a flat sandy approach from the water (Miller, Limpus, and Godfrey 2003). Nests are typically laid between the high tide line and the dune front (Hailman and Elowson 1992).

Loggerheads are distributed throughout the tropical and temperate waters of the Pacific, with all known nesting beaches located north of 25°N and south of 25°S (The SWoT Team 2007). The only known nesting areas for loggerheads in the North Pacific are found in southern Japan, where the nesting season is late May to August (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998e). Nesting in other South Pacific locations occurs in low densities or remains unsubstantiated (Conant et al. 2009).

Figure 6-9 shows loggerhead sea turtle nesting sites throughout the Pacific, as provided by turtle research groups to the State of the World's Sea Turtles (SWOT) database. Figure 6-10 shows loggerhead sea turtle nesting sites and beach-specific nesting densities in Japan, the only country in the North Pacific where loggerheads nest.

Open Ocean Waters of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. The North Pacific loggerhead distinct population segment appears to use the entire North Pacific Ocean during development, with substantial evidence that individuals make two transoceanic crossings. The first crossing (west to east) is made immediately after they hatch from the nesting beach in Japan, using the Kuroshio and North Pacific currents (Kobayashi et al. 2008) to reach foraging grounds off Baja California (Bowen et al. 1995; Peckham et al. 2007). The second (east to west) is made when they reach either the late juvenile or adult life stage, returning to their natal beaches for reproduction (Nichols et al. 2000; Resendiz et al. 1998). They remain in the western Pacific for the remainder of their life cycle (Hatase, Kinoshita, et al. 2002; Iwamoto et al. 1985; Sakamoto et al. 1997; Tetra Tech EM Inc. 2010). Offshore, in waters beyond the 330-ft. (100-m) isobath, juvenile loggerheads forage in or migrate through the North Central Pacific Gyre as they move between North American developmental habitats and nesting beaches in Japan. The highest densities of loggerheads can be found just north of Hawai'i within the North Pacific transition zone (Polovina et al. 2000). Satellite tracks of 186 loggerheads show a concentration between 30 and 45°N and 140°E to 150°W, with smaller concentrations in the East China Sea and Baja California (Kobayashi et al. 2008).

KUROSHIO CURRENT. The loggerhead turtle, known in Japan as "akaumigame," is the most common sea turtle species occurring year round in the waters off Japan. Loggerhead turtles are widely distributed from Honshū to the southern Ryukyu Islands and from the continental shelf into deep, oceanic waters of the western North Pacific (Hatase, Kinoshita, et al. 2002; Hatase, Matsuzawa, et al. 2002; Uchida and Nishiwaki 1995). Only during winter-spring in waters north of where the Kuroshio Current deflects east off the coast of Honshū is loggerhead occurrence low or unknown. Off the northeast coast of Honshū, the cold water Oyashio Current dominates the region's oceanography. To prevent themselves from stranding due to cold-stunning, most loggerhead turtles avoid this cold water current during the coldest months of the year. However, when these temperate waters warm up in the summer-fall, loggerheads expand their range north to take advantage of northward-moving prey (Morreale and Standora 1998; Shoop and Kenney 1992). The Kuroshio Extension Bifurcation, located between 155°E and the dateline, and from 30 to 40°N, is an important pelagic foraging area of juvenile loggerheads during the fall,

winter, and spring (Polovina et al. 2006), when oceanographic conditions increase primary productivity and concentrate prey species.

EAST CHINA SEA. Tag-recapture studies have shown that the East China Sea is a major foraging habitat for post-nesting adult females (Balazs and Chaloupka 2006; Chan et al. 2007; Tetra Tech EM Inc. 2010), while the shallow waters of the East China Sea are a major wintering area for adult loggerheads (Iwamoto et al. 1985). Adult female loggerheads, presumably from the North Pacific stock, have been captured in coastal set net fisheries in the eastern waters of Taiwan (Cheng and Chen 1997), indicating migration across the East China Sea.

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Loggerheads nest from 24°N on Yakushima Island in the Nansei Archipelago, along the east coast of Kyūshū and Honshū Islands to 37°N (Uchida 1994). Nesting beaches are located only on the Pacific side of these islands (Kamezaki et al. 2003). Along the Pacific coast of Japan, nine major nesting beaches (greater than 100 nests per season) and six sub-major beaches (10–100 nests per season) have been identified. The main breeding areas for loggerheads are Inakahama on Yakushima Island, Miyazaki on Kyūshū, Hiwasa in Tokusima (Shikoku), the Senri Coast (Minabe beach) in Wakayama, and Omaezaki (Atsumi Beach) on Honshū (Sea Turtle Association of Japan 2012).

Bōsō Peninsula, Izu Peninsula, and Izu Islands. There is one important nesting beach in this region, at Omaezaki Beach. Nesting occurs between late-May and August, with the number of nests ranging from 22 to over 200 nests, fluctuating widely since 1973 (Nobetsu et al. 2004). The most recent nesting counts from the late 1990s were approximately 100 nests.

Kyūshū Island, Ōsumi Islands, and Tokara Archipelago. (Kamezaki et al. 2003) identified six major and sub-major nesting sites on Kyūshū and three on the Ōsumi islands. Yakushima Island, within the Ōsumi Islands, is the most important nesting location for the North Pacific loggerhead, with approximately 30% of all loggerhead nesting in Japan on Inakahama and Maehama beaches (Kamezaki et al. 2003). Miyazaki and Fukiagahama beaches are important nesting aggregations on Kyūshū (Kamezaki et al. 2003).

Okinawa Island, Kerama Island, Kume Island, and Daitō Islands. Smaller nesting agregations occur on the southern islands in the Nansei Archipelago, as far south as Yaeyama and Miyako Islands of the Okinawa prefecture (Kamezaki et al. 2003). Known nesting beaches include Nishiohama, Ibaruma, Osaki, and Gusukube. These sites are the southernmost nesting beaches for the North Pacific loggerhead.

MARIANA ARCHIPELAGO. Loggerheads are considered rare in the waters of the Mariana archipelago. They are not known to nest on these islands.

6.5.6 Species-specific Threats

Major threats to the species are fisheries bycatch, alteration of nesting habitat, direct harvest ofadults and eggs, and predation (National Marine Fisheries Service 2012a). Incidental bycatch in commercial fisheries is currently a tremendous source of loggerhead mortality, with coastal and artisanal fisheries in Mexico and the Asian region likely representing the most serious threats to North Pacific loggerheads (Conant et al. 2009; Gilman et al. 2010; Peckham et al. 2008; Peckham et al. 2007). Coastal fisheries off Baja California have the highest bycatch rates for loggerhead worldwide (Conant et al. 2009; Peckham et al. 2008; Peckham et al. 2007). In Japan, coastal pound net fisheries result in high mortality rates of adult loggerheads (Gilman et al. 2010), while nesting females migrating to the East China Sea are at risk

from intensive trawl fisheries (Kamezaki et al. 2003). While U.S. longline fisheries have applied conservation measures that have dropped loggerhead mortality from an estimated 167 per year in 2000 to an average of 4 per year between 2004-2010, foreign longline fisheries "are likely injuring and killing at least many hundreds of turtles annually in the North Pacific" (National Marine Fisheries Service 2012a). (Lewison, Freeman, and Crowder 2004) noted that an estimated 30,000 to 75,000 loggerhead turtles were taken as pelagic longline bycatch in the Pacific Ocean in 2000.

In Japan, coastal development and beach armoring can cause loggerheads to nest below the high tide line where eggs are washed away (Matsuzawa 2006). A thriving tourism business on Yakushima, the primary nesting site for North Pacific loggerheads, has led to an increase in beachfront hotels and trampling of nests (Kudo, Murakami, and Watanabe 2003).

Japanese law prohibiting harvest of sea turtle eggs has greatly reduced this threat, although predation of nests by raccoons and weasels continues throughout the nesting range (Kamezaki et al. 2003; National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007d). Direct harvest of juvenile loggerheads has been reported in Mexico (Koch et al. 2006; Peckham et al. 2008; Peckham et al. 2007).

Marine debris, a worldwide threat to sea turtles, is likely more of a concern for the North Pacific loggerhead after the March 2011 tsunami. The Japanese government estimated that 25 million tons of debris was generated, although how much and what types remain in the North Pacific are unknown (National Marine Fisheries Service 2012a).

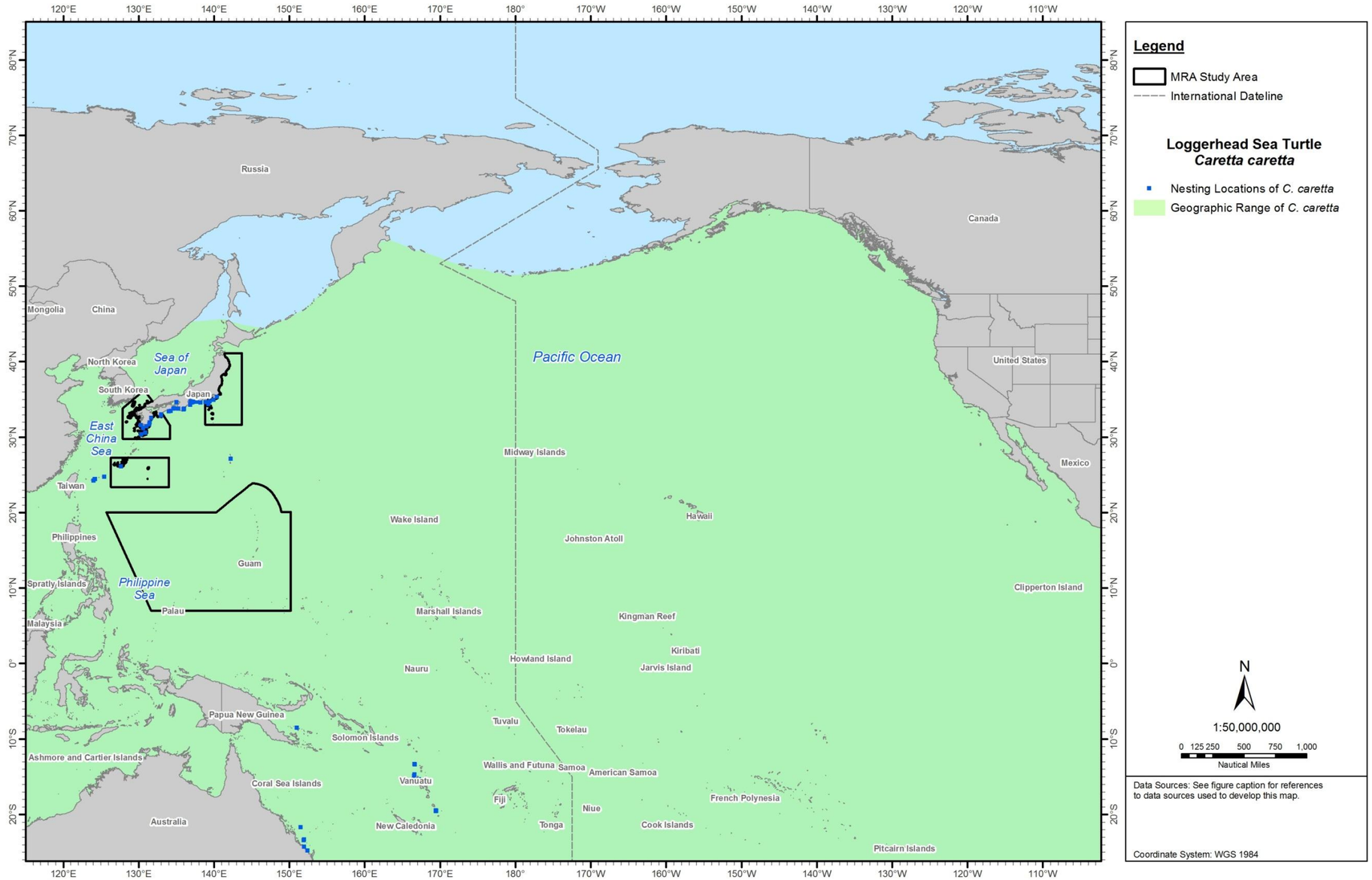

Figure 6-9: Geographic Range and Location of Nesting Beaches of the Loggerhead Sea Turtle in the North Pacific Ocean
Source: Márquez (1990). Nesting locations obtained by permission from the SWOT database.

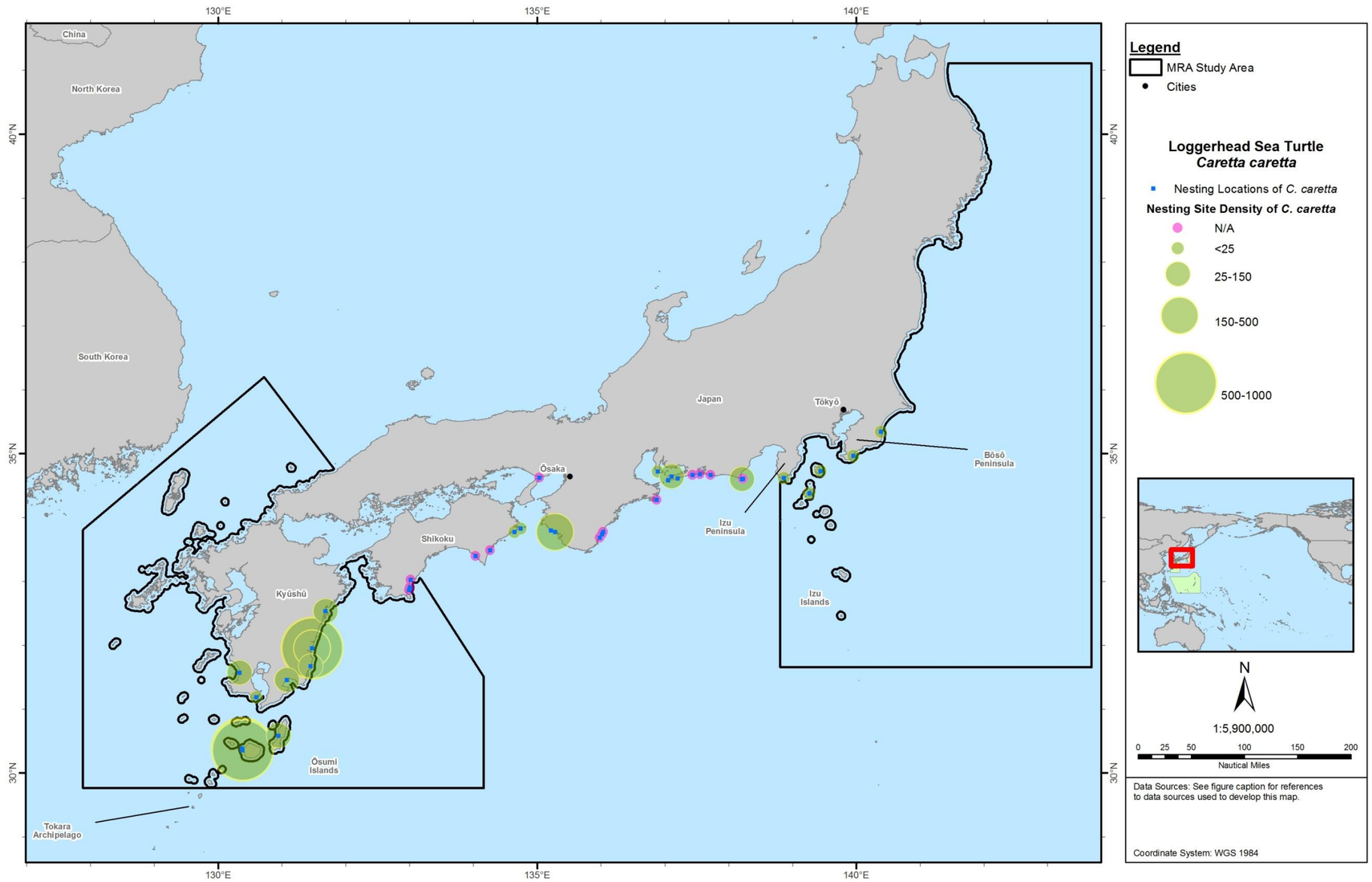

Figure 6-10: Locations and Density of the Loggerhead Sea Turtle Nesting Beaches in Japan

Sources: Nesting locations obtained by permission from the SWOT database. Densities obtained from Kamezaki et al. (2003); Matsuzawa (2006); and Watanabe et al. (2011).

6.6 OLIVE RIDLEY SEA TURTLE (LEPIDOCHELYS OLIVACEA)

6.6.1 Description

The olive ridley is a relatively small, hard-shelled sea turtle, with adults averaging 100 lbs. (45 kg) and 22–31 in. (55–80 cm). It is named for its olive green, heart-shaped top shell. The olive ridley is known as an open ocean species but can also be found in coastal areas. It is found in tropical waters of the south Atlantic, Indian, and Pacific Oceans.

6.6.2 Status and Management

The Pacific Mexican nesting population of the olive ridley has been classified as endangered due to extensive overharvesting of olive ridleys in Mexico, which caused a severe population decline (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998f). Before this commercial exploitation, the olive ridley was abundant in the eastern tropical Pacific Ocean, probably outnumbering all other sea turtle species combined in the area (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998f). Today, this population appears to be stable or increasing (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007e), although the decline of the species continues at several important nesting beaches in Central America. All other populations of olive ridleys, including major aggregations in Central America in the eastern Pacific and India in the eastern Indian Ocean, are designated as threatened (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007e). Critical habitat has not been designated for the olive ridley.

Available information indicates that the population could be separated by ocean basins under the distinct population segment policy (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007e). Based on genetic data, the worldwide olive ridley population is composed of four main lineages: east India, Indo-Western Pacific, eastern Pacific, and Atlantic (Bowen et al. 1998; Shankar et al. 2004). Furthermore, genetic diversity of the eastern Pacific subpopulation nesting on the Baja California Peninsula may indicate that this population should be considered as a distinct management unit (Lopez-Castro and Rocha-Olivares 2005).

6.6.3 Population and Abundance

The olive ridley is the most abundant sea turtle in the world (Pritchard 1997) and the most abundant sea turtle in the open ocean waters of the eastern tropical Pacific Ocean (Pitman 1990). They nest in nearly 60 countries worldwide, with an estimated 800,000 females nesting annually (National Marine Fisheries Service 2012c). This is a dramatic decrease over the past 50 years, as the population from the five Mexican Pacific beaches previously had been estimated at 10 million adults (Cliffton, Cornejo, and Felger 1995). The number of olive ridley turtles occurring in U.S. territorial waters is believed to be small (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998f). The olive ridley is scarce throughout the western Pacific (Pritchard and Plotkin 1995), and is considered a rare visitor to the MRA Study Area, with no known nesting beaches in the north Pacific.

The second most globally important nesting area for olive ridleys occurs in the eastern Pacific, along the west coast of southern Mexico and northern Costa Rica, with stragglers nesting as far north as southern Baja California (Fritts, Stinson, and Márquez 1982) and as far south as Peru (Brown and Brown 1995). Of the 160,000 olive ridleys nesting annually in Mexico, only three nests occurred in northern Baja and 71 in southern Baja, with the rest of this population nests on mainland beaches (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998f). Individuals regularly occur in waters as far north as

California and as far south as Peru, spending most of their lives in the oceanic zone (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007e). At-sea abundance surveys conducted via five ship-board line transects along the Mexican and Central American coasts between 1992 and 2006 provided an estimate of 1.39 million turtles in the region, consistent with the increases seen on the eastern Pacific nesting beaches between 1997 and 2006 (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007e). According to an analysis of nesting beach information, the endangered population of the Pacific coast of Mexico appears to be stable or increasing.

The largest olive ridley population occurs on three arribada beaches in Orissa, on India's east coast, where 150,000–200,000 females nest each year (Shankar et al. 2004). The nesting population nearest to the MRA Study Area occurs in Brunei, with an estimated 300 turtles nesting annually (The SWoT Team 2010). Data are inadequate for determining trends of any of the Indian and western Pacific olive ridley populations (National Marine Fisheries Service 2012a).

6.6.4 Biology, Ecology, and Behavior

Predator/Prey Interactions. Olive ridley turtles are primarily carnivorous throughout all life stages. They consume a variety of prey in the water column and on the seafloor, including snails, clams, tunicates, fish, fish eggs, crabs, oysters, sea urchins, shrimp, and jellyfish (Fritts 1981; Márquez 1990; Mortimer 1995; Polovina et al. 2004).

Predators of olive ridleys vary according to turtle location and size. Land-based predators on eggs and hatchlings include ants, crabs, birds, and mammals, such as dogs, raccoons, and feral pigs. Aquatic predators, mostly fish and sharks, impact hatchlings most heavily in nearshore areas. Sharks are the primary predators of juvenile and adult turtles (Stancyk 1982).

Life History. Little is known about the age and sex distribution, growth, birth and death rates, and immigration and emigration of olive ridleys. Hatchling survivorship is unknown, although presumably, as with other turtles, many die during the early life stages. Both adults and juveniles occur in open sea habitats, although sightings are relatively rare. The median age to sexual maturity is 13 years, with a range of 10–18 years (Zug, Chaloupka, and Balazs 2006).

Olive ridleys use two types of nesting strategies. At 18 locations around the world, they conduct annual synchronized nesting, a phenomenon known as an arribada (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998f), where hundreds to tens of thousands of olive ridleys emerge over a period of a few days. In the eastern Pacific, arribada nesting occurs throughout the year, although it peaks from September to December (Fretey 2001). Arribadas occur on several beaches in Mexico, Nicaragua, Costa Rica, and Panama. Olive ridleys also lay solitary nests throughout the world, although little attention has been given to this nesting strategy because of the dominant interest in arribada research (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007e). Solitary nesting occurs in at least 46 countries throughout the world (Kalb and Owens 1994), including along nearly the entire Pacific coast of Mexico, with the greatest concentrations closer to arribada beaches.

Females and males begin to group in "reproductive patches" near their nesting beaches 2 months before the nesting season, and most mate near the nesting beaches, although mating has been observed throughout the year as far as 565 miles (1,850 km) from the nearest mainland (Pitman 1990). Arribadas usually last from three to seven nights, and due to the sheer number of nesters, later arrivers disturb and dig up many existing nests, lowering overall survivorship during this phase (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998f). A typical female produces two clutches per

nesting season, averaging 105 eggs at 15- to 17-day intervals for lone nesters and 28-day intervals for mass nesters (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998f; Plotkin, Byles, and Owens 1994). Studies show that females nesting in arribadas remain within 3 miles (5 km) of the beach most of the time during the internesting period (Kalb and Owens 1994). Incubation time from egg deposition to hatching is approximately 55 days (Pritchard and Plotkin 1995). Hatchlings emerge weighing less than an ounce (less than 28 g) and measuring about 1.5 in. (3.8 cm).

Migration. The Pacific population migrates throughout the Pacific, from their nesting grounds in Mexico and Central America to the North Pacific (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007e). The post-nesting migration routes of olive ridleys tracked via satellite from Costa Rica traversed thousands of km of deep oceanic waters from Mexico to Peru, and more than 1,865 miles (3,000 km) out into the central Pacific (Plotkin, Byles, and Owens 1994). Tagged turtles nesting in Costa Rica were recovered as far south as Peru, as far north as Oaxaca, Mexico, and offshore to a distance of 1,080 nm (2,000 km) (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998f). In India, tagging data indicates that the Orissa population migrates along the coast from the Bay of Bengal to Sri Lanka, while others remain in the waters offshore of Orissa (Shankar et al. 2003).

Groups of sometimes more than 100 turtles have been observed as far as 1,620 nm (3,000 km) offshore of the Mexican Pacific coast at 120° W (Arenas and Hall 1992). Sightings of large groups of olive ridleys at sea reported by Oliver in 1946 (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998f) may indicate that turtles travel in large flotillas between nesting beaches and feeding areas (Márquez 1990). Specific post-breeding migratory pathways to feeding areas do not appear to exist, although olive ridleys swim hundreds to thousands of km over vast oceanic areas.

Hearing/Vocalization. As research into turtle hearing and vocalization is limited, a general description of hearing and vocalization is provided in Section 6.1.2, Biology, Life History and Behavior [all turtles].

Diving. Olive ridley sea turtles can dive and feed at considerable depths (260–1,000 ft. [80–300 m]) (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998f), although only about 10% of their time is spent at depths greater than 330 ft. (100 m) (Eckert et al. 1986; Polovina et al. 2003). In the eastern tropical Pacific Ocean, at least 25% of their total dive time is spent between 65 and 330 ft. (20 and 100 m) (Parker et al. 2003). In the North Pacific Ocean, two olive ridleys tagged with satellite-linked depth recorders spent about 20% of their time within the top meter and about 10% of their time deeper than 330 ft. (100 m); a daily maximum depth exceeded 490 ft. (150 m) at least once in 20% of the days, with one dive recorded at 835 ft. (254 m). While olive ridleys are known to forage to great depths, 70% of the dives from this study were no deeper than 15 ft. (5 m) (Polovina et al. 2003).

6.6.5 Habitat and Distribution

The olive ridley sea turtle is a pantropical species, occurring worldwide in tropical and warm temperate waters. The olive ridley has a large range in tropical and subtropical regions in the Pacific, and is generally found between 40° N and 40° S (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007e). In the eastern Pacific Ocean, individuals regularly occur in waters as far north as California and as far south as Peru, spending most of their lives in the oceanic zone (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007e). Most reproductively active males and females migrate to the neritic zone during the breeding season (June to December) and aggregate in the nearshore waters adjacent to nesting beaches (National Marine Fisheries Service and U.S. Fish and

Wildlife Service 2007e). Post-breeding migratory pathways to feeding areas do not appear to exist, with olive ridleys swimming hundreds to thousands of miles over vast oceanic areas.

Most olive ridley sea turtles lead a primarily open ocean existence. Outside of the breeding season, the turtles disperse, but little is known of their foraging habitats or migratory behavior. Neither males nor females migrate to one specific foraging area but tend to roam and occupy a series of feeding areas in the open ocean (Plotkin, Byles, and Owens 1994). Both adult and juvenile olive ridley sea turtles typically inhabit offshore waters, foraging from the surface to a depth of 490 ft. (150 m) (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998f).

Data obtained during tuna fishing cruises from Baja California to Ecuador and from the coast to almost 150°W, indicate that the two most important at-sea areas in the Pacific for the olive ridley are the Central American coast and the nursery and feeding area off Colombia and Ecuador, where both adults (mostly females) and juveniles are often seen (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998f).

Figure 6-11 shows olive ridley sea turtle nesting sites throughout the Pacific, as provided by turtle research groups to the State of the World's Sea Turtles (SWOT) database. With rare exceptions, olive ridley sea turtles do not nest within the MRA Study Area.

Open Ocean Waters of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. In the open ocean of the eastern Pacific, olive ridley turtles are often seen near flotsam, possibly feeding on associated fish and invertebrates (Pitman 1992). The highest densities of olive ridleys likely occur just south of Hawaiʻi. The distribution of the olive ridley in the central Pacific Ocean is primarily tropical (Polovina et al. 2004). About 18% of the sea turtles incidentally caught by the Hawaiʻi-based longline fishery are olive ridleys (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998f). Arenas and Hall (1992) found that 75% of sea turtles associated with floating objects in the eastern tropical Pacific were olive ridleys, which were present in 15% of the observations; this suggests that flotsam may provide the turtles with food, shelter, and orientation cues in an otherwise featureless landscape. Olive ridleys accidentally caught in longline gear between 20 and 30°N that were fitted with satellite tags showed that they remained south of 31°N, generally travelling between 25 and 10°N (Polovina et al. 2004).

KUROSHIO CURRENT. The olive ridley is considered a rare visitor to the western north Pacific, and no reports of sightings within the Kuroshio Current have occurred.

EAST CHINA SEA. A few olive ridleys have been caught in the coastal set net fisheries in the eastern waters of Taiwan (Cheng and Chen 1997), indicating potential presence in the East China Sea, although the species is rarely seen in the waters of Taiwan.

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. The olive ridley has been recorded in coastal Japanese waters, but is considered a rare visitor (Uchida 1994).

MARIANA ARCHIPELAGO. Because olive ridleys are the most abundant species in the Paciifc, and have been tracked caught in pelagic fisheries as far north as 31°N (Polovina et al. 2004), their occurrence in these waters is possible, although considered rare.

CAROLINE ISLANDS. The olive ridley is an infrequent visitor to this area. Only two records have been found that specifically identify the species in these waters. Falanruw observed a mating pair in M'il Channel, northwest of Yap, and observed a young juvenile (29 cm) from Lamotrek, in the eastern Yap District (Eckert 1993).

6.6.6 Species-specific Threats

The major threats to olive ridleys are direct harvest and fishing bycatch. Climate change and marine debris are growing threats to this and all species of sea turtles (National Marine Fisheries Service 2012a). Direct harvest of millions of adults and many millions of eggs in the eastern Pacific from the 1950s through the 1970s led to extirpation of major arribada beaches. While this threat has decreased, legal and illegal harvest continues (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007e).

Fisheries operations, particularly near arribada beaches, are a major threat. Olive ridley sea turtles are caught in offshore gill nets and long lines (Bagarinao 2011). The main cause of mortality of the Indian Ocean population is incidental catch from illegal gill net and trawl fishing in waters offshore of arribada beaches, where an estimated 15,000 turtles die each year (Shankar et al. 2004). Because of the distribution of nesting beaches and at-sea turtles, neither of these major threats occurs within or near the MRA Study Area. The 1998 recovery plan indicated no primary threats to olive ridleys in the Mariana Archipelago, Palau, or Yap (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998f). Longline fisheries operating in the tropical Pacific do take a small number of olive ridleys. The Hawaiʻi-based longline fishery interacts with approximately 25 olive ridleys every year, most of which drown before they can be released (National Marine Fisheries Service 2012a). International fisheries operating in the same region likely have similar interaction rates. Predation by the saltwater crocodile is a major concern for the the Northern Australia nesting aggregation (Whiting and Whiting 2011). Small-scale fisheries, generally overlooked in bycatch studies, appear to contribute significantly to sea turtle mortality (Alfaro-Shigueto et al. 2011). For example, olive ridley sea turtles are the most common bycatch in the recently expanding mahi mahi Costa Rica Pacific longline fishery (Whoriskey, Arauz, and Baum 2011).

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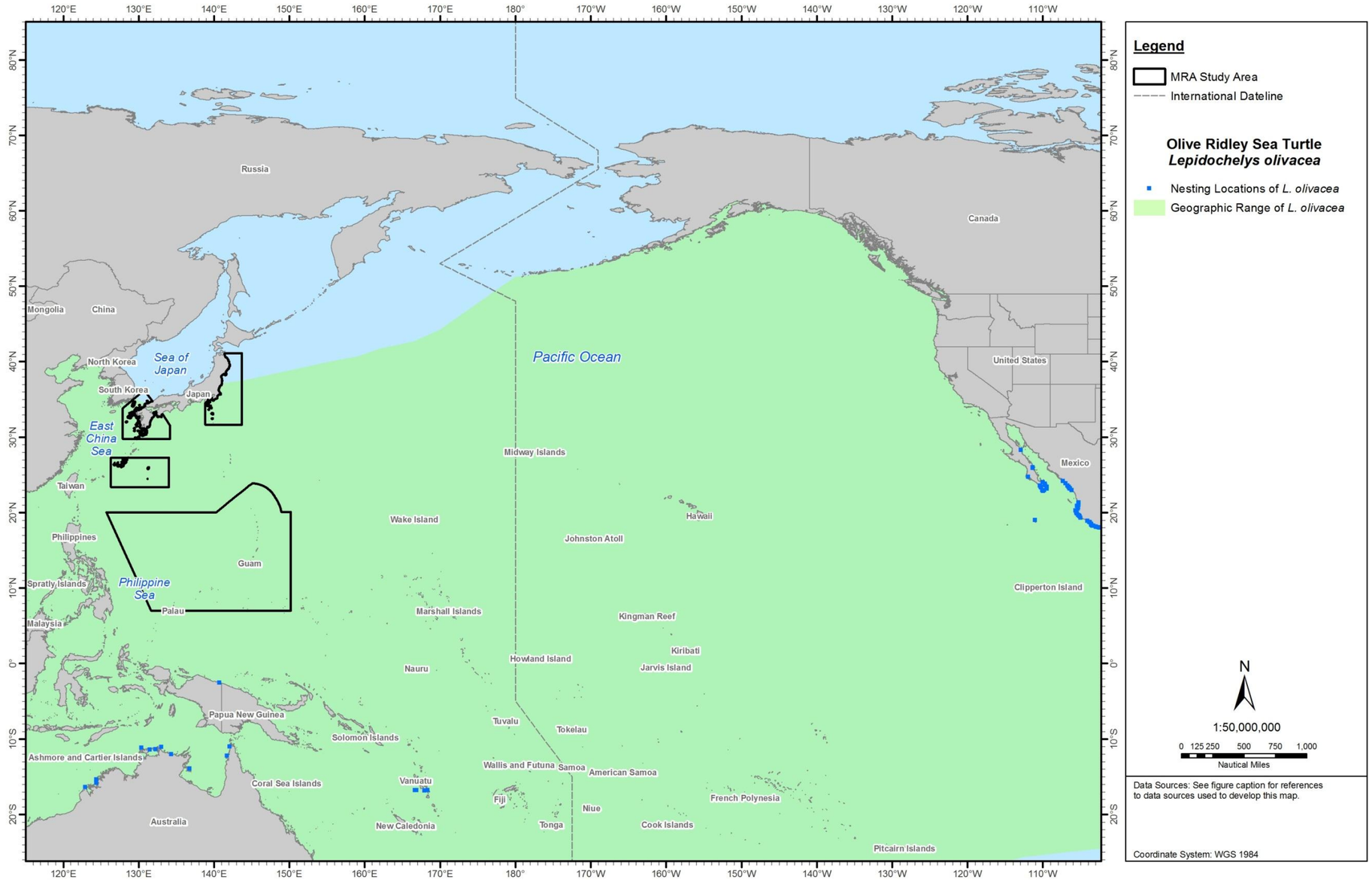

Figure 6-11: Geographic Range and Location of Nesting Beaches of the Olive Ridley Sea Turtle in the North Pacific Ocean
Source: Márquez (1990). Nesting locations obtained by permission from the SWOT database.

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6.7 LEATHERBACK SEA TURTLE (DERMOCHELYS CORIACEA)

6.7.1 Description

Among the sea turtle species, the leatherback has several unique characteristics. It has a leathery shell with seven longitudinal ridges that taper to a blunt point. Leatherbacks are the largest sea turtle species, with adults attaining 6.5 ft. (2 m) in length and 2000 lbs. (900 kg) (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1992). The carapace is primarily black, and the underside is primarily pinkish-white. The front flippers are proportionally longer than those of hard-shelled turtles. Leatherbacks are the most migratory sea turtles and are able to tolerate colder water temperatures than other species (Hughes et al. 1998; James and Mrosovsky 2004). The leatherback is also the deepest-diving sea turtle (Hays, Metcalfe, and Walne 2004). Leatherbacks occur in tropical to temperate regions of the Atlantic, Indian, and Pacific Oceans. Leatherbacks are known as an open ocean species but can also be found in coastal waters.

6.7.2 Status and Management

The leatherback turtle is listed as a single population and is classified as endangered under the ESA. Although National Oceanic and Atmospheric Administration (NOAA) Fisheries and the USFWS believe the current listing is valid, preliminary information indicates need for an analysis and review of the species to determine if the distinct population segments policy applies to leatherbacks (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007c; Turtle Expert Working Group 2007). This effort is critical to focus efforts on protecting the species, as the status of individual stocks varies widely across the world. Most stocks in the Pacific Ocean are faring poorly (nesting populations have declined more than 80%) (Sarti-Martinez 2000), while western Atlantic and South African populations are generally stable or increasing (Turtle Expert Working Group 2007). In January 2012, 16,910 square miles of critical habitat was designated in the Pacific around Point Sur, California, to the 200-m isobath; from Point Arena to Point Vincente, California, to the 3000-m isobath; and from Cape Flattery, Washington, to Cape Blanco, Oregon, to the 2,000-m isobath (National Marine Fisheries Service 2012b).

Leatherbacks have been in decline in all major Pacific basin rookeries (nesting areas/groups) (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007c; Turtle Expert Working Group 2007) for at least the last two decades (Gilman 2008; Sarti-Martinez et al. 1996; Spotila et al. 1996; Spotila et al. 2000). Causes for this decline include the near complete harvest of eggs and high levels of death during the 1980s, primarily in the high seas driftnet fishery, which is now banned (Chaloupka, Dutton, and Nakano 2004; Eckert and Sarti-Martinez 1997; Gilman 2008; Sarti-Martinez et al. 1996). With only four major rookeries remaining in the western Pacific and two in the eastern Pacific, the Pacific leatherback is at extremely high risk of extinction (Gilman 2008).

6.7.3 Population and Abundance

As of 2004, 203 leatherback nesting beaches at 46 countries around the world had been identified (Dutton 2006), with unidentified sites likely to exist. Leatherback stocks in the Atlantic are faring much better than those in the Pacific: an estimated 34,000–95,000 adult leatherbacks are in the Atlantic (Turtle Expert Working Group 2007), and most recent estimates are 2,700–4,500 adult females in the western Pacific (Dutton et al. 2007; Hitipeuw et al. 2007) and 1,690 nesting females in the eastern Pacific (Gilman 2008). Long-term monitoring of nesting beaches over the last two to three decades in Trinidad, Suriname, Guyana, Puerto Rico, Florida, and elsewhere indicates nesting population increases,

sometimes by an order of magnitude or more in the western Atlantic, while other colonies in the region (Caribbean Costa Rica, Nicaragua, Honduras, and other locations) may be stable or slightly declining. In Suriname, the annual count of leatherback nests has increased from less than 300 in the late 1960s to 30,000 nests in 2001 (Turtle Expert Working Group 2007), although a recent review of the data may indicate that the nesting population has been stable since the early 1980s. This count correlates to a minimum of 1,500 to 5,500 annually nesting females. The recent discovery of a large nesting population in Gabon in the eastern Atlantic has improved overall worldwide outlook, although populations in the Pacific, specifically in the South China Sea and East Pacific, have undergone catastrophic collapses (Turtle Expert Working Group 2007).

Genetic studies (Dutton 2006) indicate that the western Pacific population that nests in Indonesia, Papua New Guinea, Solomon Islands, and Vanuatu (Dutton et al. 1999; Dutton et al. 2007) is distinct from the Eastern Pacific population that nests in Mexico and Costa Rica, Panama, Colombia, Ecuador, and Nicaragua (Chaloupka, Dutton, and Nakano 2004; Dutton et al. 1999; Eckert and Sarti-Martinez 1997; Márquez 1990; Sarti-Martinez et al. 1996; Spotila et al. 1996). A third Malaysian population is now considered functionally extinct (Chan and Liew 1996).

Post-nesting females of the eastern Pacific population migrate southward into southern Pacific foraging grounds, while the western Pacific population migrates through the MRA Study Area to preferred foraging habitat off the coast of California (Benson et al. 2011). There are 28 known nesting sites for the western Pacific stock, with 5,000–9,100 leatherback nests laid annually across the western tropical Pacific (Chaloupka, Dutton, and Nakano 2004; Chua 1988; Dutton 2006; Hirth, Kasu, and Mala 1993; Suarez, Dutton, and Bakarbessy 2000). While nesting is widespread, 75% of the nesting occurs on the northwest coast of Papua Barat, Indonesia (Hitipeuw et al. 2007).

6.7.4 Biology, Ecology, and Behavior

Predator/Prey Interactions. Leatherbacks lack the crushing/chewing plates characteristic of sea turtles that feed on hard-bodied prey (National Marine Fisheries Service 2012c). Instead, they have pointed tooth-like cusps and sharp-edged jaws perfectly adapted for a diet of soft-bodied prey, such as jellyfish and salps (Bjorndal 1997; Grant and Ferrell 1993; James and Herman 2001; National Marine Fisheries Service and U.S. Fish and Wildlife Service 1992; Salmon, Jones, and Horch 2004). Leatherbacks feed from the surface as well as in deep water, diving to 4,035 ft. (1,230 m) (Davenport 1988; Eckert, Eckert, Ponganis, et al. 1989; Eisenberg and Frazier 1983; Grant and Ferrell 1993; Hays et al. 2004; James, Myers, and Ottensmeyer 2005; Salmon, Jones, and Horch 2004). Leatherbacks in the Caribbean may synchronize their diving patterns with the daily vertical migration of a deep-water ecosystem of fishes, crustaceans, gelatinous salps, and siphonophores, known as the deep scattering layer, which moves toward the surface of the ocean at dusk and rapidly descends in the morning (Eckert, Eckert, Ponganis, et al. 1989; Eckert et al. 1986). Whether this type of foraging is widespread among leatherbacks is unknown (Eckert, Eckert, Ponganis, et al. 1989). Those studying known feeding grounds have observed leatherbacks foraging on jellyfish at the surface (Grant and Ferrell 1993; James and Herman 2001; Starbird, Baldridge, and Harvey 1993).

Predators of leatherbacks vary according to turtle location and size. Land predators on eggs and hatchlings include ants, crabs, birds, and mammals, such as dogs, raccoons, and feral pigs. Aquatic predators, mostly fish and sharks, impact hatchlings most heavily in nearshore areas. Sharks are the primary predators of juvenile and adult turtles (Stancyk 1982).

Life History. Leatherback hatchlings are approximately 2 to 3 in. (5 to 7.6 cm) long and weigh approximately 1.4–1.8 ounces (40–50 g). Individuals with a curved shell length of less than 57 in. (145 cm) are considered juveniles (Eckert 2002; National Marine Fisheries Service 2001).

Leatherbacks are likely the fastest developing of all sea turtle species, reaching adulthood at 13–14 years (range 2–22 years) (Turtle Expert Working Group 2007; Zug and Parham 1996), and can live 30 years or more (Sarti-Martinez 2000).

The leatherback's important distinction from other turtle species in anatomy and metabolism (Bradshaw, McMahon, and Hays 2007; Goff and Stenson 1988; Greer, Lazell, and Wright 1973; Mrosovsky and Pritchard 1971; Neill and Stevens 1974; Paladino, O'Connor, and Spotila 1990) allows them to maintain a core body temperature higher than that of the surrounding water, thereby allowing them to tolerate colder waters (Frair, Ackman, and Mrosovsky 1972; James and Mrosovsky 2004). As juveniles increase in size, this ability is enhanced, allowing leatherbacks to expand their ranges into the cooler waters (Eckert 2002).

Females lay an average of five to seven clutches in a single season (with a maximum of 11) with intervals of 8 to 10 days or longer (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1992). Typical clutches are 50 to more than 150 eggs, with the incubation period lasting around 65 days. Females remain in the general vicinity of the nesting habitat for their breeding period, which can last up to 4 months (Eckert, Eckert, Adams, et al. 1989; Keinath and Musick 1993), although they may nest on several islands in a chain during a single nesting season (Pritchard 1982). Mating is thought to occur before or during the migration from temperate to tropical waters (Eckert and Eckert 1988).

Migration. The leatherback is the most oceanic and wide-ranging of sea turtles, undertaking extensive migrations along distinct depth contours for hundreds to thousands of km (Hughes et al. 1998; Morreale et al. 1996). Both trans-Atlantic (Billes et al. 2006; Ferraroli et al. 2004; Hays et al. 2006; Hays, Houghton, and Myers 2004) and trans-Pacific movements have been reported (Benson et al. 2007). After they nest, female leatherbacks migrate from tropical waters to more temperate latitudes, which support high densities of jellyfish in the summer. Late juvenile and adult leatherback turtles are known to range from mid-ocean to the continental shelf and nearshore waters (Grant and Ferrell 1993; Schroeder and Thompson 1987; Shoop and Kenney 1992), foraging within coastal areas in temperate waters and within offshore areas in tropical waters (Frazier 2001). Their movements appear to be linked to the seasonal availability of their prey and requirements of their reproductive cycle (Collard 1990; Davenport and Balazs 1991). Turtles nesting in Indonesia and Papua New Guinea migrate through waters of Malaysia, Philippines, and Japan, across the Pacific past Hawai'i, to foraging grounds in temperate waters off Washington, Oregon, and California (Benson et al. 2007; Benson et al. 2011)—swimming a distance of 6,385 miles (10,275 km) in a single year. Satellite data have identified an important migratory corridor from Central California to south of the Hawaiian Islands and on to western Pacific nesting beaches (Benson et al. 2007; Benson et al. 2011).

Hearing/Vocalization. As research into turtle hearing and vocalization is limited, a general description of hearing and vocalization is provided in Section 6.1.2, Biology, Life History and Behavior [all turtles].

Diving. Eighty percent of the leatherback's time at sea is spent diving (Fossette et al. 2007). The leatherback is the deepest diving sea turtle, with recorded depths of at least 4,035 ft. (1,230 m) (Hays, Metcalfe, and Walne 2004), although most dives are much shallower (usually less than 655 ft. [200 m]) (Hays et al. 2004; Sale et al. 2006). Leatherbacks spend most of their time in the upper 215 ft. (65 m) of

the water column (Jonsen, Myers, and James 2007). Diving is influenced by many factors, including water temperature, and local availability and vertical distribution of food resources, resulting in variations in dive times and distances (James et al. 2006; Sale et al. 2006).

The dive time limit for the leatherback is estimated at between 33 and 67 minutes (Hays et al. 2004; Hays, Metcalfe, and Walne 2004; Southwood et al. 1999), with typical durations of 6.9 to 14.5 minutes (Eckert et al. 1996). During migrations or long-distance movements, leatherbacks travel within 15 ft. (5 m) of the surface (Eckert 2002), making scouting dives to sample prey density and to feed on whatever is available (James et al. 2006; Jonsen, Myers, and James 2007).

In warm waters, leatherbacks dive deeper and longer (James, Myers, and Ottensmeyer 2005), spending only short periods at the surface between dives (Eckert et al. 1986). While diving in colder waters, sometimes just above freezing, leatherbacks make shorter dives and spend up to 50% of their time at or near the surface (James et al. 2006; Jonsen, Myers, and James 2007).

6.7.5 Habitat and Distribution

Throughout their lives, leatherbacks are essentially oceanic, yet they enter coastal waters to forage and reproduce (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1992). The species is not typically associated with coral reefs but is occasionally encountered in deep ocean waters near prominent island chains (Eckert 1993). Some evidence indicates that leatherbacks are associated with oceanic front systems, such as shelf breaks and the edges of oceanic gyre systems, where their prey is concentrated (Eckert 1993).

Leatherbacks whose shell length is less than 40 in. (100 cm) must be in waters at least 79°F (26°C), restricting their habitat primarily to the tropics (Eckert 2002; Sarti-Martinez 2000). They are not considered to associate with sargassum (floating seaweed) or other floating material in the open ocean, as is the case for all other sea turtles (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1992). Upwelling areas, such as equatorial convergence zones, serve as nursery grounds for hatchling and early juvenile leatherbacks, as these areas provide a good supply of prey (Musick and Limpus 1997).

Nesting leatherbacks prefer wide sandy beaches backed with vegetation (Eckert 1987; Hirth and Ogren 1987). In the water, they prefer steep drop-offs or mudbanks without coral or rock formations (Turtle Expert Working Group 2007). For both the western and eastern Pacific populations, the nesting season extends from October through March, with a peak in December. The single exception is the Jamursba-Medi (Papua) stock, which nests from April to October, with a peak in August (Chaloupka, Dutton, and Nakano 2004).

The leatherback turtle is distributed circumglobally in tropical, subtropical, and warm-temperate waters throughout the year and into cooler temperate waters during warmer months (James, Myers, and Ottensmeyer 2005; National Marine Fisheries Service and U.S. Fish and Wildlife Service 1992) as far north as Alaska (60° N) (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998d). The leatherback is the most oceanic and wide-ranging of sea turtles, undertaking extensive migrations along distinct depth contours for hundreds to thousands of km (Hughes et al. 1998; Morreale et al. 1996). Adult leatherback turtles forage in temperate and subpolar regions in all oceans and migrate to tropical nesting beaches between 30°N and 20°S (The SWoT Team 2006).

Leatherbacks have a wide nesting distribution, primarily on isolated mainland beaches in tropical (mainly in the Atlantic and Pacific Oceans, with few in the Indian Ocean) and temperate oceans (southwest Indian Ocean) (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1992), and to a lesser degree on some islands, such as the Greater and Lesser Antilles. Leatherback nesting in the Indian Ocean occurs in South Africa/Mozambique, Andaman and Nicobar Islands (India), Sri Lanka, and previously in Malaysia (Turtle Expert Working Group 2007). Leatherbacks nest from the southeastern U.S. to southern Brazil in the western Atlantic Ocean and from Mauritania to Angola in the eastern Atlantic Ocean (Spotila et al. 1996). The most significant nesting beaches in the world are at French Guiana and Suriname in the western Atlantic Ocean, and at Gabon in the eastern Atlantic Ocean (Spotila et al. 1996; The SWoT Team 2007).

Hatchling leatherbacks head out to the open ocean, but little is known about their distribution for the first 4 years (Musick and Limpus 1997). Sightings of turtles smaller than 55 in. (139.7 cm) indicate that some juveniles remain in coastal waters in some areas (Eckert et al. 1999). Post-nesting adult leatherbacks appear to migrate along seafloor contours, from 650 to 11,500 ft. (200 to 3,500 m) (Morreale et al. 1996), and most of the eastern Pacific nesting stocks migrate into the south Pacific ocean (Dutton unpublished data).

Figure 6-12 shows leatherback sea turtle nesting sites throughout the Pacific, as provided by turtle research groups to the State of the World's Sea Turtles (SWOT) database. Leatherback sea turtles do not nest within the MRA Study Area.

Open Ocean Waters of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. Few quantitative data are available concerning the seasonality, abundance, or distribution of leatherbacks in the central North Central Pacific Gyre province. Satellite tracking studies and occasional incidental captures of the species in the Hawaiʻi-based longline fishery indicate that deep ocean waters are the preferred habitats of leatherback turtles in the central Pacific Ocean. The primary migration corridors for leatherbacks are across the North Pacific Gyre, with the eastward migration route apparently north of the westward migration (Benson et al. 2011).

KUROSHIO CURRENT. Four of six females that nested in August in Indonesia travelled north into the Kuroshio Extension, arriving between November and April. Of 126 satellite-tagged leatherbacks, these were the only ones that exhibited a northward movement from the nesting grounds (Benson et al. 2011). Based on these recent data, and the current declining population trend for the western Pacific population, leatherbacks can be expected in the Kuroshio Current, but very infrequently.

EAST CHINA SEA. Satellite data indicate that leatherbacks have entered the East China Sea, but as this is not a suitable foraging habitat, and leatherbacks are rare visitors to the area (Benson et al. 2011). In the southern part of the East China Sea, between Taiwan and mainland China, leatherbacks have been reported feeding during the autumn jellyfish reproduction season (Chan et al. 2007).

Coastal Waters of the MRA Study Area

Given the low probability of leatherbacks occurring in the region at all, presence in the coastal waters of the Japan Archipelago, Mariana Archipelago, and the Caroline Islands is even less likely. Based on density studies across the Pacific, none of these areas at any time of the year is considered high-use (meaning multiple turtles or single individuals expected to inhabit the area for a prolonged period) (Benson et al. 2011).

JAPAN ARCHIPELAGO. Two leatherback nesting events have been recorded in Japan, with the first recording in 2001 (Hamann, Limpus, and Kamezaki 2006). Stranded leatherbacks have occurred on both the Pacific and Sea of Japan coasts, and one satellite-tagged leatherback was tracked into Japanese waters. Leatherbacks have been caught in fisheries of the Ogasawara Islands as well, indicating migration into Japanese waters (Hamann, Limpus, and Kamezaki 2006).

MARIANA ARCHIPELAGO. The thorough assessment of the status of leatherbacks made no mention of their occurance in the Marianas Archipelago (The SWoT Team 2006). The NOAA and USFWS 5-year review (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007c) also made no mention of leatherbacks in the region.

CAROLINE ISLANDS. While leatherbacks conduct extensive migrations from Indo-Pacific nesting beaches across the Pacific basin to foraging grounds off California, Oregon, and Washington, satellite telemetry data indicate that the most common pathway is between 0° and 10°N (Benson et al. 2011), indicating a potential for their occurrence in the waters of the Caroline Islands.

6.7.6 Species-specific Threats

The two primary threats to leatherbacks are harvest of eggs and nesting females, and incidental capture in fishing gear (National Marine Fisheries Service 2012a). The most common gear impacting leatherbacks is gillnets, although leatherbacks are also caught in trawls, traps, pots, longlines, and dredges. Long-term harvest of eggs and fisheries interactions have been determined the primary causes of the functional extinction of the Malaysian population, which was the largest population in the world in the 1950s (Chan and Liew 1996). These threats remain at all western Pacific rookeries, and are contributing to the ongoing decline of this population.

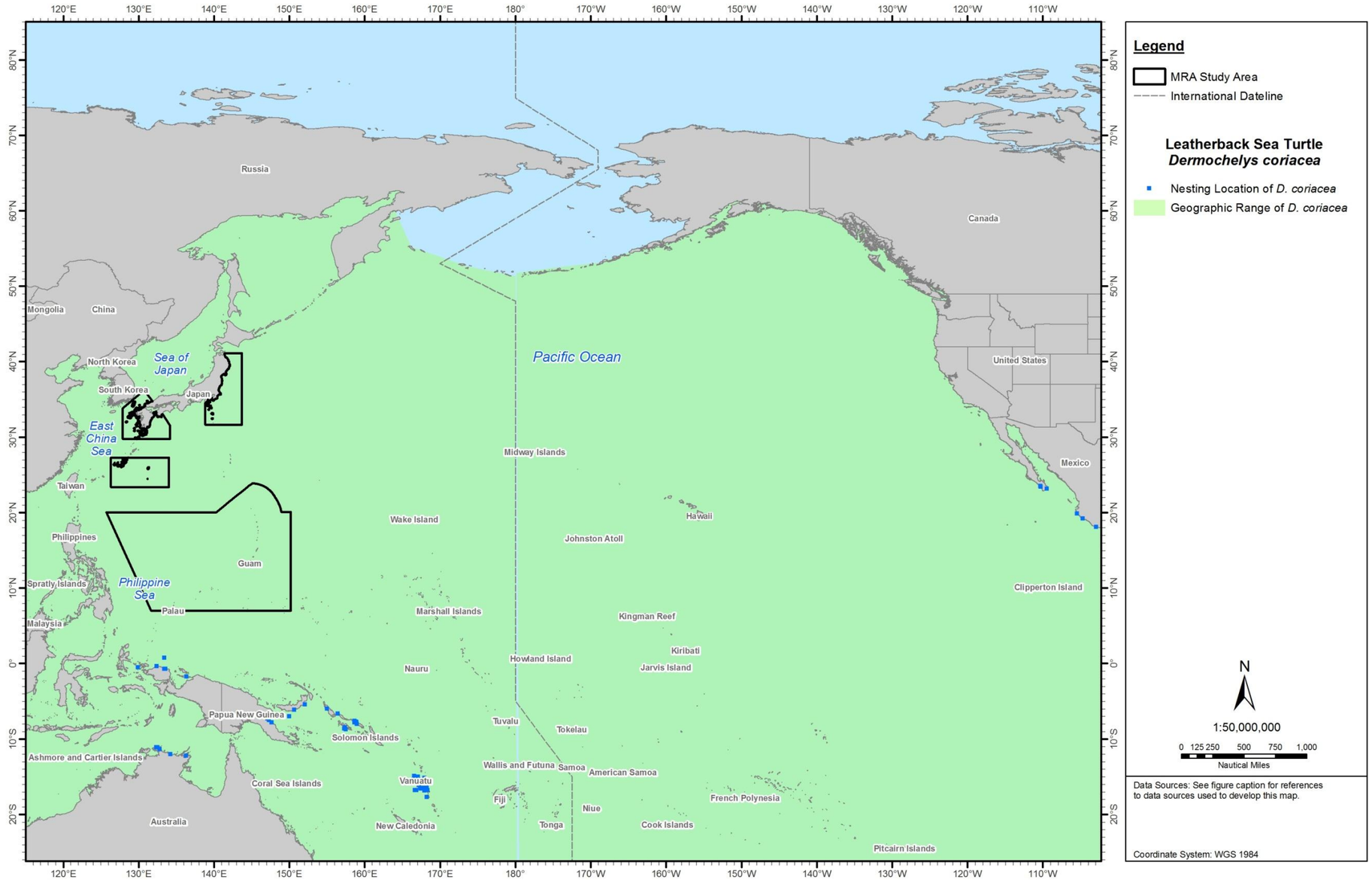

Figure 6-12: Geographic Range and Location of Nesting Beaches of the Leatherback Sea Turtle in the North Pacific Ocean
Source: Márquez (1990). Nesting locations obtained by permission from the SWOT database.

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6.8 SALTWATER CROCODILE (CROCODYLUS POROSUS)

6.8.1 Description

The saltwater crocodile, known as *ius* in Palau, is approximately 30 cm upon hatching and grows to 11 ft. (3.3 m). This species is genetically the same as the geographically widespread saltwater crocodile that occurs from Sri Lanka, eastern Indian coast, throughout Indonesia, the Philippines, Borneo, Papua New Guinea, and Northern Australia (Brazaitis et al. 2009). While emigration to Palau from other population centers must occasionally occur (i.e., a population exists in Palau), the closest populations are approximately 500 nm (926 km) away in the Philippines and Papua New Guinea, indicating that Palau has an isolated population. It is the largest living reptile, with adult males weighing as much as 2,200 lbs. (1,000 kg), although the Palauan population is substantially smaller, with the largest male measured in the most recent survey approximately 7.2 ft. (2.2 m) and 88 lbs. (40 kg). Young crocodiles are generally brightly colored yellow above and on the sides, changing to a spotted black with some yellow at about 4.9 ft. (1.5 m).

6.8.2 Status and Management

The conservation status of the global population of the saltwater crocodile is least concern (International Union for Conservation of Nature [IUCN]), while the Palau population, due to its isolation from other populations, was listed as endangered in 1979 under the ESA (U.S. Fish and Wildlife Service 1979). Critical habitat has not been designated, and a conservation plan has not been developed for the species. Palau is home to the only population of saltwater crocodiles in Micronesia (Matthews 2003). No Palauan laws prohibit killing of crocodiles (Matthews 2003).

6.8.3 Population and Abundance

Between 1967 and 1976, commercial hunting decimated the Palauan population from as many as 5,000 to tens of animals. A survey conducted 12 years after it was listed as endangered and 10 years after the last commercial hunting occurred estimated the entire Palauan population at approximately 150 animals (Messel and King 1991). The most recent survey, conducted in 2003, estimated the population at 500 to 750 crocodiles of all class sizes (except new hatchlings) throughout Palau, primarily on the main island of Babeldoab. This correlates to a density of 0.44 crocodiles per km observed over a 64 mile (103-km) length of mangrove-dominated Palauan coastline (Brazaitis et al. 2009). The carrying capacity of all size classes except hatchlings is estimated at 5,670.

6.8.4 Biology, Ecology, and Behavior

Generally, saltwater crocodiles are active and hunt prey during the night hours, and are rarely observed during the daylight hours. They first emerge from their daytime hiding immediately after sunset. While adult crocodiles feed on animals of all sizes, juveniles hunt for crabs and other crustaceans in the mangrove swamps and for reef fish in the nearshore reefs (Matthews 2003). Saltwater crocodiles can swim at 15 to 18 miles per hour (mph) (6.7 to 8.0 m/second [m/s.]) in short bursts, but when cruising they go at 2 to 3 mph (0.9 to 1.3 m/s.). Nesting season in Palau is from June through September (Brazaitis et al. 2009).

6.8.5 Habitat and Distribution

The saltwater crocodile is found in inland lakes, swamps and marshes, coastal brackish waters, and tidal sections of rivers. In Palau, an extensive coastal mangrove habitat (38 square kilometers) and 207 km of creeks and rivers provides extensive inland habitat, while a healthy coral reef ecosystem provides a wide variety of food for the population (Brazaitis et al. 2009). While distributed throughout Palau, the crocodile population is more concentrated where mangroves are a primary component of the habitat. In the ocean, particularly high densities occur in Tayo Bay and nearby coast, the mangrove-dominated Ngkeklau coast, and the Airai coast. Inland, grassy, freshwater wetlands are used for nesting, particularly Ngardok Lake and its associated watershed.

6.8.6 Species-specific Threats

The 1965 killing of a Palauan fisherman by a crocodile led the Trust Territory government to institute a program to remove all crocodiles from Palau (Matthews 2003). This led to commercial hunting and trapping program for their skins in the 1960s and 1970s, which decimated the local population. Commercial hunting was revived between 1979 and 1981, when as many as 1,000 crocodiles were killed (Brazaitis et al. 2009). Despite this extensive hunting over several decades, a viable population persists, indicating strong resiliency in this population. Today, the government is preparing a conservation and nuisance crocodile program that will allow the species to coexist with the human population (Brazaitis et al. 2009).

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7.0 SEABIRDS

7.1 Introduction

Seabirds are a diverse group that are adapted to living in marine environments (Enticott and Tipling 1997) and use coastal waters (nearshore), offshore waters (continental shelf), open ocean areas, and inland nesting sites (Harrison 1983). There are many biological, physical, and behavioral adaptations that are different for seabirds than for terrestrial birds. Seabirds typically live longer, breed later in life, and produce fewer young than other bird species (Onley and Scofield 2007). The feeding habits of seabirds are related to their individual physical characteristics, such as body mass, bill shape, and wing area (Hertel and Ballance 1999; Spear and Ainley 1998). Some seabirds look for food (forage) on the sea surface, whereas others dive to variable depths to obtain prey (Burger 2001). Many seabirds spend most of their lives at sea and come to land only to breed, nest, and occasionally rest (Schreiber and Chovan 1986). Most species nest in groups (colonies) on flat coastal area, rocky crevices, and cliffs of coastal or oceanic islands, where breeding colonies number from a few individuals to thousands. This breeding strategy is believed to have evolved in response to the limited availability of relatively predator-free nesting habitats and distance to foraging sites from breeding grounds (Siegel-Causey and Kharitonov 1990).

Seabirds are found throughout the MRA Study Area for the Japan and Mariana Archipelagos (the MRA Study Area) Harrison (1990). This section provides profiles of Endangered Species Act (ESA)-listed and ESA-candidate species, a list of species protected under the Migratory Bird Treaty Act (MBTA) and considered by the U.S. Fish and Wildlife Service (USFWS) to be Birds of Conservation Concern, and a general description of major species groups of birds in the MRA Study Area.

7.1.1 Global Distribution and Preferred Habitat

Pacific seabirds are characteristically different but can be numerous. Some seabirds migrate great distances across the Pacific Ocean, while others concentrated in restricted areas (Pacific Seabird Group 2012). In the North Central Pacific Gyre, the Hawaiian Islands are an important habitat for marine birds. The shoreline, estuarine, and open ocean environments support a variety and large populations of bird species by providing important nesting and feeding habitats as well as migration corridors. The Hawaiian Islands are in the warm North Pacific water mass (U.S. Fish and Wildlife Service 2005a). Recent research estimates that 15 million seabirds inhabit the Hawaiian Islands; 22 species of marine birds regularly nest in the Hawaiian Islands, and many more pass through during migration to and from their breeding grounds elsewhere in the Pacific (Birding Hawaii 2004).

Seabirds are found in localized areas in which sufficient food and adequate sea conditions are available, resulting in a heterogeneous distribution, over what appears to be a homogenous environment (Harrison 1990). Primary factors affecting seabird production include local water temperature and upwelling that in turn serve to concentrate prey near the water surface.

7.1.2 Biology, Life History, and Behavior

Hearing and Vocalization. The majority of the published literature on bird hearing focuses on terrestrial birds and their ability to hear in air. Thiessen (1958) reported a hearing threshold for the ring-billed gull (*Larus delawarensis*) of 2 kilohertz (kHz). Starlings (*Sturnus vulgais*) and house sparrows (*Passer domesticus*) have reported hearing ranges of 0.2 to 18 kHz (Brand and Kellogg 1939; Summers-Smith

1963). Using cochlear potentials, Wever et al. (1969) reported a hearing sensitivity range of 0.1 to 15 kHz for the blackfooted penguin (*Spheniscus demersus*) with best sensitivity in the region of 0.6 to 4 kHz. Birds do not hear at frequencies higher than the normal human hearing limit of 20 kHz (Bomford and O'Brien 1990; The Acoustical Society of America and The Acoustical Society of Japan Joint Meeting 1978).

There is little published literature on the hearing abilities of birds underwater. Melvin and Parrish (2001) tested the reduction of seabird bycatch through auditory and visual means. Auditory deterrents consisted of acoustic pingers that emitted a 1.5 kHz (± 1 kHz) frequency signal at 120 decibel (dB) re 1 micropascal (µPa) with a pulse rate of 300 milliseconds every 4 seconds. A 50 percent (%) reduction in common murre (*Uria aalge*) bycatch for gillnets was reported with the use of these auditory deterrents. However, there was no significant reduction in rhinoceros auklet (*Cerorhinca monocerata*) bycatch in the same nets with the use of auditory deterrents. The auklets responded to visual deterrents. The difference in species reaction to the pingers potentially indicates species specific reaction to sound production or differing secondary reaction to the altered behavior of the prey species (sockeye salmon) due to the emitted sounds.

Diving and Foraging Behavior. Most seabirds feed by hovering and plunging quickly into the water after prey, or skimming the water's surface while hovering; however, foraging strategies are species specific. Plunge-diving, as utilized by terns and pelicans, is a foraging strategy in which the bird hovers over the water and dives into the water to pursue fish. Diving behavior in terns is limited to plunge-diving during foraging (Tremblay et al. 2003) and, in general, tern species do not usually dive deeper than 3 feet (ft.) (0.9 meters [m]). Pursuit divers, a common foraging strategy of alcids, usually float on the water and dive under, propelling themselves by beating their wings to pursue fish and other prey. They most commonly eat fish, squid, and crustaceans (Baird 1993).

7.1.3 Global Threats and Management

Threats to seabird populations include human-caused stressors such as incidental mortality from interactions with commercial and recreational fishing gear, predation by introduced and native species, disturbance and degradation of nesting areas by humans and domesticated animals, noise pollution from construction and other human activities, nocturnal collisions with power lines and artificial lights, and pollution, such as that from oil spills and plastic items (Anderson et al. 2007; Burkett et al. 2003; California Department of Fish and Game 2010; Carter and Kuletz 1995; Carter et al. 2005; Clavero et al. 2009; International Union for Conservation of Nature and Natural Resources 2010; North American Bird Conservation Initiative 2010; Piatt and Naslund 1995; U.S. Fish and Wildlife Service 2005a, 2008a, 2010b). Disease, volcanic eruptions, storms, and harmful algal blooms are additional threats to seabirds that can occur outside of direct anthropogenic influence (Anderson et al. 2007; Finkelstein et al. 2010; Jessup et al. 2009; North American Bird Conservation Initiative 2010; U.S. Fish and Wildlife Service 2005a). In addition, seabird distribution, abundance, breeding, and other behaviors are affected by cyclical environmental events, such as the El Niño Southern Oscillation and Pacific Decadal Oscillation in the Pacific Ocean (Vandenbosch 2000).

In the long term, climate change could be the largest threat to seabirds (North American Bird Conservation Initiative 2010). Climate change effects include changes in air and sea temperatures, in precipitation, in the frequency and intensity of storms, and in sea level. These changes could affect overall marine productivity, which could affect the food resources, distribution, and reproductive success of seabirds (Aebischer, Coulson, and Colebrook 1990; Congdon et al. 2007). The projection for

global sea level rise from 2090–2099 is up to 1 ft. (0.3 m) relative to 1980–1999 levels (Church and White 2006; Solomon et al. 2007). As a result, seabird nesting colonies that occur along sections of coastlines undergoing sea level rise may experience a loss of nesting habitat (Congdon et al. 2007; Gilman and Ellison 2009; Gilman et al. 2008; Hitipeuw et al. 2007; Mullane and Suzuki 1997).

Additional information on the biology, life history, and conservation of seabird species, including species-specific profiles, can be found on the following organizations' websites: U.S. Fish and Wildlife Service Endangered Species Program (2010b), Birdlife International (2010a), and the International Union for Conservation of Nature and Natural Resources (2010).

7.2 Species List and Status

One ESA listed seabird species, the short-tailed albatross, occurs regularly within the MRA Study Area. The status, presence, and nesting occurrence of the ESA-listed species within the MRA Study Area are listed in Table 7-1. In addition to the short-tailed albatross, there are two additional ESA listed species included in Table 7-1. They are the Hawaiian petrel (*Pterodroma sandwichensis*) and the Newell's shearwater (*Puffinus auriculars newelii*) and are considered extralimital within the MRA Study Area. Three Hawaiian petrels were observed during the 2007 Mariana Islands Sea Turtle and Cetacean Survey (MISTCS) (U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007). No Newell's shearwaters were observed in the Mariana Archipelago during MISTCS, U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific (2007).

The Japanese murrelet (*Synthliboramphus wumizusume*) is also included in Table 7-1 as it is known to occur within the MRA Study Area and is listed by International Union for Conservation of Nature (IUCN) as "vulnerable" (BirdLife International 2010e) and protected by the Japanese Government. Species profiles are not included for extralimital and foreign protected species.

Table 7-1: ESA-Listed Seabird Species Found in the MRA Study Area

Species Name and Regulatory Status				Ecoregional Presence[3]						
				Open Ocean				Coastal Waters		
Common Name	Scientific Name	ESA Listing[1]	IUCN[2]	NCP	KU	ECS	PS	JA	MA	CI
Short-tailed albatross	*Phoebastria albatrus*	Endangered	Vulnerable	P	P	P	P	P^n	-	-
Hawaiian petrel	*Pterodroma sandwichensis*	Endangered	Vulnerable	-	-	-	-	-	Ex	-
Newell's shearwater	*Puffinus auriculars newelii*	Threatened	Endangered	-	-	-	-	-	Ex	-
Japanese murrelet	*Synthliboramphus wumizusume*	Not Listed	Vulnerable	-	P	P	-	Ex	-	-

[1]Endangered Species Act (ESA) listing status: U.S. Fish and Wildlife Service (2012a, b, c).
[2]International Union for Conservation of Nature (IUCN) status: BirdLife International (2010b, c, d, e).
[3]Ecoregional presence relates to open ocean and coastal waters of the MRA Study Area. Ecoregional presence in open ocean waters include: the North Central Pacific Gyre (NCP), the Kuroshio Current (KU), the East China Sea (ECS), and the Philippine Sea (PS). Ecoregional presence in coastal waters include: nearshore areas of the Japan Archipelago (JA), the Mariana Archipelago (MA), and the Caroline Islands (CI). Each species may have a primary range (P) or may be an extralimital (Ex) species in the area. P^n indicates nesting sites.

7.2.1 Migratory Bird Treaty Act

Seabirds in the MRA Study Area include those listed under the MBTA (U.S. Fish and Wildlife Service 2001). A migratory bird is any species or family of birds that live or reproduce in or migrate across international borders at some point during their annual life cycle. The MBTA established federal responsibilities for the protection of nearly all species of birds, eggs, and nests. The Department of Defense (DoD) is authorized to take migratory birds during military readiness activities necessary for national defense, however, the DoD must confer and cooperate with USFWS for any such activity that may have a "significant adverse effect" on a population of migratory bird species (see Chapter 2.0 Applicable Legislation). Of the 1,007 species protected under the MBTA, 54 seabird species occur in the MRA Study Area (Table 7-2). With the exception of ESA-listed seabirds, these species are presented for informational purposes but will not be analyzed in further detail.

7.2.2 U.S. Fish and Wildlife Service Birds of Conservation Concern

Birds of Conservation Concern are species, subspecies, and populations of migratory and non-migratory birds that the USFWS has determined to be the highest priority for conservation actions beyond those species with an endangered or threatened Federal listing (U.S. Fish and Wildlife Service 2008a). The purpose of the Birds of Conservation Concern category is to prevent or remove the need for additional ESA bird listings by implementing proactive management and conservation actions needed to conserve these species. The USFWS maintains a list of Birds of Conservation Concern (U.S. Fish and Wildlife Service 2008a). There are 10 species considered Birds of Conservation Concern that occur within the MRA Study Area (Table 7-2). DoD military readiness activities necessary for national defense are exempt from prohibitions related to Birds of Conservation Concern. With the exception of ESA-listed seabirds, these species are presented for informational purposes but will not be analyzed in further detail.

Table 7-2: Migratory Bird Treaty Act Species and Birds of Conservation Concern that Occur within the MRA Study Area

Family/Subfamily	Common Name	Scientific Name	Birds of Conservation Concern
Order PROCELLARIIFORMES			
Albatrosses (Family DIOMEDEIDAE)			
	Laysan albatross	*Phoebastria immutabilis*	X
	Black-footed albatross	*Phoebastria nigripes*	X
	Short-tailed albatross	*Phoebastria albatrus*	
Petrels and Shearwaters (Family PROCELLARIIDAE)			
	Northern fulmar	*Fulmarus glacialis*	
	Kermadec petrel	*Pterodroma neglecta*	
	Juan Fernandez petrel	*Pterodroma externa*	
	White-necked petrel	*Pterodroma cervicalis*	
	Bonin petrel	*Pterodroma hypoleuca*	
	Black-winged petrel	*Pterodroma nigripennis*	
	Cook's petrel	*Pterodroma cookii*	
	Stejneger's petrel	*Pterodroma longirostris*	
	Tahiti petrel	*Pterodroma rostrata*	
	Bulwer's petrel	*Bulweria bulwerii*	
	Streaked shearwater	*Calonectris leucomelas*	
	Flesh-footed shearwater	*Puffinus carneipes*	

Table 7-2: Migratory Bird Treaty Act Species and Birds of Conservation Concern that Occur within the MRA Study Area

Family/Subfamily	Common Name	Scientific Name	Birds of Conservation Concern
	Buller's shearwater	*Puffinus bulleri*	
	Short-tailed shearwater	*Puffinus tenuirostris*	
Family HYDROBATIDAE			
	Fork-tailed storm-petrel	*Oceanodroma furcata*	
	Leach's storm-petrel	*Oceanodroma leucorhoa*	
	Band-rumped storm-petrel	*Oceanodroma castro*	X
	Wedge-rumped storm-petrel	*Oceanodroma tethys*	
	Matsudaira's storm-petrel	*Oceanodroma matsudairae*	
	Tristram's storm-petrel	*Oceanodroma tristrami*	X
	Least storm-petrel	*Oceanodroma microsoma*	
Order PELECANIFORMES			
Family SULIDAE			
	Masked booby	*Sula dactylatra*	X
	Brown booby	*Sula leucogaster*	X
	Red-footed booby	*Sula sula*	X
Family PELECANIDAE			
	American white pelican	*Pelecanus erythrorhynchos*	
Family PHALACROCORACIDAE			
	Pelagic cormorant	*Phalacrocorax pelagicus*	X
Order PHAETHONTIFORMES			
Tropicbirds (Family PHAETHONTIDAE)			
	Red-tailed tropicbird	*Phaethon rubricauda*	
	White-tailed tropicbird	*Phaethon lepturus*	
Order CHARADRIIFORMES			
Family LARIDAE			
	Herring gull	*Larus argentatus*	
	Slaty-backed gull	*Larus schistisagus*	
	Glaucous-winged gull	*Larus glaucescens*	
	Glaucous gull	*Larus hyperboreus*	
Subfamily STERNINAE	Black noddy	*Anous minutus*	
	White tern	*Gygis alba*	
	Sooty tern	*Onychoprion fuscatus*	
	Gray-backed tern	*Onychoprion lunatus*	
	Little tern	*Sternula albifrons*	
	Caspian tern	*Hydroprogne caspia*	X
	Black-naped tern	*Sterna sumatrana*	
	Royal tern	*Thalasseus maximus*	
	Great Crested tern	*Thalasseus bergii*	
	Elegant tern	*Thalasseus elegans*	
	Gull-billed tern	*Sterna nilotica*	X
Family ALCIDAE			
	Thick-billed murrelet	*Uria lomvia*	
	Long-billed murrelet	*Brachyramphus perdix*	

Table 7-2: Migratory Bird Treaty Act Species and Birds of Conservation Concern that Occur within the MRA Study Area

Family/Subfamily	Common Name	Scientific Name	Birds of Conservation Concern
	Japanese murrelet	*Synthliboramphus wumizusume*	
	Ancient murrelet	*Synthliboramphus antiquus*	
	Parakeet auklet	*Aethia psittacula*	
	Rhinoceros auklet	*Cerorhinca monocerata*	
	Horned puffin	*Fratercula corniculata*	
	Tufted puffin	*Fratercula cirrhata*	

Sources: BirdLife International (2010a) and U.S. Fish and Wildlife Service (2010a, b).

7.3 Short-tailed albatross (*Phoebastria albatrus*)

7.3.1 Description

The short-tailed albatross (formerly in the genus *Diomedea* and known as Steller's albatross) is the largest of the North Pacific albatrosses. It is nearly 1.0 m in length with a wingspan of 2.1 to 2.3 m. In adult plumage, this is the only North Pacific albatross with a white body (Harrison 1983). Adult short-tailed albatrosses are readily distinguishable from other Pacific albatrosses by their entirely white back and large bubble-gum pink bill that is strongly hooked at the end. The upper wings are mostly white with black primaries, primary coverts, secondaries (partially) and tertials. The underwings are mostly white with narrow black margins. The rump and tail appear white with a black terminal band (Harrison 1983). They have pale bluish feet and legs (U.S. Fish and Wildlife Service 2012b). Juveniles are entirely dark brown during their first year but can be distinguished from young black-footed (*Phoebastria nigripes*) and Laysan (*Phoebastria immutabilis*) albatrosses by their large pale bill and pale legs (U.S. Fish and Wildlife Service 2001). Juveniles go through successive plumage changes until the age of 12, when they develop the characteristic golden crown and nape of adulthood (Sibley 2000).

7.3.2 Status and Management

The short-tailed albatross is widely regarded as one of the rarest species of albatrosses and one of the world's rarest birds (Harrison 1983; International Union for the Conservation of Nature 2010). The short-tailed albatross is listed as endangered under the ESA throughout its range. No critical habitat has been designated for this species because little is known about its life cycle in the open ocean (Piatt et al. 2006; U.S. Fish and Wildlife Service 2000, 2012b). It is also classified as endangered (vulnerable) by the Ministry of the Environment, Japan (Ikemoto et al. 2005).

The translocation of chicks from Torishima Island to Mukojima Island, Japan is the highest priority recovery action for short-tailed albatross chicks in order to establish a new colony away from volcanic activity. Decoys and recorded colony calls are being used to attract adult birds to safer colony locations. Roughly 85% of the global population breeds on loose volcanic ash, which is steep and eroding. Tagging of birds to delineate the habitat and distribution of the species, including seasonal variation, is being undertaken by the USFWS Short-tailed Albatross Recovery Team and other partner international and U.S. partner agencies. Studies focusing on integrated weight line technology, trawl gear interactions, and the efficiency of fisheries management have enhanced fishing practices to reduce seabird bycatch and are starting to be implemented in the fisheries (U.S. Fish and Wildlife Service 2009b). According to

U.S. Fish and Wildlife Service (2009b), if the current rate of population growth continues, the short-tailed albatross can potentially be delisted by 2033.

Current threats to this species include ingestion of plastics mistaken for food items, volcanic eruption (at Torishima, Japan), typhoons, sunken longline fishing in Alaska and Russia, jig/troll fishery in Japan, invasive species at colonies (cats, rats, and plants), and researcher disturbance (U.S. Fish and Wildlife Service 2005b).

7.3.3 Population and Abundance

The global population of Short-tailed albatross was estimated at 2,572 birds worldwide during the 2008 to 2009 breeding season (U.S. Fish and Wildlife Service 2009a); with statistical models predicting population increases (Zador, Punt, and Parrish 2008). The short-tailed albatross is known to breed on two islands, Torishima Island (which is divided into two colonies) and Minami-Kojima, Japan. At Torishima there were an estimated 418 breeding pairs (836 breeding adults), with a total estimated population of 1045 adults, including non-breeders. At Minami-Kojima (in the Senkaku Island group, located northeast of Taiwan) there were an estimated 160 breeding adults (U.S. Fish and Wildlife Service 2009a). The subadult population was estimated at 1,114 birds on Torishima and 213 bids on Minami-Kojima for 2008 to 2009. The Japan and Taiwan population is growing rapidly at about 7.3% annually (International Union for the Conservation of Nature 2010; U.S. Fish and Wildlife Service 2005b). Average population survival rate is 94% (U.S. Fish and Wildlife Service 2009a).

As of 2008, there was at least one breeding pair present on Mukojima Island and 10 transplanted chicks have successfully fledged from this location (U.S. Fish and Wildlife Service 2008b, 2009b).

7.3.4 Biology, Ecology, and Behavior

Like all albatrosses, short-tailed albatrosses use their long, low drag wings to skim the ocean waves (a method called dynamic soaring), which allows them to cover great distances with little effort.

Group Size. Albatross generally congregate in large tight flocks at sea in areas where prey densities are high (U.S. Fish and Wildlife Service 2005b). At least 200 albatrosses have been sighted within the observation range of a fishing vessel (Piatt et al. 2006). Most sightings of short-tailed albatross flocks have occurred off the coast of Alaska, and 3% of all observations included large flocks (10–136 birds). About 75% of the observations were associated with fishing vessels (Piatt et al. 2006).

Predator/Prey Interactions. Short-tailed albatrosses are surface feeders and scavengers, feeding more inshore than other North Pacific albatrosses. Short-tailed albatrosses feeds at a higher trophic level than Laysan albatrosses and at a similar level to black-footed albatrosses (Suryan and Fischer 2010). In Japan, their diet consists of shrimp, squid, and fish (including bonita, flying fish, and sardines)(Suryan et al. 2006; U.S. Fish and Wildlife Service 2005b). Short-tailed albatrosses frequently feed within sight of land. The Aleutian Islands are a primary foraging destination for this species (Suryan and Fischer 2010; Suryan et al. 2006). Foraging occurs off the east coast of Honshū, Japan (Suryan et al. 2008). The short-tailed albatross is known to forage on bait from longline and other marine fisheries, where individuals may dive underwater to retrieve bait and baited hooks. Suryan and Fischer (2010) identified the diet and trophic position of *P. albatrus* through stable isotope value. The data shows that the short-tailed albatross (along with the Black-footed albatross) obtain most of their nutrients from neritic waters. Based on the nitrogen levels measured in short-tailed albatross and the overlap of their foraging

grounds with groundfish fisheries, data indicated that during the nonbreeding season short-tailed albatrosses may increase their level of foraging on fisheries discards (Suryan and Fischer 2010).

Short-tailed albatross are predated by other birds and introduced mammals such as cats and rats on nesting colonies (U.S. Fish and Wildlife Service 2005b). The crow (*Corvus sp.)* is a reported predator of short-tailed albatross chicks, having taken an estimated 1/3 of the historical Torishima chick population (Austin 1949). There are reports from Toho University of the Steller's sea eagle (*Haliaeetus pelagicus)* taking short-tailed albatross chicks in the 1960s (U.S. Fish and Wildlife Service (2008b). Steller's sea eagle is also known to prey on black-footed albatross chicks, but is not considered a major threat to the *P. albatrus* population (U.S. Fish and Wildlife Service 2008b). Sharks are known to prey on albatross chicks, although this has not been documented for the short-tailed albatross (U.S. Fish and Wildlife Service 2008b).

Life History. The short-tailed albatross is generally long-lived, with an average lifespan of 12 to 45 years (U.S. Fish and Wildlife Service 2012b). They are slow to mature (U.S. Fish and Wildlife Service 2005b) and return to the same breeding site annually (Committee on the Status of Endangered Wildlife in Canada 2003). They begin breeding at age 7 or 8 but do not attain full adult plumage until age 12 (International Union for the Conservation of Nature 2010; U.S. Fish and Wildlife Service 2001). Nests typically consist of a sand, grass or moss-lined depression approximately 2.5 ft. in diameter (Tickell 2000). Not all breeding age birds return to nesting colonies to breed every year; as many as 25% of all breeding age birds may remain at sea in any given breeding season. Egg laying begins in late October and runs through early November. Females lay a single egg, which is not replaced if it fails (Austin 1949). Eggs hatch from late December through early January. In late May through June, adults abandon their nests and chicks fledge soon after the adults leave the colony (Suryan et al. 2008; U.S. Fish and Wildlife Service 2008b). Most of the breeding information available is based off of patterns observed on Torishima Island (U.S. Fish and Wildlife Service 2008b).

The majority of short-tailed albatrosses breed on islands south of Japan (International Union for the Conservation of Nature 2010; U.S. Fish and Wildlife Service 2005b). Single nests have been found in other locations, including the Midway Atoll in the Hawaiian Islands, although no viable eggs were found (Tickell 2000; U.S. Fish and Wildlife Service 2005b). The short-tailed albatross has been observed attempting to lay eggs several times since 1975 at Midway Atoll (U.S. Fish and Wildlife Service 2005b). The breeding season in Japanese waters is from late October to mid-June (U.S. Fish and Wildlife Service 2005b), and juvenile and immature short-tailed albatrosses are most likely to be found elsewhere at sea during that time. During the nonbreeding season, telemetry data shows albatrosses can be found along continental margins (Suryan and Fischer 2010).

The short-tailed albatross has one of the smallest breeding ranges and is typically located near coastal upwelling systems. The aerodynamic performance of the *P. albatrus* is inconsistent with its body size, but matches with the wind regime of its breeding season foraging ranges. Specialized morphology such as high wing-load (weight of area per lift) may explain the limited breeding range of *P. albatrus* (Suryan et al. 2008).

Migration. Short-tailed albatrosses disperse seasonally throughout the temperate and subarctic North Pacific, ranging from Japan to California. High densities of albatross are observed in Japan during the breeding season (Kiyota and Minami 2008; U.S. Fish and Wildlife Service 2005b, 2008b). Nonbreeders and failed breeders disperse from the colony months earlier (Suryan and Fischer 2010). While many nonbreeders return to the colonies each year, the presence of immature birds far from the colony (such

as the U.S. Pacific coast) during the breeding season suggests that some immature birds may spend years at sea before they return to the colony (U.S. Fish and Wildlife Service 2005b). Albatross tend to fly slower during high pressure conditions, and wind speed is an important variable influencing short-tailed movements (Suryan et al. 2006) .

Short-tailed albatrosses move seasonally around the North Pacific Ocean, with high densities observed during the breeding season (December through May) in Japan, and throughout Alaska and along the west coast of North America during the non-breeding season (April through September) (McDermond and Morgan 1993). Movement patterns are different between genders and age classes (Suryan et al. 2007). Female short-tailed albatross spend more time offshore of Japan and Russia in comparison to male birds which spend more time in the Aleutian Island and Bering Sea (Suryan et al. 2007). Because this species forages along continental shelves, they occur within the Exclusive Economic Zones (EEZs) of Japan, Russia, and Alaska. Overall, the short-tailed albatross spends the greatest amount of time in Alaskan waters (Suryan et al. 2007).

Hearing/Vocalization. No information is currently available.

Diving. This species is known to forage on bait from longline and other marine fisheries, where individuals may dive underwater to retrieve bait and baited hooks (U.S. Fish and Wildlife Service 2005b). There are no diving depth records available for this species at this time.

7.3.5 Habitat and Distribution

The short-tailed albatross spends the majority of its time in the EEZs of Japan, Russia (Kuril Islands and Kamchatka Peninsula), and the United States (Aleutian Islands and Bering Sea, Alaska) (Suryan et al. 2007). While they are found in the open ocean, they tend to concentrate along the edge of the continental shelf where upwellings are present (NatureServe 2004; Piatt et al. 2006; Suryan et al. 2008; Suryan et al. 2007; Suryan and Fischer 2010; Suryan et al. 2006). These upwelling zones are not only nutrient rich, but they also bring prey typically found only in deeper water to the surface (for example, squid and fish), where they become available to albatrosses. Short-tailed albatross nest on isolated, windswept, offshore islands with restricted human access (U.S. Fish and Wildlife Service 2000). Current and historical nesting habitat can be described as flat to steep slopes that are sparsely or fully vegetated (Tickell 2000). Overall, the short-tailed albatross ranges more to the north, into the Bering Sea, than the other North Pacific albatross species (Suryan and Fischer 2010). North and Central Pacific Ocean species, including the short-tailed albatross, are known to inhabit regions of lower wind speed and sea state than their southern species counterparts (Suryan et al. 2008). The primary range of the short-tailed albatross during the non-breeding season is shown in Figure 7-1.

Open Ocean Waters of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. The short-tailed albatross spends relatively little time in the central gyre preferring coastal areas, although they do transit through the gyres north of 35 degrees (Suryan et al. 2007). Although most nesting occurs within Japan, short-tailed albatrosses have been occasionally reported during the breeding season at Midway Atoll, where 2 million black-footed and Laysan albatrosses nest. (Harrison, Naughton, and Fefer 1984; Tickell 2000). In June 2011 on Midway Atoll, the first short-tailed albatross chick fledged successfully outside of Japan and a nesting pair was incubating again during the 2011-2012 breeding season (Agreement on the Conservation of Albatrosses and Petrels 2011, 2012a). Furthermore, two female short-tailed albatrosses nested and laid eggs in both 2010 and 2011 on Kure Atoll in the NWHI, and were joined by a third albatross of unknown gender in January of

2012 (Agreement on the Conservation of Albatrosses and Petrels 2011, 2012b). The eggs from the 2010 breeding season were unfertilized.

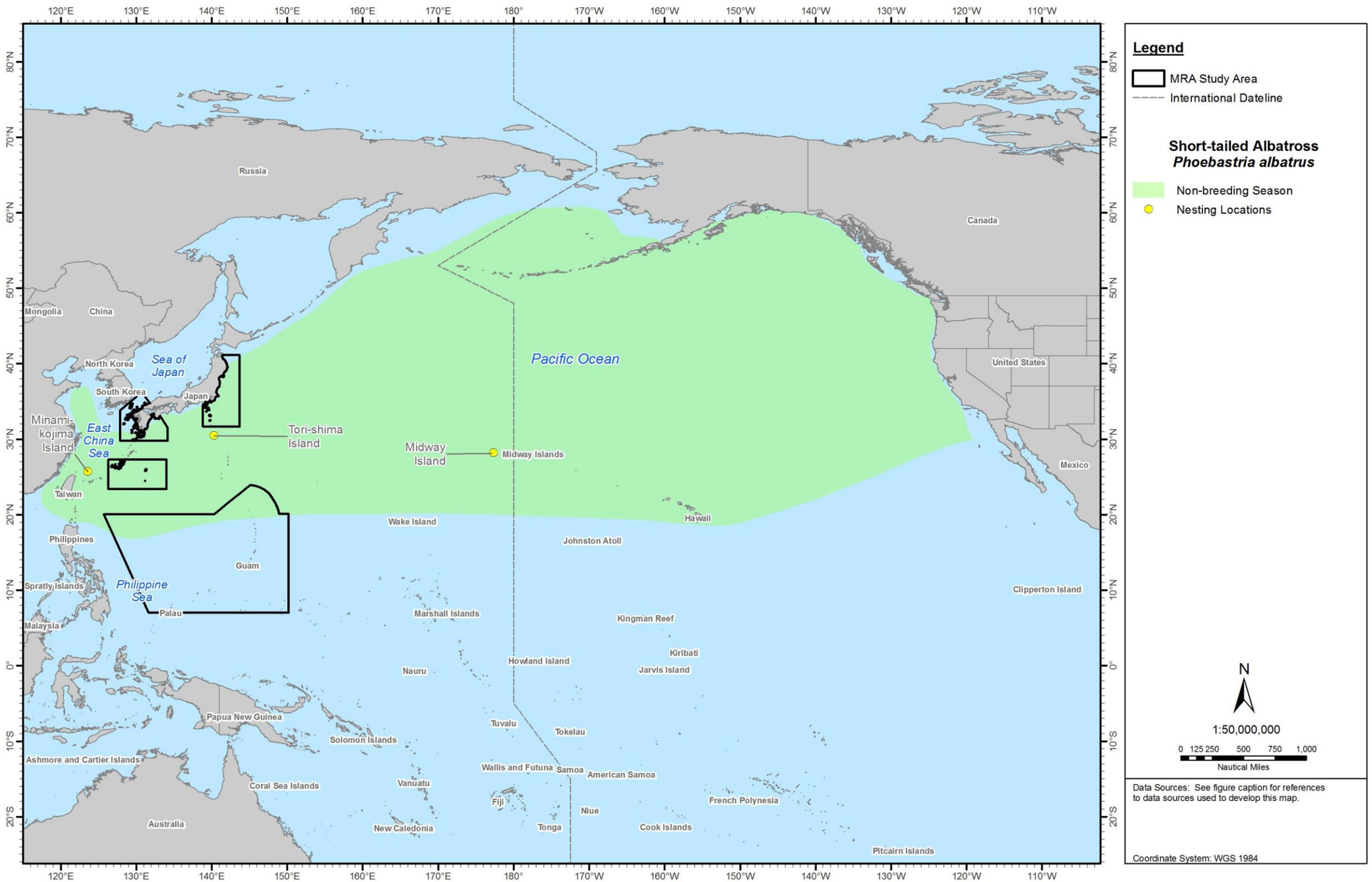

Figure 7-1: Geographic Range of the Short-tailed Albatross in the North Pacific Ocean
Sources: Agreement on the Conservation of Albatrosses and Petrels (2009, 2012a).

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KUROSHIO CURRENT. Short-tailed albatross are known to conduct area-restricted search patterns over the continental shelf break and slope regions of the Kuroshio current region (Suryan et al. 2006). Telemetry data shows that albatrosses travelling from Torishima initially travel north within the Kuroshio Current. All tagged albatross traveled to the outer continental shelf off the northeast of Honshū (36 to 40° N), where the activity was greatest during May and June. Telemetry data also indicates that the convergence zone to the east of northern Japan and south of the Kuril Islands is a hotspot for short-tailed albatross (Suryan et al. 2006).

EAST CHINA SEA. Short-tailed albatross are known to occur within this region (BirdLife International 2012a; U.S. Fish and Wildlife Service 2008b).

PHILLIPINE SEA. Short-tailed albatross are known to occur within this region (BirdLife International 2012a; U.S. Fish and Wildlife Service 2008b).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. The pelagic distribution of short-tailed albatross as examined from 1999 to 2004 reveals that the short-tailed albatross occur in three main areas off the coast of Japan: the Pacific coast of eastern Japan, near Torishima and Izu Islands, and near Minamikojima of the Senkakau Islands (Kiyota and Minami 2008). Short-tailed albatrosses tend to aggregate within 30 kilometer (km) of their breeding islands and have been observed using the Kuroshio-Oyahio mixture zone over the continental edge and slope 20 to 70 km (200/1400 m deep) off the Pacific coast of Japan. This suggests that these areas may be important marine habitats for this species during the breeding season (Kiyota and Minami 2008).

Short-tailed albatross breeds mainly on two islands in Japan, Torishima and Minami-kojima (U.S. Fish and Wildlife Service 2008b). Over 80% of the short-tailed albatross population nests on Torishima (Suryan et al. 2007). The rest of the population nests primarily on Minami-kojima, located in the Senkaku Island chain, which sits on a natural gas reserve and is under dispute of ownership between Japan, China, and Taiwan (U.S. Fish and Wildlife Service 2008b). In 2002, a short-tailed albatross chick fledged from Kitja-kojima, near Mimami-kojima (Agreement on the Conservation of Albatrosses and Petrels 2009; U.S. Fish and Wildlife Service 2008b).

In February 2008, 10 chicks were moved to Mukojima Island in the Bonin Islands of Japan. All ten chicks fledged (U.S. Fish and Wildlife Service 2008b). Short-tailed albatross are being relocated to Mukojima in order to protect the birds from volcanic threats to the population on Torishima. There is a potential for political instability on Minami-kojima since Japans control of the island is disputed by China and Taiwan (Agreement on the Conservation of Albatrosses and Petrels 2010; U.S. Fish and Wildlife Service 2008b). This instability could affect the nature and efficiency of protection for the short-tailed albatross.

Bōsō Peninsula, Izu Peninsula, and Izu Islands. Torishima in the Izu Shoto Island Group is about 375 miles (mi.) (600 km) south of Tōkyō and belongs to Japan. Over 80% of the population nests on Torishima, which is an active volcano (Suryan et al. 2007; U.S. Fish and Wildlife Service 2008b, 2009a).

There are two colonies on Torishima Island, Tsubamezaki and a new colony, Hatsunezaki, has formed on the northwest side of Torishima Island (Figure 7-1 and Figure 7-2) (U.S. Fish and Wildlife Service 2009a). The population is growing and non-breeders use the site for courting (Agreement on the Conservation of Albatrosses and Petrels 2009).

MARIANA ARCHIPELAGO. Two observations of short-tailed albatross were recorded during the 2007 MISTCS (U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007). Breeding does not occur within the Mariana Islands (U.S. Fish and Wildlife Service 2005b). Although short-tailed albatrosses have been observed in less productive waters far from regions of upwelling, the extremely rare observations in these areas suggests that these birds may be simply moving between areas of favored habitat (Figure 7-2).

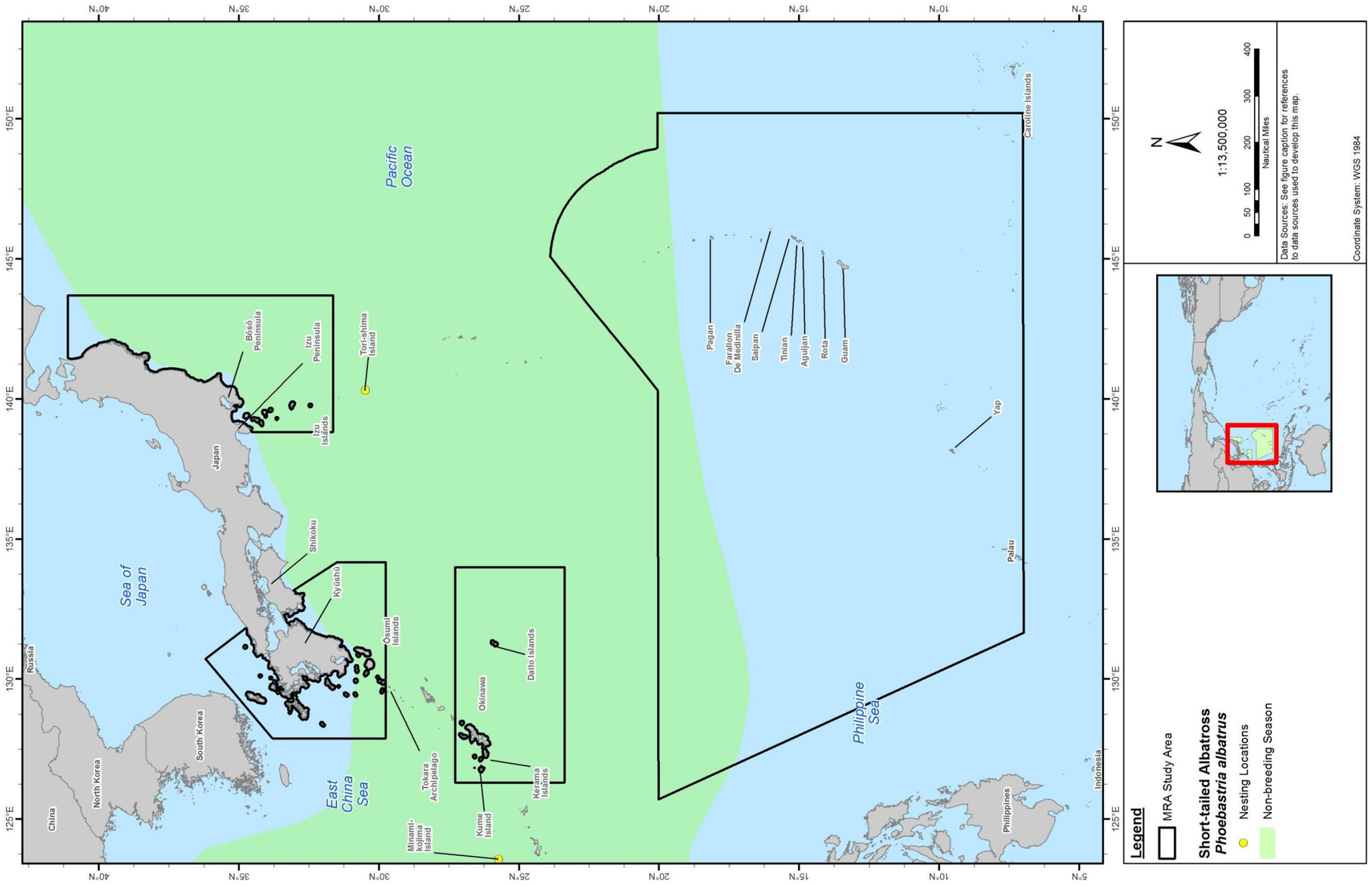

Figure 7-2: Geographic Range of the Short-tailed Albatross in the MRA Study Area
Sources: Agreement on the Conservation of Albatrosses and Petrels (2009, 2012a).

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7.3.6 Species-specific Threats

Fishery bycatch is thought to be a leading anthropogenic source of albatross mortality (Zador, Punt, and Parrish 2008). Because of the variance between gender and age of the short-tailed albatross in relation to distribution, the potential for interaction with fisheries is not evenly distributed. Female birds are more impacted by fisheries in Japan and Russia while male birds are more likely to be impacted by Alaskan fisheries. (Suryan et al. 2007). The short-tailed albatross has the highest potential for interactions with fisheries (i.e. sablefish) on continental shelf break and slope regions. Fishery interaction depends on target species and gear type (Suryan et al. 2007). There are 18 species of albatrosses threatened with extinction that are affected by longline fisheries, and it is suspected that pelagic longline fisheries are responsible for double the number of seabird mortalities than originally estimated due to bycatch observation methods (Brothers et al. 2010). Since 1990 there have been five confirmed and two suspected mortalities in Alaska longline fisheries (Suryan et al. 2007). Additionally, there has been one confirmed mortality in Russian fisheries, which occurred in 2003. No mortalities have been reported from pot fisheries in Alaska. Seabird avoidance measures are not required throughout the short-tailed albatross range, and bycatch beyond Alaska is poorly monitored. Zador, Punt, and Parrish (2008) suggest that exceeding current incidental catch rates, up to a factor of 10, would have little impact of the recovery goals for the short-tailed albatross if survival rates were high from all other sources of mortality. It is possible albatross can become entangled in trawl equipment without being noticed, so catch estimates may be biased (Zador, Punt, and Parrish 2008).

Because of their high position on the trophic level and long lifespan, albatrosses have the potential to bioaccumulate diet derived contaminants such as heavy metals. Short-tailed albatross are at risk to mercury exposure. Short-tailed albatross eggs sampled from Torishima Island contained mercury content higher than the average mercury content in seabird eggs (Ikemoto et al. 2005).

With increasing amounts of human-introduced marine debris, albatross species have a recognized tendency to ingest plastic while foraging in the open ocean (Young et al. 2009). A literature review by Derraik (2002) summarizes ingestion hazards, which include reduced food uptake, internal blockages, and reproductive failure. It is estimated that 44% of seabird species are affected by plastic ingestion (Derraik 2002). Albatrosses are considered to be especially vulnerable to ingested plastics as they cannot regurgitate them (Derraik 2002). Plastic has the potential to transport hydrophobic contaminants (Teuten et al. 2007). Data suggests contaminants associated with plastic can also be assimilated into the tissue of seabirds (Derraik 2002).

Organochlorines have been shown to alter immune function in seabirds (Finkelstein et al. 2007). Persistent organic pollutants (POPs) have been found in short-tailed albatross at levels similar to those found in the black-footed albatross (Kunisue et al. 2006). Toxic equivalents levels of POPs in short-tailed albatross eggs collected from Torishima Island in 2002 exceeded some toxicity threshold limits for avian embryos (Kunisue et al. 2006). Based off levels of polychorlinated biphenyls and dichlorodiphenyldichloroethylenes (a metabolite of dichlorodiphenyltrichloroethanes) found in Laysan and black-footed albatross, contaminants in the eastern North Pacific have been increasing over time (Finkelstein et al. 2006).

While volcanic threats do exist on Torishima Island (there is a 2.2% annual eruption probability), chronic mortalities, such as bycatch, are more likely to affect population viability (Finkelstein et al. 2010). Modeling suggest that population growth rate would remain positive until an average of four volcanic eruptions per year given the maximum short-tailed albatross presence is only 25% of the population at

any time (75% is usually out at sea) (Finkelstein et al. 2010). Chronic mortality is a greater threat to the short-tailed albatross population than periodic volcanic eruptions (Finkelstein et al. 2010).

7.4 Taxonomic Groups

Seabirds can be grouped as primarily as open ocean or coastal water feeders (U.S. Fish and Wildlife Service 2005a). Coastal seabirds rarely range far from land, foraging in marine, estuarine, freshwater, and sometimes terrestrial habitats, and most return to land to roost at night. Brown pelicans and blue noddies are examples of coastal foraging seabirds. Pelagic seabird species that forage in open ocean are strictly marine, ranging far out to sea and returning to land only to breed. Laysan, black-footed, and short-tailed albatrosses, and sooty and arctic terns are examples of Pacific pelagic seabirds that live and feed in the open ocean.

Four orders of seabirds occur worldwide and include 15 families and 312 species (Harrison 1983). These orders are Charadriiformes (skuas, jaegers, gulls, terns, noddies, skimmers, auks, and phalaropes), Pelecaniformes (pelicans, cormorants, tropicbirds, gannets, and frigatebirds), Procellariiformes (albatrosses, petrels, storm-petrels, shearwaters, prions, and fulmars), and Spenisciformes (penguins). There are three major groups of seabirds represented in the MRA Study Area (Table 7-3).

Table 7-3: Descriptions and Examples of Major Taxonomic Groups of Seabirds within the MRA Study Area

Major Bird Groups[1]	
Common Name (Taxonomic Group)	**Description**
Albatrosses, petrels, shearwaters, and storm-petrels (order Procellariiformes)	Group of large to medium winged, open ocean species
Tropicbirds, boobies, pelicans, cormorants, and frigatebirds (order Pelecaniformes)	Diverse group of large fish-eating seabirds with four toes joined by webbing
Phalaropes, gulls, noddies, terns, skua, jaegers, and alcids (order Charadriiformes)	Diverse group of small to medium sized seabirds and allies inhabiting coastal, nearshore, and pelagic waters

Notes:
[1]Major taxonomic groups based on American Ornithologists' Union (1998) and Sibley (2000).

7.4.1 Albatrosses, petrels, shearwaters, and storm-petrels (order Procellariiformes)

The Procellariiformes is a large order of open ocean (pelagic) seabirds that are divided into four families: Diomedeidae (albatrosses), Procellariidae (petrels and shearwaters), Hydrobatidae (storm-petrels), and Pelecanoididae (diving-petrels) (Enticott and Tipling 1997; Onley and Scofield 2007). Within the MRA Study Area there are at least 24 species representing three families –Diomedeidae, Procellariidae, and Hydrobatidae (see Table 7-2: Migratory Bird Treaty Act Species and Birds of Conservation Concern that Occur within the MRA Study Area). These species are generally long-lived, breed once a year, and lay only one egg. All birds in this order have tubular noses on the top of their bills, hence they are sometimes referred to as “tubenoses” (Sibley 2000). They all have webbed feet, and the hind toe is either imperfectly developed or completely absent. They have extremely broad distributions and spend most of their lives at sea and exclusively feed in the open ocean, primarily on fish, crustaceans, and crabs. They can be found in high numbers resting on the water in flocks where prey is concentrated

(Enticott and Tipling 1997). Some species feed around fishing boats and become injured from longline gear (Brothers et al. 2010; Enticott and Tipling 1997; Onley and Scofield 2007; Suryan et al. 2007). They nest in colonies on remote islands uninhabited by people. Some are ground nesters, others nest in cavities or burrows (Ramos et al. 1997). They return to their birth colonies on a yearly basis. They are monogamous and mate for life with both parents participating in egg incubation and chick rearing (Elphick, Dunning, and Sibley 2001). Albatross and petrels are thought to trade-off reproduction and survival duties (Dobson and Jouventin 2010). Representative species include Laysan albatross, Northern fulmar, Bonin petrel, short-tailed shearwater, and Least storm-petrel.

Diomedeidae (Albatrosses)

Albatrosses range widely in the southern hemisphere and the North Pacific, although occasional vagrants are recorded in the North Atlantic (Pratt, Bruner, and Berrett 1987). Albatrosses are among the largest of flying birds, and great albatrosses (*Diomedea spp*.) have the largest wingspan of any bird.

Albatrosses are highly efficient in the air, using dynamic soaring and slope soaring to cover great distances with little exertion. They feed on squid, fish, and krill by scavenging, surface seizing, or diving. Albatrosses are colonial, mostly nesting on remote oceanic islands, often with several species nesting together. Pair bonds between males and females form over several years with the use of 'ritualized dances,' and will last for the life of the pair. A breeding season can take over a year from laying to fledging, with a single egg laid in each breeding attempt (Pratt, Bruner, and Berrett 1987).

Both albatross species (black-footed albatross and short-tailed albatross) occur within the Study Area. They are rarely documented more than once per year, and range throughout the North Pacific (Pratt, Bruner, and Berrett 1987). Neither species has been recorded on land within the Mariana Archipelago portion of the MRA Study Area, although both species were observed during the 2007 MISTCS (U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007). As discussed above the short-tailed albatross species profile, this species nests and may forage within the Japan portion of the MRA Study Area.

The black-footed albatross nest colonially on isolated islands of the Northwestern Hawaiian Islands (such as Laysan and Midway), and the Japanese islands of Torishima, Bonin, and Senkaku. Their range at-sea varies amongst seasons (straying farther from the breeding islands when the chicks are older), and they make use of expansive areas of the North Pacific, feeding from Alaska to California and Japan. A USFWS status review was initiated in October 2007 to determine if listing the black-footed albatross was warranted. The USFWS issued a news release on October 6th, 2011 which stated that based on available scientific and commercial data the black-footed albatross will not be listed under the ESA (U.S. Fish and Wildlife Service 2011).

Procellariidae (Shearwaters and Petrels)

Shearwaters and petrels are medium-sized, long-winged seabirds most common in temperate and cold waters. Shearwaters and petrels come to islands and coastal cliffs to breed, with some breeding locations in the tropics. They are nocturnal at the colonial breeding sites, preferring moonless nights to minimize predation. Outside of the breeding season, they are pelagic and most migrate long distances. Shearwaters and petrels feed on marine animals such as fish and squid. Numbers of shearwaters petrels have been reduced due to predation by introduced species to islands, such as rats and cats.

Entanglement in fishing gear is another threat to these species (Pratt, Bruner, and Berrett 1987). The general problem of light attraction and its effects on birds is worldwide among the Procellariiformes; at

least 21 species of this family are known to be attracted to man-made lights (Reed, Sincock, and Hailman 1985). Fledglings typically take first flight at night, homing in on reflected natural light from the ocean. Artificial light can attract these fledglings to lighted infrastructure, causing exhaustion and increasing the probability of collision with buildings, utility poles, illuminated windows, and other structures (Reed, Sincock, and Hailman 1985).

Most species of this family observed within the MRA Study Area are considered visitors (Pratt, Bruner, and Berrett 1987; U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007). Shearwaters and petrels do not breed on DoD owned or leased lands within the MRA Study Area, although wedge-tailed shearwaters are known to breed on Bird Island (an islet off Saipan's eastern coast) and possibly along the southern coasts of Tinian. Shearwaters and petrels primarily utilize offshore and coastal waters for foraging and are typically concentrated along upwelling boundaries and other water mass convergence areas (U.S. Fish and Wildlife Service 1983). The Hawaiian petrel, observed during the 2007 MISTCS (U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007), is protected under the ESA but is considered to be extralimital within the MRA Study Area and was not described in further detail within the ESA-listed seabirds section.

7.4.2 Boobies, cormorants, frigatebirds, and tropicbirds (order Pelecaniformes)

The Pelecaniformes order includes five families Anhingidae, Fregatidae, Pelecanidae, Phalacrocoracidae, and Sulidae. There are seven species representing four families that occur in the MRA Study Area: tropicbirds, boobies, pelicans, cormorants, and frigatebirds (see Table 7-2). They all have webbed feet and eight toes, and all have a throat sac, called a gular sac (Brown and Harshman 2008). This sac is highly developed and visible in pelicans and frigatebirds but is also readily apparent in boobies and cormorants. Pelicans use the sac to trap fish; frigatebirds use it as a mating display and to feed on fish, squid, and similar marine life (Dearborn, Anders, and Parker 2001). Pelecaniformes nest in colonies, but individual birds are monogamous (Brown and Harshman 2008).

<u>Sulidae (Gannets and Boobies)</u>

Members of the seabird family Sulidae are medium to large coastal seabirds that plunge-dive for fish. Three species of booby are found within the MRA Study Area. Farallon de Medinilla (FDM) is the location of the largest nesting colony for the brown booby (*Sula leucogaster*) in the Mariana Islands. The masked booby (*Sula dactylatra*) breeds only on FDM, while the red-footed booby (*Sula sula*) breeds on FDM and Rota (SWCA Environmental Consultants 2011). Monthly aerial bird surveys via helicopter conducted by Navy biologists over FDM showed distinct oscillations in the booby populations on the island. The period from 1999 to 2002 was a low period, followed by increasing numbers recorded from 2003 through 2005. Decreases in booby numbers continued from 2006 through 2007 (Vogt 2008).

<u>Phalacrocoracidae (Cormorants)</u>

Cormorants are medium-sized diving birds with long, hook-tipped bills (Pratt, Bruner, and Berrett 1987). Only one species of cormorant breeds in the tropical Pacific, the pelagic cormorant (*Phalacrocorax pelagicus)* which breeds around North Pacific coasts from Taiwan and Japan to Alaska and California (Pratt, Bruner, and Berrett 1987). The only other cormorant species confirmed within the MRA Study Area is the little pied cormorant (*Phalacrocorax melanoleucos*), which is considered a rare visitor to the Commonwealth of the Northern Mariana Islands. There are no records associated with comorant observations on Navy lease lands in the Commonwealth of the Northern Mariana Islands, including FDM.

Fregatidae (Frigatebirds)

Members of the Fregatidae family are large seabirds, with iridescent black feathers, a wingspan up to 7.5 ft. and deeply-forked tails. The males inflate red-colored throat pouches to attract females during the mating season. Frigatebirds are distributed globally in tropical oceans. These birds do not swim, cannot walk well, and cannot take off from a flat surface, needing a slope or drop-off (e.g., a cliff) to take off. Frigatebirds are able to stay aloft for more than a week, landing only to roost or breed on trees or cliffs (Lusk, Bruner, and Kessler 2000). Frigatebirds are well known for their kleptoparasitic feeding behavior, for instance, they have been documented to stealing food from masked boobies (Vickery and Brooke 1994).

The great frigatebird (*Fregata minor*) nests on FDM, which is one of only two small breeding colonies known to exist within the Mariana Islands. The great frigatebird has a wide distribution throughout the tropical Pacific, with Hawaiʻi as the northernmost extent of their range (Harrison 1990; Pratt, Bruner, and Berrett 1987). Unlike the great frigatebird, the lesser frigatebird (*Fregata arial*) does not breed within the MRA Study Area, although Pratt, Bruner, and Berrett (1987) reports rare sightings of the lesser frigatebird on Tinian. Navy biologists conduct monthly aerial surveys by helicopter over FDM for bird counts (Vogt 2008). These index surveys began in 1999, and suggest that great frigatebird sightings are seasonally-dependent, with most sightings between December and March. Sightings of these birds increased from 2005 through 2008 during the winter months (Vogt 2008).

7.4.3 Tropicbirds (order Phaethontiformes)

Phaethontidae (Tropicbirds)

Tropicbirds were recently removed from the Pelecaniformes and placed in their own order, the Phaethontiformes (American Ornithologists' Union Checklist Committee 2009; Chesser et al. 2009). Tropicbirds are seabirds with predominantly white plumage and elongated central tail feathers. Their bills are large, powerful and slightly decurved, and they have large heads and short, thick necks. The three species within this family have a different combination of black markings on the face, back, and wings, distinctive to each species. Two of the three species of tropicbirds are known to occur within the MRA Study Area (Pratt, Bruner, and Berrett 1987).

The red-tailed tropicbird (*Phaethon rubricauda*) and the white-tailed tropicbird (*Phaethon lepturus*) are known to occur on Tinian and FDM, as well as in open waters of the MRA Study Area (U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007). The red-tailed tropicbird is the rarest of all tropicbird species, but is widely distributed with colonies on islands from Hawaiʻi to Easter Island and Mauritius. This species breeds on Guam (SWCA Environmental Consultants 2011), with other breeding records on Rota, Tinian, and FDM. The white-tailed tropicbird is the smallest of the three species within the Phaethontidae family. It occurs in the tropical Atlantic, western Pacific, and Indian Oceans. Breeding locations are recorded from Guam, Rota, Tinian, and FDM. Both species were observed during the MISTCS cruise (U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007).

7.4.4 Phalaropes, Gulls, Noddies, Terns, Skua, and Jaegers (order Charadriiformes)

There are 23 species represented from the order Charadriiformers within the MRA Study Area (see Table 7-2). Gulls, noddies, and terns of the family Laridae are a diverse group of small to medium sized seabirds that inhabit coastal, nearshore, and open ocean environments. Skuas and jaegers in the family Stercorariidae are stocky powerful birds with long pointed wings, long tails, strong hooked bills, and sharp talons known for robbing the food of smaller seabirds. Murres, murrelets, and auklets in the family Alcidae are good swimmers and divers, have short wings, which requires them to flap their wings rapidly to fly.

Species in the order Charadriiformes occupy diverse habitats. Some species in this order spend most of their time at sea (e.g., jaegers, skuas, alcids), whereas others are more coastal or nearshore (e.g., gulls). Many charadriiformes inhabit marine and freshwater wetlands; others spend most of their lives in or near the ocean. Many species breed in colonies, and some species lay more than one egg (Ericson et al. 2003; Fain and Houde 2007; Harrison 1983; Onley and Scofield 2007). Representative species within the MRA Study Area include glaucous-winged gull, black noddy, sooty tern, thick-billed murre, long-billed murrelet, rhinoceros auklet, and horned puffin.

Larinae (Gulls)

Gulls are not common in the tropical Pacific (Pratt, Bruner, and Berrett 1987), preferring shallow water habitats in temperate and polar climates along coasts and inland rivers and lakes. Gulls that have been observed in the Mariana Islands are generally associated with rare visitations and winter migrations. The common black-headed gull (*Larus ridibundus*) and salty-backed gull (*Larus schistisagus*) are the only gull species observed within the MRA Study Area, with observations occurring on Guam and Tinian (Pratt, Bruner, and Berrett 1987). Harrison (1983) notes that the occurrence of the common black-headed gull is associated with harbors and bays.

Sternidae (Terns and Noddies)

Terns and noddies are seabirds in the family Sternidae with worldwide distribution (Pratt, Bruner, and Berrett 1987). A recent taxonomic revision now separates terns and noddies out of the gull family Laridae (van Tuinen, Waterhouse, and Dyke 2004). Terns generally are medium to large birds, typically with gray or white plumage, often with black markings on the head. They have longish bills and webbed feet. Terns and noddies are lighter bodied and more streamlined than gulls, with long tails and long narrow wings. Terns and noddies hunt fish by diving, often hovering first for a few moments before a dive.

The black noddy (*Anous minutus*) is a tropical seabird with worldwide distribution in tropical and subtropical seas. Their colonies are widespread in the Pacific Ocean and more scattered across the Caribbean, central Atlantic and in the northeast Indian Ocean. The black noddy has dark plumage, a white cap, a long, straight beak and short tail. Their nests consist of a level platform, often created in the branches of trees using dried leaves covered with bird droppings. One egg is laid each season, and nests are re-used in subsequent years. At sea, it is usually seen close to its breeding colonies within 50 mi. off shore. Birds return to colonies, or other islands, in order to roost at night. The black noddy nests on Aguijan, a small island south of Tinian (Aguon et al. 2005; SWCA Environmental Consultants 2011). The black noddy is also known to breed on Guam on Neye Island and Apaoa Point at the Naval Base, and the shoreline between Pati Point and Tagua Point on Anderson Air Force Base (National Oceanic and Atmospheric Administration 2005).

The brown noddy (*Anous stolidus*) is a tropical seabird with a worldwide distribution, ranging from Hawai'i to the Tuamotu Archipelago and Australia in the Pacific Ocean, from the Red Sea to the Seychelles and Australia in the Indian Ocean, and in the Caribbean to Tristan da Cunha in the Atlantic Ocean. The brown noddy is colonial, usually nesting on cliffs or in short trees or shrubs, and occasionally nests on the ground. The female lays a single egg each breeding season. The brown noddy was observed in open water during the MISTCS cruise (U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007). It breeds on Tinian, FDM, Rota, and Guam (SWCA Environmental Consultants 2011). Orote Point on Guam supports a large brown noddy nesting colony (approximately 150 birds). Additional roosts for brown noddys are found on at least two small emergent rock islands off the north and south coast of Orote Peninsula (Lusk, Bruner, and Kessler 2000). The brown noddy was also observed in open water during the MISTCS cruise (U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007).

The brown noddy and black noddy are known to nest at FDM (U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007), and have been observed at Hagoi on Tinian, and the Navy Main Base on Guam (SWCA Environmental Consultants 2011).

The gray-backed tern (*Sterna lunata*) has not been observed on land within the MRA Study Area; however, this species was observed in open water during the MISTCS cruise (U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007). The gray-backed tern breeds on islands of the tropical Pacific Ocean (BirdLife International 2012c). At the northern end of its distribution it nests in the Northwestern Hawaiian Islands (with the largest population occurring on Lisianski Island) and two small islets off Oahu; in the east as far as the Tuamotu Islands, with other colonies occurring in the Society Islands, the Line Islands, Phoenix Islands, Mariana Islands, and American Samoa.

The sooty tern (*Sterna fuscata*) utilizes areas of the Navy Main Base and Fena Reservoir on Guam (Aguon et al. 2005; SWCA Environmental Consultants 2011), and was observed in open waters during the MISTCS cruise (U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007). Sooty terns have also been observed flocking over FDM (SWCA Environmental Consultants 2011), and are known to breed on the island (SWCA Environmental Consultants 2011). This tern is migratory and highly dispersive, wintering throughout the tropical oceans. Compared to other terns, the sooty tern is more pelagic. Sooty terns breed in colonies on rocky or coral islands. Nests are simple and consist of a ground scrape or hole in which one to three eggs are laid. Sooty terns feed by picking fish from the surface in marine environments. They are often found in large flocks and rarely come to land except to breed. This species can stay out at sea (either soaring or floating on the water) for 3 to 10 years (Pratt, Bruner, and Berrett 1987).

The white tern (*Gygis alba*) has been observed on the Navy Main Base (including the North coast of Orote Peninsula, Neye Island and Apaoa Point) and Fena Reservoir on Guam, Hagoi on Tinian, and FDM, as well as open waters within the MRA Study Area (SWCA Environmental Consultants 2011; U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007). White terns nest throughout the Commonwealth of the Northern Mariana Islands and are considered common. This tern ranges widely across the Pacific and Indian Oceans, and also nests on some Atlantic islands. White terns nest on coral islands, usually on trees with thin branches but also on rocky ledges and on man-made structures. The white tern breeds on Tinian, FDM, and Rota (SWCA Environmental Consultants 2011).

<u>Stercorariidae (Skuas and Jaegers)</u>

Members of the seabird family Stercorariidae are ground nesters in temperate and arctic regions and are long-distance migrants (Pratt, Bruner, and Berrett 1987). Outside the breeding season they feed on

fish, animal entrails, and carrion. Many are partial kleptoparasites, chasing gulls, terns and other seabirds to steal their catches. The larger species in this family also regularly kill and eat adult birds, up to the size of great black-backed gulls (the largest of all gulls). On the breeding grounds they commonly eat lemmings, and the eggs and young of other birds.

The three species of family Stercorariidae that are known to occur within the MRA Study Area include the long-tailed jaeger (*Stercorarius longicaudus*), the parasitic jaeger (*Stercorarius parasiticus*), and the pomarine jaeger (*Stercorarius pomarinus*). None are known to breed on islands within the MRA Study Area, and no observations of these birds have been recorded on land in the Mariana Islands. The long-tailed jaeger breeds in the high Arctic of Eurasia and North America, with major populations in Russia, Alaska, and Canada and smaller populations around the rest of the Arctic. It is a migrant, wintering in the south Atlantic and Pacific. The parasitic jaeger breeds on coasts of Alaska, as well as coastal and inland tundra regions of northern Canada. This species is also found in Greenland, Iceland, Scandinavia, and northern Russia. In the Pacific, parasitic jaegers winter at sea from southern California to southern Chile and Australia (BirdLife International 2012b). The pomarine jaeger is mostly a pelagic species occasionally observed inland. A large jaeger, the species is heavyset, having a thick-neck with broad-based wings and a wing span that can reach 1.2 m (U.S. Geological Survey 2008)

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8.0 MARINE INVERTEBRATES

8.1 INTRODUCTION

Marine invertebrates cover an extremely large and diverse group of animals from at least 27 phyla and include approximately 50,000 species (Brusca and Brusca 2003). Some of the better-known macrofaunal taxa include Porifera (sponges), Cnidaria (corals, sea fans, sea anemones, jellyfish, and hydra), Ctenophora (comb jellies), Mollusca (shellfish, squid, and octopus), Arthopoda (shrimp, lobsters, crabs, krill, amphipods, and barnacles), Echinodermata (sea stars, sea urchins, and sea cucumbers), Urochordata (sea squirts and salps), and Bryozoa (moss animals). Visual assessments of other phyla, including sea worms from seven phyla (Platyhelminthes, Nemertea, Annelida, Sipuncula, Echiura, Chaetognatha, and Phoronida), are generally difficult to conduct as they are either too small or are interstitial, living within the sand, mud, or cracks of hard substrate. The greatest densities of marine invertebrates are usually on the seafloor (Sanders 1968). The distribution of invertebrate species richness in the MRA Study Area for the Japan and Mariana Archipelagos (the MRA Study Area) is influenced by a latitudinal gradient, shelf area, extent of coral habitat, sea surface temperature, and net primary production (Macpherson 2002; Rosa et al. 2008). The marine biogeographic zonation described in Section 3.8 illustrates the ecological categories of invertebrate habitat in the MRA Study Area.

Many of these species are important to humans ecologically and economically, providing essential ecosystem services, as well as income from tourism and commercial and recreational fisheries (Spalding, Ravilious, and Green 2001). Invertebrates such as stony corals perform a particularly important ecological function as a key structure-forming group in the MRA Study Area. Coral reefs provide coastal protection from the tidal surges and habitat for numerous species. See Section 11.0 (Marine Habitats) for a discussion of coral reef habitat. In addition, coral reefs contribute significantly to global productivity and biodiversity, with more phyla represented on coral reefs than in any other habitat on earth (Maragos, Crosby, and McManus 1996; Sheppard, Davy, and Pilling 2009).

Other economically important invertebrate groups include crustaceans (shrimp and lobsters), molluscs (scallops and clams) and cephalopods (squid). These species make up a key part of the commercial fisheries industry in the United States. Their health and abundance are vital to marine ecosystems and the sustainability of the world's fisheries (Pauly et al. 2002). Some of these species are protected by Essential Fish Habitat (EFH) administered by the National Marine Fisheries Service (NMFS) and regional Fishery Management Councils (FMCs).

Factors that can affect, stress, or damage invertebrates include coastal development, impacts from inland pollution and erosion, overexploitation and destructive fishing practices, global climate change, disease, predation, aquarium trade, anchors, invasive species (Bryant et al. 1998; Galloway, Bruckner, and Woodley 2009; National Marine Fisheries Service 2010; Wilkinson 2002), ship groundings (National Oceanic and Atmospheric Administration 2010b), and bioprospecting (Hunt and Vincent 2006). Global climate change, caused by increased concentrations of atmospheric carbon dioxide, results in ocean acidification that inhibits invertebrates from forming hard shells (Cohen et al. 2009). Bioprospecting involves collection of organisms with the goal of discovering novel compounds for new drugs.

Marine invertebrates in the MRA Study Area are described in profiles by taxonomic group, with specific consideration to coral species that have been petitioned for listing under the Endangered Species Act (ESA). Marine invertebrate species, regulated under the Magnuson-Stevens Fishery Conservation and

Management Act (MSFCMA) of 1976, are described in Chapter 12, Managed Species and Essential Fish Habitat.

8.2 SPECIES LIST AND STATUS

There are no ESA-listed endangered or threatened marine invertebrates in the MRA Study Area. NMFS reviewed the status of 82 candidate coral species for potential listing under the ESA based on a 2009 petition (Brown and Wolf 2009). In November 2012, NMFS proposed to list 66 of those petitioned species of corals as threatened or endangered under the ESA, with 59 of these species occurring in the Pacific (National Marine Fisheries Service 2012). Of these, 52 are proposed to be listed as threatened and 7 listed as endangered, with Eastern Pacific population of *Pocillopora elegans* proposed to be listed as endangered and the Indo-Pacific population proposed to be listed as threatened. On this subset of 59 species, 49 are known to or expected to occur in the Study Area. These are listed in Table 8-1. These proposed coral species are found in eight families of corals. An overview of the proposed corals and profile of each proposed coral family is provided in Sections 8-4 through 8-12. Profiles for each coral family include a description of the biology, ecology and behavior of the family and family-specific threats, when the information is available.

Table 8-1: Coral Species Proposed for ESA Listing in the MRA Study Area

Species Name and ESA Regulatory Status			Ecoregional Presence[1]		
			Coastal Waters		
Common Name	Scientific Name	Critical Risk Threshold Rating[2]	JA	MA	CI
Family: Acroporidae					
Bottlebrush staghorn	*Acropora aculeus*	49%	X	X	X
Blue-tipped staghorn	*Acropora acuminata*	49%	X	X	X
	Acropora aspera	48%	X	X	X
	Acropora dendrum	69%	X		X
	Acropora donei	64%	X		
	Acropora globiceps	57%		X	X
	Acropora horrida	52%	X		X
	Acropora listeri	58%	X	X	
	Acropora microclados	58%	X	X	
	Acropora palmerae	52%	X	X	
Table coral	*Acropora paniculata*	53%	X	X	
	Acropora polystoma	53%	X	X	
	Acropora speciosa	55%	X	X	X
	Acropora striata	58%	X		
Fuzzy table coral	*Acropora tenella*	57%	X		X
	Acropora vaughani	52%	X	X	X
	Acropora verweyi	54%	X	X	X
False flower coral	*Anacropora puertogalerae*	57%	X	X*	X
False flower coral	*Anacropora spinosa*	59%	X	X*	X
Starflower coral	*Astreopora cucullata*	52%	X		X

Table 8-1: Coral Species Proposed for ESA Listing in the MRA Study Area

Species Name and ESA Regulatory Status			Ecoregional Presence[1]		
Common Name	Scientific Name	Critical Risk Threshold Rating[2]	Coastal Waters		
			JA	MA	CI
	Isopora cuneata	62%	X	X*	X
Pore coral	*Montipora angulata*	57%	X		X
Pore coral	*Montipora australiensis*	57%	X		
Pore coral	*Montipora caliculata*	57%	X	X	X
Pore coral	*Montipora lobulata*	58%		X	
Family: Agariciidae					
Serpent coral	*Pachyseris rugosa*	57%	X	X*	X
Leaf coral	*Pavona diffluens*	53%		X*	
Family: Euphyllidae (also known as Caryophyllidae (Brainard et al. 2011))					
	Euphyllia cristata	62%	X	X	X
	Euphyllia paraancora	63%	X	X	X
Tipped bubblegum coral	*Physogyra lichtensteini*	51%	X	X*	X
Family: Faviidae					
	Barabattoia laddi	52%		X	X
	Caulastrea echinulata	56%	X		X
Family: Milleporidae					
	Millepora foveolata	63%		X	X
	Millepora tuberosa	63%		X	X
Family: Mussidae					
	Acanthastrea brevis	50%		X	X
Starry cup coral	*Acanthastrea hemprichii*	50%	X		
Starry cup coral	*Acanthastrea ishigakiensis*	50%	X	X	X
Starry cup coral	*Acanthastrea regularis*	50%		X	X
Family: Poritidae					
Net coral	*Alveopora allingi*	57%	X	X	X
Net coral	*Alveopora fenestrata*	57%		X	X
Net coral	*Alveopora verrilliana*	56%	X	X	X
Hump coral	*Porites horizontalata*	51%	X	X	X
Hump coral	*Porites napopora*	50%	X	X	X
Hump coral	*Porites nigrescens*	50%	X	X	X
Family: Pectiniidae					
Antler coral	*Pectinia alcicornis*	48%	X	X	X
Family: Pocillopora					
Cauliflower coral	*Pocillopora danae*	54%		X	
Cauliflower coral	*Pocillopora elegans*	50% (for central and Indo-Pacific only)		X	X

Table 8-1: Coral Species Proposed for ESA Listing in the MRA Study Area

Species Name and ESA Regulatory Status			Ecoregional Presence[1]		
Common Name	Scientific Name	Critical Risk Threshold Rating[2]	Coastal Waters		
			JA	MA	CI
Bird's nest coral	*Seriatopora aculeata*	55%		X	X

Sources: Brown and Wolf (2009) and Brainard et al. (2011).
[1]Ecoregional presence in coastal waters in the Japan Archipelago (JA), Mariana Archipelago (MA), and the Caroline Islands (CI)
[2]The Critical Risk Threshold (CRT) is the point at which a species is of such low abundance, spatially fragmented, or at such reduced genetic and/or genotypic diversity that extinction is extremely likely. Members of the National Marine Fisheries Service biological review team estimated the likelihood for each of the 82 candidate coral species to fall below the CRT by 2100 (a date to which climate data have been reliably estimated) by assigning points to eight "risk likelihood" categories: exceptionally unlikely (<1%), very unlikely (1% to 10%), unlikely (10% to 33%), less likely than not (33% to 50%), more likely than not (50% to 66%), likely (66% to 90%), very likely 90% to 99%, and virtually certain (>99%). The number presented in the table is the mean likelihood score (Brainard et al. 2011).
*The distribution of these species within the Mariana Archipelago may be unsubstantiated (Brainard et al. 2011).
CRT = Critical Risk Threshold
ESA = Endangered Species Act

8.3 PROPOSED CORAL SPECIES

There are as many as 49 ESA-proposed coral species found in the MRA Study Area (Table 8-1). This section provides common characteristics and other attributes for all reef-building corals. Sections 8.4 through 8.12 provide profiles of ESA-proposed coral species by family. Within these sections, species-specific information, where available and pertinent, is provided only for currently proposed coral species (Table 8-1), as any threats or potential impacts on those species, if designated, will be subject to consultation with regulatory agencies.

8.3.1 Description

The proposed coral species are all members of the order Scleractinia, commonly known as hard or stony corals. They are members of the phylum Cnidaria[1], which consists of over 10,000 marine species worldwide (Appeltans et al. 2010). The individual coral animal is a polyp, which, after repeated asexual division, forms the coral colony. The individual coral polyp has a symmetrical body form around a central axis, with a central mouth surrounded by tentacles with stinging cells used to capture prey (Colin and Arneson 1995a).

The reef-building corals familiar to most people occur in shallow coastal waters of the tropics, and can extended throughout the photic zone (defined by the depth of light penetration), typically shallower than 650 feet (ft.) (200 meters [m]). Most reef-building corals host symbiotic algae called zooxanthellae that provide energy (e.g., carbon) to the corals as byproducts from photosynthesis (Castro and Huber 2000), thus the requirement to occur within the photic zone. Azooxanthellate deep-water corals, those that do not host symbiotic algae, also form reefs in the upper bathyal zone, although these reefs are much less extensive. Reef-forming corals have calcium carbonate skeletons and grow together to form massive structures. Non-reef building corals generally lack zooxanthellae. Most hard corals and some

[1] Non-coral cnidarians are described as a taxonomic group (see Section 8.20).

soft corals are habitat-forming (Freiwald et al. 2004; Spalding, Ravilious, and Green 2001). Corals, functioning as a marine habitat, are described in Chapter 11, Marine Habitats.

8.3.2 Status and Management

Over the past twenty years a broad scientific consensus has emerged that the world's coral reefs are rapidly degrading (Brainard et al. 2011; Bruno and Selig 2007; Hoegh-Guldberg et al. 2007; Wilkinson 2002). While this chapter focuses on proposed ESA coral species in the MRA Study Area, site-specific condition of corals within the MRA Study Area is presented in Section 11.3.7, Marine Habitats.

In February 2010, NMFS issued a "Notice of 90-Day Finding on a Petition to List 82 Species as Threatened or Endangered Under the ESA" (Brainard et al. 2011). Of the candidate species included on the petition, 12 families and 64 species occur within the MRA Study Area. As of 2013, 66 of these candidate species have been categorized as proposed, 12 of which are proposed endangered and 54 are proposed threatened.

Federal coral reef management efforts include the U. S. Coral Reef Task Force's aims to protect and preserve coral reefs (Executive Order 13089 1998). The Navy is the Department of Defense (DoD) representative to the U.S. Coral Reef Task Force. The Navy also carries out the "Coral Reef Protection Implementation Plan," which provides information regarding protection and conservation of coral reefs to DoD forces and agencies (Department of Defense 2000). The ESA regulatory status and presence of these species in the MRA Study Area are listed in Table 8-1. Proposed species are those petitioned species that are actively being considered for listing as endangered or threatened under the ESA, as well as those species for which NMFS has initiated an ESA status review that it announced in the *Federal Register* (National Marine Fisheries Service 2010).

8.3.3 Population and Abundance

The Mariana nearshore environment is characterized by extensive coral bottom and coral reef areas. There are fewer reef-building hard coral species and genera in the northern compared to the southern Mariana Islands: 159 species and 43 genera of hard coral species in the northern islands versus 256 species and 56 genera in the southern islands (Abraham et al. 2004; Randall 2003). The diversity of Mariana reef-building corals is somewhat lower than other western Pacific regions (Philippine Islands [around 411 species], Ryukyu and Japan Islands [around 381 species] (Randall 1995), but it is more diverse than other U.S. Pacific islands (Richmond et al. 2008; Riegl and Dodge 2008) .

Coral coverage throughout the Mariana Archipelago estimated from satellite imagery is about 27.8 percent of the coral reef area (National Oceanic and Atmospheric Administration 2005). Additionally, results from rapid ecological assessment benthic surveys, conducted in the fore reef habitats of the Mariana Archipelago, recorded 50 genera of Anthozoa (Brainard et al. 2012). Based on a review of the limited data, the conclusion is that between 254 and 377 species of corals could occur in the Mariana Islands (Randall 1995, 2003; Richmond et al. 2008; Riegl et al. 2008).

8.3.4 Biology, Ecology, and Behavior

The ecological and evolutionary rationale for the various sexual and asexual reproductive strategies exhibited in corals are not well understood (Fautin 2002). Most of the shallow-water species reproduce by spawning. Some species brood live young, and some coral species engage in both spawning and brooding (Fautin 2002). Furthermore, most corals are capable of asexual reproduction by fragmentation.

Successful reproduction through fragmentation is most often seen in branching corals that are more likely to break, possibly due to the greater survival rate of axial corallites (branches) over inner portions of a colony (Boulon et al. 2005; Lirman 2000). Reproductive potential (fecundity) is a function of colony age and size, while stressors to corals reduce reproductive potential relative to the level of stress experienced, up to halting reproduction for several years (Boulon et al. 2005; Fautin 2002; Lirman 2000).

Across coral species, larval duration ranges from a few days to months (reviewed by Jones et al. (2009), but short durations of 3 to 9 days are much more common (Hughes et al. 2000; Vermeij et al. 2010). Accordingly, dispersal can range from a few tens of meters to 2000 kilometers (km), but local dispersal on a scale of tens of km occurs much more frequently than long-distance dispersal (Jones et al. 2009; Mumby and Steneck 2008). Long-distance dispersal is more commonly associated with spawning corals, and these buoyant eggs and planktonic larvae (typically free-swimming planulae) are more likely to be found in open ocean areas. Within the Yaeyama Islands of the MRA Study Area, peak spawning of *Acropora* corals occurs around the full moon in May, with settlement 5–7 days after spawning (Nakamura and Sakai 2010).

Coral planulae density in the water directly over the reef is zero except during reproduction, when density peaks at 1,600 per 100 cubic meter (m^3) (brooding species) to 16,000 per 100 m^3 (spawning species) during reproduction (Hodgson 1985). On the Great Barrier Reef, similar densities of coral larvae directly over the reef rapidly dispersed by 3 to 5 orders of magnitude in waters 5 km distant from the reef (Oliver et al. 1992). However, eggs, larvae, and planulae are not homogenously distributed but sometimes travel in semi-coherent aggregations (slicks) or become concentrated along oceanic fronts (Hughes et al. 2000; Jones et al. 2009).

Coral larvae can differentiate among habitats to find sites suitable for settlement (Erwin, Song, and Szmant 2008; Raimondi and Morse 2000), and recent research suggests that coral larvae respond to sounds that may serve as a cue to orient them to suitable settlement sites (Vermeij et al. 2010). Coral growth rates are generally constant as the colony ages, varying widely among species from approximately 0.25 to 5 inches (5 to 130 millimeters) per year (Buddemeier, Maragos, and Knutson 1974; Edinger et al. 2000; Hoeke et al. 2011). In general, branching corals grow faster than massive or encrusting corals. Reproductive maturity is reached between 3 and 8 years, the average generation time is 10 years, and longevity ranges from several decades to millennia (Brainard et al. 2011).

Predators of corals include sea stars, snails, and fishes (Boulon et al. 2005; Gochfeld 2004; Gulko 1998). The crown of thorns sea star is the primary predator of most proposed ESA coral species (Gulko 1998).During the larval stage, coral planulae may experience 90 percent (%) or higher mortality from zooplankton and filter-feeders (Boulon et al. 2005). Coral defenses against predation include the presence of symbiotic crabs and biological responses, including withdrawing tentacles and increasing the number of nematocysts on previously damaged polyps (Gochfeld 2004; Gulko 1998).

Corals prey on zooplankton, which are small, often microscopic, organisms found in the water column. Corals capture prey in tentacles armed with stinging cells that surround the corals' mouths or by employing a mucus-net to catch suspended prey (Brusca and Brusca 2003). In addition to capturing prey, corals possess a unique method of acquiring essential nutrients through their symbiotic relationship with zooxanthellae (Dubinsky and Berman-Frank 2001). The coral host provides nitrogen in the form of waste to the zooxanthellae, and the zooxanthellae provide organic compounds produced by photosynthesis to its host (Brusca and Brusca 2003; Schuhmacher and Zibrowius 1985). Some corals derive most of their energy from their zooxanthellae symbionts, resulting in dramatically reduced need

for the coral to feed on zooplankton (van Oppen and Lough 2009). Zooxanthellae are also responsible for the characteristic color of a given species.

8.3.5 Habitat and Distribution

Corals are typically found in oligotrophic, shallow waters that allow sufficient sunlight penetration to support the zooxanthellae unicellular algae that they host. They primarily inhabit areas facing the seaward margins of islands where waves and currents provide optimal mixing and flushing of seawater, support propagation of gametes and coral fragments, and transport essential minerals and nutrients to the corals (Ginsburg and Shinn 1964).

Corals are found throughout the MRA Study Area, concentrated at shallow reef and seamount habitats. Apart from a few exceptions, coral reefs in the Pacific Ocean are confined to the warm tropical and subtropical waters between 30° N and 30° S. Over 400 scleractinian and hydrozoan coral species representing 21 families and 108 genera have been identified from the shallow-water coral reefs of U.S. Territory of Guam (Guam) and the Mariana Islands.

Coral growth and distribution in the Mariana archipelago are positively influenced by relatively high salinity levels, low-to-moderate wave action, and minimal volcanic activity in the past 90 years (Houk and Starmer 2010). Positive geomorphological settings include islands that are large enough to provide a variety of habitats, yet small enough that reef-inhibiting effects of rivers and runoff are generally trivial (Brainard et al. 2012; Riegl et al. 2008), except as noted in the U.S. Department of the Navy (2010) report where radical land cover changes have occurred on Guam.

The islands of the Commonwealth of the Northern Mariana Islands (CNMI) are principally surrounded by fringing spur-and-groove reefs; barrier, lagoon, patch, and bank reefs are infrequent (Riegl et al. 2008). Four distinct geomorphological reef types encompass most reefs of the CNMI (Houk and Starmer 2010; Houk and van Woesik 2010; Minton et al. 2009), as follows:

- Holocene spur-and-groove—high coral densities, species richness, and large colony size
- Holocene high-relief slope—low coral species richness and high intra-site variation
- Holocene low-relief—low species richness, few large corals, many small corals
- Pleistocene basement—few corals and little three-dimensional relief

Constructional spur-and-groove reefs support larger coral colony size and higher coral species in comparison to other habitat types in the CNMI (Houk and Starmer 2010; Minton et al. 2009). The most developed and oldest coral reefs of CNMI are on the southern archipelago islands (Starmer et al. 2008). The younger active volcanic islands are in the northern part of the CNMI. Studies indicate an increase in generic richness in the Mariana Islands from north to south (Brainard et al. 2012; Randall 1995). *Acropora, Montipora, Pocillopora, and Favia* corals are the characteristic groups of reefs exposed to moderate wave energy (Houk and van Woesik 2010). Harsh environments are not conducive to colonization and growth, although whether this is because of fewer corals settling or few corals surviving post-settlement is unclear. Small, low relief, and encrusting colonies dominate harsh environments (Houk and van Woesik 2010).

The dominant coral species in Apra Harbor, Guam, is *Porites rus*, which is not a proposed species (Dollar and Hochberg 2010, 2011). This is the primary species on patch reefs and harbor slopes to the seafloor (Helber Hastert & Fee 2007). Despite patches of higher diversity, Apra Harbor coral diversity is relatively low, and generally increases outside the harbor and away from major streams (e.g., Sasa Bay, Piti Bay,

and Agat Bay) (Helber Hastert & Fee 2007). One study (Smith 2007) indicated *Pavona cactus* is the dominant species at a site named DryOck within Apra Harbor.

Of the proposed species in the MRA Study Area, *Acropora verweyi* occurs at high densities (0.90 colonies per square meter [m^2]) at one site (Chul-A9) on Tinian. None of the dominant corals at Orote Point on Guam is a proposed species (Smith and Marx 2006).

8.3.6 Threats

Because corals are key habitat-forming invertebrates, threats to them and to coral reefs are well studied. Factors that can stress or damage coral reefs are coastal development (Field et al. 2008; Risk 2009), impacts from inland pollution and erosion (Cortes and Risk 1985), coastal runoff (Downs et al. 2009), overexploitation and destructive fishing practices (Jackson et al. 2001; Pandolfi et al. 2003), global climate change and ocean acidification (Hughes et al. 2003), disease (Lesser et al. 2007; Porter et al. 2001), predation (Hayes 1990), harvest for the aquarium trade (Caribbean Fishery Management Council 1994), anchor damage (Burke and Maidens 2004), invasive species (Bryant et al. 1998; Galloway, Bruckner, and Woodley 2009; National Marine Fisheries Service 2010; Wilkinson 2002), ship groundings (National Oceanic and Atmospheric Administration 2010a), oil spills (National Oceanic and Atmospheric Administration 2001), bioprospecting (Hunt and Vincent 2006), and possibly human-made noise which may mask the natural reef sounds that serve as cues the planulae use to orient them toward suitable settlement sites (Vermeij et al. 2010). Coral growth rates are reduced because of a decrease in the pH of the ocean linked to global climate change (Cohen et al. 2009).

All of the threats cited above reduce tolerance to global climate change (Ateweberhan and McClanahan 2010; Carilli et al. 2010; Sheppard, Davy, and Pilling 2009) and coral bleaching. The causes of coral bleaching are reasonably well understood, and are often tied to atypically high sea temperatures (Brown 1997; Glynn 1993; van Oppen and Lough 2009), causing the coral to expel the symbiotic algae. This relationship with zooxanthellae is essential for reef-building corals because zooxanthellae supply essential nutrients to corals and give them their distinctive colors. When the algae dies or is expelled, the colors disappear and corals appear white or bleached. If the coral remains without the nutrients provided by the zooxanthellae for too long, the bleached coral can die.

Once a species is made vulnerable by human-caused events, impacts from natural events corals have adapted to recover from can magnify, ultimately causing mortality (Knowlton 2001). These factors have led to a conclusion that the coral reefs in the MRA Study Area are among the most degraded in the world (Bryant et al. 1998; Pandolfi et al. 2005).

Coastal Development, Land-based Pollution, Erosion, and Runoff*.* Land-based pollutants include nutrients, sediment, toxins, and salinity stressors (Brainard et al. 2011). These stressors can act synergistically and are influenced by biological and hydrological factors (Brainard et al. 2011). Land-based sources of pollution may pose significant threats at local scales and reduce the resilience of corals to bleaching (Carilli et al. 2009; Wooldridge 2009). This is particularly important for species with limited range (Brainard et al. 2011). The impacts of watershed pollution on vulnerable corals species are most apparent in less harsh environments, including enclosed bays and sheltered shorelines (Houk and van Woesik 2010).

Some toxins such as Irgarol-1051, an antifouling biocide, have been detected along Okinawan shorelines and pose threats to reef life. Ecotoxicological experiments showed a significant reduction in the photosynthetic rate of a common octocorol, *Galexa fascicularis,* when the corals were exposed to 1,000

and 10,000 nanograms per liter of Irgarol. Average in-water concentrations were well below these values, and Irgarol does not appear to pose a serious threat to carbon metabolisms of scleractinian corals at this time (Sheikh et al. 2009).

Natural processes can also have harmful effects on marine ecosystems. Biological surveys after the 2003 eruption of the volcano on Anahatan Island in CNMI show that ash from volcanic eruptions can cover the benthos and thus coral reef communities. Post-eruption, corals showed signs of stress in the form of bleaching (Vroom and Zgliczynski 2011). In general, coral species may show differing levels of stress from pyroclastic events based on differences in polyp ability to cope with sedimentation.

Global Climate Change and Acidification*.* Most coral studies have shown negative relationships between ocean acidification and growth. Ocean acidification likely will contribute to future reef destruction (Brainard et al. 2011; Hoegh-Guldberg et al. 2007; Silverman et al. 2009). Physiological stress and decrease in nutrition associated with bleaching are likely to result in lowered fecundity and increased susceptibility to disease (Bruno et al. 2007; Muller et al. 2008; Whelan et al. 2007).

Disease*.* While there are no confirmed species-specific diseases, coral disease scientists have noted that some diseases appear to be species-specific, at least within a given location. Some "white" diseases, including white band, white pox, and white plague, seem to preferentially impact colonies of *Acropora* (Galloway, Bruckner, and Woodley 2009). Diseases can devastate individual coral species within a region (Aronson and Precht 2001; Bruckner and Hill 2009). Data indicate increasingly broad impacts of disease—geographically and within taxa (Brainard et al. 2011).

Predation*.* Some groups of corals are more or less susceptible to predation and general threats. For example, the predatory snail (*Drupella cornus*) feeds preferentially, but not exclusively, on *Acropora* species (Grober-Dunsmore, Bonito, and Frazer 2006). The crown-of-thorns sea star feeds preferentially, but not exclusively, on *Montipora* and *Acropora* coral species (Colgan 1987).

Aquarium Trade*.* The aquarium industry harvested approximately 5% of the global wild coral population in the late 1980s, with harvest levels increasing every year until 1997 (Sakashita and Wolf 2009). Indonesia has historically supplied approximately 71% of this live coral trade. The live coral trade has various taxa-specific preferences, including many Acropora and Porites species, *Caulastrea echinulata*, *Heliopora coerulea*. (Sakashita and Wolf 2009), and as the greatest consumer of aquarium animals, the U.S. holds considerable sway over the conduct of the aquarium trade (Tissot et al. 2010).

Oil*.* Exposure to oil runoff from land, natural seepage, or spills from offshore drilling or tankers are threats to coral reefs (National Oceanic and Atmospheric Administration 2001). Factors such as the oil type, quantity, exposure time, and season can affect organism toxicity levels. Branching corals such as the ESA-listed elkhorn and staghorn corals are less resistant to oil than other types of coral (National Oceanic and Atmospheric Administration 2001). Reproductive and early life stages are especially sensitive to oil exposure (Shafir, Van Rijn, and Rinkevich 2007), which can result in coral death, delayed reproduction, altered development and growth, and altered behavior (National Oceanic and Atmospheric Administration 2001). Overall, the impact of oil spills on coral reefs is poorly documented.

Threat Assessment Associated with the 82 Candidate Coral Species*.* As part of the assessment to address the petition on the 82 candidate coral species, NMFS identified the following threats on corals: disease outbreaks since 1980; habitat degradation and modification due to sedimentation; increased predation; hurricanes; pollution; alien species; invasive green algae; limited distribution; damage from

mechanical fishing gear, anchors, fish pots, divers, and swimmers; and coral bleaching (Brainard et al. 2011).

8.4 ACROPORIDAE PROPOSED CORALS

Within the MRA Study Area, 24 species of Acroporidae corals have been proposed to be listed as threatened under the ESA (National Marine Fisheries Service 2012). These proposed species represent four genera; *Acropora* (17 species), *Anacropora* (2 species), *Astreopora* (1 species), and *Montipora* (4 species) (see Table 8-2; Brainard et al. (2011).

8.4.1 Description

All species of Acroporid corals are colonial and zooxanthellate (Veron 2000). Except in the genus *Astreopora*, corallites of species within this family are small, with two or fewer cycles of septa and seldom developed columellae. In the Pacific, the genus *Acropora* are considered a particularly important group ecologically, exhibiting both a longitudinally and latitudinally wide range, and have been the subject of extensive ecological and taxonomic research (Brainard et al. 2011). Bare et al. (2010) reports living Acroporid corals occur at depths to 60 m and deeper in clear water. Colony structure of some species, such as *A. aspera*, can vary greatly throughout habitat types (Brainard et al. 2011).

8.4.2 Biology, Ecology, and Behavior

Data indicate that *Acroporid corals* have adapted for rapid growth as a mechanism to compete for space. This strategy limits their biochemical defenses (Palmer, Bythell, and Willis 2010) and weakens their ability to withstand environmental stressors because of their thinner and less nutrient-rich tissue (Brainard et al. 2011; Loya et al. 2001; Rotjan 2007). To date, all species of *Acroporid corals* that have been studied are simultaneous hermaphrodites (Baird, Guest, and Willis 2009). Some *Acroporid corals* have branching morphologies, and can reproduce via fragmentation, although this only increases survival in the short term (Brainard et al. 2011). *A. paniculata* extends its tentacles only at night, feeding on drifting particles in its shallow reef habitat (Veron 2000).

The species *Isopora cuneata* reproduces via external fertilization and larval development (Wallace et al. 2007), where its zooxanthellate larvae can survive from 4 to 209 days in the planktonic stage (Graham, Baird, and Connolly 2008). Because the colonies are sessile, close proximity to each other is necessary for successful fertilization (Coma and Lasker 1997). Gametes are released in bundles of egg and sperm by each polyp. Fertilization occurs at the sea surface after the bundles open. Self-fertilization is infrequent (Brainard et al. 2011). Gametes are viable with high fertilization rates for 8 hours after spawning (Brainard et al. 2011).

Spatial-temporal recruitment patterns of corals around Irimote Island, Japan suggest that at a local scale, larval dispersal and subsequent recruitment patterns are influenced by embryonic development time and wind-driven surface currents. Acroporid corals and poritid corals are likely more resilient to local disturbances than pocilliporid corals, as pocilliporid larvae depend on local stocks (i.e., their larvae do not disperse as far) (Nakamura and Sakai 2010).

8.4.3 Family-specific Threats

Acroporid corals tend to be highly vulnerable to predations, disease, sedimentation, and high temperatures (Brainard et al. 2011), and are known to be among the first coral to display high mortality during times of stress (Riegl 2002). Acroporid corals are also a focus of the aquarium trade.

Predation. Most corallivorous invertebrates prey upon Acroporid corals, although this preference is not exclusive (Motta 1989). Wrasses prey upon *Anacropora spinosa* in proportion to availability (Cole, Pratchett, and Jones 2010), although population-level effects of this predation are unknown.

Disease. From 1950 to 2012, 1302 disease counts covered 17,480 m^2 of transects across the tropics in Acroporid corals. These diseases include trematodiasis (the most prevalent), growth anomalies, Caribbean yellow band disease, dark spot disease, white plaque, black band disease, and other unspecified diseases (UNEP World Conservation Monitoring Centre 2010). Disease counts of Montipora corals numbered 75 from 5,250 m^2 of global transects during 1950-2012; these diseases, categorized by coral disease scientists, include growth anomalies, other, and white syndrome in order of prevalence (UNEP World Conservation Monitoring Centre 2010). No disease counts have been recorded in the Global Coral Disease Database for *Astreopora*, *Anacropora*, and *Isopora* corals.

Sedimentation and Water Quality. *Monitpora* has been reported as a "sediment-intolerant" genus, with some congeners characterized as sediment tolerant (Hodgson 1990; McClanahan and Obura 1997; Stafford-Smith 1993). In Egypt, *A. spinosa* is not vulnerable to sedimentation or macroalgal interactions, in contrast to congener *A. forbesi* (Brainard et al. 2011). The growth rate of *Isopora cuneata* has been noted to decrease in competition with algae (Tanner 1995). *I. cuneata* can host specialized types of C zooxanthellae in turbid environments at high latitudes (Wicks et al. 2010), and can adapt to low light environments by altering photosynthetic operations, by increasing zooxanthellae density (Thinh 1991).

Global Climate Change. According to published rankings, branching *Montipora* species have a relatively high response to bleaching in both Australia and east Africa (Marshall and Baird 2000; McClanahan et al. 2007). Of the 18 *Montipora* species listed on the Great Barrier Reef, *Monitpora caliculata* was ranked as the seventh most susceptible to bleaching (Brainard et al. 2011). *M. caliculata* showed only moderate bleaching in French Polynesia during the 2002 bleaching event (Hughes et al. 2003). In *Acropora verweyi,* reduced carbonate concentration can decrease calcification rates (Marubini, Ferrier-Pages, and Cuif 2003).

Aquarium Trade. Collection and trade pose risks to Acroporid corals. According to the International Union for Conservation of Nature (IUCN) Species Accounts, the *Acropora* genus is among the top three coral genera collected and exported for the aquarium trade (Convention on International Trade in Endangered Species 2010). According to the Convention on the Conservation of Migratory Species of Wild Fauna and Flora (CITES) database, 270,000 pieces of Acroporid corals were exported from Indonesia in 2010, while the export quota was only 2,600 pieces (Convention on International Trade in Endangered Species 2010).

Table 8-2 lists habitats and ranges of Acroporidae corals.

Table 8-2: Acroporidae Corals Habitat and Range

Species	Global Range (including relative range of *Acropora spp.*)[1]	Habitat	Depth	Abundance	ESA Status
Acropora aculeus	(15th) From East Africa to the Pitcairn Islands; Japan to Great Barrier Reef, including CNMI and Guam	Shallow lagoon, protected from wave action	Low tide to 20m	Common and locally abundant, esp. in Indo-Pacific	Proposed Threatened
Acropora acuminata	(5th) Red Sea to Pitcairn Islands; Taiwan to Great Barrier Reef. Common in center of range, can be uncommon elsewhere	Not available	15 to 20 m	Occasionally in extensive clumps with dimensions of several meters	Proposed Threatened
Acropora aspera	(46th) Red Sea and Oman to Samoa; Japan to Great Barrier Reef, including CNMI and Guam	Broad with varying colony structure	Low tide to at least 10 m	Can live in extensive clumps with dimensions of several meters	Proposed Threatened
Acropora dendrum	Sri Lanka and Northern Bay of Bengal to central Indo-Pacific, Japan to east and west coasts of Australia	Upper reef slopes	5 to 20 m	Uncommon or rare	Proposed Threatened
Acropora donei	(44th) Sri Lanka and Northern Bay of Bengal to central Indo-Pacific, Japan to east and west coasts of Australia	Shallow fringing reefs and upper slopes where *Acropora* diversity is high	5 to 20 m	Uncommon but distinctive	Proposed Threatened
Acropora globiceps	(88th) Bay of Bengal to Pitcairn Islands, Ogasawara Islands to the equator, including Marianas Archipelago and Micronesia	Intertidal, upper reef slopes and reef flats	0 m to 8 m	Common	Proposed Threatened
Acropora horrida	(14th) Indian Ocean to Pitcairn Islands, Japan to Australia, including Palau	Fringing reefs with turbid water, subtidal, sheltered habitats, including deep water flats, lagoons, and sandy slopes	5 to 20 m	Usually uncommon	Proposed Threatened

Table 8-2: Acroporidae Corals Habitat and Range

Species	Global Range (including relative range of *Acropora spp.*)[1]	Habitat	Depth	Abundance	ESA Status
Acropora listeri	(13th) Red Sea, western Indian Ocean to central Indo-Pacific, Japan to Australia, including Marianas and Caroline Islands	Subtidal shallow reef edges, upper reef slopes, and in strong wave action	Near surface to 15 m	Uncommon	Proposed Threatened
Acropora microclados	(20th) Red Sea, western Indian Ocean to central Indo-Pacific, Japan to Australia, including Marianas and Caroline Islands	Upper reef slopes	5 to 20 m	Uncommon	Proposed Threatened
Acropora palmerae	(52nd) Northern Indian Ocean, central Indo-Pacific, from Japan to west and east coasts of Australia, including Marianas	Reef flats, tops and edges exposed to strong wave action; shallow lagoons to subtidal	5 to 20 m	Uncommon	Proposed Threatened
Acropora paniculata	(40th) Red Sea, Indo-Pacific to Pitcairn Islands; Japan to Great Barrier Reef; Hawai'i	Upper reef slopes, just subtidal, reef edges, sheltered lagoons	10 to 35 m	Uncommon or rare, except in Papua New Guinea where it is common	Proposed Threatened
Acropora polystoma	(29th) Red Sea, southwest and central Indian Ocean, central Indo-Pacific to Cook Islands, Japan to west and east coasts of Australia	Upper reef slopes exposed to strong wave action; reef tops and edges in high current areas; intertidal to subtidal	3 to 10 m	Uncommon	Proposed Threatened
Acropora speciosa	(63rd) Western Indian Ocean to Pitcairn Islands; Micronesia to Northern Great Barrier Reef, including Palau	Protected environments with clear water and high diversity of *Acropora*	14 to 40 m, mesophotic assemblages	Uncommon	Proposed Threatened
Acropora striata	(54th) Indo-Pacific to Pitcairn Islands, Japan to Indonesia, including Marianas Archipelago	Shallow rocky foreshores and shallow reef flats	10 to 25 m	Rare, but may be locally-dominant in some areas of Japan	Proposed Threatened

Table 8-2: Acroporidae Corals Habitat and Range

Species	Global Range (including relative range of *Acropora spp.*)[1]	Habitat	Depth	Abundance	ESA Status
Acropora tenella	(72nd) Indo-Pacific to Japan, including Mariana Archipelago and Palau	Below 40 m t0 70 m on protected slopes and shelves, specialized to calm, deep conditions	25 to 70 m, known for mesophotic habitats	Locally common in some locations	Proposed Threatened
Acropora vaughani	(34th) Red Sea, Western Indian Ocean to Pitcairn Islands; Japan to Australia, including Marianas Archipelago and Palau	Fringing reefs with turbid waters, protected lagoon and sandy slopes	Low tide levels to 30 m	Uncommon	Proposed Threatened
Acropora verweyi	(16th) East Africa to southeastern Pacific; Japan to the Great Barrier Reef including the Marianas Archipelago	Shallow-water species, upper reef slopes and reef where circulation is good	Low tide to at least 10 m	Generally common, and can be locally abundant	Proposed Threatened
Anacropora puertogalerae	Indo-Pacific to Fiji; Japan to Great Barrier Reef, including Mariana Archipelago and Palau	Shallow reefs, found separated from reefs	5 to 20 m	Uncommon but can form large thickets in the Philippines	Proposed Threatened
Anacropora spinosa	Indo-Pacific, Japan to Fiji, including Mariana Archipelago	Shallow reef in clear or slightly turbid water and soft substrates of lower reef slopes; found separated from reefs	5 to 15 m	Uncommon but may occur in extensive tracts in certain areas	Proposed Endangered
Astreopora cucullata	Red Sea; Indo-Pacific to Samoan archipelago; Taiwan to Great Barrier Reef	Protected reef environments	5 to 15 m	rare	Proposed Threatened
Montipora angulata	Sri Lanka through Indo-Pacific to Pitcairn Islands; Japan to both coasts of Australia	Fringing reefs and reef flats	At least 1 m to 20 m	Mostly rare	Proposed Threatened
Montipora australiensis	East Africa and southern Indian Ocean to east-central Pacific; Japan to both coasts of Australia	Shallow reef environments with high wave action	2 to 30 m	Rare	Proposed Threatened

Table 8-2: Acroporidae Corals Habitat and Range

Species	Global Range (including relative range of *Acropora spp.*)[1]	Habitat	Depth	Abundance	ESA Status
Montipora caliculata	East Africa to Rapa Nui; Southern Japan Islands to both coasts of Australia, including Mariana Archipelago and Palau	Found in most reef environments	Up to 20 m	Uncommon	Proposed Threatened
Montipora lobulata	East Africa, Marianas Archipelago, Fiji to Rapa Nui	Shallow reef environments	Up to 20 m	Rare	Proposed Threatened

Sources: Brown and Wolf (2009); Brainard et al. (2011); Carpenter et al. (2008); and Veron (2000).
[1] Species of the genus Acropora underwent ecological and genetic comparison of naturally rare and very common species (Richards et al. 2008), including a ranking of 114 species by geographic range size (i.e., #1 has the broadest range while #114 has the most restricted range). The rankings are providing in the parentheses under the global range column.
CNMI = Commonwealth of the Northern Mariana Islands
m = meter

8.5 AGARICIDAE PROPOSED CORALS

Within the MRA Study Area, two species of Agariciidae corals, *Pavona diffluens* and *Pachyseris rugosa,* have been proposed to be listed as threatened under the ESA (National Marine Fisheries Service 2012).

8.5.1 Description

Species in the *Leptoseris* genus have generally small (fewer than 20 centimeters [cm]) colonies that are boulder-shaped or encrusting, or more commonly plate or leaf-like. They often have a distinctive central corallite distinguished by central columellae, usually separated by ridges and interconnected by fine septocostal walls (Veron 2000). Immersed corallites have poorly defined thickened walls, while loosely packed septa have smooth or finely serrated margins, are continuous between adjacent corallite centers, and seldom fuse (Veron 2000). All species in the Agariciidae family are colonial, and all extant species are zooxanthellate (Veron 2000). Tentacles generally extend only at night.

8.5.2 Habitats and Distribution

Agariciidae corals are common on protected reef slopes and in lagoons and form a small part of the large number of reef-building corals in the Pacific (Randall 2003). Of six extant genera, *Leptoseris* occurs in both the Western Atlantic and the Indo-Pacific, *Agaricia* is restricted to the Western Atlantic, and the other four genera (*Pavona*, *Gardineroseris*, *Pachyseris*, and *Coeloseris*) are restricted to the Indo-Pacific (Veron 2000). The Agaricidae is represented in the Mariana Archipelago portion of the MRA Study Area by the swelling coral *Leptoseris incrustans*, cactus coral *Pavona cactus*, and leaf corals *Pavona spp.* (Randall 2003).

8.5.3 Family-specific Threats

Disease. *Pachyseris rugosa* is known to be vulnerable to the ciliate disease *skeletal eroding band* (Antonius and Lipscomb 2000). A survey in Indonesia showed that the black-band disease progressed across *Pachyseris rugosa* at an average rate of 0.63 cm per day (Haapkyla et al. 2009).

Sedimentation and Water Quality. Within the family Agariciidae*, Pavona* species are regarded as moderately tolerant to sediment stress (Brainard et al. 2011). Dredging has resulted in a high partial mortality for *Pachyseris rugosa* (Brainard et al. 2011). The disappearance of *Pachyseris rugosa* in Jakarta Bay between 1920 and 2005 was attributed to decreased water quality from coastal development (van der Meij, Suharsono, and Hoeksema 2010). However, the branch structure of this species renders it efficient at dealing with sediment (Stafford-Smith 1993).

Global Climate Change. *Pavona* species are susceptible to bleaching (Marshall and Baird 2000) and acidification may slow calcification rates of *Pavona* species (Manzello 2010; Marubini, Ferrier-Pages, and Cuif 2003). *Pachyseris* species undergo high, variable bleaching (Bruno et al. 2001; Marshall and Baird 2000; McClanahan et al. 2007; Stimson, Sakai, and Sembali 2002). This high bleaching rate and relative rarity of the species may put *Pachyseris* at a relatively high risk of local extinction in the western Indian Ocean (McClanahan et al. 2007). In 1994 in Guam, *Pachyseris speciosa* showed heavy bleaching (Paulay and Benayahu 1999). Among the 17 genera evaluated, McClanahan et al. (2007) reported that the genus *Leptoseris* has no bleaching response. *Leptoseris yabei* (LaJeunesse et al. 2004) may also be relatively resistant to bleaching (LaJeunesse et al. 2004; Smith et al. 2004).

Aquarium Trade. According to the CITES database, more than 1000 pieces of *Pavona* species are traded each year, with Fiji the main exporter (Convention on International Trade in Endangered Species 2010). The genus *Pachyseris* is traded, with substantial export of *Pachyseris rugosa*—averaging 1195 specimens annually from 1991 to 2008 (Convention on International Trade in Endangered Species 2010).

Table 8-3 lists the habitats and ranges of Agariciidae corals.

Table 8-3: Agariciidae Corals Habitat and Range

Species	Global Range	Habitat	Depth	Abundance	ESA Status
Pachyseris rugosa	Red Sea, east Africa to central Pacific; Japan to Australia, including Marianas Archipelago, Micronesia, and Palau	Reefs exposed to strong wave action; may be associated with fine grain sediments	5 to 20 m	Common	Proposed Threatened
Pavona diffluens	Narrow distribution, only in Red Sea, Arabian Gulf; recorded in Mariana Archipelago and American Samoa by Carpenter et al (2008)	Found in most reef habitats	5 to 20 m	Uncommon	Proposed Threatened

Sources: Brown and Wolf (2009); Brainard et al. (2011); Carpenter et al. (2008); and Veron (2000).
m = meter

8.6 EUPHYLLIDAE PROPOSED CORALS

Within the MRA Study Area, three species of Euphyllidae corals, *Euphyllia cristata, E. paraancora*, and *Physogyra lichtensteini*, have been proposed to be listed as threatened under the ESA (National Marine Fisheries Service 2012). Euphyllidae contains five colonial, zooxanthellate, Indo-Pacific genera. *Euphyllia cristata* occurs on all reef sections at depths of 1 to 35 m (3.3 to 114.8 ft.) Stevely and Sweat (2008).

8.6.1 Family-specific Threats

Aquarium Trade. The CITES database reports that *Euphyllia cristata* is heavily involved in the aquarium trade from Indonesia, Fiji, Malaysia, and Tonga. Reportedly, annual exports from Indonesia averaged over 36,000 pieces from 2000 to 2008 (Convention on International Trade in Endangered Species 2010).

Table 8-4 lists the habitats and ranges of Euphyllidae corals.

Table 8-4: Euphyllidae Corals Habitat and Range

Species	Global Range	Habitat	Depth	Abundance	ESA Status
Euphyllia cristata	Indo-Pacific to central Pacific; Ryukyu Islands to both coasts of Australia including Mariana Archipelago	Shallow reef habitats	1 to 35 m	Common to uncommon but conspicuous	Proposed Threatened
Euphyllia paraancora	Restricted range and highly centered in the Coral Triangle Region; reported in Japan, Mariana Archipelago and Palau	Shallow and deep reef environments protected from wave action	3 to 30 m	Uncommon; found in monospecific carpets at 6 to 8 m	Proposed Threatened
Physogyra lichtensteini	Red Sea, Arabian Sea, Indian Ocean, Indo-Pacific to central Pacific; Japan to both coasts of Australia, including Marianas Archipelago and Palau	Turbid reef environments with tidal currents, protected habitats (crevices and overhangs) in turbid waters	1 to 20 m	Common in protected habitats	Proposed Threatened

Sources: Brown and Wolf (2009) and Brainard et al. (2011).
m = meter

8.7 FAVIIDAE PROPOSED CORALS

Within the MRA Study Area, two species of Faviidae corals, *Barabattoia laddi* and *Caulastrea echinulata*, have been proposed to be listed as threatened under the ESA (National Marine Fisheries Service 2012).

8.7.1 Family-specific Threats

Global Climate Change. In general, the genus *Cyphastrea* is resistant to bleaching, demonstrated during the 1998 mass bleaching on the Great Barrier Reef, where the genus was unaffected (Marshall and Baird 2000). Absence of bleaching notwithstanding, elevated temperatures have been shown to induce mortality in *Cyphastrea species* (McClanahan 2004).

Aquarium Trade. Within the family, trade of *Caulastrea echinulata* is high, with an annual average of 8,713 specimens from 1999 to 2009. The vast majority of these originated from Indonesia (Convention on International Trade in Endangered Species 2010). Take quotas increased from 9,000 corals in 1999 to 10,670 in 2010. Trade of the genus *Cyphastrea* is light-to-moderate (Convention on International Trade in Endangered Species 2010). From 1993 to 2008, an average of 70 specimens were exported worldwide, except for a single year's exports from Indonesia (2810 specimens exported in 1993).

Table 8-5 lists the habitats and ranges of Faviidae corals.

Table 8-5: Faviidae Corals Habitat and Range

Species	Global Range	Habitat	Depth	Abundance	ESA Status
Barabattoia laddi	Highly centered in the Coral Triangle; stretches to Pitcairn Islands and Rapa Nui; Ogasawara Islands to Great Barrier Reef, including Mariana Archipelago	Shallow lagoons	0 to 10 m	Rare	Proposed Threatened
Caulastrea echinulata	Primarily in Australia, Fiji, Indonesia, Japan; has been observed in Philippines, New Caledonia, and the Solomon Islands	Horizontal substrates protected from wave action and with turbid water	1to 20 m	Uncommon	Proposed Threatened

Sources: Brown and Wolf (2009) and Brainard et al. (2011).
m = meter

8.8 MILLEPORIDAE PROPOSED CORALS

Within the MRA Study Area, two species of Milleporidae coral, *Millepora foveolata* and *M. tuberosa,* have been proposed to be listed as threatened under the ESA (National Marine Fisheries Service 2012). *Millepora* appears to have become locally extinct in the tropical eastern Pacific (Glynn and Deweerdt 1991). *M. foveolata* is proposed to be listed as endangered and *M. tuberosa*is is proposed to be listed as threatened.

8.8.1 Family-specific Threats

Predation. *Millepora* species are preyed on by the crown-of-thorns seastar, although less preferred than other corals species (Colgan 1987). They are also preyed on by the polychaete *Hermodice carunculata,* the nudibranch (*Phyllidia*), and filefish of the genera *Alutera* and *Cantherhines* (Brainard et al. 2011).

Disease. *Millepora* species have been observed with skeleton-eroding-band disease in the Red Sea (Winkler, Antonius, and Renegar 2004), black-band disease on the Great Barrier Reef (Brainard et al. 2011), and white plague in Florida (Richardson et al. 1998).

Global Climate Change. The genus *Millepora* has a high susceptibility to bleaching (Loya et al. 2001), ranking most susceptible to bleaching initiated by high seawater temperature among 40 hermatypic coral genera evaluated from the Great Barrier Reef (Marshall and Baird 2000). High seawater temperatures can kill *Millepora* in the absence of visibly appreciable bleaching (McClanahan 2004). While *Millepora* species are among the first to bleach and die, those that do not die from thermal stress appear to be proficient at recovering by recruiting new colonies (Brainard et al. 2011). *Millepora* is

reportedly highly susceptible to bleaching in the western Indian Ocean (McClanahan et al. 2007), but has undergone low bleaching in French Polynesia (Gleason 1993).

Aquarium Trade. The genus *Millepora* is exported from Indonesia, Solomon Islands, and Fiji; exports levels were between 200 and 3,000 pieces annually from 2000 to 2008 (Convention on International Trade in Endangered Species 2010).

Table 8-6 lists the habitats and ranges for Milleporidae corals.

Table 8-6: Milleporidae Corals Habitat and Range

Species	Global Range	Habitat	Depth	Abundance	ESA Status
Millepora foveolata	Northern Mariana Islands (but not southern), Palau, Great Barrier Reef, Taiwan, Philippines	Forefront of reef slope and upper surface of buttress ridges	1 to 8 m	Occasional	Proposed Endangered
Millepora tuberosa	Western Pacific (Taiwan, Mariana Islands, Caroline Islands), occasionally in American Samoa; the species is often confused with crustose coralline algae and *Millepora exaese.*	Fore reef and lagoon areas	1 to 12 m	Occasional, but is predominant at Agat Boat Harbor	Proposed Threatened

Sources: Brown and Wolf (2009) and Brainard et al. (2011).
m = meter

8.9 MUSSIDAE PROPOSED CORALS

Within the MRA Study Area, four species of Mussidae corals, *Acanthastrea brevis*, *Acanthastrea hemprichii*, *Acanthastrea ishigakiensis*, and *Acanthastrea regularis,* (Brown and Wolf 2009) (Brown and Wolf 2009) (Brown and Wolf 2009) have been proposed to be listed as threatened under the ESA (National Marine Fisheries Service 2012).

8.9.1 Family-specific Threats

Global Climate Change. The genus *Acanthastrea* is reported as highly susceptibility to bleaching in the western Indian Ocean (Marshall and Baird 2000; McClanahan et al. 2007), as well as in Australia, although some species were unaffected during the 2002 Great Barrier Reef bleaching event (Brainard et al. 2011). *Acanthastrea* sustained moderate bleaching in Palau in 1994 (Paulay and Benayahu 1999).

Table 8-7 lists the habitats and ranges of Mussidae corals.

Table 8-7: Mussidae Corals Habitat and Range

Species	Global Range	Habitat	Depth	Abundance	ESA Status
Acanthastrea brevis	Red Sea, Gulf of Aden, Indian Ocean to central Indo-Pacific and western Pacific; Ogasawara Islands to Great Barrier Reef; reported in Guam	Shallow reef environments, all types of reef habitats	1 to 20 m	Uncommon but conspicuous	Proposed Threatened
Acanthastrea hemprichii	Red Sea, Gulf of Aden, Western Indian Ocean, Coral Triangle to Samoan Archipelago; Japan to Great Barrier Reef	Most reef environments	2 to 20 m	Uncommon	Proposed Threatened
Acanthastrea ishigakiensis	Red Sea, Gulf of Aden, East Africa, Coral Triangle to central Pacific Ocean; Japan to Indonesia, including Palau	Shallow protected reef environments	1 to 15 m	Uncommon but conspicuous	Proposed Threatened
Acanthastrea regularis	Central Indo-Pacific, eastern Australia, oceanic West Pacific, the Solomons, Fiji, Marianas and Caroline Islands	Shallow reef environments	1 to 20 m	Uncommon	Proposed Threatened

Sources: Brown and Wolf (2009) and Brainard et al. (2011).
m = meter

8.10 PECTINIIDAE PROPOSED CORALS

Within the MRA Study Area, one species of Pectiniidae coral, *Pectinia alcicornis,* has been proposed to be listed as threatened under the ESA (National Marine Fisheries Service 2012).

8.10.1 Family-specific Threats

Predation. Pectinid corals are highly susceptible to predation by the crown-of-thorns seastar (Brainard et al. 2011).

Sedimentation and Water Quality. *Pectina* is in general a sediment-tolerant genus (Dikou and van Woesik 2006), although on the Great Barrier Reef, *P. alcicornis* abundance and health decreased with deteriorating water quality (Fabricius et al. 2005). *P. alcicornis* raised in the Waikiki Aquarium on Oahu, Hawaiʻi is characterized by high-nutrient, low-pH tolerance (Atkinson, Carlson, and Crow 1995), which may imply that this species can tolerate acidic water and eutrophic conditions, although the impact of acidification on growth has not been quantified (Brainard et al. 2011).

Global Climate Change. The genus *Pectinia* was among the most highly susceptible to bleaching on the Great Barrier Reef in 1998 (Marshall and Baird 2000), but the species *Pectinia alcicornis* showed low mortality on the Great Barrier Reef in the 2001 to 2002 mass bleaching event (Brainard et al. 2011).

Aquarium Trade. The genus *Pectina* is heavily exported, primarily from the Philippines, Indonesia, and the Solomon Islands. *P. alcicornis* exports were reported at 113 specimens during 2000 to 2003 (Convention on International Trade in Endangered Species 2010).

Table 8-8 lists the habitat and range of *Pectinia alcicornis*.

Table 8-8: Pectiniidae Corals Habitat and Range

Species	Global Range	Habitat	Depth	Abundance	ESA Status
Pectinia alcicornis	Indo-Pacific, including Australia, Fiji, Indonesia, Japan, Philippines, Palau, and India	Turbid waters, often on horizontal substrates, most reef habitats, shallow and deep; found in caves in the great Barrier Reef	5 to 25 m	Usually uncommon	Proposed Threatened

Sources: Brown and Wolf (2009) and Brainard et al. (2011).
m = meter

8.11 POCILLOPORIDAE PROPOSED CORALS

Within the MRA Study Area, three species of Pocillopora corals, *Pocillopora danae, Pocillopora elegans,* and *Seriatopora aculeata*, have been proposed to be listed as threatened under the ESA (National Marine Fisheries Service 2012).

8.11.1 Description

Pocilloporidae family is represented in the MRA Study Area by two cauliflower corals*, Pocillopora danae* and *P. elegans*, and birds nest coral, *Seriatopora acualeata* (Randall 2003). The Pocilloporidae family of corals is colonial and zooxanthellate, and is found in partly protected reef slopes to depths of 15 m. The family's range encompasses the Central Indo-Pacific.

8.11.2 Biology, Ecology, and Behavior

Spatio-temporal recruitment patterns of corals around Irimote Island of the Yaeyama group suggest that on a local scale, larval dispersal and subsequent recruitment patterns are influenced by embryonic development duration and wind-driven surface currents. This difference in embryonic coral duration indicates that Acroporid and Poritid corals are likely more resilient to local disturbances than pocilliporid corals, as pocilliporid corals depend on local stocks (i.e., their larvae do not disperse as far) (Nakamura and Sakai 2010).

8.11.3 Family-specific Threats

Predation. *Pocillopora* species are among the most commonly consumed coral by the crown-of-thorns seastar (Glynn 1976), and are defended from *Acanthaster* predation by a crab and a snapping shrimp. *Acanthaster* often target young colonies because they do not have these protective symbionts, although large areas of continuous live pocilliporid corals can create protective barriers around young and unprotected colonies (Glynn 1976). *Pocillopora* has also been identified as a preferred prey of corallivorous invertebrates such as the asteroid *Culcita novaeguineae* (Glynn and Krupp 1986), the gastropod *Jenneria pustulata* (Glynn 1976), and corallivorous fishes (Cole, Pratchett, and Jones 2008).

Active predation could decrease recruitment success, due to the preference *Acanthaster* exhibits for young, unprotected colonies.

Disease. Limited reports of disease in pocilliporids indicate that infectious disease is not a major threat to members of this genus (Brainard et al. 2011).

Sedimentation and Water Quality. In the western Indian Ocean, *Pocillopora* is characterized as sediment intolerant (McClanahan and Obura 1997). However this genus is often found in relatively turbid waters in the eastern Pacific and Guam, and is considered sediment-tolerant in these areas (Randall and Birkeland 1978; Rogers 1990). In Costa Rica, however, excess sedimentation has been identified as the cause of reef collapse (Cortes 1990).

Global Climate Change. *Pocillopora* is among the genera most sensitive to bleaching—ranked eighth in sensitivity among 39 genera (McClanahan et al. 2007). *Pocillopora* sensitivity to thermal stress has been observed in the field and demonstrated in controlled laboratory settings (Berkelmans and Willis 1999; Glynn and Dcroz 1990; Hueerkamp et al. 2001; Jokiel and Coles 1977). Manzello (2010) attributed the 25 to 30% decline in growth in *P. elegans* and *P. damicornis* in the eastern Pacific over the past 30 years to acidification. The dominance of pocilloporids in the eastern Pacific implied a degree of tolerance to acidification, but they may have actually been living close to a threshold for skeletal growth (Brainard et al. 2011).

Table 8-9 lists the habitats and ranges of Pocillopora corals.

Table 8-9: Pocillopora Corals Habitat and Range

Species	Global Range	Habitat	Depth	Abundance	ESA Staus
Pocillopora danae	Western Pacific, part of the central Pacific, Great Barrier Reef, Sri Lanka; observed around Easter Island and in the Red Sea, CNMI, Guam	Partially protected reef slopes	1 to 15 m	Uncommon	Proposed Threatened
Pocillopora elegans	Indo-Pacific, Guam, Mariana Islands, central Pacific, eastern tropical Pacific, Galapagos	Shallow reef environments	1 to 20 m, observed at 60 m	Locally common in some regions	Proposed Threatened
Seriatopora aculeata	Indo-Pacific, including Australia, Fiji, Indonesia, Japan, Papua New Guinea, Madagascar, Bikini Atoll, Palau; reported in Guam but likely a mistake from picture attributed to Guam from Palau	Shallow reef environments	3 to 40 m	Uncommon	Proposed Threatened

Sources: Brown and Wolf (2009) and Brainard et al. (2011).
CNMI = Commonwealth of the Northern Mariana Islands
m = meter

8.12 PORITIDAE PROPOSED CORALS

Within the MRA Study Area, six species of Poritidae corals, *Alveopora allingi, Alveopora fenestrata, Alveopora verrilliana*, *Porites horizontalata, Porites napopora,* and *Porites nigrescens*, have been proposed to be listed as threatened under the ESA (National Marine Fisheries Service 2012).

8.12.1 Description

Porites corals are colonial. *Alveopora* is typically found in protected reef environments. While it is most commonly reported at depths of 5 to 10 m, its tolerance of dim light conditions suggests that it can occur at depths greater than 10 m (32.8 ft.), and its exact depth range is unknown. Poritidae corals exhibit high percent cover and population density throughout various habitats within the Mariana Archipelago (Houk and van Woesik 2010).

8.12.2 Biology, Ecology, and Behavior

Based on studies in Japan's Irimote Island , a longer embryonic (i.e. pelagic dispersal) period indicates that Poritid corals may be relatively more resilient to local disturbances than pocilliporid corals, as Poritid corals can be reseeded from colonies much further removed from the site of a disturbance (Nakamura and Sakai 2010).

8.12.3 Family-specific Threats

Predation. *Porites* are preyed upon by the crown-of-thorns seastar and corallivorous snails, and are preyed upon but not preferred by the predatory asteroid *Culcita novaeguineae* and the butterflyfish *Chaetodon unimaculatus* (Brainard et al. 2011).

Disease. A number of genus-level disease reports regarding *Porites* have cited subacute tissue loss, black band disease, and fungus named *Endolithis hypermycosis* (UNEP World Conservation Monitoring Centre 2010).

Sedimentation and Water Quality. *Porites* are considered to have intermediate sediment tolerance in the western Indian Ocean (McClanahan and Obura 1997), but are considered sediment-tolerant in Asia and the eastern Pacific (Brown 1997; Rogers 1990).

Global Climate Change. Of the 39 genera tested,McClanahan et al. (2007) listed the genus *Alveopora* as having the highest bleaching response in the Indian Ocean. In other studies, *Alveopora* also showed a low tolerance to thermal stress in Guam in 1994 and South Africa in 2000 (Paulay and Benayahu 1999). Massive *Porites* species are reported to have moderate susceptibility to bleaching (Marshall and Baird 2000; McClanahan et al. 2007), while branching *Porites* are comparable to *Pocillopora* and *Acropora* in their bleaching susceptibility (Marshall and Baird 2000; McClanahan et al. 2007). *Porites horizontalata* disappeared in Okinawa after the 1998 bleaching event (Loya et al. 2001). In a study focusing on Poritid species (Barshis et al. 2010), the thermal history plays a large part in the reaction to subsequent thermal stress, indicating the potential to adapt to cyclical warm-water events.

Aquarium Trade. According to the CITES Trade Database; 25,000 to 50,000 pieces of *Porites* species are traded annually (Convention on International Trade in Endangered Species 2010).

Table 8-10 lists the habitats and ranges of Poritidae corals.

Table 8-10: Poritidae Corals Habitat and Range

Species	Global Range	Habitat	Depth	Abundance	ESA Status
Alveopora allingi	Red Sea to East Africa and central Pacific; from Ryukyu Islands and Red Sea to the Great Barrier Reef and both coasts of Australia to South Africa, Mariana Islands	Protected reef environments	5 to 10 m	Usually uncommon	Proposed Threatened
Alveopora fenestrata	Red Sea to west Pacific; Mariana Islands to southern Africa and both coasts of Australia	Shallow reef environments	3 to 30 m	Uncommon	Proposed Threatened
Alveopora verrilliana	Red Sea to central Pacific; Ryukyu Islands to both Australian coasts; possibly Hawai‘i, Mariana Islands	Shallow reef environment	3 to 40 m, 20 to 80 m in the Red Sea	Uncommon	Proposed Threatened
Porites horizontalata	Maldives to central Pacific; from Japan to New Caledonia, Northern Mariana Islands	Shallow reef environments	5 to 20 m, has been observed in deep waters in American Samoa and New Caledonia	Sometimes common	Proposed Threatened
Porites napopora	Limited to the west and central Pacific, particularly the Coral Triangle; reported in Guam but likely a mistake from picture attributed to Guam from Palau	Shallow reef environments	3 to 15 m	Sometimes common	Proposed Threatened
Porites nigrescens	East Africa to central Pacific; Red Sea and south of Japan to halfway down both coasts of Australia; no substantiated published or unpublished records of its occurrence in the Northern Mariana Islands or the U.S. minor outlying islands could be identified, although listed on IUCN	Lower reef slopes and lagoons protected from wave action	0.5 to 20 m	Sometimes common; can be locally abundant in Poritid assemblage	Proposed Threatened

Sources: Brown and Wolf (2009) and Brainard et al. (2011).
IUCN = International Union for Conservation of Nature
m = meter

8.13 TAXONOMIC GROUPS

Major invertebrate species groups include those with greater than 1,000 species (Appeltans et al. 2010). All major marine invertebrate species groups are represented in the MRA Study Area, and are listed in Table 8-11. As corals as a taxonomic group were already described in Section 8.3, discussion of the phylum Cnidaria (Section 8.20) does not include a discussion on corals.

Table 8-11: Major Taxonomic Groups of Marine Invertebrates in the MRA Study Area

Major Invertebrate Groups[1]		Physical Habitat
Common Name (Species Group)	**Description**	
Foraminifera, radiolarians, ciliates (phylum Protozoa)	Bottom-dwelling and planktonic single-celled organisms, many with shells made of calcium carbonate or silica	Water column, seafloor
Sponges (phylum Porifera)	Bottom-dwelling animals; large species have calcium carbonate or silica spicules or bodies embedded in cells to provide structural support	Seafloor
Hydroids and jellyfish (phylum Cnidaria)	Bottom-dwelling and planktonic animals with stinging cells	Water column, seafloor
Flatworms (phylum Platyhelminthes)	Mostly bottom-dwelling; simplest form of marine worm with a flattened body	Water column, seafloor
Ribbon worms (phylum Nemertea)	Bottom-dwelling marine worms with proboscis or long extension from the mouth that helps capture food	Seafloor
Round worms (phylum Nematoda)	Small bottom-dwelling marine worms; many live in close association with other animals	Water column, seafloor
Segmented worms (phylum Annelida)	Mostly bottom-dwelling, highly mobile marine worms; many tube-dwelling species	Seafloor
Bryozoans (phylum Ectoprocta)	Lace-like animal; filter feeding colonies attached to the seafloor	Seafloor
Squid, bivalves, sea snails, chitons (phylum Mollusca)	Bottom-dwelling and planktonic predators, filter feeders, and grazers, with a foot and in some groups a ribbon-like band of teeth used to scrape food off rocks	Water column, seafloor
Shrimp, crab, lobster, barnacles, copepods (phylum Arthropoda - Crustacea)	Bottom-dwelling and planktonic predators and filter feeders with a skeleton that covers the animal	Water column, seafloor
Sea stars, sea urchins, sea cucumbers (phylum Echinodermata)	Bottom dwelling predators and filter feeders with tube feet	Seafloor

[1]Major species groups (those with more than 1,000 species) are based on the World Register of Marine Species (Appeltans et al. 2010) and Catalogue of Life (Bisby et al. 2010).

8.14 FORAMINIFERA, RADIOLARIANS, CILIATES (PHYLUM PROTOZOA)

Foraminifera, radiolarians, and ciliates are minute, singled-celled organisms, sometimes forming colonies of cells, belonging to the phylum Protozoa (Castro and Huber 2000). They are found in the water column and seafloor of the world's oceans. Foraminifera form diverse and intricate shells out of calcium carbonate (Wetmore 2006). The shells of foraminifera that live in the water column eventually sink to the deep seafloor, forming sediments known as foraminiferan ooze. Four new species of foraminifera were recently discovered in the Challenger Deep at a depth of over 10,800 m (35,400 ft.) in the Marianas Trench (Gooday et al. 2008). Foraminifera feed on diatoms and other small organisms. Their predators include copepods and other zooplankton. Peculiar types of foraminifera are Xenophyophores that have plex, habitat-forming structures similar to sponges (Buhl-Mortensen et al. 2010). Individual Xenophyophores are sometimes larger than 5 inches (10 cm), and they occur throughout the oceans in waters deeper than 500 m. Radiolarians are microscopic organisms that form glass-like shells made of silica. Radiolarian ooze covers large areas of the ocean floor (Castro and Huber 2000; Wetmore 2006). Ciliates are protozoans with small hairs that are used to feed and move around. Over 300 species of the clade Foraminifera occur in the sands, sediment, substrate and marine waters surrounding Guam (Richardson and Clayshulte 2003).

8.15 SPONGES (PHYLUM PORIFERA)

Sponges include over 8,000 marine species worldwide, and are classified in the phylum Porifera (Appeltans et al. 2010). Sponges are bottom dwelling, multi-cellular animals that can be best described as an aggregation of cells that perform different functions. Sponges are ubiquitous on the seafloor at all depths but are most common on shaded ledges, vertical reef faces, and other hardbottom and reef substrates (Colin and Arneson 1995d). Sponges range from robust species capable of surviving wave energy and temperature extremes, to specialized species that are delicate and cryptic. Some sponges are boring or bioeroding, and inhabit carbonate sediments such as limestone and coral skeletons. Sponges reproduce both sexually and asexually. Reproduction may be a combination of asexual budding or sexual spawning (Stevely and Sweat 2008). Spawning sponges are often sequentially hermaphroditic, and sperm are released to be taken in by a female (University of California Berkeley 2010b). The fertilized eggs or developing larvae are released some time later, and free-swimming larvae are competent for tens of days (University of California Berkeley 2010b).

Water flowing through the sponge provides food and oxygen and removes wastes (Castro and Huber 2000; Collins and Waggoner 2006). Most sponges are filter-feeders and prey on plankton, bacteria, and particulate organic matter (University of California Berkeley 2010a). A few sponges are carnivorous (University of California Berkeley 2010b). Sponges filter surprising quantities of water, from 10,000 to 20,000 times the volume of the sponge per day (Stevely and Sweat 2008; University of California Berkeley 2010b). Although most sponges contain toxins as a mechanism to deter predation, they are a crucial food source for nudibranchs, some demersal reef fish and sea turtles (Colin and Arneson 1995d; Stevely and Sweat 2008). Sponges play an important role in the marine environment (Bell 2008). Sponges provide habitat for a variety of animals, including shrimp, crabs, barnacles, worms, brittle stars, holothurians, and other sponges (Colin and Arneson 1995d). They can stabilize sediment or cause bioerosion of coral reefs (Bell 2008). Many sponges form calcium carbonate or silica spicules or bodies embedded in cells to provide structural support (Castro and Huber 2000), and play a role in cycling nutrients (Bell 2008). Over 100 species of siliceous sponges (class Demospongiae) and 4 species of the calcareous sponges (class Calcarea) have been identified within the marine waters of the Mariana Islands (Kelly et al. 2003).

8.16 HYDROIDS AND JELLYFISH (PHYLUM CNIDARIA)

The phylum Cnidaria includes over 10,000 marine species worldwide (Appeltans et al. 2010). Corals (discussed in Section 8.3), hydroids, jellyfish, and sea anemones have a body form that is symmetrical around a central axis and have a central mouth surrounded by tentacles with stinging cells used to capture prey (Colin and Arneson 1995a). Corals and hydroids occur as single polyps, the cylindrical attached phase of the animal or colonies of polyps. Medusae, commonly referred to as jellyfish, are the free-swimming bell-shaped forms (Castro and Huber 2000; Spalding, Ravilious, and Green 2001). The life history of individual species within this phylum can include one or both of these phases (Castro and Huber 2000).

Hydroids are colonial animals similar in form to corals. Hydroids have both flexible and rigid skeletons, and are considered to be habitat-forming, although not all hydroids create skeletons that persist beyond their deaths as do corals (Colin and Arneson 1995a; Gulko 1998).

Jellyfish are motile as larvae, sessile as an intermediate colonial polyp stage, and motile as adults (Brusca and Brusca 2003). They are predatory at all stages and, like all Cnidaria, use tentacles equipped with stinging cells to capture prey (Castro and Huber 2000). Jellyfish are an important prey species to a range of organisms, including some sea turtles and some ocean sunfish (*Mola spp.*) (Heithaus et al. 2002; James and Herman 2001).

8.17 FLATWORMS (PHYLUM PLATYHELMINTHES)

Flatworms are the simplest form of marine worm, with a central nervous system that controls movement, but a single opening for the digestive system, similar to cnidarians (Castro and Huber 2000). Classified in the phylum Platyhelminthes, more than 8,000 marine species of flatworms occur worldwide (Appeltans et al. 2010). Because many groups of flatworms are parasites, their life histories play a role in regulating populations of the marine vertebrates that they inhabit; parasitic flatworms are commonly found in fishes, seabirds, and whales (Castro and Huber 2000), and are not typically found in the water column outside of a host organism. The other groups of flatworms are non-parasitic carnivores, living without a host. These flatworms can live on rocks in tide pools and reefs, or within the top layer of sandy areas (Castro and Huber 2000). Eighty-eight species of flatworms have been identified from Micronesia, with 60 species occurring in the Marinas Archipelago and 28 from Palau (Newman, Paulay, and Ritson-Williams 2003). Given the limited amount of effort made on taxonomic determinations, the authors believe more than 100 species of flatworms may actually occur in Guam. Platyhelminthes are found throughout the MRA Study Area in all bathymetric zones.

8.18 RIBBON WORMS (PHYLUM NEMERTEA)

Ribbon worms are more complex than flatworms, having a complete digestive tract, including mouth, gut, and anus, as well as a circulatory system (Castro and Huber 2000). Classified in the phylum Nemertea, approximately 1,000 marine species of ribbon worms occur worldwide (Appeltans et al. 2010). Ribbon worms are predatory, bottom-dwelling marine worms with long extensions from the mouth that help capture food (Castro and Huber 2000). Ribbon worms occupy an important place in the marine food web as prey for a variety of fish and invertebrates, and as a predator of other bottom-dwelling organisms such as worms and crustaceans (Castro and Huber 2000). Some ribbon worms are parasitic and occupy the inside of the mantle of molluscs, where they feed on the waste products of their host (Castro and Huber 2000). Ribbon worms are found throughout the MRA Study Area in all bathymetric zones.

8.19 ROUND WORMS (PHYLUM NEMATODA)

Round worms are small and cylindrical worms that live in abundance in sediments and as parasites (Castro and Huber 2000). Classified in the phylum Nematoda, more than 5,000 marine species of round worms occur worldwide (Appeltans et al. 2010), but this number may be a gross underestimate. Like parasitic flatworms, parasitic nematodes provide important ecosystem services in regulating populations of other marine organisms by causing illness or mortality in less viable organisms (Castro and Huber 2000). Species in the family Anisakidae infect marine fish and may cause illness in humans if fish are consumed raw without proper precautions (Castro and Huber 2000).Free-living round worms inhabit sediments, feeding on bacteria and organic material. Round worms are found throughout the MRA Study Area in all bathymetric zones. Round worms are one of the most widespread marine invertebrates, with population densities of one million organisms per 11 square feet (1 m^2) of mud (Levinton 2009).

8.20 SEGMENTED WORMS (PHYLUM ANNELIDA)

Segmented worms are the most complex of marine worms, with well-developed respiratory and gastrointestinal systems (Castro and Huber 2000). Classified in the phylum Annelida, approximately 12,000 marine species of segmented worms occur worldwide; most marine forms are in the class Polychaeta (Appeltans et al. 2010). Different species of segmented worm species may be highly mobile or attached to the seafloor. Most segmented worms are predators; others are scavengers, deposit feeders, filter feeders, or suspension feeders of sand, sediment, and water (Castro and Huber 2000; Hoover 1998c). The variety of feeding strategies and close connection to the seafloor make Annelids an integral part of the marine food web (Levinton 2009)**.** Burrowing into the seafloor and agitating the sediment, they increase the oxygen content of the seafloor and make important buried nutrients available to other organisms. This ecosystem service allows bacteria and other organisms, which are also an important part of the food web, to flourish on the seafloor.

Segmented worms are found throughout the MRA Study Area in all bathymetric zones. There are 104 known polychaete species in the Marianas Archipelago (Abraham et al. 2004).They commonly inhabit rocky, sandy, and muddy areas of the seafloor. These worms also colonize corals, vessel hulls, docks, and floating debris.

8.21 BRYOZOANS (PHYLUM ECTOPROCTA)

Bryozoans are small, lace-like, colony-forming animals, many of which create habitat similar in complexity to Xenophyophores or sponges (Buhl-Mortensen et al. 2010). Classified in the phylum Ectoprocta, approximately 5,000 marine species occur worldwide (Appeltans et al. 2010). Bryozoans attach to a variety of surfaces, including rocks, shells, wood, and algae, and feed on particles suspended in the water (Hoover 1998a). They are of economic importance for bioprospecting. Bryozoans are considered members of the “fouling community,” thriving in harbors and marinas where they grow on boat bottoms and other surfaces, slowing boat operations and clogging industrial water intakes and conduits (Hoover 1998a). Ectoprocta are found throughout the MRA Study Area in all bathymetric zones.

8.22 SQUID, BIVALVES, SEA SNAILS, CHITONS (PHYLUM MOLLUSCA)

The general Mollusca body plan exhibited by bivalves (e.g., clams, mussels), sea snails, and chitons is a soft body covered by a layer of tissue that produces a shell, and a muscular foot used for mobility

(Castro and Huber 2000). Squids and other cephalopods, such as octopuses and cuttlefish, have a modified body plan; they lack an external shell, and the foot is modified into tentacles. Approximately 27,000 marine species are classified in the phylum Mollusca worldwide (Appeltans et al. 2010). Molluscs exhibit a range of feeding types, including grazers, carnivores, and deposit feeders (Castro and Huber 2000). Squids and octopuses exhibit a range of feeding habits and food preferences. Squids prey on fish, shrimp, and other squids. Some species of squid are important commercial species, and they are key prey for many species, including marine mammals (Colin and Arneson 1995c). Octopuses mostly prey on fish, shrimp, eels, and crabs (Wood and Day 2005). Bivalves feed on phytoplankton and other suspended food particles (Castro and Huber 2000). Sea snails and slugs eat fleshy algae and a variety of invertebrates, including hydroids, sponges, sea urchins, worms, and small crustaceans, as well as detritus (Castro and Huber 2000; Colin and Arneson 1995c). Some snails (*Drupella* species) prey on corals (Maragos et al. 2009). Most marine molluscs use a ribbon of teeth called a radula to feed (Castro and Huber 2000; Colin and Arneson 1995c), and chitons, notably, bore deep pits into rocks as they scrape algae (Pearse 1987).

Mollusca are found throughout the MRA Study Area in all bathymetric zones. There are 1,722 known mollusc species in the Marianas Archipelago (Abraham et al. 2004). Creel surveys (estimates of local fisheries catch data) in Guam have shown that the main species collected for boat-based and shore-based fishing are octopuses (*Octopus cyanea, O. ornatus*) and topsnails (*Trochus niloticus*), as well as giant spider conches (*Lambis truncata*) and bigfin reef squids (*Sepioteuthis lessoniana*) (Burdick et al. 2008).

8.23 SHRIMP, CRAB, LOBSTER, BARNACLES, COPEPODS (PHYLUM ARTHROPODA)

Shrimp, crab, lobster, barnacles, and copepods are animals with skeletons that form outside the body (Castro and Huber 2000). The skeletons are based on a polymer called chitin, similar to cellulose in plants, to which the animals add compounds such as proteins or carbonates to achieve various properties of flexibility or hardness. Classified in the phylum Arthropoda, over 50,000 species belong to the marine subphylum Crustacea (Appeltans et al. 2010). Crabs and shrimp are typically carnivorous or omnivorous predators or scavengers, preying on molluscs (primarily gastropods), other crustaceans, echinoderms, small fish, algae, and seagrass (Waikiki Aquarium 2009a, b, c; Western Pacific Regional Fishery Management Council 2009). Barnacles and copepods filter algae and other small organisms from the water (Levinton 2009). Sea spiders and horseshoe crabs (subphylum Chelicerata) are also marine arthropods.

Arthropoda are found throughout the MRA Study Area in all bathymetric zones. There are 840 known arthropod species in the Marianas Archipelago (Abraham et al. 2004).Important human-harvested species of Crustacea, as indicated by creel surveys of the shore-based fishery in Guam, are lobsters (*Panulirus penicillatus*), slipper lobsters (*Parribacus antarticus*), and crabs (*Scylla serrate*). The important harvested species of the boat-based fishery of Guam are lobsters (*Panulirus penicillatus, P. versicolor*), and slipper lobsters (Burdick et al. 2008).

8.24 SEA STARS, SEA URCHINS, SEA CUCUMBERS (PHYLUM ECHINODERMATA)

Sea stars (asteroids), sea urchins (echinoids), sea cucumbers (holothuroids), brittle stars and basket stars (ophuiroids), and feather stars and sea lilies (crinoids) are symmetrical around the center axis of the body (Castro and Huber 2000). Classified in the phylum Echinodermata, over 6,000 marine species occur worldwide. All echinoderms are benthic (live on the seafloor), but some can also swim. Most

echinoderms have separate sexes, but unisexual forms occur among the sea stars, sea cucumbers, and brittle stars. Many species have external fertilization, producing planktonic larvae, but some brood their eggs, never releasing free-swimming larvae (Colin and Arneson 1995b). Many echinoderms are either scavengers or predators on organisms that do not move, such as algae, stony corals, sponges, clams, and oysters (Hoover 1998b). Some species, however, filter food particles from sand, mud, or water.

There are 196 known echinoderm species in the Marianas Archipelago (Abraham et al. 2004). There is a relatively low abundance of echinoid species around Guam, except for sea urchin and *A. planci* at some locations (Burdick et al. 2008). Nevertheless, the sea urchins *Tripneustes gratilla* and *Toxipneustes pilolus* are important species in the shore-based fishery of Guam (Burdick et al. 2008). Ecologically, the crown-of-thorns sea star (*Acanthaster planci*) preys on corals and can devastate reefs, as was observed in 1969, when an infestation off Tanguisson Reef devastated *Montipora* and *Acropora* coral species, but did not prey upon *Porites* or *Leptastrea* species (Colgan 1987).

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9.0 FISH

9.1 INTRODUCTION

Approximately two-thirds of the more than 32,000 known fish species (Eschmeyer and Fong 2012) inhabit marine environments throughout the world (Helfman et al. 2009). Of that total, over 8,700 described marine fish species occur within the Pacific Ocean (Froese and Pauly 2012). Some marine fish species in the MRA Study Area for the Japan and Mariana Archipelagos (the MRA Study Area) are listed as candidates under the Endangered Species Act (ESA), while others are species of concern (National Marine Fisheries Service 2012a). Profiles of these species, along with major taxonomic groups in the MRA Study Area, appear in this section. Marine fish species regulated under the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) and the Sustainable Fisheries Act (SFA) of 1996 are described in Section 10, Essential Fish Habitat.

9.1.1 Global Distribution and Preferred Habitat

Fishes are not distributed uniformly but are closely associated with a variety of habitats. Some species, such as large sharks, tuna, and billfishes, range across thousands of square miles; others, such as gobies and reef fishes, have small home ranges and restricted distributions (Helfman et al. 2009). Movements of some open-ocean species may never overlap with coastal fishes that spend their lives within several hundred feet (a few hundred meters) of the shore. Even within a single fish species, the distribution and specific habitats in which individuals occur may be influenced by developmental stage, size, sex, reproductive condition, and other factors (Helfman et al. 2009).

Distribution of fish species is influenced primarily by temperature, salinity, oxygen, pH, physical habitat, ocean currents, and latitudinal gradients (Helfman et al. 2009; Macpherson 2002; Nelson 2006). In general terms, the coastal-centered large marine ecosystems support a greater diversity of coastal and reef-associated species, while the open ocean areas support a lower diversity of oceanic and deep-sea species (Helfman et al. 2009; Nelson 2006). Each major habitat type in the MRA Study Area (e.g., coral reef, hard bottom, soft bottom, aquatic beds) supports a fish community associated with that habitat type. Specific characteristics of the wide diversity of habitat types within the MRA Study Area are discussed in Chapter 11 (Marine Habitats). Biological factors affecting distribution are complex and include variables such as population dynamics, predator/prey oscillations, seasonal movements, reproductive/life cycles, and recruitment success (Helfman et al. 2009). These factors, in combination, are typically responsible for distribution of fishes. For example, pelagic species optimize their growth, reproduction, and survival by tracking gradients of temperature, oxygen, or salinity (Helfman et al. 2009). Additionally, spatial distribution of food resources is variable and changes with prevailing physical habitat parameters. Another major component in understanding species distribution are locations of highly productive regions, such as frontal zones. These areas concentrate higher trophic-level predators, including tuna, and provide indicators to fishers of the location of these predators targeted in commercial fisheries (National Marine Fisheries Service 2001).

Large-scale environmental perturbations such as the Pacific decadal oscillation events and El Niño Southern Oscillation (ENSO), as described in Chapter 4 (Oceanography), also influence fish distribution. Pacific decadal oscillation events change the normal water temperatures in an area, which affects distribution, habitat range, and movement of open ocean species (Adams et al. 2002; Bakun et al. 2010; Sabarros et al. 2009). The North Equatorial Current (westward) and the Subtropical Countercurrent (eastward) are major influences on distribution of fishes in the MRA Study Area and vicinity (Eldredge 1983). Pacific decadal oscillation events alter normal current patterns, alter productivity, and

dramatically affect distribution, habitat range, and movement of pelagic species (National Marine Fisheries Service 2012b). In the northern hemisphere, Pacific decadal oscillation events typically result in tropical, warm-water species moving north (extending species range), and cold-water species moving north or into deeper water (restricting their range). Surface-oriented, schooling fish often disperse and move into deeper waters. Fishes that remain in an affected region experience reduced growth, reproduction, and survival (National Atmospheric and Oceanic Administration 2002). Pacific decadal oscillation events have caused the distribution of fisheries, such as that of the skipjack tuna (*Katsuwonus pelamis*), to shift by more than 620 miles (1,000 kilometers) (National Marine Fisheries Service 2001; Stenseth et al. 2002).

Marine fishes can also be broadly categorized into horizontal and vertical distributions within the water column. The primary ecological groups of fishes that occur in the marine environment in the MRA Study Area include the reef community, the unstructured seafloor community, and the surface community (Schwartz 1989). The highest number and diversity of fishes typically occur where the habitat is most diverse, characterized by structural complexity (reef systems, continental slopes, deep canyons, currents, temperature), biological productivity (areas of nutrient upwelling), and a variety of physical and chemical conditions (water flow, nutrients, dissolved oxygen, temperature) (Bergstad et al. 2008; Helfman et al. 2009; Moyle and Cech 1996; Parin 1984; Reshetiloff 2004). Some coastal zone marine fishes migrate between marine and freshwater habitats. Other distribution factors, including predator/prey relationships, water quality, and refuge (e.g., physical structure or vegetation cover) vary on more regional or local spatial scales (Reshetiloff 2004). Also, fish may move among habitats throughout their lives, based on changing needs during different life stages (Schwartz 1989).

9.1.2 Fishes of the Japan Archipelago

The Kuroshio and Oyashio Currents and the transition region (Pearcy 1991) between these subtropical and subarctic currents to the east of Japan, and the Tsushima Current to the west of Japan greatly influence the distribution of fishes within the Japan Archipelago (Ministry of the Environment 2007). These currents bring tropical species into subtropical regions, resulting in a very high diversity of fishes (more than 3,000 species) within this portion of the MRA Study Area.

Highly productive fishing grounds are located at the juncture (from just beyond the east coast of Japan to 160° E and from 37° N to 50° N) of the warm Kuroshio and cold Oyashio currents, where highly migratory species (e.g., skipjack tuna and bluefin tuna [*Thunnus orientalis*],) feed on smaller pelagic species (e.g., Japanese sardine [*Sardinops melanostictus*], Pacific saury [*Cololabis saira*], and anchovy [*Engraulis japonicus*]), thus exploiting temperature gradients and phytoplankton blooms (Sassa et al. 2002; Sassa, Konishi, and Mori 2006). This transitional region of the western North Pacific functions as spawning and nursery grounds for various epipelagic and mesopelagic fishes, including subtropical-tropical, transitional, and subarctic species (Watanabe et al. 1999). Current velocities have been demonstrated to influence distribution of coastal species, with an increase in the number of species and individuals as current velocity increases (Inui et al. 2010). Further offshore, certain fishes (e.g., rockfishes, yellowtail, mackerel blennies, and filefishes) are often associated with drifting sea weed (*Sargassum* sp.) along the front between the Kuroshio current and coastal waters, particularly during summer months (Komatsu et al. 2007; Nishida et al. 2008).

Species associated with the Kuroshio Current include Japanese sardine, Pacific saury, anchovy, jack mackerel (*Trachurus japonicus*), bluefin tuna, frigate mackerel (*Auxis thazard thazard*), filefish, and herring (Froese and Pauly 2012; Sherman and Hempel 2009). Species found in the Oyashio Current include Japanese sardine, walleye pollock (*Theragra chalcogramma*), tuna, chub mackerel (*Scomber*

japonicus), Pacific saury, anchovy, lantern fish, Pacific cod (*Gadus macrocephalus*), flounder, rockfish, chum (*Oncorhynchus keta*), and pink salmon (*O. gorbuscha*) (Fujita, Inada, and Ishito 1993). The Tsushima Current splits from the Kuroshio Current at the Korean peninsula and enters the Sea of Japan, gradually losing tropical species as it moves north along the west coast of Japan. More than 800 species representing 38 Indo-Pacific ichthyofaunal families inhabit the West Japan portion of the MRA Study Area (Kafanov et al. 2000). Midwater ichthyoplankton tows collected from an average depth of 1,290 meters (m) offshore of the Bōsō Peninsula in central Japan contained 66 species, represented primarily by gonostomatids (75 percent [%] of total abundance), followed by myctophids (20%), and melamphaids and sternoptychids (both at approximately 1%) (Miya, Yamaguchi, and Okiyama 1995). These results are consistent with expected abundances of the common pelagic and deepsea fish groups (Nelson 2006), as well as the tropical-subtropical zoogeographic origin of 43 of the 66 fish species—demonstrating the importance of the Kuroshio current in transporting tropical-subtropical fishes to central Japan (Miya, Yamaguchi, and Okiyama 1995).

Japanese waters range from tropical to subarctic, with hard corals present from the southern Ryukyu Islands north to Tōkyō Bay along the eastern coast, and to Sado Island in the Sea of Japan (Kimura et al. 2004). The coral reef communities occurring in the waters surrounding Japan are a result of unique climatic and biogeochemical conditions. The warm equatorial waters of the Kuroshio Current contribute to the growth of the most diverse and northernmost reefs in the world (Lecchini et al. 2003). The Kuroshio Current is so efficient at transporting coral larvae that the biodiversity around Japan rivals that of the Philippines (Burke, Selig, and Spalding 2002). Ninety percent of the corals that occur in Japan can be found around Okinawa (Wilkinson 2004).

True coral reef fish communities in the Ryukyu Islands are dominated by damselfishes, common to most coral reef systems (Lecchini et al. 2003), although this baseline community is likely influenced by human harvest of larger fishes. This is evident on Sesoko Island near Okinawa (Lecchini et al. 2003). However, individual abundances of other major reef taxa, such as surgeonfishes, butterflyfishes, wrasses, and parrotfishes, are low at these islands (Lecchini et al. 2003). Daito Island supports the most highly diversified assemblage in the Ryukyu Archipelago (Sergeeva, Titlyanova, and Titlyanov 2007). Non-reef coral communities are represented by various species encompassing the following major taxa: Chaetodontidae (butterflyfishes/angelfishes), Acanthuridae (surgeonfishes/rabbitfishes/moorish idols), and Labridae (parrotfishes/damselfishes/wrasses) (Choat and Bellwood 1991). The outlying coral communities in the Izu Islands are dominated by wrasses (Donaldson et al. 1994).

Fisheries harvest information within the MRA Study Area appears in Chapter 13 (Human Uses).

9.1.3 Fishes of the Mariana Archipelago

Approximately 1,106 known marine fish species occur in the Mariana Archipelago, 1,020 of which are known to occur in the coastal zone (Myers and Donaldson 2003). The species found in the MRA Study Area include widespread Indo-Pacific species (58%), circumtropical species (3.6%), Indo-west Pacific and west Pacific species (17.6%), west-central Pacific and Pacific Plate species (18.3%), and species confined to specific geographic areas, such as Micronesia, the Philippine plate and endemic to the Marianas (2.5%) (Myers and Donaldson 2003). Only 10 species found in the MRA Study Area are endemic to the Mariana Islands (Myers and Donaldson 2003). Houk et al. (2010) have estimated reef-fish abundances and occurrences since 2003 at 42 reef slopes within the Commonwealth of the Northern Mariana Islands (CNMI). Results from their surveys have shown that the greatest diversities occurred at areas with high salinity levels, low-to-moderate wave exposure, smaller island size, and an absence of volcanic activity for at least 90 years (Houk and Starmer 2010).

Most fishes in the coral reef communities of the MRA Study Area exhibit year-round uniformity and stability in their abundances (Amesbury and Myers 2001). Exceptions include several reef fish species (juvenile rabbitfish, juvenile jacks, juvenile goatfish, and bigeye scad, *Selar crumenophthalmus*) targeted in the MRA Study Area that show strong seasonal fluctuation in abundance, usually related to juvenile recruitment (Amesbury and Myers 2001).

Fish species composition within the MRA Study Area is typical of most Indo-Pacific insular, coral reef-bordered coastal areas. Seventy-three percent of the total number of documented species are in 20 families (Myers and Donaldson 2003). Fish community diversity in the Mariana Archipelago is lower than that of the Hawaiian Archipelago; however, this may be an artifact of insufficient sampling (Paulay 2003). Many other factors, such as larval recruitment, natural disturbances, and local habitat quality dramatically impact species diversity (Randall 1995). The reefs adjacent to Neye Island and the patch reefs in North Agat Bay host some of the highest diversity on the U.S. Territory of Guam (Guam), with levels declining from Orote Point southeastward and then increasing again near Agat Bay (Porter et al. 2005). Fish abundance at Orote reef sites is generally higher than in Agat Bay. Of the 25 families recorded during the Paulay et al., (2001) surveys, the family Pomacentridae (69%) was most abundant, followed by the Acanthuridae (10%), Labridae (4%), Chaetodontidae (4%), Scaridae (3%), and Balistidae (2%) (Porter et al. 2005). Other portions of Guam exhibit very low diversity, such as the inner Apra Harbor (Smith et al. 2009).

Approximately two-thirds of the inshore species of the CNMI represent widespread Indo-Pacific species, with the remainder consisting of circumtropical species (Myers and Donaldson 2003). Ten species of inshore and epipelagic fishes are currently considered endemic to the Marianas; however, this number is probably exaggerated due to observations of transient species in the area (Myers and Donaldson 2003). Extensive studies have focused on the biogeography of inshore and epipelagic fauna found in the Marianas from 0 to 100 m depth. Occurrence and distribution of benthic and mesopelagic species from 100 m to greater than 200 m have been incompletely studied, and are poorly understood (Myers and Donaldson 2003). Lack of adequate data has made it difficult to identify and interpret other sources of variation in distribution and decline of the fisheries resources of these islands. Large-bodied coral reef fishes are less abundant in Guam than in the CNMI (Richards et al. 2012).

Fisheries harvest information within the MRA Study Area appears in Chapter 13 (Human Uses).

9.1.4 Global Threats and Management

Human impacts are widespread throughout the world's oceans, such that very few habitats remain unaffected by human influence (Halpern et al. 2008). Some marine fishes with large body sizes and late maturity ages are especially vulnerable to habitat losses and fishing pressure (Reynolds et al. 2005). For example, large sharks account for 60% of the marine fishes of conservation concern (International Union for Conservation of Nature and Natural Resources 2011). Conservation statuses of only 3% of the world's marine fish species have been evaluated, so threats to the remaining species are currently unknown (Reynolds et al. 2005).

Overfishing is the most serious threat (having led to listing of ESA-protected marine species (Crain et al. 2009; Kappel 2005), with habitat loss also contributing to extinction risk (Cheung et al. 2007; Dulvy, Sadovy, and Reynolds 2003; Musick et al. 2000). Overfishing occurs when the rate of removal from a stock is too high, and a stock is considered overfished when the population falls below a prescribed threshold (National Marine Fisheries Service 2011). Sixteen percent of the fishery stocks managed by the United States are subject to overfishing, and 23% are overfished (National Marine Fisheries Service

2011). Overfishing impacts both targeted species and non-targeted species (or "bycatch" species) that are often important in marine food webs. Bycatch may also include seabirds, turtles, and marine mammals. In recent decades, marine fisheries have targeted species lower on the food web as abundance of higher-level predators has decreased; some entire marine food webs have collapsed as a result (Crain et al. 2009; Pauly and Palomares 2005). Other factors, such as fisheries-induced evolution and intrinsic vulnerability to overfishing, have been shown to reduce abundance of some populations (Kuparinen and Merila 2007). Fisheries-induced evolution is a change in genetic composition of the population, such as a reduction in the overall size and individual growth rates resulting from intense fishing pressure. Intrinsic vulnerability describes certain life history traits, such as large body size, late maturity age, and low growth rate, which increase susceptibility of a species to overfishing (Cheung et al. 2007).

Pollution primarily impacts coastal fishes near the pollution source. However, global oceanic circulation patterns scatter a considerable amount of marine pollutants and debris throughout the open ocean (Crain et al. 2009). Pollutants in the marine environment that may impact marine fishes include organic contaminants (e.g., pesticides, herbicides, polycyclic aromatic hydrocarbons, flame retardants, and oil), inorganic chemicals (e.g., heavy metals), and debris (e.g., plastics and wastes) (Pew Oceans Commission 2003). High chemical pollutant levels in marine fishes may induce behavioral changes, physiological changes, or genetic damage in some species (Goncalves et al. 2008; Moore 2008; Pew Oceans Commission 2003; van der Oost, Beyer, and Vermeulen 2003). Bioaccumulation of metals and organic pollutants is also a concern in shallow harbors and coastal portions of both the Japan (Malarvannan et al. 2011) and CNMI portions of the MRA Study Area (Denton et al. 2006a, b). This is also a concern to human health, because people consume top predators with possibly high pollutant loads. Bioaccumulation is the net buildup of substances (e.g., chemicals or metals) in an organism from taking in contaminated water or sediment through the gills or skin, from ingesting food containing the substances (Newman 1998), or from ingesting those substances directly (Moore 2008). The physical presence of marine debris such as abandoned nets and lines also poses a threat to marine fishes. Entanglement in abandoned commercial and recreational fishing gear has caused declines of some marine fishes; some species, such as sawfishes, are more susceptible to entanglement by marine debris than others (Musick et al. 2000).

Non-native fishes threaten native fishes when they are introduced into an environment lacking natural predators by competing with native fishes for resources and/or preying upon native fishes (Crain et al. 2009) (e.g., tilapia escapees from aquaculture facilities threaten native reef-associated fishes in the CNMI and Okinawa (Pew Oceans Commission 2003). In a survey of inner Apra Harbor, Smith et al. (2009) reported new records of two fishes within the areas of Guam and the Mariana Islands: *Amblyglyphidodon ternatensis* (a damselfish) and *Rhamdia cypselurus* (a cardinalfish). These occur elsewhere in the western Indo-Pacific region in habitats similar to those at Inner Apra Harbor (Myers 1999). Whether these species pose an invasive threat to the native fishes of Guam is not yet clear.

Global climate change threatens fishes by contributing to a shift in fish distribution from lower to higher latitudes (Brander 2009; Dufour et al. 2010; Wilson et al. 2010). One example is the Pacific bluefin tuna, which has spawning grounds limited to southern Okinawa to east of Taiwan and connected to nursery grounds by the Kuroshio current (Kimura et al. 2010). Experimental results have led to a prediction that survival rates of larvae arriving in Japanese coastal waters in 2100 would decline to 36% of present recruitment levels. The change is attributed to thermal mortality of larvae subject to a substantially greater temperature differential between the warmer spawning grounds and the comparatively colder nursery grounds (Kimura et al. 2010).

Other threats to fish include aquaculture, vessel strikes, and underwater noise. Threats to wild fish populations that are consequences of aquaculture operations include the following: reduced water quality, competition for food, predation by escaped or released farmed fishes, spread of disease, and reduced genetic diversity (Kappel 2005; Ormerod 2003). The National Oceanic and Atmospheric Administration (NOAA) is developing an aquaculture policy aimed at promoting sustainable marine aquaculture (National Oceanic and Atmospheric Administration 2011a). Vessel strikes pose threats to some large, slow-moving fishes at the surface, although this is not considered a major threat to most marine fishes (Kappel 2005). Whale sharks, basking sharks, ocean sunfish, and manta rays are susceptible to vessel strikes (National Marine Fisheries Service 2010; Rowat et al. 2007; Speed et al. 2008; Stevens 2007; The Hawaii Association for Marine Education and Research Inc. 2005). Underwater noise is a threat to marine fishes. However, physiological and behavioral responses of marine fishes to underwater noise have been investigated for only a limited number of species (approximately 100; many of which are freshwater species) (Popper and Hastings 2009). In addition to vessels, other sources of underwater noise include pile-driving activity and seismic activity (California Department of Transportation 2001; Carlson, Hastings, and Popper 2007; Feist, Anderson, and Miyamoto 1992; Mueller-Blenkle et al. 2010; Nedwell et al. 2003; Popper et al. 2006; Popper and Hastings 2009).

9.2 SPECIES LIST AND STATUS

Fish species occurring within the MRA Study Area that are listed as endangered, threatened, or candidate species under the ESA are listed in Table 9-1 along with their ecoregional presence. Currently, no marine fishes in the MRA Study Area are listed as endangered or threatened—as a species, an evolutionarily significant unit, or a distinct population segment. However, two fish species are considered ESA candidate species, which means that they could be listed as endangered or threatened in the future. The other level of consideration for protection is the species of concern category. Species of concern are those species that the National Marine Fisheries Service (NMFS) has some concern regarding status and threats, but for which insufficient information is available to indicate a need to list the species under the ESA (National Marine Fisheries Service 2012a). Two species of concern occur within the MRA Study Area. The following profiles emphasize species-specific information regarding the two ESA candidate species because regulatory agencies must consult about any threats to or potential impacts on ESA candidate species that could result in threatened or endangered status. The broad taxonomic groups are also included to cover the nonregulated fishes within the marine ecosystem of the MRA Study Area (see Section 9.6).

Table 9-1: Status and Presence of ESA-Listed Fish Species Found in the MRA Study Area

Species Name and Regulatory Status			Ecoregional Presence[1]						
Common Name	Scientific Name	ESA Listing	Open Ocean				Coastal Waters		
			NCP	KU	ECS	PS	JA	MA	CI
Scalloped hammerhead shark	*Sphyrna lewini*	Candidate	X	X	X	X	X	X	X
Knifetooth sawfish	*Anoxyprisitis cuspidata*	Candidate			X	X	X		
Humphead wrasse	*Cheilinus undulatus*	Candidate[2]/ Species of Concern					X	X	X

Notes: ESA = Endangered Species Act, MRA = Marine Resources Assessment.
[1]Ecoregional presence relates to open ocean and coastal waters of the MRA Study Area. Ecoregional presence in open ocean waters includes– the North Central Pacific Gyre (NCP), the Kuroshio Current (KU), the East China Sea (ECS) and the Philippine Sea (PS). Ecoregional presence in coastal waters includes nearshore waters of the Japan Archipelago (JA), Mariana Archipelago (MA), and the Caroline Islands (CI).
[2]In October 2012, NMFS received a petition to list the humphead wrasse as threatened or endangered under the ESA, and to designate critical habitat concurrently with the listing (WildEarth Guardians 2012). On 28 February 2013, NMFS announced a 90-day finding on the petition and will conduct a review of the species' status to determine if further action is warranted (National Marine Fisheries Service 2013). Due to the late nature of the status change a species profile is not included here.

9.3 SCALLOPED HAMMERHEAD SHARK (*SPHYRNA LEWINI*)

9.3.1 Description

The scalloped hammerhead shark (*Sphyrna lewini*) is one of eight elasmobranch species in the family Sphyrnidae (hammerhead sharks) of the order Carcharhiniformes (ground sharks) (Nelson 2006). They are the most abundant of the hammerhead species based on catch (Maguire et al. 2006), and feature lateral bladelike extensions on the head where the eyes are located (Nelson 2006). Scalloped hammerhead sharks are brownish-gray to bronze or olive green on the dorsum and ventrally pale yellow or white (Bester 1999). The species has two dorsal fins and is typically 360 centimeters (cm) total length (Castro 1983), with a maximum length and weight of 430 cm and 152 kilograms (kg), respectively (Froese and Pauly 2012). The scalloped hammerhead is distinguished from other hammerhead species by the distinctive indentation located anteriorly, at the center of its broadly arched head (Bester 1999). Teeth are triangular and smooth-edged (Castro 1983).

9.3.2 Status and Management

In August 2011, NMFS received a petition to list the scalloped hammerhead shark as threatened or endangered under the ESA, and to designate critical habitat concurrently with the listing (National Oceanic and Atmospheric Administration 2011b). In its 90-day review, NMFS concluded that substantial scientific information may warrant listing under the ESA; a status review for the scalloped hammerhead shark is underway (National Oceanic and Atmospheric Administration 2011b), and its status remains as a "candidate" species pending the outcome of that review. The scalloped hammerhead shark is managed under the Potentially Harvested Coral Reef Species Management Unit by the Western Pacific Regional Fishery Management Council (WPRFMC) through the Coral Reef Ecosystem (CRE) Fishery Management

Plan (FMP) (Western Pacific Regional Fishery Management Council 2009). As discussed in Chapter 10, a fishery management plan and designated essential fish habitat (EFH) have been specified for the scalloped hammerhead shark (National Oceanic and Atmospheric Administration 2012).

9.3.3 Population and Abundance

Data and information provided in the NMFS listing petition suggest that the scalloped hammerhead shark has undergone significant declines throughout its range (National Oceanic and Atmospheric Administration 2011b). Data from 1986 to 2000 from the United States (U.S.) pelagic longline fleet indicate a decreasing trend in the abundance of the scalloped hammerhead shark (Baum et al. 2003). More recent Food and Agriculture Organization of the United Nations (FAO) catch data indicate that similar fishing efforts in 2002 and 2009 achieved catches of scalloped hammerhead sharks that peaked at 8,000 metric tons in 2002 and fell to only 1,000 metric tons in 2009 (Food and Agriculture Organization of the United Nations 2012; Maguire et al. 2006).

9.3.4 Biology, Ecology, and Behavior

Group Size. Scalloped hammerhead sharks occur as solitary individuals, or in aggregations or schools associated with feeding habitats (e.g., near islands, reefs, or seamounts) or with spawning during that season (Compagno 1984; Food and Agriculture Organization of the United Nations 2012; Klimley 1981). Aggregations of scalloped hammerhead sharks range between 20 and 100 individuals (Klimley 1981). Behavioral characteristics of individuals observed by divers within aggregations near islands or seamounts include accelerated swimming with occasional headshaking, corkscrew swimming with rotation around their longitudinal axes, striking other individuals with their snouts, and flexing claspers. Some of these displays may involve aggression or courtship; however, this has not been confirmed (Food and Agriculture Organization of the United Nations 2012). Many females, and a smaller proportion of males, bear scars that could have resulted from these aggressive behavioral displays (Food and Agriculture Organization of the United Nations 2012).

Predator/Prey Interactions. Scalloped hammerhead sharks follow diel vertical movement patterns within their home range (Holland et al. 1993; Klimley and Nelson 1984), and feed primarily at night (Compagno 1984). They are a high trophic level predator (Bethea et al. 2011; Bush and Holland 2002; Hussey et al. 2011), and feed opportunistically on all types of teleost fishes, cephalopods, crustaceans, and rays (Bethea et al. 2011; Compagno 1984; Torres-Rojas et al. 2010; Vaske, Vooren, and Lessa 2009). They consume a higher daily ration (2.12–3.54% of total body weight) than other shark species (Bush and Holland 2002; Lowe 2002). No predators of adult scalloped hammerhead sharks are known, but other sharks (e.g., white sharks, reef sharks) prey on juveniles (Bester 1999). Females move offshore sooner than males, where they feed on pelagic prey with greater success (Motta and Wilga 2001).

Life History. Scalloped hammerhead sharks are viviparous (give birth to live young), with a gestation period of 9–12 months, and typically breed every other year (Branstetter 2002; Chen et al. 1990; Liu and Chen 1999; Stevens and Lyle 1989), although some populations exhibit annual breeding (Castro 1983). Females utilize nearshore nursery areas to give birth to their litter of 2–41 “pups” during the summer months (Branstetter 2002; Hazin, Fischer, and Broadhurst 2001; Heupel, Carlson, and Simpfendorfer 2007; Stevens and Lyle 1989; White, Bartron, and Potter 2008). Nursery areas consist of shallow nearshore estuaries geographically separate from adult nursery grounds (Duncan and Holland 2006). Females outnumber males up to 3:1 in large aggregations, but these groups do not likely play a reproductive role (Klimley 1981). The type of habitat where mating occurs is unknown.

Estimates of age and length at sexual maturity vary widely by region, with females ranging from 4–15 years and 140–270 cm, respectively (Branstetter 2002; Chen et al. 1990). Demographic analyses in the northwestern Pacific indicate that females mature at 5 years, reproducing every other year (Liu and Chen 1999). In northeastern Taiwan waters, females mature at 4 years (Chen et al. 1990). Juveniles typically remain in these nearshore waters for up to a year (Duncan and Holland 2006) before dispersing to deeper waters of the continental shelf or insular waters as they grow (National Oceanic and Atmospheric Administration 2011b). The lifespan of scalloped hammerhead sharks is approximately 30 years (Bester 1999), with a maximum reported age of 35 years (Froese and Pauly 2012).

Sensory Capabilities. Scalloped hammerhead sharks are hearing generalists and, as many fishes, possess a lateral line sensory system sensitive to particle motion in the water column (Popper 2003). Electroreception is the primary sensory mechanism used by many sharks. They possess ampullary (pouch) organs sensitive to electric fields as low as 1–2 nanovolts per centimeter (Kajiura 2001; Kalmijn 1982; Rivera-Vicente, Sewell, and Tricas 2011) at frequencies of 50 Hertz to more than 2 kiloHertz (Helfman et al. 2009). The distribution of electroreceptors (e.g., along the ventral portion of the head of the scalloped hammerhead shark) suggests that these sensory organs may be used in foraging (Kajiura 2001; Kajiura, Forni, and Summers 2005). Additionally, some researchers hypothesize that the electroreceptors aid in social communication (Collin and Whitehead 2004). While electroreception may aid in foraging, the shape of the head with the eyes positioned laterally limits the field of vision by creating a large “blind spot” directly in front of the shark—a factor for which one study has suggested hammerhead sharks behaviorally compensate by increasing “head yaw” (side-to-side motion) during swimming (McComb, Tricas, and Kajiura 2009).

9.3.5 Habitat and Distribution

The scalloped hammerhead shark is circumglobal, occurring in all temperate to tropical waters (Duncan and Holland 2006). They are highly mobile (Maguire et al. 2006), with a distribution in the western Pacific from Japan and China to New Caledonia, including throughout the Philippines, Indonesia, Australia, and all of the tropical/temperate Pacific Islands (Compagno 1984). While scalloped hammerhead sharks are typically non-migratory, some schools of juveniles have been known to undergo poleward migrations during the summer months (Bester 1999). The scalloped hammerhead shark typically inhabits nearshore waters of bays and estuaries, where water temperatures are at least 22 degrees Celsius (°C) (72 degrees Fahrenheit [°F]) (Castro 1983; Compagno 1984). They remain close to shore during the day and move to deeper waters at night to feed (Bester 1999). Neonates and young-of-the-year depend on coastal nursery areas.

Open Ocean Waters of the MRA Study Area

The scalloped hammerhead shark occurs in the North Pacific Subtropical Gyre, Kuroshio Current, East China Sea, and Philippine Sea open ocean areas from the surface to depths of 902 feet (ft. [275 m]) (Fodrie et al. 2010; Froese and Pauly 2012).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. No specific information is available for this area at this time.

Bōsō Peninsula, Izu Peninsula, and Izu Islands. No specific information is available for this area at this time.

Kyūshū Island, Ōsumi Islands, and Tokara Archipelago. No specific information is available for this area at this time.

Okinawa Island, Kerma Island, Kume Island, and Daito Islands. No specific information is available for this area at this time.

MARIANA ARCHIPELAGO. The scalloped hammerhead shark depends on all portions of the water column from the shoreline to the outer boundary of the Exclusive Economic Zone (EEZ) within CNMI, Guam, and Palau, to a depth of 300 ft. (90 m) (Western Pacific Regional Fishery Management Council 2004). The scalloped hammerhead shark has been reported from the CNMI and Guam (Myers and Donaldson 2003), and has EFH designated within the boundaries of the MRA Study Area (Western Pacific Regional Fishery Management Council 2004). Females produce 15 to 31 pups per litter, utilizing shallow coastal waters, such as Guam's inner Apra Harbor, as nursery areas (Compagno 1984).

CAROLINE ISLANDS. No specific information is available for this area at this time.

9.3.6 Species-specific Threats

The primary threat to the scalloped hammerhead shark is direct take, especially by the foreign commercial shark fin market (National Oceanic and Atmospheric Administration 2011b). The species is a principal component of the total shark bycatch in the swordfish and tuna longline fishery and shrimp trawls (Branstetter 2002), and is particularly susceptible to overfishing and bycatch in gillnet fisheries because of its schooling habits. Longline mortality is estimated between 91.4 and 93.8% (National Oceanic and Atmospheric Administration 2011b). The schooling behavior of scalloped hammerhead sharks may contribute to their vulnerability to fishing pressure (Food and Agriculture Organization of the United Nations 2012).

Fungal infections (Crow, Brock, and Kaiser 1995) and parasites (Bester 1999) have been observed on scalloped hammerhead sharks. In some cases, fungal infections of captive individuals may affect sensitivity of the lateral line system (Crow, Brock, and Kaiser 1995). Most parasites are kept under control by cleaner wrasses that pick parasites (e.g., copepods) from their skin and from inside their mouths when the sharks visit "cleaning stations" in coral reef ecosystems (Bester 1999).

9.4 KNIFETOOTH SAWFISH (ANOXYPRISTIS CUSPIDATA)

9.4.1 Description

The knifetooth sawfish (*Anoxypristis cuspidata*) is one of seven elasmobranch species in the family Pristidae of the order Pristiformes (sawfishes) (Nelson 2006). They have a flattened head and are somewhat ventrally compressed, with a streamlined body shape similar to other sharks (Seitz 2012). Knifetooth sawfish have small nasal flaps over their nostrils (Froese and Pauly 2012). The dorsal side of the knifetooth sawfish is greyish, and the ventral side and fins are typically pale.

The most distinguishing feature of sawfishes is the long rostral saw extending from its snout. This rostral saw contains lateral teeth-like structures (denticles) along the edges. The rostral saw of the knifetooth sawfish is not distally tapered, containing 18–22 pairs of lateral teeth in specimens from northern Australia waters and 24–25 pairs in specimens originating from the Indo-Pacific (Seitz 2012). Rostral teeth are short, flattened, triangular, and lack grooves along the posterior margins (Deynat 2005; Seitz 2012). The lower quarter of the rostrum, toward the head, lacks teeth and is a distinguishing characteristic of knifetooth sawfish. The dermal denticles along the body and fins are flat and display

three posterior cusps, and fin denticles are slightly larger. Adults have widely spaced dermal denticles, except along the anterior portion of the head and fins (Deynat 2005). Juveniles up to approximately 25 inches (64 cm) in total length lack any denticles (Seitz 2012).

Little information is available on the size, age, and growth of this species; however, a maximum length of approximately 11.5 ft. (3.5 m) has been recorded in Australia (Froese and Pauly 2012). Larger individuals ranging from 6–8 m have been reported, but not confirmed, in India and Thailand (Seitz 2012). Knifetooth sawfish are estimated to be 1.5–2.5 ft. (0.5–0.8 m) long at birth (Seitz 2012).

9.4.2 Status and Management

The current status of all knifetooth sawfish is unknown. The IUCN considers the species "Critically Endangered"(Compagno et al. 2006). At present, no existing protective regulation is effective for this species (Seitz 2012). However, in 2010, Wild Earth Guardians submitted a petition to NMFS requesting threatened or endangered ESA listing for six species of sawfish, including knifetooth sawfish (WildEarth Guardians 2010). The six species included in the petition are *Anoxypristis cuspidate, Pristis clavata, P. microdon, P. pristis, P. zijsron,* and the remaining non-listed populations of *P. pectinata* (National Oceanic and Atmospheric Administration 2011c; WildEarth Guardians 2010). NMFS issued a 90-day finding that the petition warrants a status review, and is completing this work (National Oceanic and Atmospheric Administration 2011c).

9.4.3 Population and Abundance

Data are unavailable regarding the number of remaining populations or individuals of sawfish worldwide. However, all documented populations of sawfish are severely fragmented and have undergone substantial decline (National Oceanic and Atmospheric Administration 2011c). Many known populations have been extirpated from large portions of their historic range, with few or no observations since the 1960s. Voluntary interviews with sawfish fishers reported very few, sporadic observations (National Oceanic and Atmospheric Administration 2011c).

Sawfish landings worldwide were recorded between 1962 and 2001; the highest reported landings were in 1978 (1,759 metric tons [t] [1,939 tons]) (Compagno et al. 2006).

9.4.4 Biology, Ecology, and Behavior

Group Size. No group size information is available for the knifetooth sawfish.

Predator/Prey Interactions. Knifetooth sawfish primarily feed on schooling fishes, such as clupeids, mullet, and squid (WildEarth Guardians 2010). They generally use a side-to-side slashing movement of their rostral saw to impale their prey (Seitz 2012). Some sawfish species may also use their rostrum to scavenge beneath the substrate for benthic crustaceans (National Oceanic and Atmospheric Administration 2011c); however, this behavior is not prevalent among knifetooth sawfish (Wueringer, Peverell, Seymour, Squire, and Collin 2011).

Knifetooth sawfish are preyed upon only by large apex predators. Sharks, including hammerhead sharks (*Sphyrna* sp.), bull sharks (*Carcharhinus leucas*), and copper sharks (*Carcharhinus brachyurus*) (Seitz 2012). Saltwater crocodiles (*Crocodylus porosus*) also prey on knifetooth sawfish (Peverell 2005).

Life History. Knifetooth sawfish life history information is very limited. Like many elasmobranch species, fertilization is internal and development is most likely ovoviviparous (National Oceanic and Atmospheric

Administration 2011c). Embryos develop by consuming their attached yolk sac and emerge in the spring as fully developed juveniles 1.5–2.5 ft. in length. Most sawfishes have litter sizes that range between six and 23 individuals (Seitz 2012). Young sawfish are born with a protective sheath around their rostral teeth to prevent injury to the mother during birth (Seitz 2012). Most sawfish species reproduce once every other year (National Oceanic and Atmospheric Administration 2011c).

The mating habits, gestation period, growth rates, and lifespan of knifetooth sawfish are unknown.

Migration. No data are available on migration of the knifetooth sawfish.

Sensory Capabilities. Whether knifetooth sawfish are hearing generalists or specialists is not known, but they possess a lateral line sensory system, as do many fishes, that is sensitive to particle motion in the water column (Wueringer, Peverell, Seymour, Squire, and Collin 2011). The morphology of this system provides some insight into sawfish feeding strategies. For knifetooth sawfish, the lateral line canals on both the dorsal and ventral sides of the rostrum contain tubules with pores, suggesting that they do not use their rostrum to search in the substrate for prey. Furthermore, lateral line canals located between the mouth and nostrils do not have pores, suggesting that the area near the mouth can perceive stimuli only by direct contact (Wueringer, Peverell, Seymour, Squire, and Collin 2011).

Electroreception is the primary sensory mechanism used by many elasmobranchs, including sawfishes (Kalmijn 1982; Rivera-Vicente, Sewell, and Tricas 2011). They possess ampullary (pouch) organs sensitive to electric fields, but the extent of the sensitivities is unknown. The distribution and density of ampullary canals along the ventral side of the rostrum suggest that electroreception is important to sawfish feeding strategy (Wueringer, Peverell, Seymour, Squire, Kajiura, et al. 2011).

9.4.5 Habitat and Distribution

The knifetooth sawfish is known to occur only in the Indo-West Pacific region between east Africa, Australia, China, and Taiwan; however, its complete distribution is unknown (National Oceanic and Atmospheric Administration 2011c). The Red Sea marks the boundary of its western range, with its eastern range reaching the South China Sea to the Yellow Sea and southwestern Japan, and the southern range extending to the western Philippine Sea and Gulf of Carpentaria (Seitz 2012). The Australian range of the knifetooth sawfish occurs from Cape Talbot east to the northern Great Barrier Reef (Peverell 2005). It is considered “moderately common” in the Gulf of Carpentaria, Australia (Seitz 2012).

The knifetooth sawfish is a benthic species that prefers sandy or muddy bottoms, but possibly occurs over sea grasses and other bottom types (Froese and Pauly 2012). Sawfish are generally encountered in shallow coastal environments, including estuaries and freshwater habitats, often in less than 32 ft. (10 m) in depth (Peverell 2005). Adults have been recorded at depths of 164 ft. (50 m), but these reports are uncommon (National Oceanic and Atmospheric Administration 2011c). Juveniles are most often found in shallower water than adults. Sawfish are often encountered in lower salinity environments such as river mouths and mangrove forests (National Oceanic and Atmospheric Administration 2011c). Knifetooth sawfish have been encountered far upstream in rivers such as the Tachin River in Thailand (Seitz 2012).

Open Ocean Waters of the MRA Study Area

Knifetooth sawfish is a coastal shallow-water species and is not found in open ocean areas (Seitz 2012).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. The distribution of knifetooth sawfish includes southwestern Japan (Seitz 2012), to the southern portion of Honshū (WildEarth Guardians 2010).

MARIANA ARCHIPELAGO. No specific information regarding knifetooth sawfish is available for this area.

CAROLINE ISLANDS. No specific information regarding knifetooth sawfish is available for this area.

9.4.6 Species-specific Threats

Bycatch and entanglement from net and hook-and-line fisheries appear to be the largest threat to the knifetooth sawfish throughout most of its range (Seitz 2012). This fish is highly vulnerable to net entanglement because of its elongated, tooth-covered rostrum, and many are injured or killed during removal (WildEarth Guardians 2010). It is also thought that predation increases on net-entangled sawfish (National Oceanic and Atmospheric Administration 2011c). Certain fisheries have targeted this species for its highly prized rostrum, which is used in traditional medicine and religious offerings, and sold as curios (Seitz 2012).

The parasites *Nonacotyle pristis* and *Neoheterocotyle darwinensis* that inhabit the gills of other sawfishes may also occur in knifetooth sawfish (Seitz 2012).

9.5 HUMPHEAD WRASSE (CHEILINUS UNDULATUS)

9.5.1 Description

The humphead wrasse (*Cheilinus undulates*), also known as the Napolean or Maori wrasse, is one of the largest reef fishes in the world (Sadovy 2010), with a maximum size exceeding 6 feet (2 m) and 420 pounds (190 kg) (Choat et al. 2006). Juviniles are white and black, becoming pale to olive and blue-green with an elongated black spot on each scale as they mature. Two black lines that extend from each eye, are present in all color phases. Adults exhibit large lips and a predominate dorsal hump on their head (National Marine Fisheries Service 2009).

9.5.2 Status and Management

Even in remote and undisturbed habitats, natural densities of this species are low(Choat et al. 2006), although populations are typically higher where preferred habitat exists. The humphead wrasse is identified as an ESA candidate species, throughout its range (National Marine Fisheries Service 2013). A status review is currently underway to determine whether it will be listed under the ESA. This species falls under Appendix II in CITES, throughout its range (National Marine Fisheries Service 2009). The humphead wrasse is also a Management Unit Species in the Coral Reef Ecosystems Fisheries Management Plan for the Western Pacific Regional Fishery Management Council, where it is identified as heavily fished in many of the management areas (Western Pacific Regional Fishery Management Council 2009). In 1996, Palau set aside management areas, and juveniles have begun to thrive in those areas. The management in Palau also bans the export of fish under 25 inches (64 cm) in total length. In 2006 the Government of Palau placed a total moratorium on fishing for the humphead wrasse (National Marine Fisheries Service 2009).

9.5.3 Population and Abundance

Densities of humphead wrasse are low (less than 20 per 10,000 square meters), even within preferred habitats (National Marine Fisheries Service 2013). This was once an economically important species for Guam, yet is now rarely seen on its reefs. Biology, Ecology, and Behavior

Group Size. Humphead wrasse are a generally solitary species, requiring a large area of reef for each adult. As such, even among unexploited populations, the humphead wrasse rarely exceeds densities of 1 to 8 individuals per acre of reef (WildEarth Guardians 2012). Females pairs are also seen, or in groups with 2 to 7 individuals (National Marine Fisheries Service 2009).

Predator/Prey Interactions. Humphead wrasse diet consists of mollusks, other fishes, crustaceans, sea urchins, and invertebrates. They are also known to prey upon some toxic animals, such as sea horses, boxfish, and crown-of-thorns starfish (Sadovy 2010). Since the humphead wrasse is such a large reef fish, it has few predators (National Marine Fisheries Service 2009).

Life History. The humphead wrasse is a large, longlived, slow growing, and naturally rare species. The humphead wrasse are long-lived and can live at least 30 yrs (Choat et al. 2006). Humphead wrasse have delayed reproduction and thus, low rates of replenishment (National Marine Fisheries Service 2009). Sexual maturity is reached at 5 to 7 years (Choat et al. 2006). The generation time is thought to be 10 yrs or more, thus contributing to the low rate of population replenishment (National Marine Fisheries Service 2009). Spawning activity is tidally influenced and, can occur in any month of the year (Russell 2004). The spawning location appears unrelated to reef formation type, and is not far from where an individual is living. This species exhibits protogynous hermaphroditism, where individuals can change form female to male (National Marine Fisheries Service 2009). The factors leading to their sex change is not well understood.

Migration. Humphead wrasse move from locations on the reef where they live as solitary animals, to spawning locations, but are not believed to relocate for spawning far from where they are living (National Marine Fisheries Service 2009).

9.5.4 Habitat and Distribution

This species is widely distributed in coral reefs and inshore habitats. It is found throughout much of the Indo-Pacific (Russell 2004). Adult humphead wrasse are thought to prefer steep outer reef edges, channels, and lagoon reef slopes at about 2–60 m depth (Sadovy et al. 2003; WildEarth Guardians 2012). Adults have been documented by divers as a sedentary species which remains in one reef location for a long period of time. Juveniles often occur within the shelter of dense branching coral, algae and seagrasses (Tupper 2007). Juveniles typically occur inshore, while larger fish are more common in deeper, outer reefs or lagoons (Sadovy et al. 2003). The presence of seagrass habitats enhances the adult densities of the humphead wrasse on adjacent coral reefs (Dorenbosch et al. 2006).

Open Ocean Waters of the MRA Study Area. The humphead wrasse is a reef-dependent species and does not occur in the open ocean.

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. The humphead wrasse is known to occur in the southern Islands of Japan, from the Ryukyu Islands to the southern tip of Kyushu and the Ogasawara Islands (Froese and Pauly 2011).

MARIANA ARCHIPELAGO.

Guam. In Guam, the humphead wrasse typically occurs in bushy macroalgae and mixed branching coral habitats (Tupper 2007). This was once and economically important species for Guam, yet is now rarely seen on its reefs (National Marine Fisheries Service 2009).

Marianas Islands. During NOAA Coral Reef Ecosystem Division marine surveys, large individuals of the humphead wrasse were observed in the southern islands, with a mean density of 10.9 individuals per square km of reef (Brainard et al. 2012). In the northern islands (north of Farallon de Medinilla), densities were about 2.2 individuals per square km of reef. Average size was 115.8 cm and 92.8 cm for southern and northern individuals, respectively. The highest mean density of 39.5 individuals per square km of reef was recorded at Rota, although this was much higher than any other location with the CNMI (Brainard et al. 2012).

CAROLINE ISLANDS. The humphead wrasse is known to occur throughout the Caroline Islands, including Yap and Palau (Froese and Pauly 2011). In Palau, the humphead wrasse typically occurs in bushy macroalgae and mixed branching coral habitats (Tupper 2007). In 1996, Palau set aside management areas, and juveniles have begun to thrive in those areas. The management in Palau also bans the export of fish under 25 in in total length. Also, during the summer of 2006 the Government of Palau places a temporary memorandum on fishing for the humphead wrasse (National Marine Fisheries Service 2009).

9.5.5 Species-specific Threats

Habitat loss and degradation, the marine aquarium trade, and poor fisheries management are also factors in the decline of their population on tropical reefs across the Western Pacific (National Marine Fisheries Service 2009). The primary threat to the humphead wrasse is intensive directed reef fishing, for use in the food trade or for personal consumption. In areas where this fish is even lightly fished, population reductions of up to 25% are seen (Russell 2004). Fishing is done commercially or by the use of SCUBA and spears at night (National Marine Fisheries Service 2009). In many areas, the live reef fish trade has caused severe depletions of the humphead wrasse (Poh and Fanning 2012). Destructive fishing techniques such as dynamite fishing and sodium cyanide, and other illegal, unregulated, and unreported fisheries have further exacerbated this issue (National Marine Fisheries Service 2009). The global annual take of this species is believed to be around 400 metric tonnes (Sadovy et al. 2003). The use of sodium chloride for fishing, also kills coral, which reduces the foraging habitat of the surviving population (Sadovy et al. 2003). The late age at maturity combined with the protogynous hermaphroditic life history of this species makes it especially vulnerable to overfishing (Sadovy et al. 2003). Humphead wrasse are beginning to be farm-raised, or cultured, to meet growing demand, internationally. This also poses problems for wild populations as juveniles are taken from the reef, before they have an opportunity to reproduce, and are grown to market size in offshore aquaculture operations. This practice, in addition to the demand of juvenile humphead wrasse in the aquarium trade, is reducing the number of juveniles seen on a reef (Sadovy et al. 2003) and consequently the number of mature individuals contributing to the spawning population. The full reproduction cycle of this fish is not well understood, thus the removal of immature fish has negative consequenses on total reproductive potential within a population.

9.6 TAXONOMIC GROUPS

Taxonomic groupings of marine fishes in the MRA Study Area are listed in Table 9-2. These taxonomic groups are included to provide information on other marine fishes representative of the MRA Study

Area but not federally managed, and to supplement the ESA-listed species profiles. Additional information on the federally managed species (and management units) within each of these groups is included in Chapter 10, Essential Fish Habitat.

Table 9-2: Major Taxonomic Groups of Marine Fishes within the MRA Study Area

Major Marine Fish Groups[1]		Ecoregional Presence[2]	
Common Name (Taxonomic Group)	**Description**	**Open Ocean**	**Coastal Waters**
Jawless fishes (order Myxiniformes and order Petromyzontiformes)	Hagfishes (Myxiniformes) are the most primitive fish group (Nelson 2006). In fact, recent taxonomy for this group suggests that Myxiniformes are a "sister" group to vertebrates altogether (Nelson 2006). However, these are generally thought of as fishes and are therefore included in this section. Hagfishes occur exclusively in marine habitats and include 70 species worldwide in temperate marine locations. They feed on dead or dying fishes and have very limited external features often associated with fishes, such as fins and scales (Helfman et al. 2009). The members of this group are important scavengers that recycle nutrients back through the ecosystem. Lampreys (Petromyzontiformes) are represented by approximately 11 marine or saltwater/freshwater species distributed primarily throughout the temperate regions of the Northern Hemisphere, between the surface and 4,000 ft. Lampreys typically are parasitic, feeding on other live fishes. The most striking feature of the lampreys is the oral disc mouth, which they use to attach to other fishes and feed on their blood (Moyle and Cech 1996; Nelson 2006). Hagfishes and lampreys occur in the seafloor habitats of all open ocean areas and coastal waters of the MRA Study Area (Paxton and Eshmeyer 1998). Hagfishes are typically found at depths greater than 80 ft. (25 m) and temperatures below 55°F (13°C).	Water column, seafloor	Seafloor
Sharks, skates, rays, and chimaeras (class Chondrichthyes)	The cartilaginous (non-bony) marine fishes of the class Chondrichthyes are distributed throughout the world's oceans, occupying all areas of the water column (Paxton and Eshmeyer 1998). This group is mainly predatory and contains many of the top predators found in the ocean, such as the white shark (*Carcharodon carcharias*), mako shark (*Isurus oxyrinchus*), and tiger shark (*Galeocerdo cuvier*) (Helfman et al. 2009). As filter-feeders, the whale shark (*Rhincodon typus*), manta ray (*Manta birostris*), and basking shark (*Cetorhinus maximus*) are notable exceptions. Sharks, skates, and rays have protective tooth-like scales called placoid scales and no swim bladder. While not exclusive to sharks, skates, and rays, specialized sensory systems (electroreception and mechanoreception) allow them to detect and respond to electrical or mechanical impulses (Collin and Whitehead 2004; Kajiura and Fitzgerald 2009; Marcotte and Lowe 2008; McGowan and Kajiura 2009; Rivera-Vicente, Sewell, and Tricas 2011). Sharks, skates, and rays also bear young in a variety of life history strategies, including vivipary, ovipary, or ovovivipary (a combination of vivpary and ovipary) (Moyle and Cech 1996). The subclass Elasmobranchii contains more than 850 marine species, including sharks, skates, and rays spread across nine orders (Nelson 2006). Sharks, skates, and rays occupy relatively shallow temperate and tropical waters throughout the world. More than half of these species occur in less than 655 ft. (200 m) of water and nearly all are found at depths less	Surface, water column, seafloor	Surface, water column, seafloor

Table 9-2: Major Taxonomic Groups of Marine Fishes within the MRA Study Area

Major Marine Fish Groups[1]		Ecoregional Presence[2]	
Common Name (Taxonomic Group)	**Description**	**Open Ocean**	**Coastal Waters**
	than 6,560 ft. (2,000 m) (Nelson 2006). Very little is known about the Holocephali subclass, which contains 58 marine species of chimaeras (Nelson 2006). Chimaeras are cool-water marine fishes that inhabit depths between 260 and 8,500 ft. (80 and 2,600 m) (Nelson 2006). They occur in the open-ocean portions of the MRA Study Area, up to the lower continental shelf (Paxton and Eshmeyer 1998).		
Sturgeons (order Acipenseriformes)	Sturgeon (order Acipenseriformes) are among the most primitive orders in the class Actinopterygii (Nelson 2006). Twenty-seven species of sturgeon are found worldwide, most of which migrate between freshwater and saltwater. Four sturgeon species may occur within the Japan portion of the MRA Study Area only (Chinese sturgeon [*Acipenser sinensis*], Amur sturgeon [*Acipenser schrenckii*], Kaluga [*Huso dauricus*], and Sakhalin sturgeon [*Acipenser mikadoi*]) (Froese and Pauly 2012).	Not Present	Surface, water column, seafloor
Eels and bonefishes (order Anguilliformes, order Elopiformes)	The eels (Anguilliformes) have an elongated snakelike body. These fishes have a unique leptocephalus larval stage (small head and a long, thin body). Eels generally feed on other fishes or on small bottom-dwelling invertebrates, but they also feed on larger organisms (Helfman et al. 2009). Moray eels, snake eels, and conger eels occur in the MRA Study Area (Paxton and Eshmeyer 1998). The fishes in the order Elopiformes include two distinct groups that exhibit very different forms: the bonefishes, predators of shallow tropical waters, and the little-known spiny eels that feed on decaying organic matter in deep ocean areas (Paxton and Eshmeyer 1998). Eels are found in all marine habitat types, although most inhabit shallow subtropical or tropical marine waters (Paxton and Eshmeyer 1998) in the MRA Study Area. Eels utilize the south and north equatorial currents to migrate to their spawning habitats in the western South Pacific region (Miller et al. 2006). Very little is known about the halosaurs and spiny eels, found at depths ranging from 400 to 16,000 ft. (120 to 4,900 m) in the open-ocean portions of the MRA Study Area and throughout the North Pacific Subtropical Gyre on the seafloor and in the water column (Paxton and Eshmeyer 1998).	Surface, water column, seafloor	Surface, water column, seafloor
Herrings (order Clupeiformes)	Many of the 364 species of the order Clupeiformes are found primarily in the Indo-West Pacific Ocean or the western Atlantic Ocean. These herring, menhaden, sardine, and anchovy species are the basis of many commercial fisheries (Nelson 2006). While not exclusive to this group, the schooling behavior exhibited by herrings helps to conserve energy and minimize predation (Brehmer et al. 2007). Herrings account for a large portion (approximately 20%) of the total worldwide fish catch (Food and Agriculture Organization of the United Nations 2005, 2009). Pacific herring (*Clupea pallasii*) are included in this group. Herrings are also an important part of marine food webs because they are the targeted prey for many marine species, including other fishes,	Surface, water column	Surface, water column

Table 9-2: Major Taxonomic Groups of Marine Fishes within the MRA Study Area

Major Marine Fish Groups[1]		Ecoregional Presence[2]	
Common Name (Taxonomic Group)	**Description**	**Open Ocean**	**Coastal Waters**
	birds, and mammals. The clupeids feed on organic matter and plankton (Moyle and Cech 1996). Herring are common in the coastal waters of the MRA Study Area, including all of the large marine ecosystems (Paxton and Eshmeyer 1998).		
Dragonfishes and lanternfishes (orders Stomiiformes and Myctophiformes)	At more than 500 species, the orders Stomiiformes and Myctophiformes are one of the largest groups of the world's deepwater fishes; containing nearly 60% of total biomass in the deep sea (Nelson 2006). Many of the species in these orders are not very well described in the scientific literature (Nelson 2006); thus their ecological role is also not well understood (Helfman et al. 2009). These fishes are known for their unique body forms and light-producing capabilities. Other adaptations that likely present some advantages in the deepwater habitats in which they occur include large mouths, sharp teeth, and sensory systems that allow them to find prey and avoid predators in total darkness (Haedrich 1996; Koslow 1996; Marshall 1996; Rex and Etter 1998; Warrant and Locket 2004). The dragonfishes and lanternfishes typically occur in deep ocean waters, ranging from 3,280 to 16,000 ft. (1,000 to 4,900 m) in the open-ocean portions of the MRA Study Area, and throughout the North Pacific Subtropical Gyre (Paxton and Eshmeyer 1998), although some myctophids do occur closer to the surface during daily vertical migrations, providing a food source for some marine mammals.	Water column, seafloor	Water column, seafloor
Greeneyes, lizardfishes, lancetfishes, and telescopefishes (order Aulopiformes)	Fishes of the order Aulopiformes are a diverse group that possess both primitive features (adipose fin, abdominal pelvic fins, rounded scales, and absence of fin spines) and advanced features (unique swim bladder and jawbone) of marine fishes (Paxton and Eshmeyer 1998). They are common in estuarine and coastal waters as well as deep ocean waters. The lizardfishes (Synodontidae), Bombay ducks (Harpadontidae), and greeneyes (Chlorophthalmidae) primarily occur in coastal waters to the outer shelf, where they rest on the bottom and are well camouflaged with the substrate (Paxton and Eshmeyer 1998). Lancetfishes (Alepisauridae) are primarily mid-water column fishes, but can be found ranging from the surface to deep water. Telescopefishes are primarily found in deep waters from 1,640 to 3,280 ft. (500 to 1,000 m), but they can also be found at shallower depths and may approach the surface at night (Paxton and Eshmeyer 1998). In general, greeneyes, lizardfishes, and lancetfishes occur in the coastal waters of the MRA Study Area, while telescopefishes occur primarily in the deeper waters associated with the open oceans of the MRA Study Area (Paxton and Eshmeyer 1998).	Seafloor	Water column, seafloor
Cods (orders Gadiformes and	The cods and cusk eels include more than 900 species, several of which are important target species of commercial fisheries. The cods, or groundfish, account for a substantial portion of the world's commercial	Water column,	Water column,

Table 9-2: Major Taxonomic Groups of Marine Fishes within the MRA Study Area

Major Marine Fish Groups[1]		Ecoregional Presence[2]	
Common Name (Taxonomic Group)	**Description**	**Open Ocean**	**Coastal Waters**
Ophidiiformes)	fishery landings (Food and Agriculture Organization of the United Nations 2005). Gadiforms, such as cods, are almost exclusively marine fishes, and occupy seafloor habitats in temperate to arctic regions. Cods are generally found near the bottom in these continental shelf areas, and feed on benthic resources (Paxton and Eshmeyer 1998). The order Ophidiiformes includes cusk eels and brotulas, which have long eel-like tapering bodies and are distributed in deepwater areas throughout the tropical and temperate oceans. Several cusk eel species are open-ocean or are found on the continental shelves and slopes. Cusk eels occur near the seafloor of the tropical and temperate coastal waters of the MRA Study Area (Paxton and Eshmeyer 1998).	seafloor	seafloor
Toadfishes and anglerfishes (orders Batrachoidiformes and Lophiiformes)	The toadfishes and anglerfishes include nearly 400 species, but the order Batrachoidiformes includes only the toadfish family. Many toadfishes produce sounds by vibrating their swim bladder (Luczkovich, Mann, and Rountree 2008). They spawn in and around bottom structures and invest a substantial amount of parental care by defending their nests, a trait uncommon in most marine fishes (Paxton and Eshmeyer 1998). The order Lophiiformes includes all of the world's anglerfishes, goosefishes, frogfishes, batfishes, and deepwater anglerfishes, most of which occur in seafloor habitats of all oceans. Some deepwater anglerfish use highly modified "lures" containing photophores (light-emitting organs) to attract prey (Helfman et al. 2009; Koslow 1996). Only the females have lures, while the males are small and parasitic, and spend their lives attached to the side of the female (Helfman et al. 2009). These fishes are also an important predator among the deepwater seafloor habitats of the MRA Study Area (Nelson 2006). The primary distribution of the toadfishes in the MRA Study Area is limited to coastal seafloor habitats in all of the large marine ecosystems. Anglerfishes are also found in seafloor habitats but with a wider distribution covering all waters of the MRA Study Area (Froese and Pauly 2012).	Seafloor	Seafloor
Mullets, silversides, needlefishes, and killifish (orders Mugiliformes, Atheriniformes, Beloniformes, and Cyprinodontiformes)	Mugiliformes (mullets) include 71 marine species that occupy coastal marine and estuarine waters of all tropical and temperate oceans. Disagreement has arisen regarding the species classification of this group: some have included this group in the super order Athinerimorpha (Nelson 2006), while others have placed it as a suborder in the Perciformes (Moyle and Cech 1996). Mullets feed on organic matter in estuaries, and possess a filter-feeding mechanism, with a gizzard-like digestive tract. They feed on the bottom by scooping up food and retaining it in their very small gill rakers (Moyle and Cech 1996). The feeding behavior of goatfishes stirs up sediments, transporting and depositing associated detritus particles in other habitats as allochthonous inputs (Uiblein 2007). Atherinomorpha contains the silversides (Atheriniformes), needlefishes and flyingfishes	Surface	Surface, water column, seafloor

Table 9-2: Major Taxonomic Groups of Marine Fishes within the MRA Study Area

Major Marine Fish Groups[1]		Ecoregional Presence[2]	
Common Name (Taxonomic Group)	**Description**	**Open Ocean**	**Coastal Waters**
	(Beloniformes), and killifishes (Cyprinodontiformes). Most species in these groups are important prey in all estuarine habitats in the MRA Study Area (Paxton and Eshmeyer 1998). Most of these fishes are found in tropical or temperate marine waters, and occupy shallow habitats near the water surface. Exceptions to this nearshore distribution are the flyingfishes and halfbeaks, which occur in oceanic or shallow coastal regions where light penetrates, in tropical to warm-temperate regions. The silversides are a small inshore species often found in intertidal habitats. The Cyprinodontiformes include the killifishes, which are often associated with intertidal coastal zones and salt marsh habitats, and are highly tolerant of pollution. These fishes are found in all coastal waters and open ocean areas of the MRA Study Area (Froese and Pauly 2012).		
Oarfishes, squirrelfishes, dories (orders Lampridiformes, Beryciformes, Zeiformes)	The order Lampridiformes includes only 19 species, the oarfishes (Nelson 2006). They exhibit diverse body shapes, and some have a protruding mouth that allows for a suction feeding technique while feeding on plankton. Other species, including the crestfish, possess grasping teeth used to catch prey. They occur only in the mid-water column of the open ocean, and are rarely observed (Nelson 2006). Fishes in the order Beryciformes are primarily nocturnal species, many of which are poorly described. A few shallow-water exceptions, including squirrelfishes, are distributed throughout reef systems in tropical and subtropical marine regions (Nelson 2006). Squirrelfishes are an important food source for subsistence fisheries (Froese and Pauly 2012). They possess specialized eyes and large mouths, and primarily feed on bottom-dwelling crustaceans (Goatley and Bellwood 2009). Very little is known about the order Zeiformes, or dories, which includes some very rare families, many containing only a single species (Paxton and Eshmeyer 1998). Even general information on their biology, ecology, and behavior is limited. Squirrelfishes are common in coral reef systems in the MRA Study Area. Most of the Lampridiformes and Zeiformes are confined to seafloor regions in all coastal waters of the MRA Study Area, as well as the open ocean areas at depths of 130–330 ft. (40–100 m) (Moyle and Cech 1996).	Surface, water column, seafloor	Surface, water column, seafloor
Pipefishes and seahorses (order Gasterosteiformes)	Gasterosteiformes include sticklebacks, pipefishes, and seahorses, many of which are common in the MRA Study Area. Most of these species are found in brackish water throughout the world (Nelson 2006) and occur in surface, water column, and seafloor habitats. Small mouths on a long snout and armor-like scales are characteristic of this group. Most of these species exhibit a high level of parental care by the males (Sogabe and Yanagisawa 2007), either through nest-building (sticklebacks) or brooding pouches (seahorses, pipefishes), which results in production of relatively few young (Helfman et al. 2009). This group also includes the	Not Present	Surface, water column, seafloor

Table 9-2: Major Taxonomic Groups of Marine Fishes within the MRA Study Area

Major Marine Fish Groups[1]		Ecoregional Presence[2]	
Common Name (Taxonomic Group)	**Description**	**Open Ocean**	**Coastal Waters**
	trumpetfishes and cornetfishes, which are ambush predators, with large mouths used to capture smaller fishes. This group is associated with tropical and temperate reef systems. They are found in the coastal waters of the MRA Study Area in the large marine ecosystems, but not in the open ocean (Froese and Pauly 2012). They also migrate into freshwater streams on Okinawa (Maeda and Tachibara 2010).		
Scorpionfishes (order Scorpaeniformes)	The order Scorpaeniformes is a diverse group of more than 1,400 marine species, all with bony plates or spines near the head. Many of these species have venomous spines. This group contains the scorpionfishes, waspfishes, rockfishes, velvetfishes, pigfishes, sea robins, gurnards, sculpins, snailfishes, and lumpfishes (Paxton and Eshmeyer 1998). Many of these fishes have modified pectoral fins or suction discs adapted for inhabiting the seafloor of the marine environment, where they feed on smaller crustaceans and fishes. Sea robins are capable of generating sounds with their swim bladders, and are among the noisiest of all fish species (Moyle and Cech 1996). Scorpionfishes are widely distributed in open-ocean and coastal habitats, at all depths, throughout the world. They occur in all waters of the MRA Study Area. Most occur at depths of less than 330 ft. (100 m), but others are found in deepwater habitat down to 7,000 ft. (2,200 m) (Paxton and Eshmeyer 1998).	Seafloor	Seafloor
Drums, snappers, snooks, Temperate Basses, and Reef Fishes (order Perciformes*** with representative families; Sciaenidae, Lutjanidae, Centropomidae, Moronidae, Apogonidae, Chaetodontidae, Pomacanthidae, and Mullidae)	The families Sciaenidae and Lutjanidae include mainly predatory coastal marine fishes, including the recreationally important snappers, drums, and croakers. These fishes are sometimes distributed in schools as juveniles, and then become more solitary as they grow larger. They feed on fishes and crustaceans. Drums and croakers (Sciaenidae) produce drumming sounds via their swim bladders, and like the sea robin, are among the noisiest of all fish species. The snappers (Lutjanidae) are generally associated with the seafloor, and tend to congregate near structured habitats, including natural and artificial structure (Moyle and Cech 1996). Snappers also generate sound (Luczkovich et al. 2008). Other representative families in this group include the brightly colored and diverse forms of reef-associated cardinalfishes (Apogonidae), butterflyfishes (Chaetodontidae), some of which generate sound, and angelfishes (Pomacanthidae) (Paxton and Eshmeyer 1998). Perciforms are widely distributed in open-ocean and coastal habitats throughout the world. They are particularly concentrated at depths of less than 330 ft. (100 m). They are often associated with reef systems in the temperate and tropical coastal waters of the MRA Study Area (Froese and Pauly 2012).	Surface, water column, seafloor	Surface, water column, seafloor

Table 9-2: Major Taxonomic Groups of Marine Fishes within the MRA Study Area

Major Marine Fish Groups[1]		Ecoregional Presence[2]	
Common Name (Taxonomic Group)	**Description**	**Open Ocean**	**Coastal Waters**
Groupers and sea basses (order Perciformes***, with representative families; Serranidae)	The family Serranidae are primarily nearshore marine fishes that support recreational and commercial fisheries. Sea basses and groupers are nocturnal predators found primarily in coastal and offshore reef systems in the tropical/temperate portions of the MRA Study Area. They possess large eyes and mouths, and feed mostly on bottom-dwelling fishes and crustaceans (Goatley and Bellwood 2009). Some groupers and sea basses take advantage of feeding opportunities in the low-light conditions of twilight when countershaded fishes (dark colored dorsal, light colored ventral) become conspicuous and are easier for these predators to locate (Rickel and Genin 2005). Other groupers are active during the day and exhibit a variety of opportunistic predatory strategies (Wainwright and Richard 1995). Some of the serranids are protogynous hermaphrodytes (Coulson et al. 2009; Kline, Khan, and Holt 2011)—beginning life as female and then become male as they grow larger (Moyle and Cech 1996). Their slow maturation has caused a change in the conservation status of many of the grouper species in the MRA Study Area from vulnerable to critically endangered (International Union for Conservation of Nature and Natural Resources 2010).	Water column, seafloor	Surface, water column, seafloor
Wrasses and parrotfishes (order Perciformes***, with representative families; Labridae and Scaridae)	The suborder Labroidei includes many nearshore marine reef or structure-associated fishes, including the diverse wrasses (Labridae) and parrotfishes (Scaridae). Most of the wrasses are conspicuous, brightly colored, coral reef fishes, but others are found in temperate waters. Most are active during the day, and exhibit a variety of opportunistic predatory strategies, such as ambush (Wainwright and Richard 1995). Parrotfishes provide important ecological functions to the reef system by grazing on coral and processing sediments (Goatley and Bellwood 2009). Similar to the Serranidae, many wrasses and parrotfishes begin life as female but change into male as they grow larger (Asoh 2005; McCormick et al. 2010; Morton et al. 2008), and they exhibit a variety of reproductive strategies among the species and between populations (Moyle and Cech 1996).	Water column, seafloor	Surface, water column, seafloor
Gobies, blennies, damselfishes (order Perciformes***, with representative suborders; Gobioidei, Blennioidei, and Acanthuroidei)	The seafloor-dwelling gobies (suborder Gobioidei) include Gobiidae, the largest family of marine fishes (Nelson 2006), which have modified pelvic fins that allow them to adhere to various bottom surfaces (Helfman et al. 2009). Fishes of the suborder Blennioidei primarily occupy the intertidal zones throughout the world (Mahon et al. 1998; Moyle and Cech 1996; Nelson 2006). The blennies and gobies primarily feed on seafloor detritus. The suborder Acanthuroidei contains the surgeonfishes, moorish idols, and rabbitfishes of tropical reef systems. They have elongated small mouths used to scrape algae from coral. These grazers provide an important function to the reef system by controlling growth of algae on the reef (Goatley and Bellwood 2009). The territorial nature of damselfishes may actually facilitate some level of protection from coral predators; Gochfeld et al. (Gochfeld 2010) reported significantly higher coral diversity within damselfish territories at several western Pacific sites, including one site in Guam. Some of these species are adapted to target particular	Surface, water column, seafloor	Surface, water column, seafloor

Table 9-2: Major Taxonomic Groups of Marine Fishes within the MRA Study Area

Major Marine Fish Groups[1]		Ecoregional Presence[2]	
Common Name (Taxonomic Group)	**Description**	**Open Ocean**	**Coastal Waters**
	prey species; for example, the elongated snouts of butterflyfishes allow them to bite off exposed parts of invertebrates (Leysen et al. 2010). This group is widely distributed throughout the world, primarily in coastal habitats. The fishes occur in all coastal waters of the MRA Study Area, but they are mostly concentrated and exhibit the most varieties at depths of less than 100 ft. (31 m) (Froese and Pauly 2012).		
Jacks, tunas, mackerels, and billfishes (order Perciformes***, with representative families; families Carangidae, Scombridae, Xiphiidae, and Istiophoridae)	The suborder Scombroidei contains some of the most voracious open-ocean predators, besides sharks: the jacks, mackerels, barracudas, billfishes, and tunas (Estrada et al. 2003; Sibert et al. 2006). Many jacks are known to feed nocturnally (Goatley and Bellwood 2009) and in the low light of twilight (Rickel and Genin 2005) by ambushing their prey (Sancho 2000). The open-ocean, highly migratory tunas, mackerels, and billfishes are extremely important to fisheries; they constitute a large component of the total annual worldwide catch by weight, with tunas and swordfish as the most important species (Food and Agriculture Organization of the United Nations 2005, 2009). One unique adaptation found in these fishes is ram ventilation (Wegner, Sepulveda, and Graham 2006), which uses the motion of the fish through the water to increase respiratory efficiency (Wegner, Sepulveda, and Graham 2006). Many fishes in this group undergo large-scale migrations that allow feeding in highly productive areas, which vary by season (Pitcher 1995). These fishes occupy the largest area of ocean, but make up only about 2% of the total marine fishes (Froese and Pauly 2010; Froese and Pauly 2012; Helfman et al. 2009). They are mostly found near the surface or in the upper portion of the water column, in all coastal waters and open ocean areas of the MRA Study Area, including all of the large marine ecosystems.	Surface	Surface, water column
Flounders (order Pleuronectiformes)	The order Pleuronectiformes includes flatfishes (flounders, sanddabs, soles, and tonguefishes) found in all marine seafloor open-ocean and coastal habitats throughout the world (Nelson 2006). They are particularly concentrated and exhibit the most varieties at depths of less than 330 ft. (100 m) which is often associated with sandy bottoms in the MRA Study Area (Paxton and Eshmeyer 1998).Fishes in this group have eyes on either the left side or the right side of the head, and are not symmetrical like other fishes (Saele et al. 2004). Flounders do not possess swimbladders and therefore are not sensitive to underwater sounds (U.S. Department of the Navy 2005). All flounder species are ambush predators, feeding mostly on other fishes and bottom-dwelling invertebrates (Drazen and Seibel 2007; Froese and Pauly 2010; Froese and Pauly 2012). Several species of flounder are common within the Japan portion of the MRA Study Area: flathead flounder (*Hippoglossoides dubius*), Kamchatka flounder (*Atheresthes evermanni*), roughscale sole (*Clidoderma*	Seafloor	Seafloor

Table 9-2: Major Taxonomic Groups of Marine Fishes within the MRA Study Area

Major Marine Fish Groups[1]		Ecoregional Presence[2]	
Common Name (Taxonomic Group)	**Description**	**Open Ocean**	**Coastal Waters**
	asperrimum), slime flounder (*Microstomus achne*), and Korean flounder (*Glytocephalus stelleri*) (Hattori et al. 2010).		
Triggerfishes, puffers, and molas (order Tetraodontiformes)	The fishes in the order Tetraodontiformes are the most highly evolved group of modern bony fishes (Nelson 2006). This order includes the triggerfishes, filefishes, puffers, and ocean sunfishes. Like the flounders, this group exhibits body shapes unique among marine fishes, including modified spines or other structures advantageous in predator avoidance. The unique body shapes also require use of a fin-propulsion swimming style, rather than body propulsion, because some species lack the muscle structure and body shape of other fishes (Wainwright and Richard 1995). The ocean sunfishes (*Mola* species) are the largest, and most fecund, bony fish (Moyle and Cech 1996). They occur very close to the surface, are slow swimmers, and feed on a variety of plankton, jellyfish, crustaceans, and fishes (Froese and Pauly 2012). Their only natural predators are sharks, orcas, and sea lions (Helfman et al. 2009). Most other species in this group are associated with reef systems. This group is widely distributed in tropical and temperate bottom or mid-water column habitats (open-ocean and coastal) throughout the world. They occur in all waters of the MRA Study Area, but are particularly concentrated and exhibit the most varieties at depths of less than 330 ft. (100 m). This habitat is often associated with reefs or structured seafloors in the coastal waters and open-ocean portions of the MRA Study Area (Paxton and Eshmeyer 1998). One major exception is the ocean sunfishes, which occur at the surface in all open ocean areas (Helfman et al. 2009).	Surface, water column, seafloor	Surface, water column, seafloor

Notes: the MRA Study Area = MRA Study Area for the Japan and Mariana Archipelagos, ft. = feet, m = meters.
[1] Taxonomic groups are based on the following commonly accepted references: (Helfman et al. 2009; Moyle and Cech 1996; Nelson 2006).
[2] Ecoregional presence relates to open ocean and coastal waters of the MRA Study Area.
*** The fishes in this section are all in the order Perciformes, the largest order of vertebrates (Nelson 2006), representing approximately 40% of all bony fishes. Representative families are included here to cover this diversity.

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10.0 MANAGED SPECIES AND ESSENTIAL FISH HABITAT

10.1 INTRODUCTION

The fisheries of the United States (U.S.) are managed within a framework of overlapping federal, state, interstate, and tribal authorities. Individual states and territories typically have jurisdiction over fisheries in marine waters within 3 nautical miles (nm) of their coasts. Federal jurisdiction includes fisheries in marine waters inside the U.S. Exclusive Economic Zone (EEZ), which typically encompasses the area from 3 nm out to 200 nm offshore of any U.S. territorial coastline (except when EEZs overlap, in which case the relevant states, territories, or nations delineate the maritime boundary) (National Oceanic and Atmospheric Administration 1996). Within the MRA Study Area for the Japan and Mariana Archipelagos (the MRA Study Area), the U.S. EEZ comprises only the Northern Mariana Islands and U.S. Territory of Guam (Guam) EEZ; other nations (e.g., Japan, China, Palau, Federated States of Micronesia) have jurisdiction for fisheries management within their own EEZs.

As described in Chapter 2 (Applicable Legislation), the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) was amended by the Sustainable Fisheries Act of 1996 (Public Law 104-267), and followed a decade later by the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006. The reauthorized MSFCMA mandated numerous changes to the existing legislation designed to prevent overfishing, rebuild depleted fish stocks, minimize bycatch, enhance research, improve monitoring, and protect fish habitat. The term “fish” is defined in the MSFCMA as “finfish, molluscs, crustaceans, and all other forms of marine animals and plant life other than marine mammals and birds.” One of the most significant mandates in the MSFCMA that came out of the reauthorization was the essential fish habitat (EFH) provision, which specifies the means to conserve fish habitat.

The EFH mandate requires that the regional fishery management councils, through federal fishery management plans, describe and identify EFH for each federally managed species; minimize, to the extent practicable, adverse effects on such habitat caused by fishing; and identify other actions to encourage conservation and enhancement of such habitats. Congress defines EFH as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity” (16 U.S.C. 1802[10]). The regulations for implementing EFH clarify the following terms:

- **Waters**—Aquatic areas and their associated physical, chemical, and biological properties that are used by fish and may include aquatic areas historically used by fish where appropriate
- **Substrate**—Sediments, hardbottoms, structures underlying the waters, and associated biological communities
- **Necessary**—The habitat required to support a sustainable fishery and the managed species’ contribution to a healthy ecosystem
- **Spawning, breeding, feeding, or growth to maturity**—Stages representing a species’ full life cycle.

In 2002, the National Marine Fisheries Service (NMFS) issued a final rule for the MSFCMA that simplified EFH provisions (National Marine Fisheries Service 2002a). This final rule includes: (1) clearer standards for identifying and describing EFH, such as inclusion of the geographic boundaries and a map of the EFH, as well as guidance for the fishery management councils to distinguish EFH from other habitats; (2) more guidance for the fishery management councils on evaluating the impact of fishing activities on

EFH, and clearer standards for deciding when fishery management councils should act to minimize adverse impacts; and (3) clarification and reinforcement of the EFH consultation procedures (National Marine Fisheries Service 2002a). In accordance with this final rule, habitats used at any time during a species' life cycle (i.e., during at least one of its lifestages) must be accounted for when describing and identifying EFH (National Marine Fisheries Service 2002b).

Authority to implement the MSFCMA is given to the Secretary of Commerce through NMFS. The MSFCMA requires that EFH be identified and described for each federally managed species. The MSFCMA also requires federal agencies to consult with NMFS on activities that may adversely affect EFH or when NMFS independently learns of a federal activity that may adversely affect EFH. The MSFCMA defines an adverse effect as

> *any impact that reduces quality and/or quantity of EFH. Adverse effects may include direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality and/or quantity of EFH. Adverse effects to EFH may result from actions occurring within EFH or outside of EFH and may include site-specific or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810).*

In addition to EFH, the regional fishery management councils are also empowered to designate as habitat areas of particular concern (HAPCs) discrete subsets of EFH that provide extremely important ecological functions or are especially vulnerable to degradation (50 CFR 600.805-600.815). A HAPC is a subset of the habitats that a species is known to occupy and could include spawning habitat; nursery habitat for larvae, juveniles, and subadults; and some amount of foraging habitat for mature adults (Greene et al. 2009). Regional fishery management councils may designate a specific habitat area as a HAPC based on one or more of the following criteria (National Marine Fisheries Service 2002b):

- importance of the ecological function provided by the habitat;
- the extent to which the habitat is sensitive to human-induced environmental degradation;
- whether, and to what extent, development activities are, or will be, stressing the habitat type; and
- rarity of the habitat type.

Classification of an area as a HAPC does not confer additional protection or impose additional restriction at the designated area.

The Mariana Archipelago portion of the MRA Study Area is under the jurisdiction of the Western Pacific Regional Fishery Management Council (WPRFMC) (Figure 10-1).

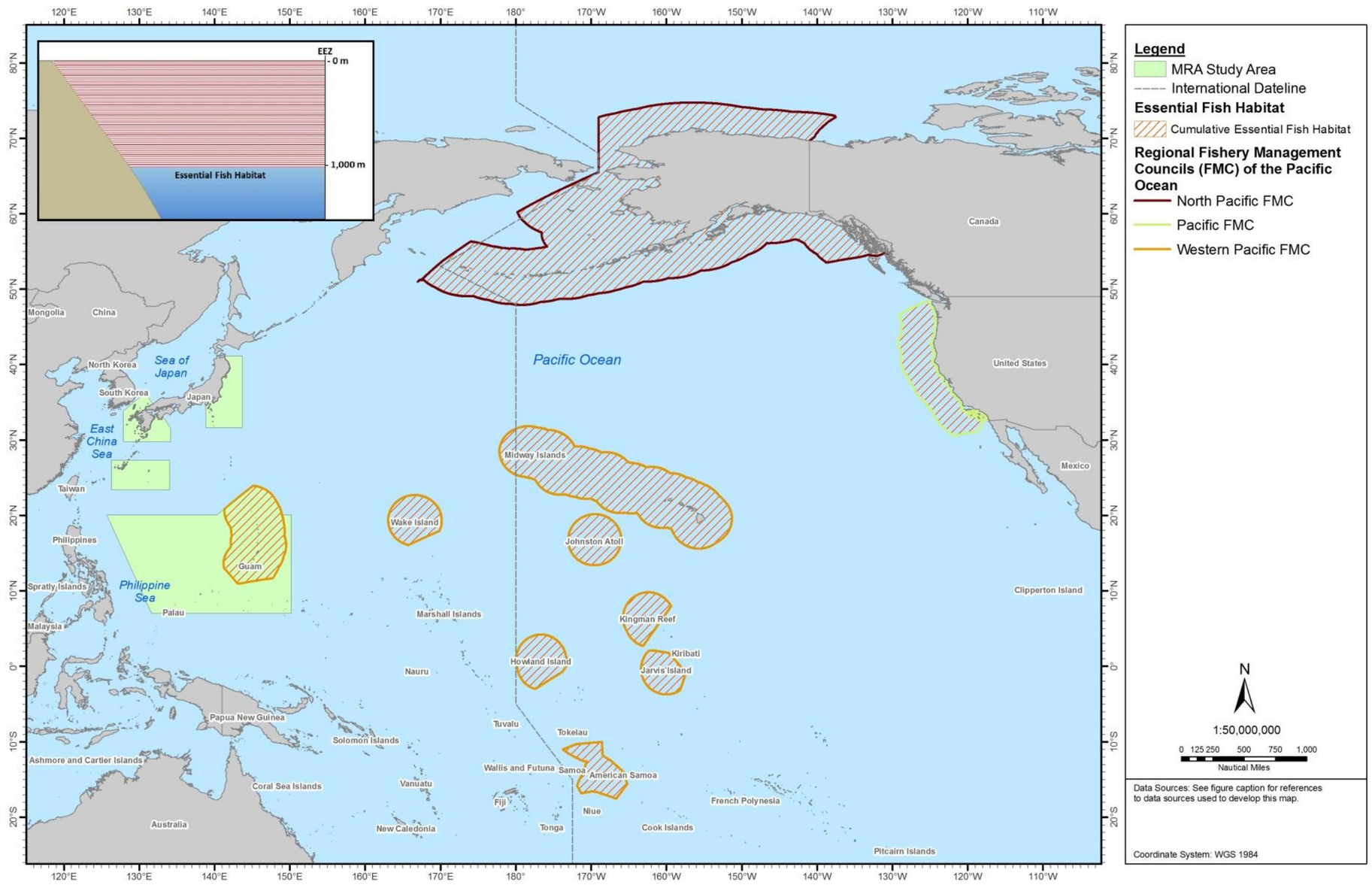

Figure 10-1: Fishery Management Councils in the Pacific Ocean

Sources: National Oceanic and Atmospheric Administration (2012b) and Western Pacific Regional Fishery Management Council (2013).

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10.2 WESTERN PACIFIC REGIONAL FISHERIES MANAGEMENT COUNCIL

The WPRFMC is responsible for managing fisheries in the 1.5 million square nm (5.15 million square kilometers) of the Pacific Ocean under U.S. jurisdiction. This management area is the largest of any of the Fishery Management Councils (FMCs) of the United States, covering almost half of all U.S. EEZ waters. The U.S. territories, possessions, and states in the Pacific covered by this management area include the territories of American Samoa and Guam; the U.S. Pacific atoll and island possessions of Jarvis, Johnston, Wake, Howland, Baker, Kingman Reef, Palmyra, and Midway; the Commonwealth of the Northern Mariana Islands (CNMI); and the State of Hawaiʻi, including the Northwestern Hawaiian Islands (Simonds 2003). Among these, only Guam and the CNMI are within the MRA Study Area (Figure 10-1).

10.3 THREATS TO ESSENTIAL FISH HABITAT

Many anthropogenic threats degrade and diminish the areas suitable for fish species to spawn, breed, feed, and grow to maturity in the marine environment; losses of such fish habitat are widespread (Halpern et al. 2008). These threats include dredging, conversion to land, harvesting/destruction of live habitats (e.g., corals, oyster reefs), conversion to open water or other less complex habitat type, and destruction (Crain et al. 2009). Because many of these impacts primarily occur within coastal systems, coastal fishes are most at risk for habitat losses. For example, in areas where coral has been mined or otherwise removed, quantity and diversity of fishes have declined substantially (Helfman et al. 2009). Fishing activities in which the gear alters the habitat itself (e.g., bottom trawling) may pose an additional threat to the offshore environment (Pews Oceans Commission 2003). See Chapter 9 (Fish) for additional information on threats to fishes within the MRA Study Area.

10.4 ESSENTIAL FISH HABITAT TYPES AND HABITAT AREAS OF PARTICULAR CONCERN

Habitat types designated as EFH for the fishery resources within the MRA Study Area are summarized in Table 10-1. Detailed descriptions of marine habitats in the MRA Study Area are provided in Chapter 11 (Marine Habitats).

The designation of HAPC is not included for all EFH species/groups, and the designation process may vary among the eight regional FMCs. Some councils specify individual or specific habitats, while others designate broad geographic areas. Furthermore, some councils designate HAPC for all managed species, while others designate HAPC for particular species or life stages. Table 10-1 lists the HAPC designated for all species and management units within the MRA Study Area.

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Table 10-1: Essential Fish Habitat and Habitat Areas of Particular Concern in the MRA Study Area

Management Units	Essential Fish Habitat (EFH)		Habitat Types (see Chapter 11 for detailed descriptions)	Habitat Areas of Particular Concern (HAPC)
	Juveniles and Adults	Eggs and Larvae		
Bottomfish	Water column and bottom habitat down to 1,310 feet (400 meters)	Water column down to 1,310 feet (400 meters)	Softbottom Habitats, Rocky Reef, Deep Reef Slopes, Banks, Deep Ocean Floor, Abyssal Plain	All escarpments and slopes between 130 and 920 feet (40 and 280 meters) and three known areas of juvenile opakapaka habitat
Seamount groundfish	Water column and bottom from 260 to 1,970 feet (80 to 600 meters), bounded by 29° N–35° N and 171° W–179° W (adults only)	Near-surface zone (0–655 feet [0–200 meters]) bounded by 29° N–35° N and 171° W–179° W (includes juveniles)	Rocky Reef, Deep Reef Slopes, Seamounts, Banks	Not identified
Pelagic	Water column down to 3,280 feet (1,000 meters)	Water column down to 655 feet (200 meters)	Softbottom Habitats, Fish Aggregating Devices, Seamounts	Water column down to 3,280 feet (1,000 meters) that lies above seamounts and banks
Crustaceans	Lobsters: Bottom habitat from shoreline to a depth of 330 feet (100 meters) Deepwater shrimp: The outer reef slopes at depths between 985 and 2,295 feet (300 and 700 meters)	Lobsters: Water column down to 490 feet (150 meters)	Estuaries, Lagoons, Submerged Aquatic Vegetation, Intertidal Zone, Mangroves, Coral Reefs, Softbottom Habitats, Rocky Reef, Deep Reef Slopes, Outer Reef Slopes, Seamounts, Banks, Deep Ocean Floor	Lobsters: All banks with summits less than 100 feet (30 meters) Deepwater shrimp: No habitat areas of particular concern designated for deepwater shrimp
Coral reef ecosystem	Water column and seafloor to a depth of 330 feet (100 meters)	Water column and seafloor to a depth of 330 feet (100 meters)	Lagoons, Submerged Aquatic Vegetation, Intertidal Zone, Mangroves, Coral Reefs, Rocky Reef, Artificial Reef/Shipwreck	All marine protected areas identified in the fisheries management plan, all Pacific Remote Insular Areas, many specific areas of coral reef habitat

Source: Western Pacific Regional Fishery Management Council (2009b).

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10.5 ESSENTIAL FISH HABITAT DESIGNATIONS

Fishery management councils are required to identify EFH for each fishery covered under a Fishery Management Plan (FMP). The fishery management councils classify EFH for temperate and subtropical-tropical managed species in terms of five basic life stages: eggs, larvae, juveniles, adults, and spawning adults (Moyle and Cech 1996; Pacific Fishery Management Council 1998, 2003a, b, 2007, 2008; Western Pacific Regional Fishery Management Council 2004). Eggs are the fertilized product of individuals that have spawned, and in this unhatched phase, they depend completely on their yolk for nutrition. Larvae are individuals that have hatched and can capture prey. Juveniles are individuals that are not sexually mature but possess fully formed organ systems similar to those of adults. Adults are sexually mature individuals that are not necessarily in spawning condition, and spawning adults are individuals capable of producing offspring (Moyle and Cech 1996; Pacific Fishery Management Council 1998, 2003a, b, 2007, 2008; Western Pacific Regional Fishery Management Council 2004).

The WPRFMC, in conjunction with the Guam Division of Aquatic and Wildlife Resources and the CNMI Division of Fish and Wildlife, manages the fishery resources in the MRA Study Area. The WPRFMC manages major fisheries within the U.S. EEZ (3 to 200 nm [5.6 to 370 km]) around Hawai‘i and the territories and possessions of the United States in the Pacific Ocean (Western Pacific Regional Fishery Management Council 1998, 2001), while the Guam Division of Aquatic and Wildlife Resources is responsible for fisheries in territorial waters surrounding the island of Guam (0 to 3 nm [0 to 5.6 km]). The WPRFMC has also proposed to defer responsibility for fisheries management in the waters surrounding the Northern Marianas Islands from 0 to 3 nm (0 to 5.6 km) to the CNMI Division of Fish and Wildlife (Western Pacific Regional Fishery Management Council 2001).

The WPRFMC focuses on the major fisheries in the MRA Study Area that require regional management. The WPRFMC currently oversees four major FMPs, including (1) bottomfish, (2) pelagics, (3) crustaceans, and (4) coral reef ecosystems. Each management unit is described below in Sections 10.5.1 through 10.5.6. No FMP has been developed for precious corals within the MRA Study Area. In 2007, the WPRFMC approved Fishery Ecosystem Plans shifting management focus from a species-based to a place-based conservation ethic. Bottomfish, crustaceans, and reef fish in the MRA Study Area are all now managed under the Marianas Archipelago Fishery Ecosystem Plan.

The WPRFMC designates EFH via a regional, ecosystem-based approach based on the best scientific information available on habitats essential to the managed species in the Western Pacific Region. EFH designation guidelines recommend preparation of an inventory of available environmental and fisheries information for each managed species. Some basic information needed includes data on current and historic stock size, geographic range of the species, habitat requirements by life history stage, and distribution and characteristics of those habitats (Western Pacific Regional Fishery Management Council 2009a, b, c, d). Because EFH must be identified for each major life history stage, information about a species’ distribution, density, growth, mortality, and production within all of the habitats it occupies, or formerly occupied, is also necessary. Due to large gaps in scientific knowledge about the life histories and habitat requirements of many managed species in the Western Pacific Region, the WPRFMC adopted a precautionary approach in designating EFH to ensure that enough habitats are protected to sustain managed species. The preferred depth ranges of specific life stages were used to designate EFH for bottomfish and crustaceans. The WPRFMC designated EFH for adult and juvenile bottomfish as the water column and all bottom habitat extending from the shoreline to a depth of 400 meters (m), encompassing the steep drop-offs and high-relief habitats important for bottomfish throughout the

Western Pacific Region. Designation for crustaceans was further refined based on productivity data. Determination that a type or area of EFH should be designated as a HAPC requires satisfaction of one or more of the criteria established by NMFS (listed above in Section 10.1, Introduction). Nevertheless, it should be emphasized that if an area meets only one of the HAPC criteria, it will not necessarily be designated an HAPC (Western Pacific Regional Fishery Management Council 2009a, b, c, d).

The WPRFMC has designated EFH for its managed species using the methods prescribed by the WPRFMC. The specific EFH designations for each of the species within the FMPs are listed in the EFH source documents maintained by NMFS, on the *EFH Mapper and Data Inventory* (National Oceanic and Atmospheric Administration 2012a). This tool is updated, as needed, with addition of amendments to FMPs.

Species with EFH designated under each FMP by the WPRFMC are listed in Table 10-2 through Table 10-5. The profiles for federally managed fish species with designated EFH or HAPC are described in the text as species/group profiles for each of the taxa listed in Table 10-2 through Table 10-5 contained in the following sections (10.5.1 through 10.5.6).

10.5.1 Bottomfish Management Unit

Status and Management. Seventeen species are currently managed within the Bottomfish Management Unit by the WPRFMC through the Bottomfish and Seamount Groundfish Fishery Management Plan (Western Pacific Regional Fishery Management Council 1986) and subsequent amendments (Western Pacific Regional Fishery Management Council 1998). In the CNMI, Guam, and American Samoa, the species are grouped into a shallow-water complex and a deep-water complex based on habitat preferences. All 17 species have viable recreational, subsistence, and commercial fisheries (Western Pacific Regional Fishery Management Council 2004), and none of the species in the Bottomfish Management Unit is approaching an overfished condition (National Marine Fisheries Service 2011). None of the species within the Bottomfish Management Unit found in the MRA Study Area is listed on the International Union for Conservation of Nature (IUCN) Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Habitat and Distribution. The shallow-water (0 to 328 feet [ft.] [0 to 100 m]) and the deep-water (328 to 1,312 ft. [100 to 400 m]) complexes are distributed throughout the tropical and subtropical waters of the insular and coral reef bordered coastal areas of Pacific islands (Myers and Donaldson 2003). Underwater video surveys have confirmed the published depth ranges and habitat preferences of bottomfish species (Merritt et al. 2011). EFH for bottomfish species are shown in Figure 10-2 to Figure 10-5.

Bottomfish comprising the shallow-water and deep-water complexes concentrate around the 600 ft. (183 m) contour (index of bottomfish habitat) that surrounds Guam and the Northern Mariana Islands (Western Pacific Regional Fishery Management Council 1998). Juvenile and adult bottomfish are usually found in habitats characterized by a mosaic of sandy bottoms and rocky areas of high structural complexity (Western Pacific Regional Fishery Management Council 1998). Habitats encompassing the shallow-water complex consist of shelf and slope areas (Spalding, Ravilious, and Green 2001). The shelf area includes various habitats such as mangrove swamps; seagrass beds; shallow lagoons; hard, flat, and coarse sandy bottoms; coral and rocky substrate; sandy inshore reef flats and deep channels. Seaward reefs, outer deep reef slopes, banks, and deeper waters of coral reefs comprise the slope areas (Allen 1985; Allen and Adrim 2003; Heemstra 1993; Myers and Donaldson 2003). Species of the deep-water

complex inhabit areas of high relief with hard rocky bottoms such as steep slopes, pinnacles, headlands, rocky outcrops, and coral reefs (Allen 1985; Haight, Kobayashi, and Kawamoto 1993; Parrish 1987).

Life History. Very little is known about the ecology (life history, habitat, feeding, and spawning) of the bottomfish species managed in the MRA Study Area (Western Pacific Regional Fishery Management Council 1998, 2009c). However, limited information is available regarding various larval, juvenile, and adult bottomfish genera of the shallow-water and deep-water complexes.

Within the shallow-water complex, snappers form large aggregations, whereas groupers and jacks occur in pairs within large aggregations near areas of prominent relief (Amesbury and Myers 2001; Grimes 1987; Myers 1999). The spawning season for snappers in coastal Okinawa waters is between May and October (Nanami et al. 2010). Groupers have been shown to undertake small, localized migrations of several kilometers to spawn (Heemstra 1993; Hutchinson and Rhodes 2010; Nakamura et al. 2008). Large jacks are highly mobile, wide-ranging predators that inhabit the open waters above the reef or swim in upper levels of the open sea (Sudekum et al. 1991), and spawn at temperatures of 18 to 30 degrees Celcius (°C) (Miller et al. 1979).

Within the deep-water complex, snappers aggregate near areas of bottom relief as solitary individuals or in small groups (Allen 1985). Snappers may be batch (or serial) spawners, spawning multiple times over the course of a protracted spawning season (e.g., spring and summer, or June through December peaking in August); or may exhibit a shorter, more well-defined spawning period (e.g., July to September) (Allen 1985; Moffitt 1993; Parrish 1987). Some snappers display a crepuscular periodicity (active during twilight hours) and migrate from areas of high relief during the day at depths of 328 to 656 ft. (100 to 200 m) to shallow (98 to 262 ft. [30 to 80 m]), flat, shelf areas at night (Moffitt and Parrish 1996). Other snapper species exhibit higher densities on up-current side islands, banks, and atolls (Moffitt 1993).

EFH Designations

Eggs and Larvae – EFH for these life stages is the water column extending from the shoreline to the outer limit of the U.S. EEZ down to a depth of 400 m, and encompasses both the shallow-water and deep-water complexes (Figure 10-2) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 1998).

Juveniles and Adults – For these life stages, EFH encompasses the water column and all bottom habitat extending from the shoreline to a depth of 400 m, and includes the shallow-water and deepwater complexes (Figures 10-3, 10-4, and 10-5) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 1998).

HAPC Designations

Based on the known distribution and habitat requirements, all life stages of the Bottomfish Management Unit species have HAPC designated in the MRA Study Area that includes all slopes and escarpments between 40 and 280 m (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 1998).

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Table 10-2: Bottomfish Management Unit Species Essential Fish Habitat Designations

Management Unit Species/Taxa	Habitat Type										Known Depth Range
	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	
Shallow-water Species Complex (0 to 100 meters [m])											
Gray jobfish (*Aprion virescens*)		A		J	J	A,J	A,J		A	E,L	Adult depth of 3–180 m
Lunartail grouper (*Variola louti*)		A				A	A			E,L	Adult depth of 4–200 m
Blacktip grouper (*Epinephelus fasciatus*)				J		A,J	A		A	E,L	Adult depth of 0–160 m
Ambon emperor (*Lethrinus amboinensis*)						A,J	A,J		A,J	E,L	No data
Redgill emperor (*Lethrinus rubrioperculatus*)									A	E,L	Adult depth of 0–160 m
Giant trevally (*Caranx ignoblis*)			J		J					E,L	Adult depth of 80 m
Black jack (*Caranx lugubris*)									A	A,J,L,E	Adult depth of 12–354 m
Amberjack (*Seriola dumerili*)						J	A,J		A	A,J,L,E	Adult depth of 0–250 m
Blue stripe snapper (*Lutjanus kasmira*)		A		J		A,J			A	E,L	Adult depth of 0–265 m
Deep-water Species Complex (100 to 400 m)											
Squirrelfish snapper (*Etelis carbunculus*)						A			A	E,L	Adult depth of 90–350 m
Longtail snapper (*Etelis coruscans*)						A			A	E,L	Adult depth of 164–293 m
Pink snapper (*Pristipomoides filamentosus*)					J				A	E,L	Juvenile depth of 65–100 m
Yellowtail snapper (*Pristipomoides auricilla*)									A	E,L	Adult depth of 180–270 m
Yelloweye snapper (*Pristipomoides flavipinnis*)									A	E,L	Adult depth of 180–270 m
Pink snapper (*Pristipomoides sieboldii*)									A	E,L	Adult depth of 180–360 m
Yellow-barred snapper (*Pristipomoides zonatus*)									A	E.L	Adult depth of 100–200 m
Silver jaw jobfish (*Aphareus rutilans*)						A			A	E,L	Adult depth of 6–100 m

Source: Western Pacific Regional Fishery Management Council (1998, 2001).
Notes on habitat types: Mangrove (Ma), Lagoon (La), Estuarine (Es), Seagrass Beds (SB), Soft Substrate (Ss), Coral Reef/Hard Substrate (Cr/Hs), Patch Reefs (Pr), Surge Zone (Sz), Deep-slope Terraces (DST), Pelagic/Open Ocean (Pe).
Life History Stage: Egg (E), Larvae (L), Juvenile (J), Adult (A).

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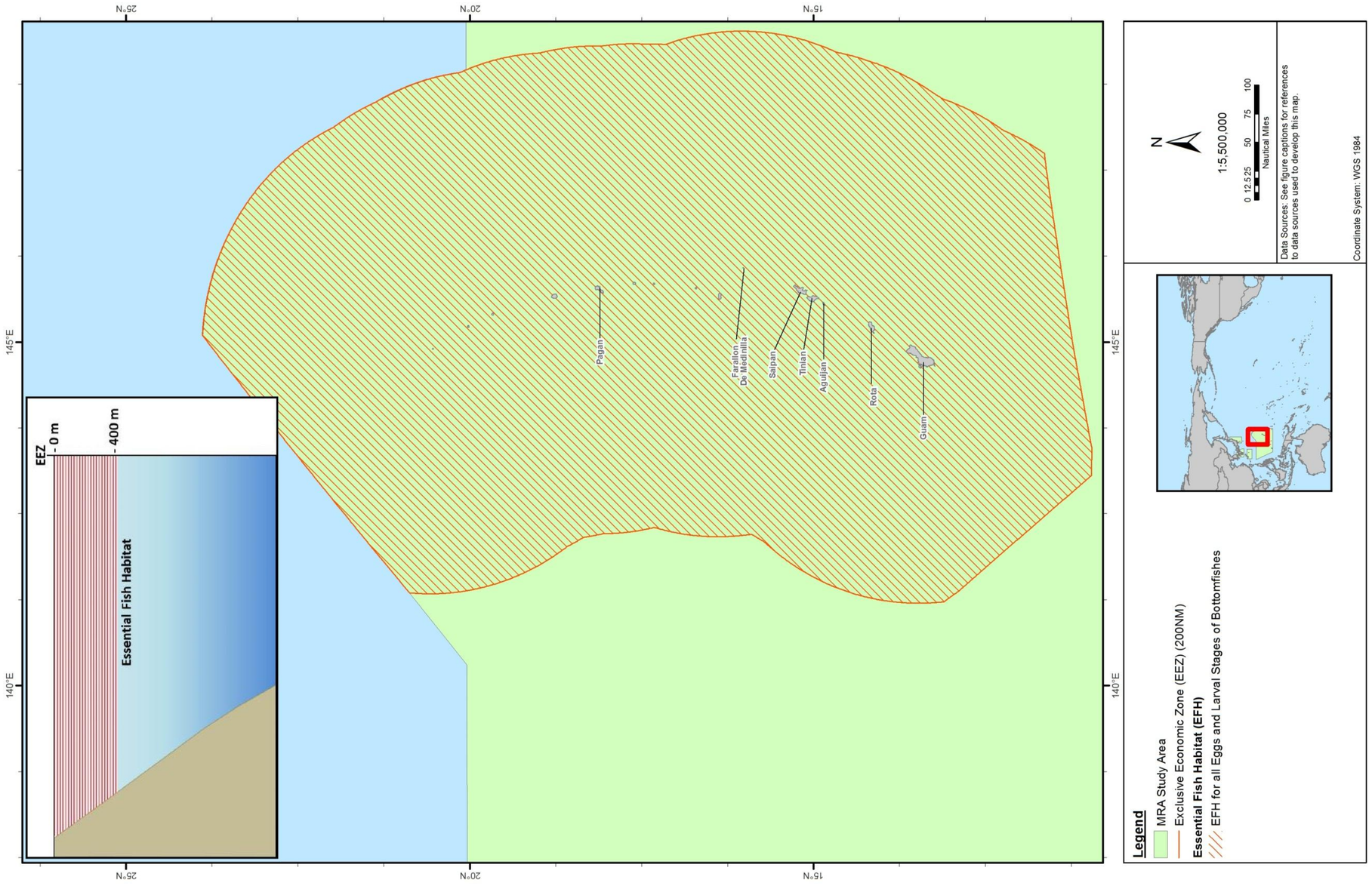

Figure 10-2: Essential Fish Habitat for Egg and Larval Lifestages of Bottomfish Designated for the Mariana Archipelago
Sources: National Oceanic and Atmospheric Administration (2012b) and Western Pacific Regional Fishery Management Council (2013).

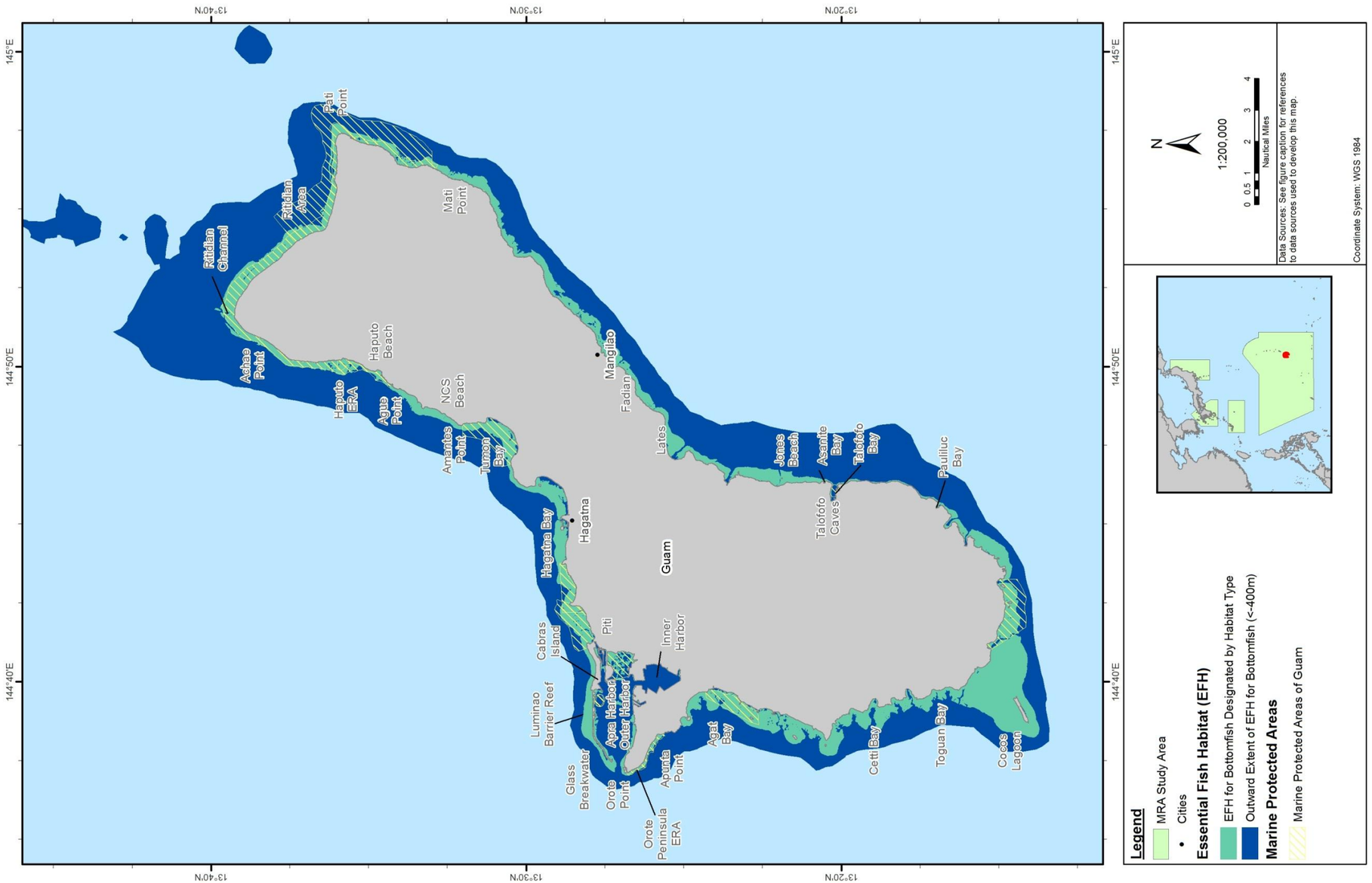

Figure 10-3: Essential Fish Habitat for Juvenile and Adult Lifestages of Bottomfish Designated for Guam
Sources: National Oceanic and Atmospheric Administration (2013, 2005) and Western Pacific Regional Fishery Management Council (2009b).

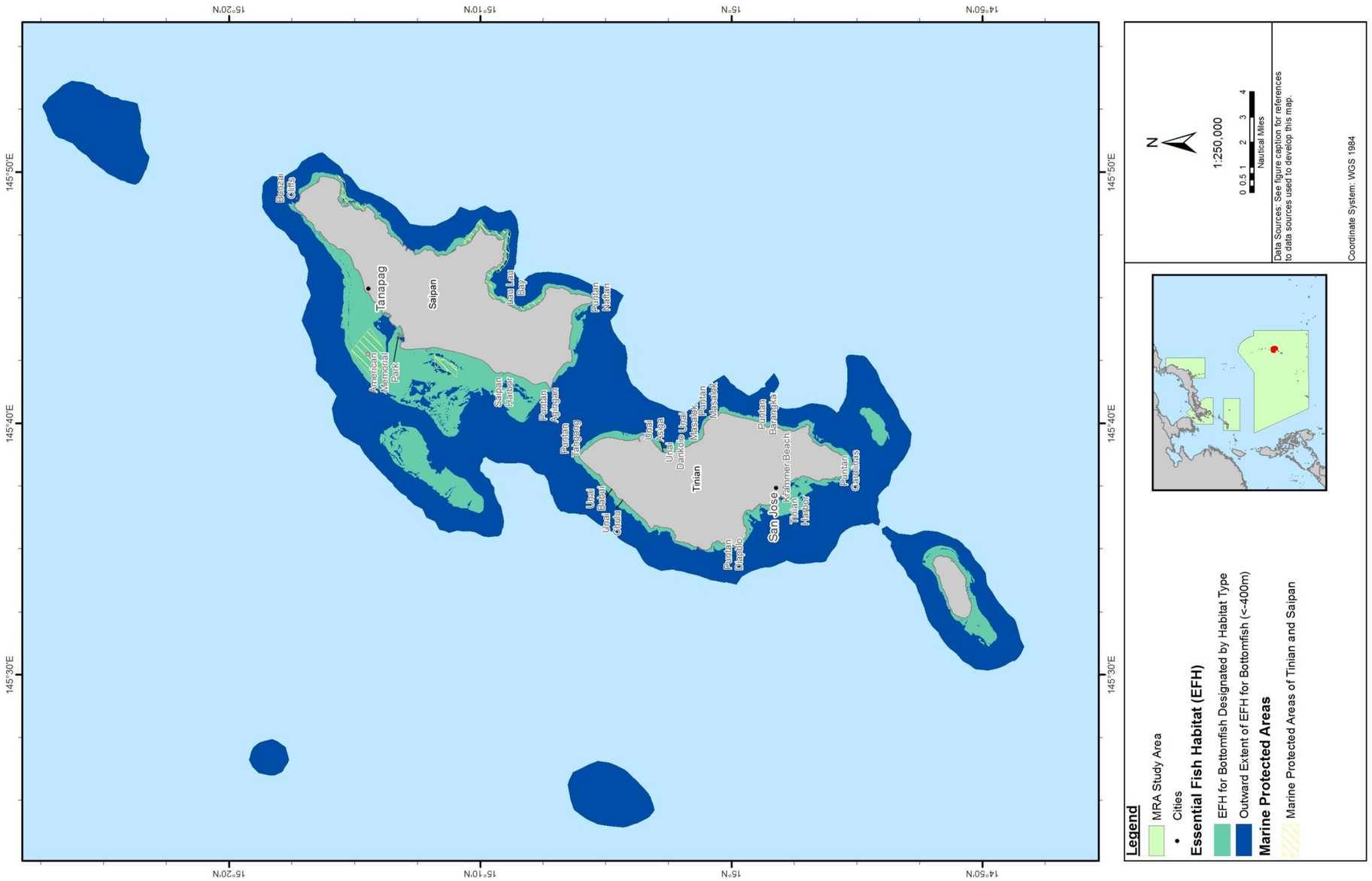

Figure 10-4: Essential Fish Habitat for Juvenile and Adult Lifestages of Bottomfish Designated for Tinian and Saipan
Sources: National Oceanic and Atmospheric Administration (2013, 2005) and Western Pacific Regional Fishery Management Council (2009b).

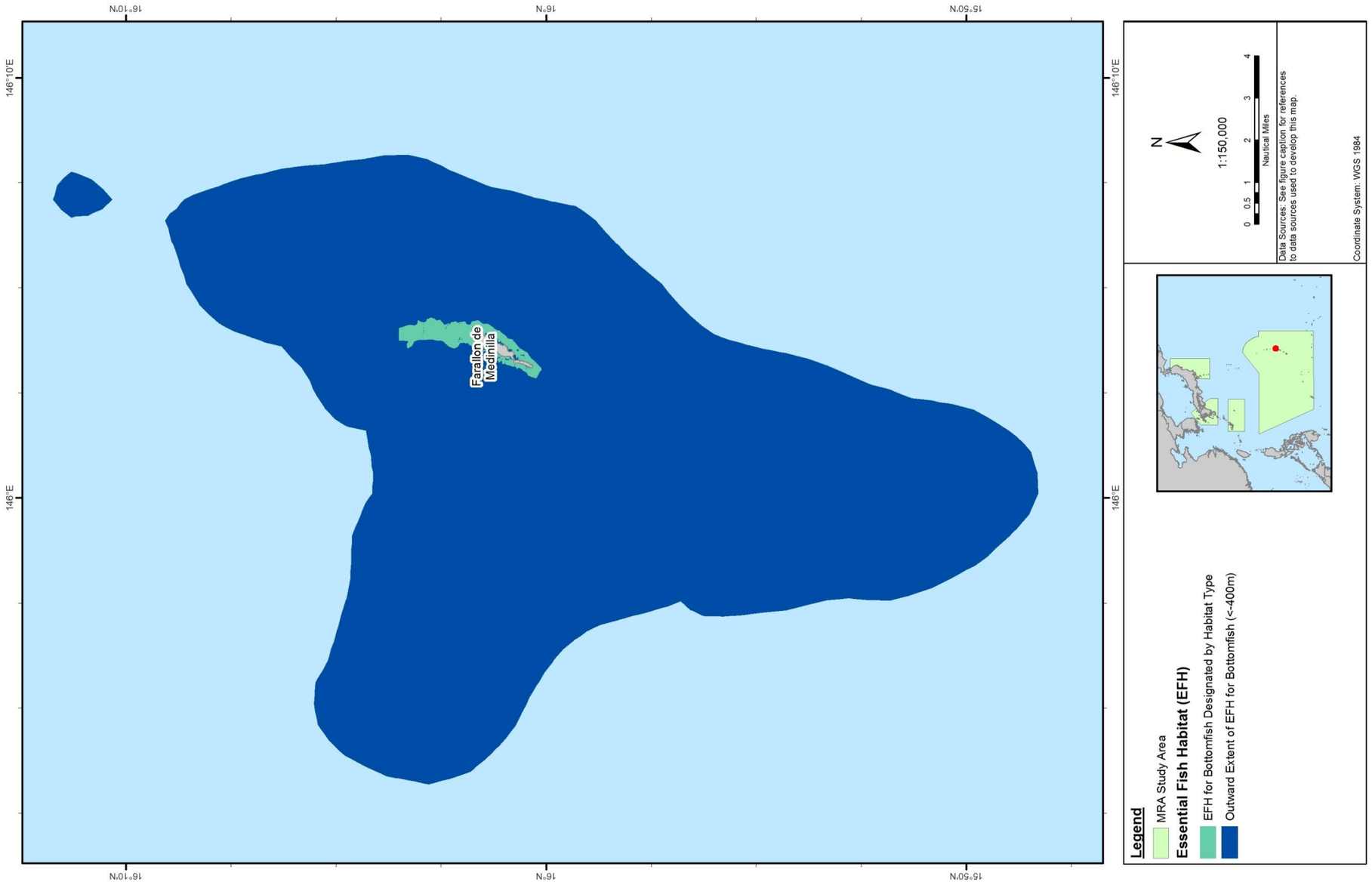

Figure 10-5: Essential Fish Habitat for Juvenile and Adult Lifestages of Bottomfishes Designated for Farallon de Medinilla
Sources: National Oceanic and Atmospheric Administration (2005) and Western Pacific Regional Fishery Management Council (2009b).

10.5.2 Pelagic Management Unit

Status and Management. Thirty-three species are currently managed within the Pelagic Management Unit by the WPRFMC through the Fishery Ecosystem Plan for the Pelagic Fisheries of the Western Pacific Region (Western Pacific Regional Fishery Management Council 2009a). These species are divided into the following species complex designations: temperate species, tropical species, and sharks. The designation of these complexes is based on the ecological relationships among the species and their preferred habitats (Western Pacific Regional Fishery Management Council 2009a). The temperate species complex includes those pelagic species found in greater abundance outside tropical waters at higher latitudes (e.g., broadbill swordfish [*Xiphias gladius*], bigeye tuna [*Thunnus obesus*], northern bluefin tuna [*T. thynnus*], and albacore tuna [*T. alalunga*]).

Data to determine if the species within the Pelagic Management Unit are approaching an overfished condition are available only regarding the bigeye tuna (National Marine Fisheries Service 2011); NMFS determined that overfishing of this species was occurring Pacific-wide. NMFS believes that Pacific bluefin tuna (*T. orientalis*) is undergoing overfishing (National Marine Fisheries Service 2011).

The shark species are afforded protection under the Shark Conservation Act of 2010 (H.R. 81, S. 850).

The broadbill swordfish, albacore tuna, common thresher shark (*Alopias vulpinus*), and salmon shark (*Lamna ditropis*) have been identified as data deficient on the IUCN Red List of threatened species (Goldman, Baum, et al. 2009; Goldman, Kohin, et al. 2009). The shortfin mako shark (*Isurus oxyrinchus*), oceanic whitetip shark (*Caracharhinus longimanus*), and the blue shark (*Prionace glauca*) have been listed as near threatened (Baum et al. 2006; Stevens 2009). The bigeye tuna is listed as vulnerable (Collette, Acero, et al. 2011), and the southern bluefin tuna is listed as critically endangered (Collette, Fox, et al. 2011).

Habitat and Distribution. Pelagic fishes occur in tropical and temperate waters of the Western Pacific Ocean. Geographical distribution among the pelagic species varies with seasonal changes in ocean temperature. These species range from as far north as Japan to as far south as New Zealand. Albacore tuna, striped marlin (*Tetrapurus audax*), and broadbill swordfish have broader ranges and occur from 50° N to 50° S (Western Pacific Regional Fishery Management Council 1998). Many pelagic fishes are known to aggregate near seamounts, with the highest diversities occurring within 30–40 km of the summit (Morato et al. 2010). EFH for pelagic species in the Mariana Archipelago is shown in Figure 10-6.

The pelagic species are typically found in epipelagic to pelagic waters; however, shark species can be found in inshore benthic, neritic to epipelagic, and mesopelagic waters. Oceanic zonation is discussed in Chapter 4 (Oceanography) and Chapter 11 (Habitats). Gradients in temperature, oxygen, or salinity can affect the suitability of a habitat for pelagic fish. Skipjack tuna (*Katsuwonus pelamis*), yellowfin tuna (*T. albacares*), and Indo-Pacific blue marlin (*Makaira nigricans*) prefer warm surface layers, where the water is well mixed and relatively uniform in temperature. Species such as albacore tuna, bigeye tuna, striped marlin, and broadbill swordfish prefer cooler temperate waters associated with higher latitudes and greater depths. Certain species are known to aggregate near the surface at night. However, during the day, broadbill swordfish can be found at depths of 800 m, while bigeye tuna can be found around 275 to 550 m. Juvenile albacore tuna generally concentrate above 90 m, with adults found in deeper waters (90 to 275 m) (Western Pacific Regional Fishery Management Council 1998).

Tagging data suggests that pelagic shark species aggregate according to daytime temperature preferences. Epipelagic species (silky sharks [*Carcharhinus falciformis*] and oceanic whitetip sharks)

spend at least 95 percent (%) of their time at temperatures within 2°C of sea surface temperature. Some mesopelagic species (blue sharks and shortfin makos) spend 95% of their time at temperatures from 9.4 to 26.9°C, while other mesopelagic species (bigeye threshers [*Alopias superciliosus*]) spend 95% of their time at temperatures from 6.7 to 21.2°C (Musyl et al. 2011). Body size and latitude may also influence more specific thermal niche utilization within epipelagic species (Musyl et al. 2011).

Life History. Migration and life history patterns of most pelagic fish in the Pacific Ocean are poorly understood. Additionally, very little is known about the distribution and habitat requirements of the juvenile life stages of tuna and billfish prior to recruitment into fisheries. Seasonal movements of cooler-water tunas such as the northern blue fin and albacore are more predictable and better defined than billfish migrations. Tuna and related species tend to move toward the poles during the warmer months and return to the equator during cooler months. Most pelagic species make daily vertical migrations, inhabiting surface waters at night and deeper waters during the day. Spawning for pelagic species generally occurs in tropical waters but may include temperate waters during warmer months. Very little is known about the life history stages of species not targeted by fisheries in the Pacific such as snake mackerels, sharks, and pomfrets (Western Pacific Regional Fishery Management Council 1998).

EFH Designations

Eggs and Larvae – The epipelagic zone, which comprises the water column down to a depth of 200 m from the shoreline to the outer limit of the U.S. EEZ (Figure 10-6) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 1998).

Juveniles and Adults – The water column down to a depth of 1,000 m from the shoreline to the outer limit of the U.S. EEZ (Figure 10-6) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 1998).

HAPC Designations

HAPC for this group is the entire water column to a depth of 1,000 m above all seamounts and banks with summits shallower than 2,000 m within the U.S. EEZ (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 1998).

Table 10-3: Pelagic Management Unit Species Essential Fish Habitat Designations

Management Unit Species/Taxa	Habitat Type										Known Depth Range
	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	
Marketable Species Complex:											
Temperate Species											
Striped marlin (*Tetrapurus audax*)										A,J,L,E	Depth Distribution: governed by temperature stratification
Broadbill swordfish (*Xiphias gladius*)										A,J,L,E	Depth Distribution: surface to 1,000 meters (m)
Northern bluefin tuna (*Thunnus thynnus*)										A,J,L,E	No data
Albacore tuna (*Thunnus alalunga*)										A,J,L	Depth Distribution: surface to 380 m
Bigeye tuna (*Thunnus obesus*)										A,J,L,E	Depth Distribution: surface to 600 m
Mackerel (*Scomber* spp.)										A,J,L,E	No data
Sickle pomfret (*Tatactichthys steindachneri*)										A,J,L,E	Depth Distribution: surface to 300 m
Lustrous pomfret (*Eumegistus illustris*)										A,J,L,E	Depth Distribution: surface to 549 m
Tropical Species											
Yellowfin tuna (*Thunnus albacares*)										A,J,L,E	Depth Distribution: upper 100 m with marked oxyclines
Kawakawa (*Euthynnus affinis*)										A,J,L,E	Depth Distribution: 36–200 m
Skipjack tuna (*Katsuwonus pelamis*)										A,J,L,E	Depth Distribution: surface to 263 m
Frigate tuna (*Auxis thazard*)										A,J,L,E	No data
Bullet tuna (*Auxis rochei*)										A,J,L,E	No data
Indo-Pacific blue marlin (*Makaira nigricans*)										A,J,L,E	Depth Distribution: 80–100 m
Black marlin (*Makaira indica*)										A,J,L,E	Depth Distribution: 457–914 m
Shortbill spearfish (*Tetrapturus angustirostris*)										A,J,L,E	Depth Distribution: 40–1,830 m
Sailfish (*Istiophorus platypterus*)										A,J,L,E	Depth Distribution: 10–20 to 200–250 m
Dolphinfish (*Coryphaena hippurus*)			A,J							A,J,L,E	No data
Pompano dolphinfish (*Coryphaena equiselas*)										A,J,L,E	No data
Wahoo (*Acanthocybium solandri*)										A,J,L,E	Adult depth <200 m
Moonfish (*Lampris guttatus*)										A,J	Depth Distribution: surface to 500 m

Table 10-3: Pelagic Management Unit Species Essential Fish Habitat Designations

Management Unit Species/Taxa	Habitat Type										Known Depth Range
	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	
Non-marketable Species Complex:											
Snake mackerels/oilfish (Gempylidae)											
Escolar (*Lepidocybium flavobrunneum*)										A,J,L,E	Depth Distribution: surface to 200 m
Oilfish (*Ruvettus pretiosus*)										A,J,L,E	Depth Distribution: surface to 700 m
Shark Species Complex											
Common thresher shark (*Alopias vulpinus*)		J								A,J	Depth Distribution: surface to 366 m
Pelagic thresher shark (*Alopias pelagicus*)		A				A				A,J	Depth Distribution: surface to 152 m
Bigeye thresher shark (*Alopias superciliosus*)										A,J	Depth Distribution: surface to 500 m
Shortfin mako shark (*Isurus oxyrinchus*)										A,J	Depth Distribution: surface to 500 m
Longfin mako shark (*Isurus paucus*)										A,J	No data
Salmon shark (*Lamna ditropis*)										A,J	Depth Distribution: surface to 152 m
Silky shark (*Carcharhinus falcirormis*)									A	A,J	Adult depth of 18–500 m
Oceanic whitetip shark (*Carcharhinus longimanus*)										A,J	Adult depth of 37–152 m
Blue shark (*Prionace glauca*)										A,J,L,E	Depth Distribution: surface to 152 m

Source: Western Pacific Regional Fishery Management Council (1998, 2001).
Notes on habitat types: Mangrove (Ma), Lagoon (La), Estuarine (Es), Seagrass Beds (SB), Soft Substrate (Ss), Coral Reef/Hard Substrate (Cr/Hs), Patch Reefs (Pr), Surge Zone (Sz), Deep-slope Terraces (DST), Pelagic/Open Ocean (Pe).
Life History Stage: Egg (E), Larvae (L), Juvenile (J), Adult (A), Spawners (S)

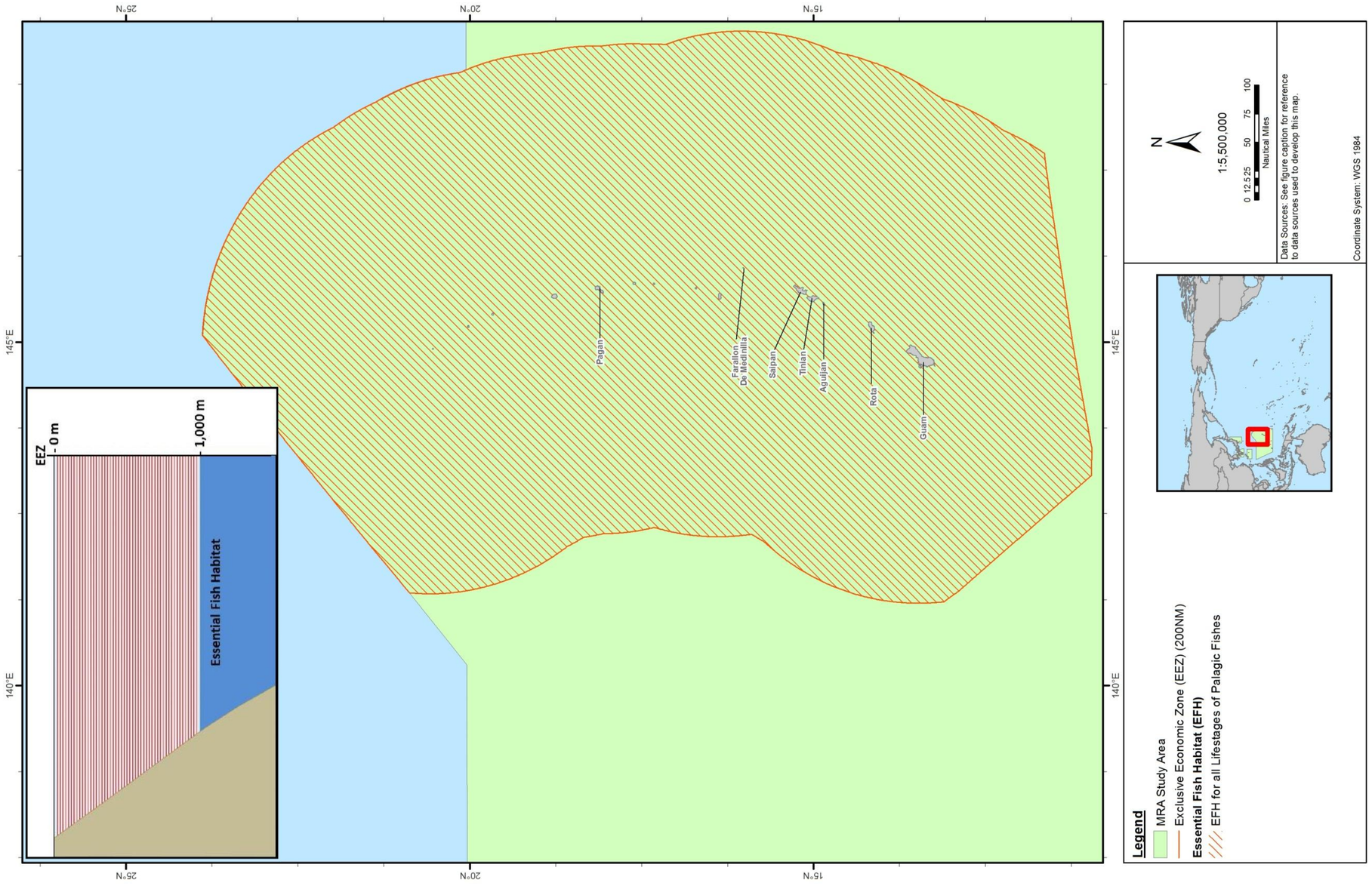

Figure 10-6: Essential Fish Habitat for Lifestages of Pelagic Fishes Designated for the Mariana Archipalego
Sources: National Oceanic and Atmospheric Administration (2012b) and Western Pacific Regional Fishery Management Council (2013).

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10.5.3 Crustacean Management Unit

Status and Management. Thirteen species (including four lobsters, one crab, and eight species of deepwater shrimp) are currently managed as Crustacean Management Unit species (CMUS) by the WPRFMC through the Fishery Management Plan of the Crustaceans Fisheries of the Western Pacific Region and the Final Combined FMP, Environmental Impact Statement, Regulatory Analysis, and Draft Regulations for the Spiny Lobster Fisheries of the Western Pacific Region (Western Pacific Regional Fishery Management Council 1981, 1982) and subsequent amendments (Western Pacific Regional Fishery Management Council 1998). Four species are managed under the umbrella of the Spiny and Slipper Lobster Complex by the CMUS FMP (Western Pacific Regional Fishery Management Council 1998, 2001): spiny lobster (*Panulirus marginatus, P. penicillatus* and *Panulirus* sp.), ridgeback slipper lobster (*Scyllarides haani*), and Chinese slipper lobster (*Parribacus antarcticus*). The Kona crab (*Ranina ranina*) is managed as a single species under the CMUS (Western Pacific Regional Fishery Management Council 1998, 2001). The deepwater shrimp species complex was added to the FMP in 2008 and includes all eight western Pacific species: *Heterocarpus ensifer, H. laevigatus, H. sibogae, H. gibbosus, H. lepidus, H. dorsalis, H. tricarinatus* and *H. longirostris* (National Marine Fisheries Service 2008a). No data are available to determine if these lobster species or the Kona crab of the CMUS are approaching an overfished condition (National Marine Fisheries Service 2011) except in Guam where spiny lobster is overfished and is a main component of the inshore lobster catch (Hensley and Sherwood 1993). There are currently no resource concerns for western Pacific deepwater shrimp species (National Marine Fisheries Service 2008a). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Habitat and Distribution. Members of CMUS occur in the Indo-Pacific region (Holthuis 1991; Western Pacific Regional Fishery Management Council 1998). There are 839 species of crustaceans in the Mariana Islands (Paulay 2003b). Thirteen species of spiny lobster occur in the tropical and subtropical Pacific between 35° N and 35° S (Holthuis 1991; Western Pacific Regional Fishery Management Council 1998). Five species of *Panulirus* occur in the Mariana Islands; *P. penicillatus* is the most common species among them (Paulay 2003b; Western Pacific Regional Fishery Management Council 2001). Eight species of *Heterocarpus* are extant in the western Pacific (National Marine Fisheries Service 2008a). EFH for crustacean species in the Mariana Archipelago are shown in Figure 10-7 to Figure 10-10.

In general, adults of the crustacean species included in this management unit favor sheltered areas with rocky substrates and/or sandy bottoms. Published data are lacking that pertain to the preferred depth distribution of decapod larvae and juveniles in this region (Western Pacific Regional Fishery Management Council 2001). The spiny lobster is mainly found in windward surf zones of oceanic reefs, but some are also found on sheltered reefs (Pitcher 1993). Adult spiny lobsters are typically found on rocky substrate in well-protected areas, such as crevices and under rocks (Holthuis 1991; Pitcher 1993). Some spiny lobsters prefer depths less than 33 ft. (10 m), while others are found to depths of around 361 ft. (110 m) (Holthuis 1991; Pitcher 1993; Western Pacific Regional Fishery Management Council 2001). Small juvenile spiny lobsters prefer the same habitat as larger individuals (Pitcher 1993). The ridgeback slipper lobster likely inhabits rocky bottoms; it is known to occur at depths between 3 and 41 ft. (10 and 135 m) (Holthuis 1991). The depth distribution of the Chinese slipper lobster is 0 to 33 ft. (0 to 10 m), and some are taken as incidental catch in the spiny lobster fishery (Polovina 1993). The Chinese slipper lobster prefers to live in coral or stone reefs with a sandy bottom (Holthuis 1991). The Kona crab is found in a number of environments, from sheltered bays and lagoons to surf zones, but prefers sandy habitat at depths of 79 to 377 ft. (24 to 115 m) (Poupin 1996; Smith 1993; Western Pacific Regional Fishery Management Council 1998). Deepwater shrimp are reported throughout the tropical

Pacific on outer reef slopes around islands and deepwater banks at depths of 656 to 3,937 ft. (200 to 1,200 m) (National Marine Fisheries Service 2008b). Deepwater shrimp species are distributed at different but overlapping depths, although they may move between different depths.

Life History. Decapods exhibit a wide range of feeding behaviors, but most combine nocturnal predation with scavenging; large invertebrates are the typical prey items (Western Pacific Regional Fishery Management Council 2001). Both lobsters and crabs are ovigerous (females carry fertilized eggs on the outside of the body). The relationships between egg production, larval settlement, and stock recruitments are poorly understood (Western Pacific Regional Fishery Management Council 1998, 2001). Spiny lobsters produce eggs in summer and fall. The larvae have a pelagic duration of about 1 year, undergoing as many as 12 planktonic stages before settlement, and can be transported up to 2,302 miles (mi.) (3,704 km) by prevailing ocean currents (Western Pacific Regional Fishery Management Council 1998). This species is nocturnal, hiding during the daytime in crevices in rocks and coral reefs. At night, this lobster moves up through the surge channels to forage on the reef crest and reef flat (Pitcher 1993). The Kona crab spawns at least twice during the spawning season; data are insufficient to identify the exact spawning season in the MRA Study Area (Western Pacific Regional Fishery Management Council 1998). This species remains buried in the substratum during the day, emerging only at night to search for food (Bellwood 2002). Deepwater shrimp appear to spawn during the winter and their larvae survival decreases with increasing depth (King 1986).

EFH Designations

Eggs and Larvae – EFH for this lifestage, for all species except deepwater shrimp, is the water column from the shoreline to the outer limit of the U.S. EEZ down to a depth of 150 m (Figure 10-7) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 1998). EFH is not designated for deepwater shrimp for this lifestage.

Juveniles and Adults – EFH for these lifestages, for all species except deepwater shrimp, includes all bottom habitat from the shoreline to a depth of 100 m (Figures 10-8, 10-9, and 10-10) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 1998). EFH for deepwater shrimp is the water column and associated outer reef slopes at depths between 300 and 700 m (National Marine Fisheries Service 2008a).

HAPC Designations

No HAPC is designated for Guam and the Northern Mariana Islands.

Table 10-4: Crustacean Management Unit Species Essential Fish Habitat Designations

Management Unit Species/Taxa	Habitat Type											Known Depth Range
	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	ORS	
Spiny and Slipper Lobster Complex												
Spiny lobster (*Panulirus marginatus, P. penicillatus, Panulirus* sp.)		All			A, J	All	All		All	L		Depth Distribution: 0 to 150 meters (m)
Ridgeback slipper lobster (*Scyllarides haanii*)		All			A, J	All	All		All	L		Depth Distribution: 0 to 150 m
Chinese slipper lobster (*Parribacus antarticus*)		All			A, J	All	All		All	L		Depth Distribution: 0 to 150 m
Kona Crab Complex												
Kona crab (*Ranina ranina*)	A, J	All	A, J	A, J	A, J	All	All		All	All		Depth Distribution: 0 to 150 m
Deepwater Shrimp Complex												
Deepwater shrimp (*Heterocarpus* spp.)											A, J	Depth Distribution: 200 to 1,200 m

Sources: National Marine Fisheries Service (2004a); Western Pacific Regional Fishery Management Council (1998, 2001).
Notes on habitat types: Mangrove (Ma), Lagoon (La), Estuarine (Es), Seagrass Beds (SB), Soft Substrate (Ss), Coral Reef/Hard Substrate (Cr/Hs), Patch Reefs (Pr), Surge Zone (Sz), Deep-slope Terraces (DST), Pelagic/Open Ocean (Pe), Outer Reef Slope (ORS).
Life History Stage: Egg (E), Larvae (L), Juvenile (J), Adult (A), Spawners (S)

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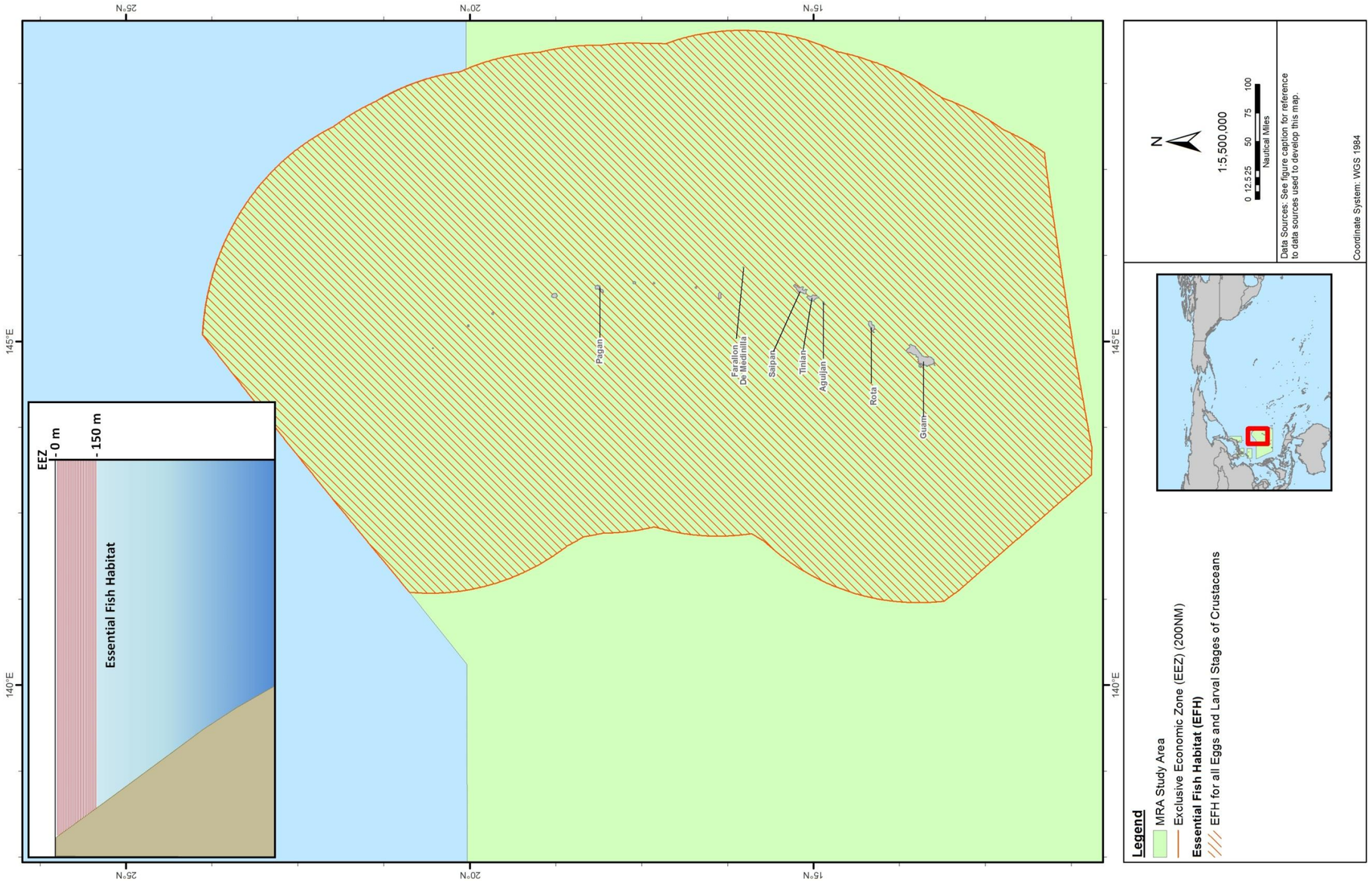

Figure 10-7: Essential Fish Habitat for Eggs and Larval Lifestages of Crustaceans (Excluding Deepwater Shrimp) Designated for the Mariana Archipelago

Sources: National Oceanic and Atmospheric Administration (2012b) and Western Pacific Regional Fishery Management Council (2013).

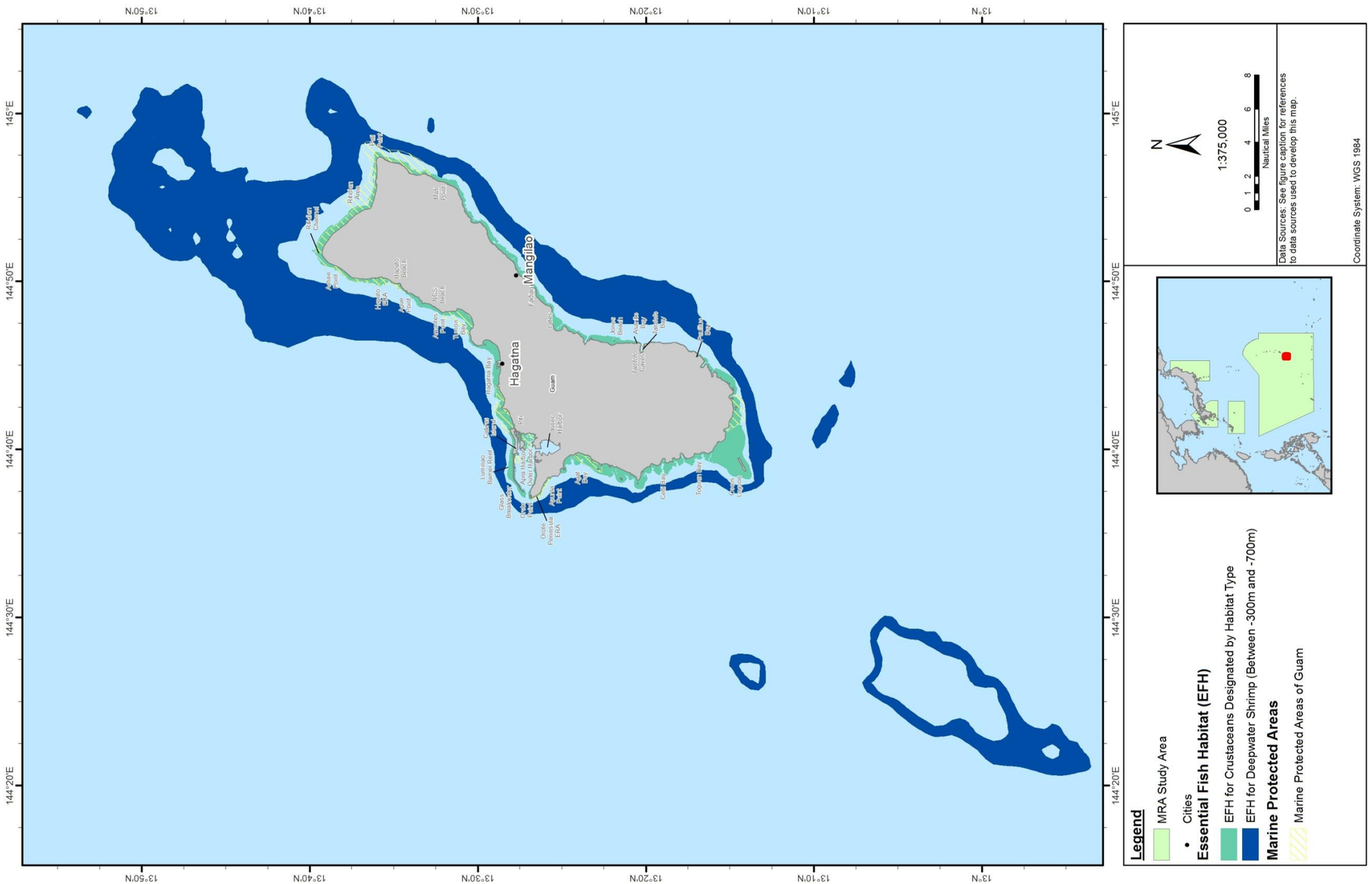

Figure 10-8: Essential Fish Habitat for Juvenile and Adult Lifestages of Crustaceans Designated for Guam
Sources: National Oceanic and Atmospheric Administration (2013, 2005) and Western Pacific Regional Fishery Management Council (2009b).

Figure 10-9: Essential Fish Habitat for Juvenile and Adult Lifestages of Crustaceans Designated for Tinian and Saipan
Sources: National Oceanic and Atmospheric Administration (2013, 2005) and Western Pacific Regional Fishery Management Council (2009b).

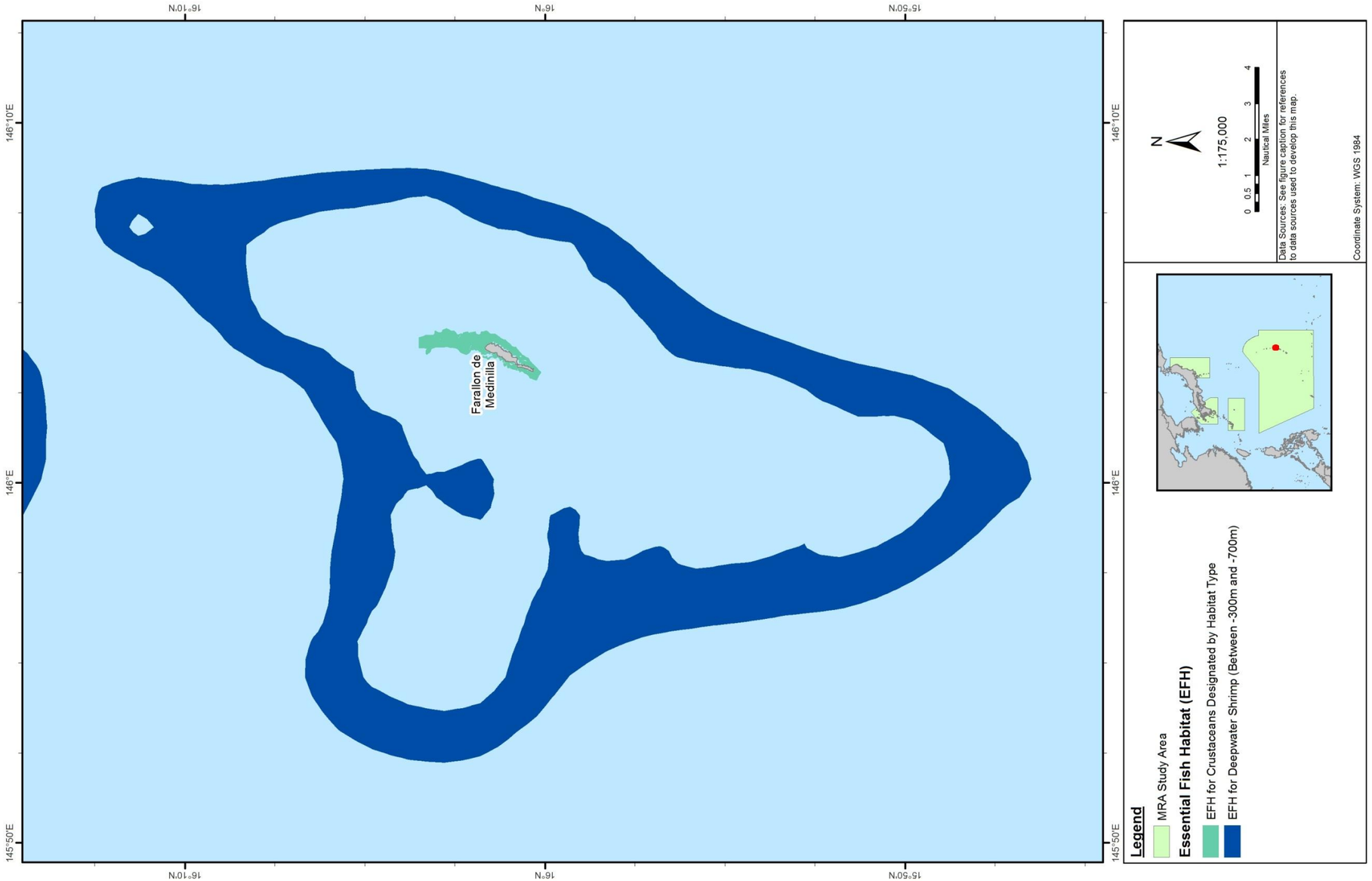

Figure 10-10: Essential Fish Habitat for Juvenile and Adult Lifestages of Crustaceans Designated for Farallon de Medinilla
Sources: National Oceanic and Atmospheric Administration (2005) and Western Pacific Regional Fishery Management Council (2009b).

10.5.4 Coral Reef Ecosystem Management Unit – Currently Harvested Coral Reef Taxa

The Coral Reef Ecosystem (CRE) FMP manages coral reef ecosystems surrounding the following U.S. Pacific Island areas: the State of Hawai'i; the Territories of American Samoa and Guam; the CNMI; the Pacific remote island areas of Johnston Atoll, Kingman Reef, Palmyra and Midway Atolls; and Jarvis, Howland, Baker, and Wake Islands (Western Pacific Regional Fishery Management Council 2001). Guam and the CNMI are located within the MRA Study Area. Under this plan, 80 coral reef species are managed (Western Pacific Regional Fishery Management Council 2009c).

In addition to EFH, WPRFMC also identified HAPC that are specific areas within EFH essential to the life cycle of important coral reef species. HAPC for all life stages of these species within this management unit includes all hardbottom substrate between depths of 0 and 328 ft. (0 and 100 m) in the MRA Study Area. Five individual HAPC sites have been identified for the island of Guam; of these, one (Jade Shoals) occurs within Apra Harbor. Another, Orote Point Ecological Reserve Area, lies immediately outside of Apra Harbor. The remaining three HAPC sites occur in the northern (Ritidian Point), northwest (Haputo Ecological Preserve), and southern (Cocos Lagoon) areas of the island (Western Pacific Regional Fishery Management Council 2001). Within the CNMI, Saipan Lagoon off Saipan has been designated HAPC because it represents rare habitats, ecological function, susceptibility to human impact, and may be subject to future development impacts. The HAPC designations apply to all 80 species managed within this unit.

The Currently Harvested Coral Reef Taxa (CHCRT) are managed under the CRE FMP by the WPRFMC (2001). CHCRT are identified species that (1) are currently harvested in state and federal waters and for which some fishery information is available, and (2) are likely to be targeted in the near future based on historical catch data. The WPRFMC has designated EFH for these MUs based on the ecological relationships among the species and their preferred habitat. These species complexes are grouped by the known depth distributions of individual species (Western Pacific Regional Fishery Management Council 2001). A complete list of the managed species of the coral reef ecosystem occurring in the MRA Study Area, and their respective fishery management units, are in Table 10-5 and 10-6. EFH for currently harvested coral reef taxa in the Mariana Archipelago are shown in Figure 10-11 to Figure 10-20. Adult and juvenile CHCRT that have shallower EFH depth designations (flagtails, mullets and rudderfish) than the other CHCRT are shown in Figures 10-13 (flagtails and mullets) and 10-14 (rudderfish), Figures 10-16 (flagtails and mullets) and 10-17 (rudderfish), and Figures 10-19 (flagtails and mullets) and 10-20 (rudderfish).

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Table 10-5: Coral Reef Ecosystem Currently Harvested Management Unit Species Essential Fish Habitat Designations

Management Unit Species/Taxa	Habitat Type										Known Depth Range
	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	
Currently Harvested Coral Reef Taxa - Fish											
Surgeonfishes (Acanthuridae)	J	A,J.S	A,J,S	J	A,J,S	A,J,S	A,J,S		A,J	E,L	Adult depth of 0–150 meters (m)
Unicornfishes (Subfamily Nasinae)	J	A,J,S	J		A,S	A,J,S	A,J,S		A,S	All	Adult depth of 0–150 m
Triggerfishes (Balistidae)	J	A,J,S	J	J		A,J,S	A,J,S	A	A,S	E,L	Adult depth of 0–100 m
Jacks (Carangidae)	A,J,S	A,J,S	A,J,S	J	A,J,S	A,J,S	A,J,S		A,J,S	All	Adult depth of 0–350 m
Requiem Sharks (Carcharhinidae)	A,J	A,J	A,J	J	A,J	A,J	A,J		A,J	A,J	Adult depth of 1–300 m
Soldierfishes/Squirrelfishes (Holocentridae)		A,J,S	A,J,S	J		A,J,S	A,J,S		A,S	E,L	Adult depth of 0–235 m
Flagtails (Kuhliidae)	A,J	A,J	A,J	A,J				A		E,L	Adult depth of 3–18 m
Rudderfishes (Kyphosidae)	J	A,J,S	A,J,S		A,J	A,J,S	A,J,S	A,J		All	Adult depth of 1–24 m
Wrasses (Labridae)		J	J	J	A,J,S	A,J,S	A,J,S		A,J,S	E,L	Adult depth of 1–200 m
Bodianus and *Xyricthys* spp.		J	J	J	A,J,S	A,J,S	A,J,S		A,J,S	E,L	Juvenile depth of 2 m; Adult depth of 2–20 m
Cheilinus and *Choerodon* spp.		A,J	J		A,J,S	A,J,S	A,J,S		A,J,S	E,L	Adult depth of 1–30 m
Oxycheilinus spp.		A,J			A,J,S	A,J,S	A,J,S		A,J,S	E,L	Adult depth of 1–160 m
Hemigymnus spp.		A,J		J	A,J,S	J	J,S		A,J,S	E,L	Adult depth of 1–40 m
Cheilio spp.											Adult depth of 1–30 m
Halichoeres spp.		A,J	J		A,J,S	A,J,S		A,J		E,L	Adult depth of 1–30 m
Thalassoma spp.		A,J		J	A,J,S	A,J,S	A,J,S			E,L	Adult depth of 1–30 m
Hologynmosus and *Novaculichthys*		A,J			A,J,S	A,J,S		A,J			Adult depth of 1–30 m
Napoleon wrasse (*Cheilinus undulatus*)	J	J		J		A,J,S	A,J,S		A,S	E,L	Adult depth of 2–60 m
Goatfishes (Mullidae)		A,J	A	A,J	A,J	A,J	A,J			E,L	Adult depth of 1–10 m
Mullets (Mugilidae)	J	A,J,S	A,J,S	J		A,J		A		E,L	Adult depth of 0–20 m
Moray Eels (Muraenidae)	A,J,S	A,J,S	A,J,S	A,J	A,J,S	A,J,S	A,J,S	A,J,S	E,L		Adult depth of 0–150 m
Threadfins (Polynemidae)	A,J	A,J,S	A,J,S		A,J,S			A,J		E,L	Juvenile depth of 0–100 m; Adult depth of 20–50 m
Bigeyes (Priacanthidae)						A,J	A,J		A,J	E,L	Adult depth of 5–400 m
Parrotfishes (Scaridae)	J	A,J,S		A,J		A,J,S	A,J,S			E,L	Adult depth of 1–30 m
Humphead parrotfish (*Bolbometopon muricatum*)	J	J		J		A,J,S	A,J,S			E,L	Adult depth of 1–30 m
Mackerels (Scomberidae)		A,J,S			A,J	A,J,S	A,J		A,J	E,L	Adult depth of 0–100 m

Table 10-5: Coral Reef Ecosystem Currently Harvested Management Unit Species Essential Fish Habitat Designations

Management Unit Species/Taxa	Habitat Type										Known Depth Range
	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	
Dogtooth tuna (*Gymnosarda unicolor*)		A,J,S			A,J	A,J,S	A,J		A,J	E,L	Adult depth of 0–100 m
Rabbitfishes (Siganidae)	A,J,S	A,J,S	A,J,S	J		A,J,S	A,J,S		E,L		Adult depth of 0–50 m
Barracudas (Sphyraenidae)	A,J	A,J,S	A,J,S	J		A,J,S	A,J,S		A,S	All	Adult depth of 0–100 m
Currently Harvested Coral Reef Taxa – Invertebrates											
Octopuses (Octopodidae)	A,J,S	All	A,J,S	All	All	All	All		All	L	Adult depth of 0–50 m
Turban shells/green snails (Turbinidae)		A,J,S				A,J,S	A,J,S		A	E,L	Juvenile depth of 1–5 m; Adult depth of 1–20 m

Sources: Colin and Arneson (1995); Myers (1999); Western Pacific Regional Fishery Management Council (2001).
Notes on habitat type: Mangrove (Ma), Lagoon (La), Estuarine (Es), Seagrass Beds (SB), Soft Substrate (Ss), Coral Reef/Hard Substrate (Cr/Hs), Patch Reefs (Pr), Surge Zone (Sz), Deep-slope Terraces (DST), Pelagic/Open Ocean (Pe).
Life History Stage: Egg (E), Larvae (L), Juvenile (J), Adult (A), Spawners (S).

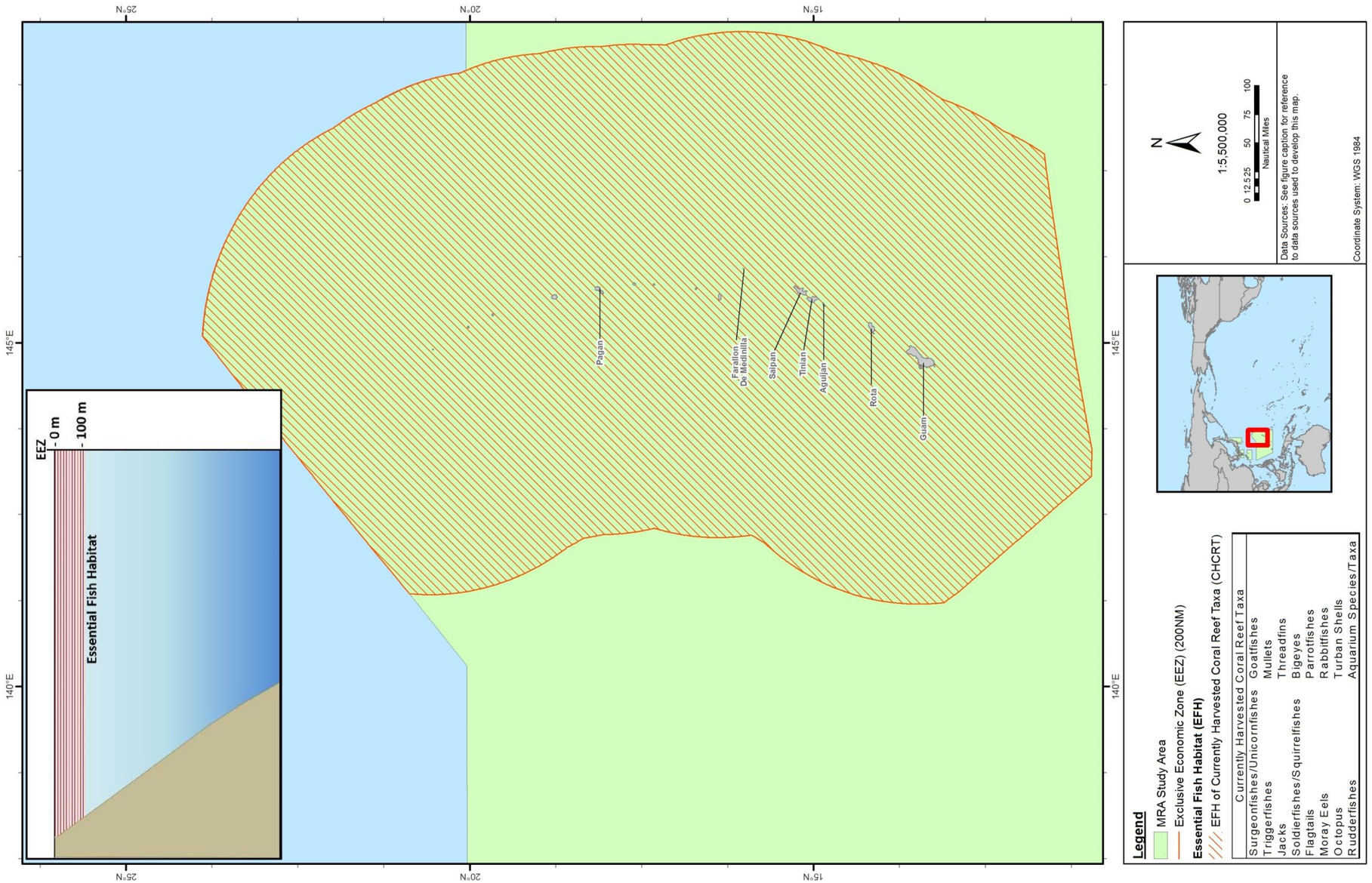

Figure 10-11: Essential Fish Habitat for Lifestages of the Currently Harvested Coral Reef Taxa Designated for the Mariana Archipelago

Sources: National Oceanic and Atmospheric Administration (2012b) and Western Pacific Regional Fishery Management Council (2013).

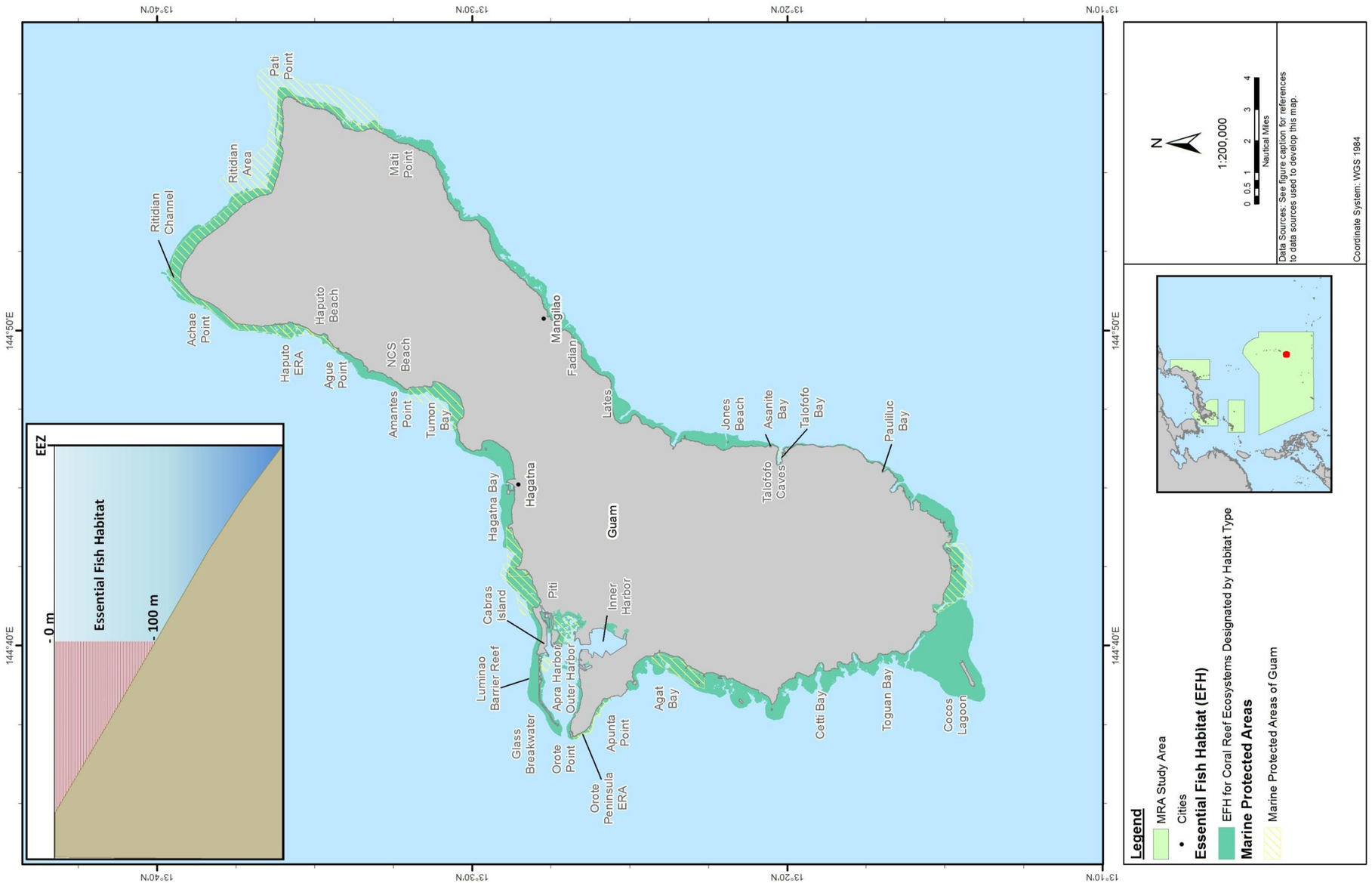

Figure 10-12: Essential Fish Habitat for Juvenile and Adult Lifestages of the Currently Harvested Coral Reef Taxa Designated for Guam

Sources: : National Oceanic and Atmospheric Administration (2013, 2005) and Western Pacific Regional Fishery Management Council (2013).

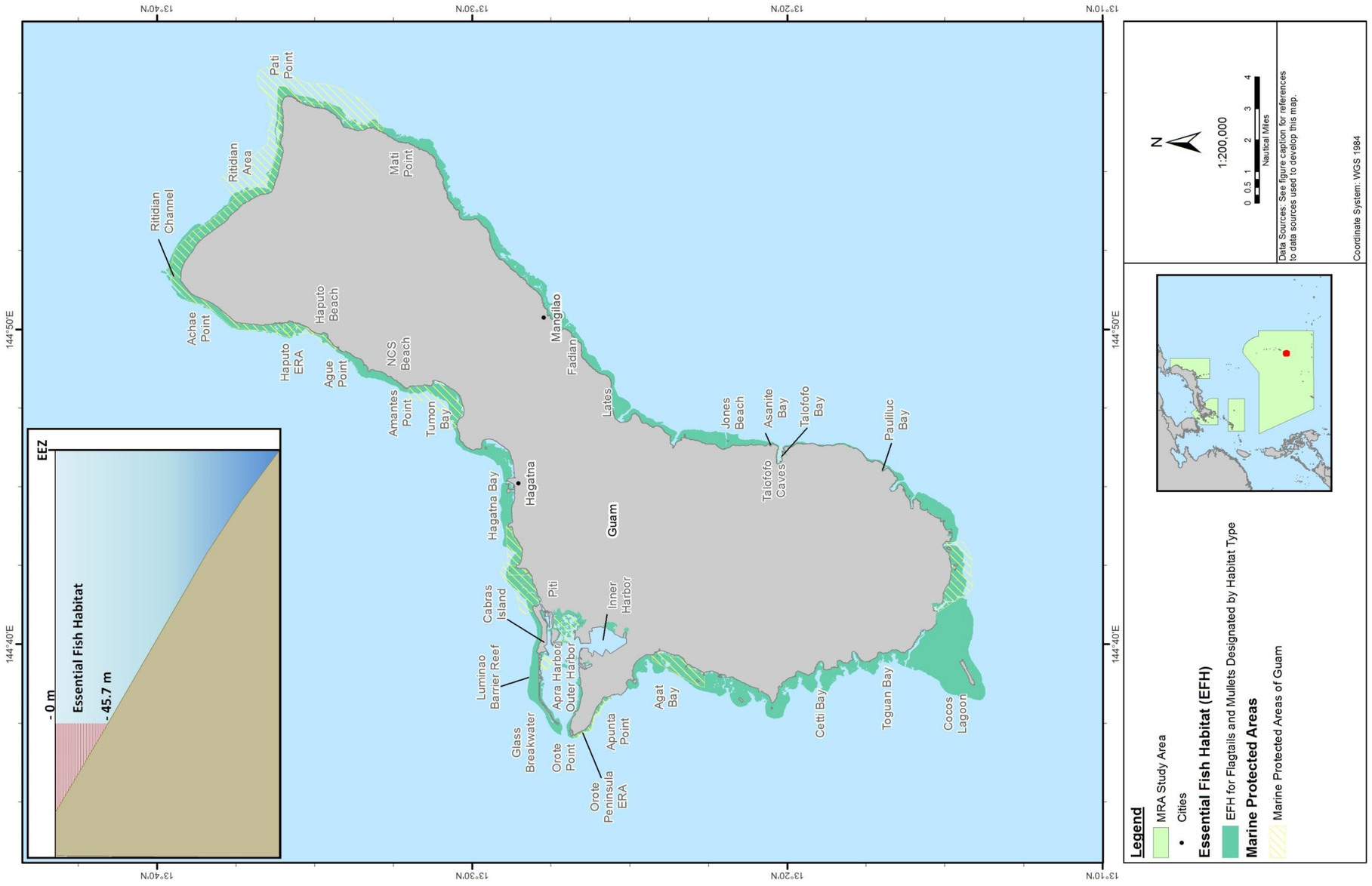

Figure 10-13: Essential Fish Habitat for Juvenile and Adult Lifestages of Flagtails and Mullets of the Currently Harvested Coral Reef Taxa Designated on Guam in the Mariana Archipelago

Sources: National Oceanic and Atmospheric Administration (2013, 2005) and Western Pacific Regional Fishery Management Council (2013).

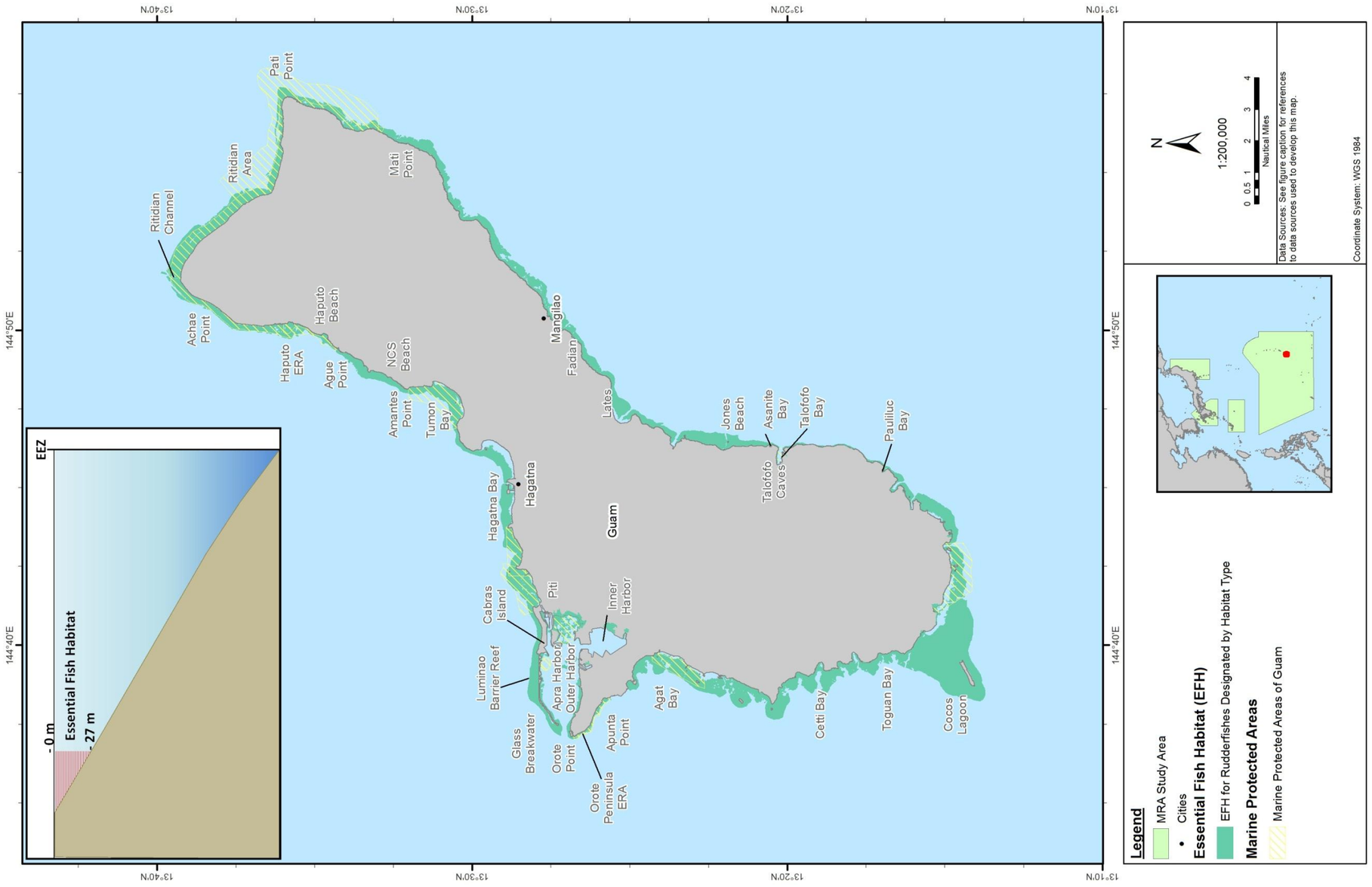

Figure 10-14: Essential Fish Habitat for Adult Lifestages of Rudderfishes of the Currently Harvested Coral Reef Taxa Designated on Guam in the Mariana Archipelago

Sources: National Oceanic and Atmospheric Administration (2013, 2005) and Western Pacific Regional Fishery Management Council (2013).

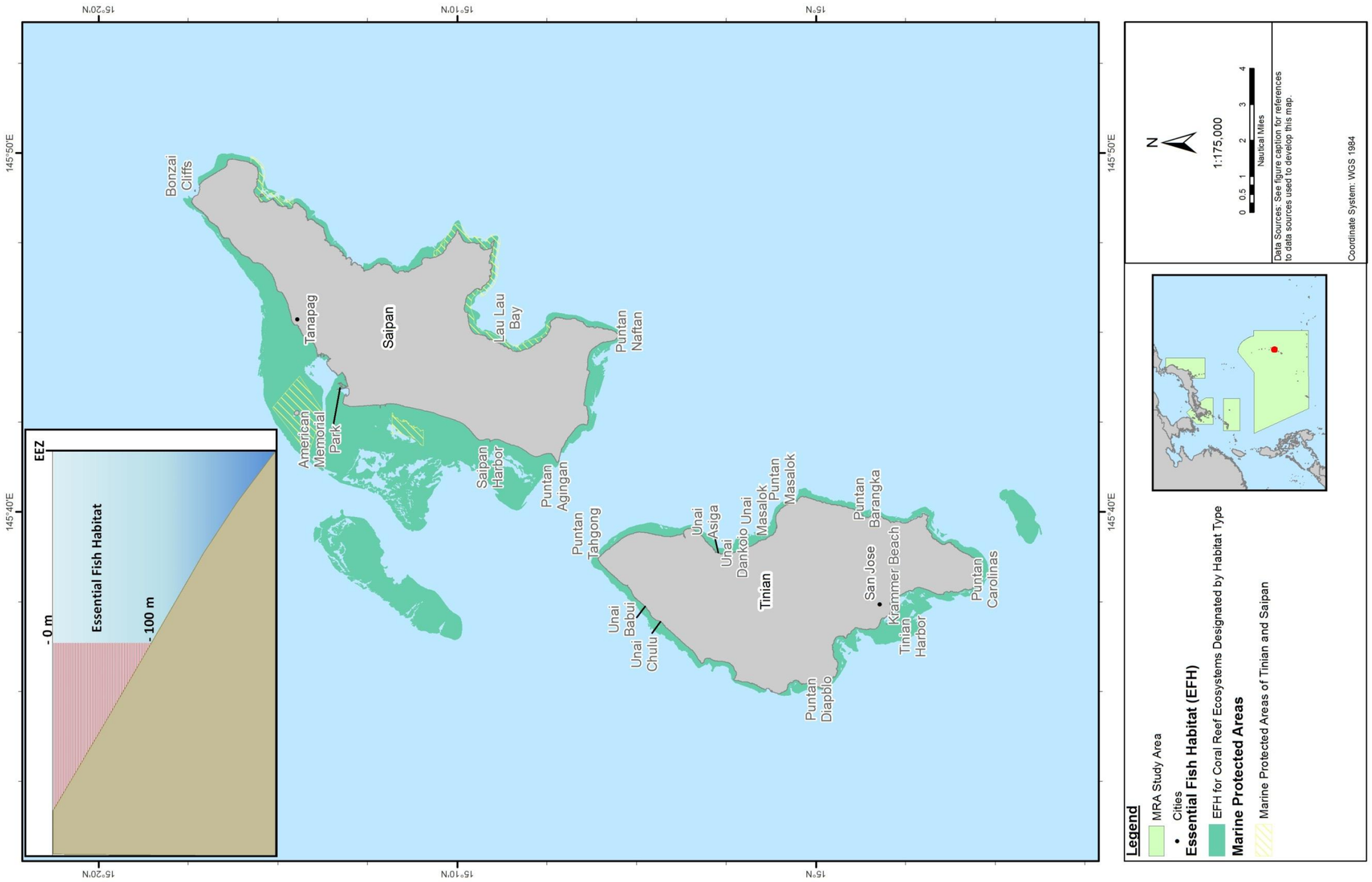

Figure 10-15: Essential Fish Habitat for Juvenile and Adult Lifestages of the Currently Harvested Coral Reef Taxa Designated for Tinian and Saipan

Source: National Oceanic and Atmospheric Administration (2013, 2005).

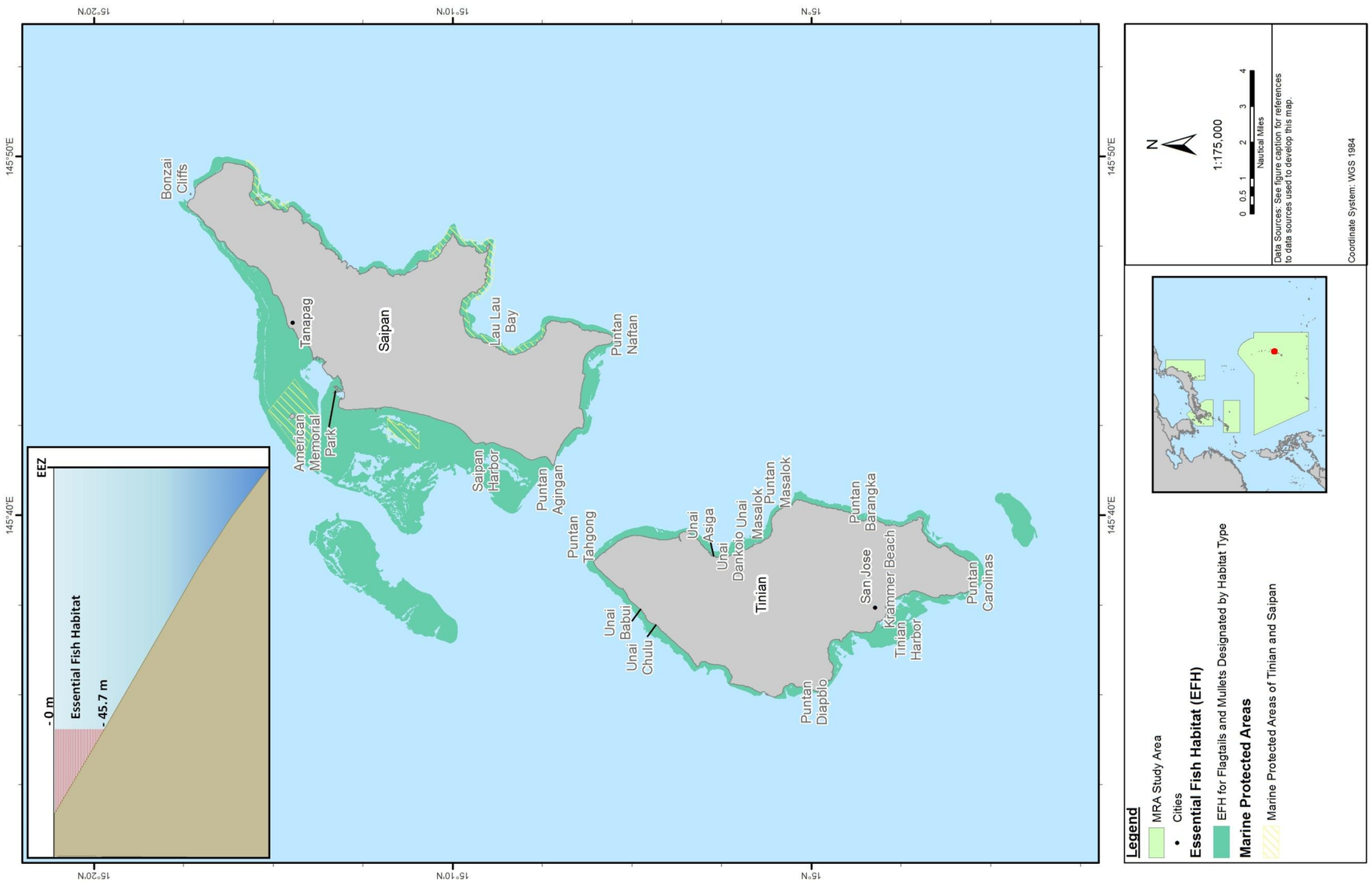

Figure 10-16: Essential Fish Habitat for Juvenile and Adult Lifestages of Flagtails and Mullets of the Currently Harvested Coral Reef Taxa Designated on Tinian and Saipan in the Mariana Archipelago
Source: National Oceanic and Atmospheric Administration (2013, 2005).

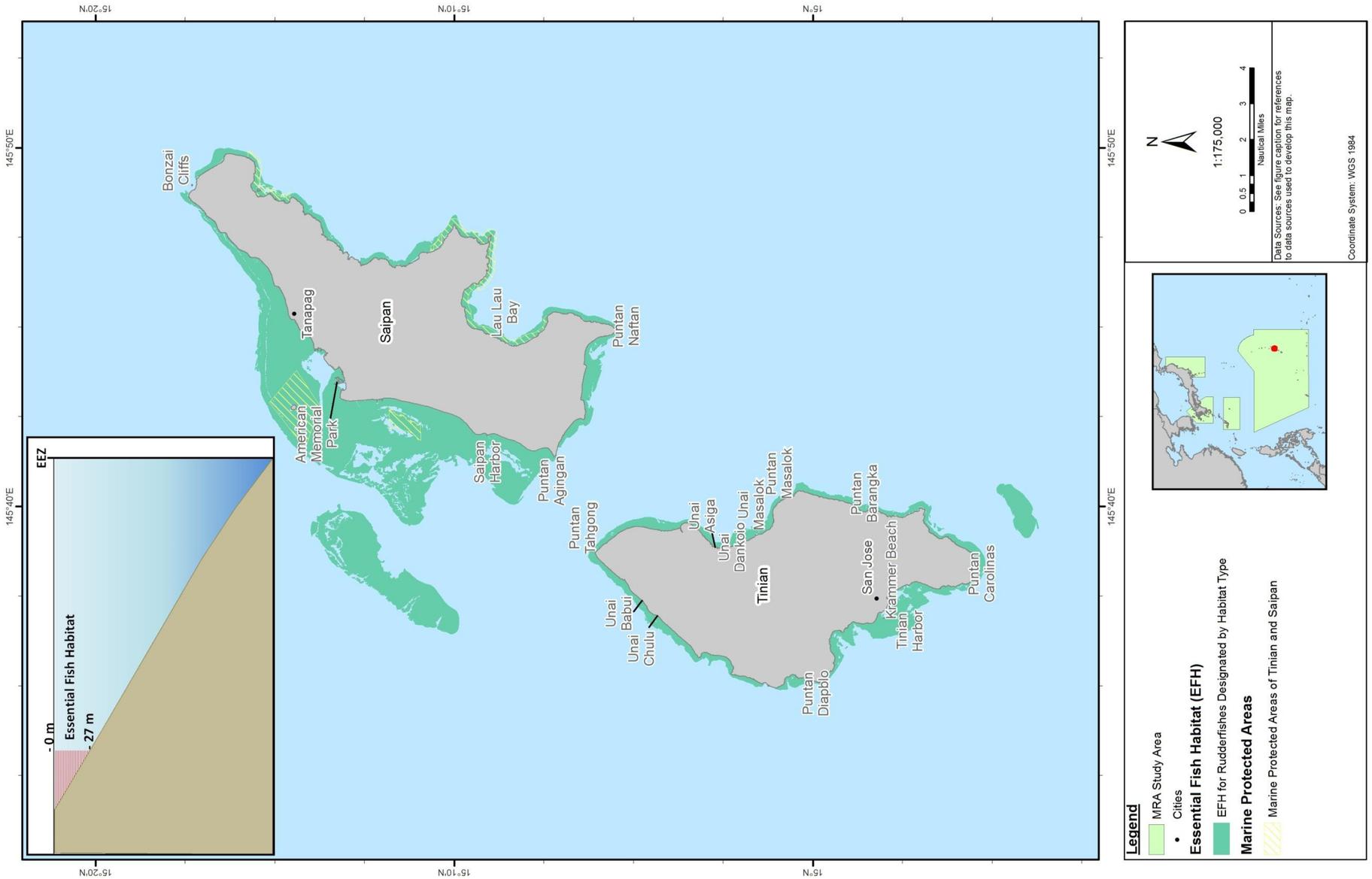

Figure 10-17: Essential Fish Habitat for Adult Lifestages of Rudderfishes of the Currently Harvested Coral Reef Taxa Designated on Tinian and Saipan in the Mariana Archipelago
Souce: National Oceanic and Atmospheric Administration (2013, 2005).

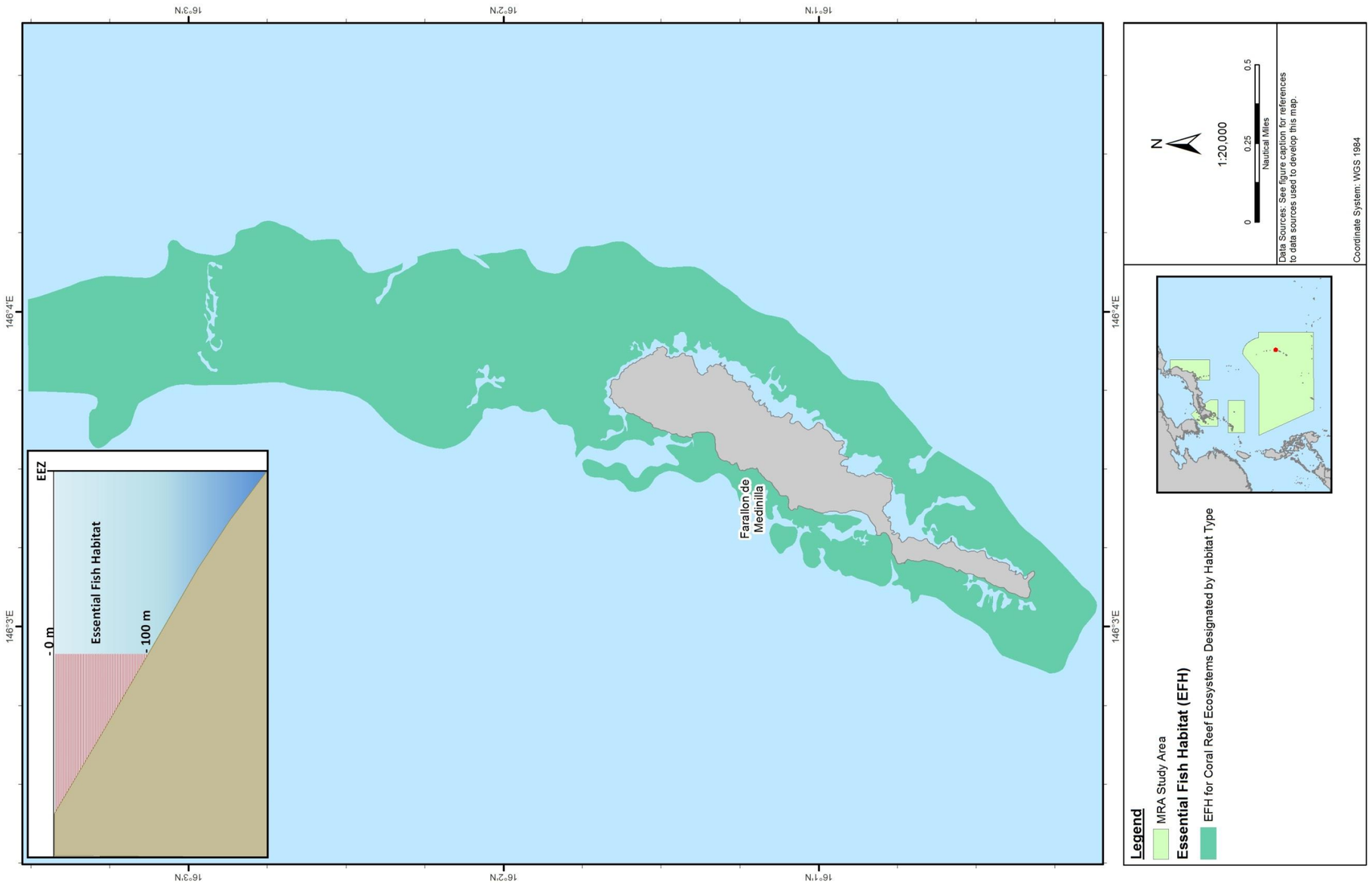

Figure 10-18: Essential Fish Habitat for Juvenile and Adult Lifestages of the Currently Harvested Coral Reef Taxa Designated for Farallon de Medinilla

Source: National Oceanic and Atmospheric Administration (2005).

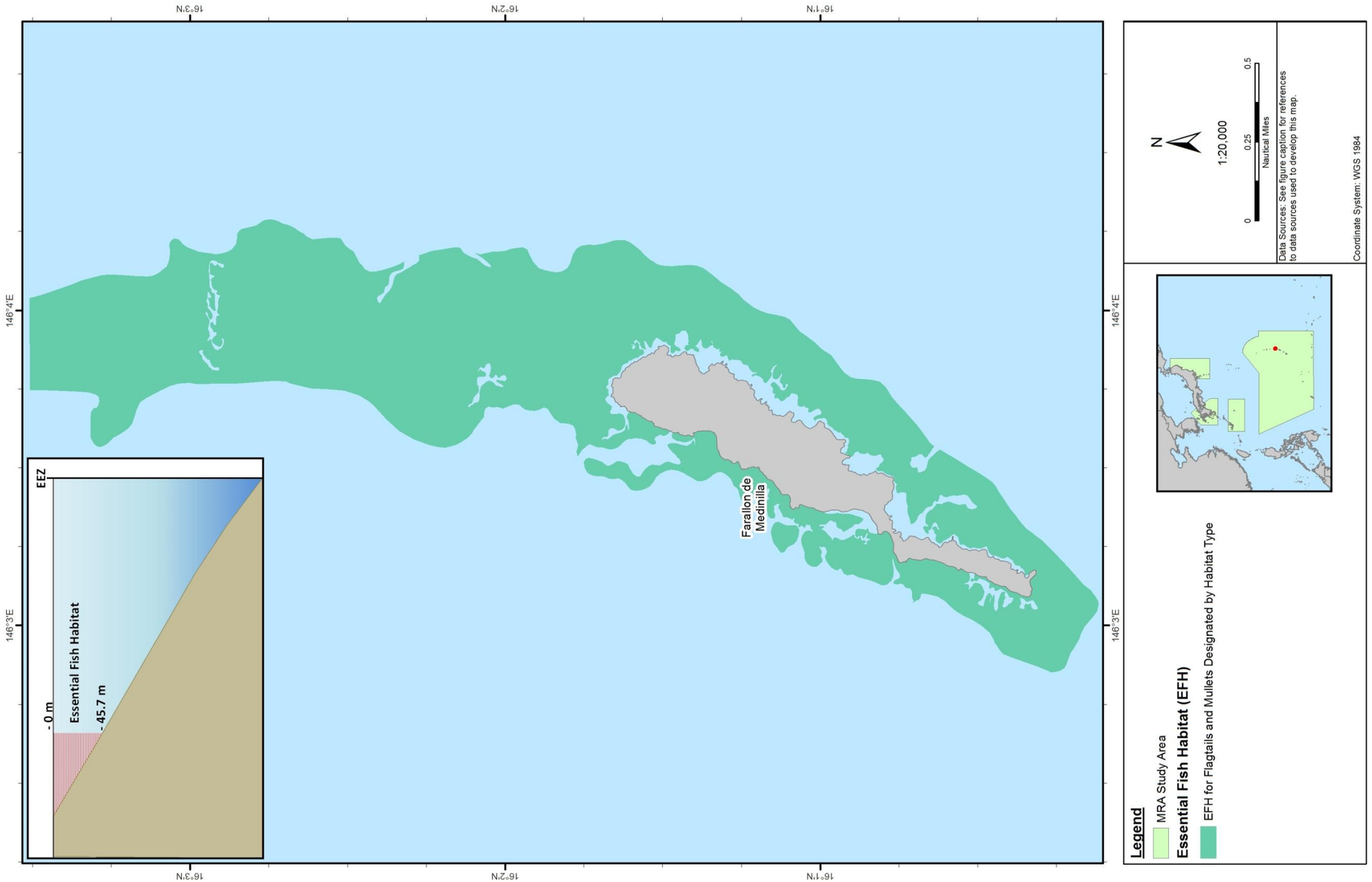

Figure 10-19: Essential Fish Habitat for Juvenile and Adult Lifestages of the Flagtails and Mullets Currently Harvested Coral Reef Taxa Designated on Farallon de Medinilla in the Mariana Archipelago
Source: National Oceanic and Atmospheric Administration (2005).

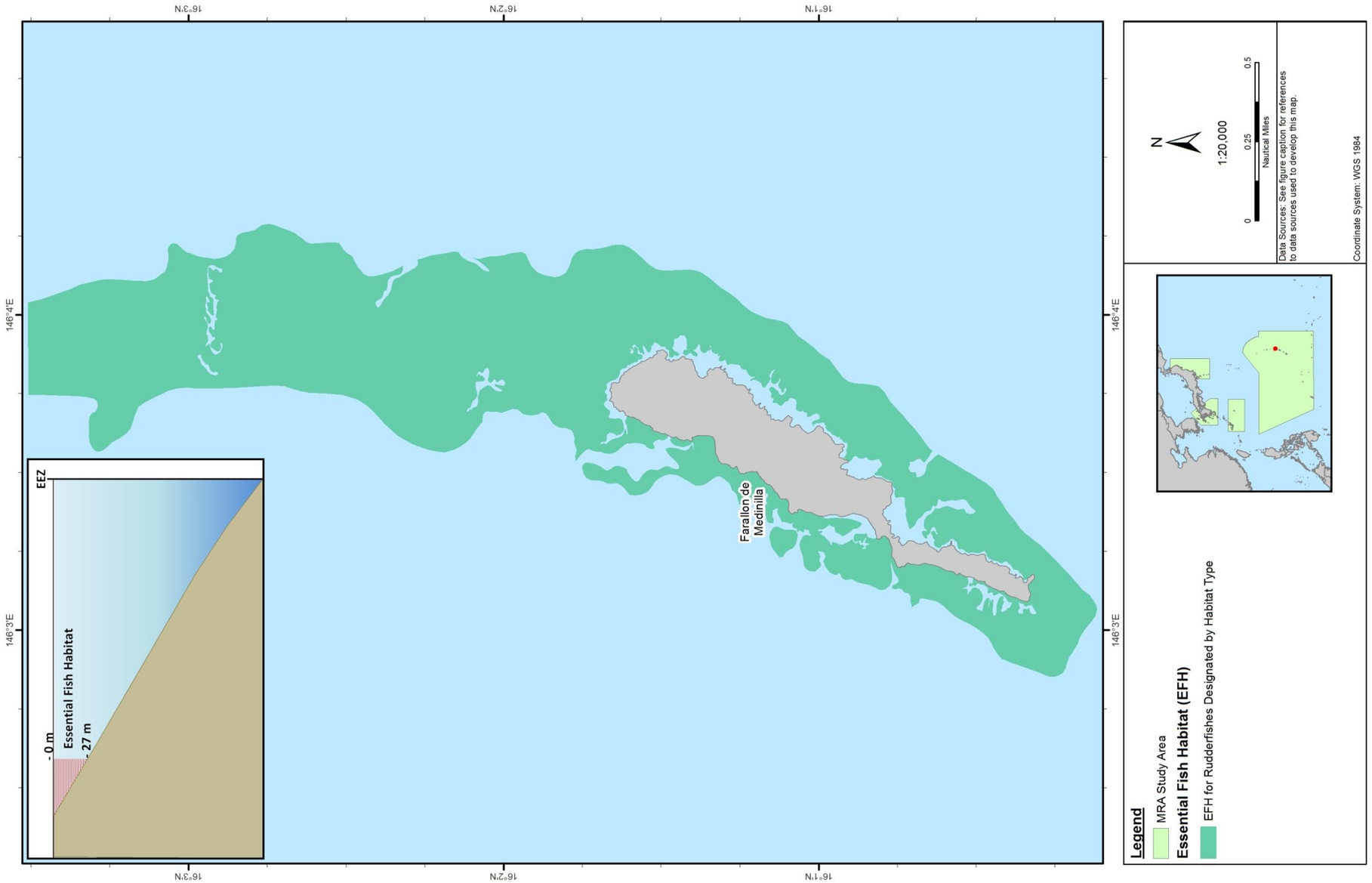

Figure 10-20: Essential Fish Habitat for Adult Lifestages of Rudderfishes of the Currently Harvested Coral Reef Taxa Designated on Farallon de Medinilla in the Mariana Archipelago
Source: National Oceanic and Atmospheric Administration (2005).

10.5.4.1 Acanthuridae (Surgeonfishes and Unicornfishes)

Status. Twenty-seven species of acanthurids are managed in Micronesia[1] as as part of the CHCRT by the WPRFMC (2001); of these, 24 occur in CNMI and Guam (Myers and Donaldson 2003). All have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if acanthurids of the CHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). However, Acanthuridae stocks have been found to approach overfished status on a localized scale (Guillemot et al. 2009). Acanthurids are an important food source and are typically caught by spearfishing or nets as part of the traditional fishery in the insular and coastal region with coral reefs (Randall 2001a). While some studies indicate that no-take marine reserves encourage recovery of these species and spillover (i.e., greater abundance outside of reserves) (Russ et al. 2004; Stockwell et al. 2009) and removal of such protection has a negative impact (Ferraris et al. 2005), a contrasting greater abundance of acanthurids within fished zones than in reserves has been documented, likely due to reduced competition or predation (Ashworth and Ormond 2005). Surgeonfishes are also valuable in the aquarium trade. Aquarium species are discussed further as part of a separate management unit species assemblage (Western Pacific Regional Fishery Management Council 2001). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Acanthurids are found circumtropically around coral reefs, with the majority of the species occurring in the Pacific and Indian Oceans (Allen and Steene 1987).

Habitat Preferences. Surgeonfish are diurnal herbivores and planktivores, seeking shelter on the reef at night. These fishes are associated with many of the major coral reef habitat types including mid-water, sand patch, subsurged reef, and seaward or surge zone reef. While recruits are associated with rubble substratum (Ochavillo et al. 2011), juvenile acanthurids are found in reef areas until mature. Adults are found throughout coral reef habitats, are typically associated with subsurge reef habitats or barrier forereefs (Adams et al. 2011; Nemeth and Appeldoorn 2009), and have been positively correlated with water transparency and topographic relief (Nemeth and Appeldoorn 2009; Ochavillo et al. 2011). They are found at depths from 0 to 150 m, but commonly between 0 and 30 m (Western Pacific Regional Fishery Management Council 2001).

Life History. Acanthuroid species are characterized by rapid growth to a distinct asymptotic size, generally living longer in the Pacific than in the Indian Ocean, and also showing greater longevity at higher latitudes (Trip et al. 2008). Many species of surgeonfish form large, single-species or mixed-species schools (some numbering in the thousands), which are often associated with spawning or feeding behavior. Certain species of acanthurids migrate 500 to 600 m daily for feeding (Western Pacific Regional Fishery Management Council 2001). They are herbivores, known to consume and reduce macroalgal growth on corals (Burkepile and Hay 2010; Stockwell et al. 2009). Spawning activities are often associated with the lunar cycle and occur throughout the year, with peak activity during the winter and early spring (Myers 1999). Acanthurids may also spawn during a new moon or full moon depending on species and geography (Kuiter and Debelius 2001). Generally, spawning occurs at dusk involving groups, pairs, or both (Myers 1999). Surgeonfish eggs and larvae have a wide distribution and are found in pelagic waters (Myers 1999); they settle in seagrass beds, coral rubble, branching coral, and tabular coral, which

[1] Throughout this Chapter, Micronesia refers to the geographic region of the western Pacific Ocean that encompasses Guam, CNMI, Palau, Yap, Caroline Islands, Wake Island, Line Islands, Marshall Islands, and the Federated States of Micronesia.

minimizes the transition time from the larval pelagic stage to the juvenile stage (Nakamura, Shibuno, et al. 2009).

EFH Designations

Eggs and Larvae – The water column from the shoreline to the outer boundary of the U.S. EEZ to a depth of 100 m (Figure 10-11) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

Adult and Juveniles – All bottom habitat and the adjacent water column from 0 to 100 m (Figures 10-12, 10-15 and 10-18) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

10.5.4.2 Balistidae (Triggerfishes)

Status. Nine species of triggerfish are managed in Micronesia as part of the CHCRT by the WPRFMC (2001), and occur in CNMI and Guam (Myers and Donaldson 2003). All have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004b; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if triggerfishes of the CHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Triggerfishes are an important food fish in western Pacific, and some of the more colorful species are popular as aquarium fish (Myers 1999). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Triggerfish are predominately tropical reef dwellers found in the Atlantic, Indian, and Pacific Oceans (Allen and Steene 1987).

Habitat Preferences. Habitat preferences for triggerfishes include protected lagoons, high-energy surge zones, ledges and caves of deep drop-offs, sand bottoms, and rocky coral areas. Adults prefer steeply sloping areas with high coral cover and many caves and crevices. Some triggerfish species have been observed in small, multi-species assemblages of reef fishes (Garcia-Sais 2010). Depth preferences depending on species range from shallow sub tidal zones to waters deeper than 100 m (Myers 1999).

Life History. Triggerfish are omnivorous and prey on other reef-associated organisms. The life span of one species was estimated at 11 years (Kavanagh and Olney 2006). Little information is available on the spawning and migrational patterns of triggerfish in the western Pacific. Triggerfish are generally solitary, but do form pairs during spawning. In the Okinawa coral reef, the halfmoon triggerfish (*Sufflamen chrysopterum*) demonstrated female defense polygyny: both sexes defended territories exclusively against consexual individuals of the same species, and each male territory included one to three distinct female territories (Seki et al. 2009). Balistid spawning events show some correlation to lunar cycles, and eggs are typically deposited in shallow pits excavated by the parents. Larvae are pelagic, with prejuveniles often associated with floating algae (Western Pacific Regional Fishery Management Council 2001).

EFH Designations

Eggs and Larvae – The water column from the shoreline to the outer boundary of the U.S. EEZ to a depth of 100 m (Figure 10-11) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

Adult and Juveniles – All bottom habitat and the adjacent water column from 0 to 100 m (Figures 10-12, 10-15 and 10-18) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

10.5.4.3 Carangidae (Jacks)

Status. Two species of carangids, the bigeye scad (*Selar crumenophthalmus*) and the mackerel scad (*Decapterus macarellus*), are managed in Micronesia as part of the CHCRT by the WPRFMC (2001), and occur in CNMI and Guam (Myers and Donaldson 2003). Both species have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if the bigeye and mackerel scads of the CHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Both of these fishes are economically important food fish on many of the U.S. Pacific Islands, and a small seasonal fishery for bigeye scad is present in the Mariana Archipelago (Uchida 1983; Western Pacific Regional Fishery Management Council 2001). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. The Carangids are a large family represented in all tropical and temperate seas, with the majority found in coral reef waters (Allen and Steene 1987; Myers 1999). The mackerel scad is a circumtropical species and is widespread throughout the Indian Ocean. This species ranges from the Indo-West Pacific to the Marquesas Islands in the east, and from Japan in the north, south to Australia (Smith-Vaniz 1999). The mackerel scad can be found from the Carolines to the Marianas in the MRA Study Area (Myers 1999). Bigeye scad range from Japan and the Hawaiian Islands in the north, south to New Caledonia and Rapa, and throughout Micronesia (Myers 1999), and are distributed in the Indian Ocean as far west as Reunion Island (near Madagascar) (Roos, Roux, and Conand 2007). This species can be found off the coast of Guam year round but is scarce in July and August, possibly due to spawning in other locations (Uchida 1983).

Habitat Preferences. Carangid eggs are planktonic and larvae are common in nearshore waters. For example, larval fish assemblages of bigeye scad are common in the summer in the Taiwan Strait, generally linked to topographic upwelling of phyto- and zooplankton, which serve as food sources (Hsieh et al. 2011). Juveniles can be found in nearshore and estuarine waters, and occasionally form small schools over sandy inshore reef flats (Myers 1999). Adults are widely distributed in shallow coastal waters, estuaries, shallow reefs, deep reef slopes, banks, and seamounts (Western Pacific Regional Fishery Management Council 2001). Adult Carangids can range from reef habitats to deep slope habitats at depths of 0 to 350 m (Western Pacific Regional Fishery Management Council 2001). Mackerel scad are a schooling species most often found in open water and frequently in insular habitats. This species can be found near the surface, but is commonly taken at depths from 40 to 200 m (Froese and Pauly 2012). Small to large schools of bigeye scad are typically found inshore or in shallow-water, and occasionally over shallow reefs in turbid water to depths of 170 m (Smith-Vaniz 1999). Large schools of bigeye scad appear seasonally in the Mariana Islands from August to November in shallow sandy lagoons, bays, and channels (Myers 1999).

Life History. Carangid species spawn in pairs within larger aggregations associated with the lunar cycle. Little is known about the reproduction of these species but peak spawning occurs between May and August (Western Pacific Regional Fishery Management Council 2001). *Decapterus* spp. and *Selar* spp. tend to spawn in pelagic environments. Eggs are also found in pelagic waters; after hatching, larvae and juvenile fish remain in the pelagic environment where they frequently form large aggregating schools. Juvenile aggregations have been identified as far as 90 mi. offshore. Larval and juvenile fish remain in offshore pelagic waters for the first several months of their lives, after which they migrate to the nearshore adult habitat. Spawning occurs from March to August, peaking from May to July (Western Pacific Regional Fishery Management Council 2001). Bigeye scad in the Indian Ocean have been observed to mature by April, with size of first maturity reached at 215 millimeters (mm) fork length; sex ratio remained equal as the fish continued to mature, reaching a maximum fork length of 255 mm. Gonad

indices peaked in November, and reproduction was followed by massive mortality (Roos, Roux, and Conand 2007).

EFH Designations

Eggs and Larvae – The water column from the shoreline to the outer boundary of the U.S. EEZ to a depth of 100 m (Figure 10-11) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

Adult and Juveniles – All bottom habitat and the adjacent water column from 0 to 100 m (Figures 10-12, 10-15 and 10-18) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

10.5.4.4 Carcharhinidae (Requiem Sharks)

Status. Five carcharhinid sharks are managed in Micronesia as part of the CHCRT by the WPRFMC (2001), and occur in CNMI and Guam (Myers and Donaldson 2003); these include the grey reef shark (*Carcharinus amblyrhynchos*), silvertip shark (*C. albimarginatus*), Galapagos shark (*C. galapagensis*), blacktip reef shark (*C. melanopterus*), and whitetip reef shark (*Triaenodon obesus*). All have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004b; Western Pacific Regional Fishery Management Council 2001). All of the requiem sharks are afforded protection under the Shark Conservation Act of 2010 (H.R. 81, S. 850). No data are available to determine if requiem sharks of the CHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). All five of the CHCRT sharks are listed on the IUCN Red List of threatened species; each is categorized as near threatened. Another species of requiem shark not specifically managed as a CHCRT, the tiger shark (*Galeocerdo cuvier*) has been documented in the waters around the Mariana Islands (Whitney and Crow 2007), is a near threatened species (Simpfendorfer 2009; Smale 2009) with low fecundity, which limits its ability to rebound from fishing pressure (Whitney and Crow 2007).

Distribution. The requiem sharks comprise one of the largest and most important shark families. These species are common, wide-ranging, and can be found in all warm and temperate seas (Western Pacific Regional Fishery Management Council 2001).

In the western Pacific, the grey reef shark ranges from southern China to northern Australia and the Tuamoto Archipelago (Compagno 1984).

The silvertip shark ranges from off southern Japan to northern Australia and French Polynesia (Compagno 1984).

The Galapagos shark is circumtropical in distribution, with a preference for waters surrounding oceanic islands. In the tropical regions of the Pacific, the Galapagos shark can be found around Lord Howe Island, the Tuamoto Archipelago, Middleton and Elizabeth Reefs, Hawai‘i, Revillagigedo, Clipperton, Cocos, and the Galapagos Islands (Compagno 1984). In the western Pacific, the blacktip reef shark ranges from South Africa, the Red Sea, Pakistan, and India eastward to the western Central Pacific (Compagno 1984).

The whitetip reef shark is common in Polynesia, Melanesia, and Micronesia, northward to the Hawaiian Islands, and southwest to the Pitcairns (Compagno 1984).

Habitat Preferences.. Most species of requiem sharks inhabit tropical continental coastal and offshore waters, but several species prefer coral reefs and oceanic islands (Compagno 1984). Requiem sharks inhabit a wide variety of coral reef habitats with no apparent preference.

Grey reef sharks prefer open water, above reefs, particularly along steep outer slopes or dropoffs at depths from 1 to 274 m. This species is common around the islands of the northern Mariana Islands and Micronesian atolls, where it frequents lagoons, channels, and seaward reefs (Myers 1999).

Silvertip sharks are typically found over dropoffs and offshore banks at depths of 30 to 400 m but have been observed in lagoons, deep channels, and surface waters (Myers 1999).

Adult Galapagos sharks can be found over steep outer reef slopes and offshore banks at depths of 30 to 180 m. Juveniles are more commonly found in waters between 2 and 25 m (Myers 1999).

Blacktip reef sharks are common inshore and occasionally offshore on continental and insular shelves. This species is generally associated with reef flats, shallow lagoons, and reef margins (Compagno and Niem 1998).

The whitetip reef shark is one of the most common sharks in lagoons and over seaward reefs, and is frequently found resting on the bottom over sand patches. This species is generally found at depths greater than 3 m and has been observed as deep as 300 m (Compagno and Niem 1998; Myers 1999).

The tiger shark inhabits coastal and offshore waters, throughout the water column, and often occurs shallow waters close inshore, including river estuaries (Compagno and Niem 1998).

Life History. Carcharhinid sharks reproduce by internal fertilization, and all but one species (tiger shark) in this family are placental viviparous (embryos are nourished by a placenta-like organ in the female) (Western Pacific Regional Fishery Management Council 2001). Tiger shark females give birth only once every 3 years to litters with average of 33 pups (Whitney and Crow 2007). Evidence supports the occurrence of mating in January–February, ovulation in May–June, and a 15–16 month gestation period leading to births in September–October of the following year. Juvenile carcharhinids are often associated with inshore areas such as bays, seagrass beds, and lagoon flats, but move into deeper waters as they mature. Adult sharks frequent inshore areas during mating or birthing events and on occasion for foraging (Western Pacific Regional Fishery Management Council 2001).

EFH Designations

Eggs and Larvae – Not available

Adult and Juveniles - All bottom habitat and the adjacent water column from 0 to 100 m to the outer extent of the U.S. EEZ (Figures 10-12, 10-15 and 10-18) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

10.5.4.5 Holocentridae (Soldierfishes/Squirrelfishes)

Status. Of the 21 holocentrid species managed in Micronesia as part of the CHCRT by the WPRFMC (2001), 17 (9 soldierfishes and 8 squirrelfishes) are reported as occurring in CNMI and Guam (Myers and Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if soldierfishes/squirrelfishes of the CHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Squirrelfish and soldierfish are found throughout the tropical Atlantic, Indian, and Pacific Oceans, with most species occurring in the Indo-Pacific region (Allen and Steene 1987). The bigscale

soldierfish (*Myripristis berndti*) ranges from the western Indian Ocean to the eastern Pacific (Craig et al. 2007).

Habitat Preferences. Soldierfish and squirrelfish occupy relatively shallow water over coral reefs or rocky bottoms (Randall and Greenfield 1999); they have also been observed in seagrass beds adjacent to coral reefs (Nakamura and Tsuchiya 2008). Most holocentrid fishes are nocturnally active and occupy the water column above the reef at night (Myers 1999). During the day, they can be found along dropoffs, in or near caves and crevices, under rocks or coral overhangs, or among branching corals. Certain squirrelfish species demonstrate site fidelity and selectivity of holes that are open at one or both ends for diurnal refuges (Menard, Turgeon, and Kramer 2008). Holocentrid fishes are found from shallow water down to approximately 40 m, with some species occurring as deep as 235 m (Western Pacific Regional Fishery Management Council 2001). Adults are usually demersal, and larvae are planktonic for several weeks (Froese and Pauly 2012).

Life History. Little is known about the embryonic development and larval cycles of Holocentrids. In one species of Holocentridae, the brick soldierfish (*Myripristis amaena*), spawning occurs in open water and peaks in early April to early May, with a secondary peak in September. Spawning for this species is correlated with the lunar cycle (Western Pacific Regional Fishery Management Council 2001). Study of bigscale soldierfish populations indicate that these and other soldierfishes may extensively disperse larvae (Craig et al. 2007).

EFH Designations

Eggs and Larvae – The water column from the shoreline to the outer boundary of the U.S. EEZ to a depth of 100 m (Figure 10-11) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

Adult and Juveniles – All rocky and coral areas and the adjacent water column from 0 to 100 m (Figures 10-12, 10-15 and 10-18) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

10.5.4.6 Kuhliidae (Flagtails)

Status. One flagtail species, the barred flagtail (*Kuhlia mugil*) is managed in Micronesia as part of the CHCRT by the WPRFMC (2001). This species has been reported as occurring in CNMI and Guam (Myers and Donaldson 2003), and has EFH designated within the boundaries of the MRA Study Area (Western Pacific Regional Fishery Management Council 2001). No data are available to determine if the barred flagtail of the CHCRT are approaching an overfished situation (National Marine Fisheries Service 2004a, 2011). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Flagtails are distributed throughout the Indo-Pacific region (Western Pacific Regional Fishery Management Council 2001). In the Indo-Pacific, the barred flagtail ranges in the west from the Red Sea and East Africa to the eastern Pacific, and from southern Japan in the north, south to New South Wales and Lord Howe Island (Carpenter 2001b).

Habitat Preferences. Adult flagtails are usually found in shallow waters and form schools on the outer edge of surge-swept reefs, where they aggregate under ledges, in holes, or in caves during the day (Froese and Pauly 2012; Western Pacific Regional Fishery Management Council 2001). At night, the schools break up and the fish forage in the water column above the reef (Froese and Pauly 2012). Juveniles are found individually or in small aggregations in tide pools or along shallow shoreline areas (Froese and Pauly 2012). Flagtails can tolerate a wide range of salinities and can be found in freshwater,

brackish water, or salt water (McRae, McRae, and Fitzsimons 2011; Western Pacific Regional Fishery Management Council 2001), although some kuhlid species are exclusive to marine waters. The barred flagtail is found in tropical waters from 32° N to 32° S at depths from 3 to 18 m (Froese and Pauly 2012).

Life History. Information is lacking on the life history of this family (Western Pacific Regional Fishery Management Council 2001). One species, the spotted flagtail (*K. marginata*), spends the early lifestage at sea, then grows to maturity in freshwater streams such as the Genka River on Okinawa Island, Japan, and ultimately returns to the sea to spawn (Oka and Tachihara 2008). A female may spawn several times in the inshore area during its lifespan, but many males do not return to the freshwater environment after spawning.

EFH Designations

Eggs and Larvae – The water column from the shoreline to the outer limits of the U.S. EEZ to a depth of 100 m (Figure 10-11) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

Adult and Juveniles – All bottom habitat and the adjacent water column from 0 to 46 m (Figures 10-13, 10-16, and 10-19) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

10.5.4.7 Kyphosidae (Rudderfishes)

Status. Three species of the family Kyphosidae are managed in Micronesia as part of the CHCRT by the WPRFMC (2001), and are reported as occurring in the CNMI and Guam (Myers and Donaldson 2003). These species include the grey rudderfish (*Kyphosus bigibbus*), the blue sea chub (*K. cinerascens*)—known in Guam as the highfin rudderfish, and the lowfin rudderfish (*K. vaigiensis*). All three species have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if rudderfishes of the CHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). These species are highly valued food-fish and are taken by handline, gill net, and spear fishing (Sakai 2001). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Rudderfish are found in the Atlantic, Indian, and Pacific oceans (Froese and Pauly 2012). In the Indo-Pacific, this family is found throughout tropical and subtropical waters from Easter Island westward to the Red Sea (Western Pacific Regional Fishery Management Council 2001).

The grey rudderfish is found in tropical waters from 35° N to 28° S typically associated with reefs (Froese and Pauly 2012).

The blue sea chub is found in tropical waters from 35° N to 30° S at depths from 1 to 24 m (Froese and Pauly 2012).

The lowfin rudderfish (*K. vaigiensis*) is found in tropical waters from 30° N to 28° S at depths from 1 to 24 m (Froese and Pauly 2012).

Habitat Preferences. Rudderfish are found near shore over rocky bottoms or associated with coral reefs along exposed coasts (Froese and Pauly 2012; Western Pacific Regional Fishery Management Council 2001). Adults are usually found swimming several meters above the bottom. The blue sea chub occurs at depths of at least 24 m (Western Pacific Regional Fishery Management Council 2001). Eggs, larvae, and juveniles are found in the upper layer of pelagic waters. Juveniles are often found far out at sea

associated with floating debris (Myers 1999; Western Pacific Regional Fishery Management Council 2001).

Life History. Very little information is available on the spawning and migration of rudderfish. Eggs and larvae are both subject to advection by ocean currents (Western Pacific Regional Fishery Management Council 2001). Adults spawn in large numbers in pelagic waters (Froese and Pauly 2012). Kyphosids are herbivores and have been documented in some regions to subsist primarily on macroalgae (Ferreira and Goncalves 2006). The highfin rudderfish has a diet of macroscopic brown algae, while the lowfin rudderfish feeds on turfing and filamentous red and green algae (Choat, Robbins, and Clements 2004).

EFH Designations

Eggs, Larvae, and Juvenile – The water column from the shoreline to the outer boundary of the U.S. EEZ to a depth of 100 m (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

Adult – All rocky and coral bottom habitat and the adjacent water column from 0 to 27 m (Figures 10-14, 10-17, and 10-20) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

10.5.4.8 Labridae (Wrasses)

Status. Twenty-two species of the family Labridae are managed in Micronesia as part of the CHCRT by the WPRFMC (2001); of these, 20 occur in CNMI and Guam (Myers and Donaldson 2003). All 20 species have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if wrasses of the CHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Very little information is available regarding the commercial harvest of labrids in Guam or the Northern Mariana Islands. However, wrasses make up a small percentage of the commercial fish trade in numbers, value, and weight within both areas (Western Pacific Regional Fishery Management Council 2001).

One species of wrasse found in the MRA Study Area, the humphead wrasse (*Cheilinus undulatus*), also known as the Napoleon wrasse, is listed by the IUCN Red List as “Endangered” (International Union for Conservation of Nature and Natural Resources 2011). The humphead wrasse was also listed as a “Species of Concern” by the NOAA Fisheries Office of Protected Resources in 2004 (National Marine Fisheries Service 2004c), and a 90-day finding on a petition to list as threatened or endangered waspublished on February 28, 2013 (78FR13614) . The humphead wrasse was once an economically important reef fish in Guam but is rarely seen around reefs or reported in inshore survey catch results (Western Pacific Regional Fishery Management Council 2001). Factors influencing the decline of this species include (1) intensive and species-specific removal in the live reef food-fish trade; (2) spearfishing at night using self contained underwater breathing apparatus (SCUBA) gear; (3) lack of coordinated, consistent national and regional management; (4) illegal, unregulated, or unreported fisheries; and (5) loss of habitat (National Marine Fisheries Service 2004c). International trade has targeted juvenile humphead wrasses (based on the typical sizes of those sold in Hong Kong retail markets between 1995 and 2009), and threatens to leave an insufficient spawning biomass to sustain the species (de Mitcheson, Liu, and Suharti 2010).

Distribution. Wrasses are found in shallow tropical and temperate seas of the Atlantic, Indian, and Pacific Oceans (Froese and Pauly 2012). This species family is distributed throughout the shallow areas of the western Pacific (Western Pacific Regional Fishery Management Council 2001). The humphead wrasse can be found in the Indo-Pacific region from the Red Sea in the west to the Tuamotus in the east, and from the Ryukyu Islands in the north, including China and Chinese Taipei, east to Wake Island, south to New Caledonia, and throughout Micronesia (Myers 1999). The humphead wrasse’s distribution includes the

Pacific islands of Palau (Tupper 2007), New Caledonia (Chateau and Wantiez 2007), and American Samoa (Sabater and Carroll 2009).

Habitat Preferences. Labrids prefer shallow waters closely associated with coral reefs (Western Pacific Regional Fishery Management Council 2001). They inhabit steep outer reef slopes, channel slopes, and lagoon reefs. Wrasses can be found in virtually every habitat on tropical reefs, including rubble, sand, algae, seaweeds, rocks, flats, tidepools, crevices, caves, fringing reefs, and patch reefs (Allen and Steene 1987; Western Pacific Regional Fishery Management Council 2001). Most wrasses are found in relatively calm waters at depths between about 3 and 20 m; however, some species occur at depths greater than 200 m (Allen and Steene 1987; Western Pacific Regional Fishery Management Council 2001). Adults roam the coral reefs during the day, keeping close to coral or rocky cover (Froese and Pauly 2012). At night, they may rest in caves or under coral ledges, bury themselves in the sand, or lie motionless on the bottom (Froese and Pauly 2012; Western Pacific Regional Fishery Management Council 2001). Labrid eggs and larvae are pelagic and are routinely found in the open ocean (Western Pacific Regional Fishery Management Council 2001). Juveniles, like adults, inhabit a wide range of habitats from shallow lagoons to deep reef slopes (Western Pacific Regional Fishery Management Council 2001).

Humphead wrasses occur along steep outer reef slopes, channel slopes, and occasionally on lagoon reefs, at depths from 1 to 60 m (Froese and Pauly 2012; Western Pacific Regional Fishery Management Council 2001). Adults are usually solitary and can be found roaming the coral reefs by day and resting in reef caves and under coral ledges at night (Froese and Pauly 2012). One study of humphead wrasse nursery habitat in Palau found that early juvenile stages primarily utilize branching coral structures mixed with bushy macroalgae (Tupper 2007), while a study in the western Indian Ocean found juvenile humphead wrasses predominantly in seagrass beds (Dorenbosch et al. 2006). Juveniles are associated with coral-rich areas of lagoon reefs, usually among thickets of Acropora corals (Froese and Pauly 2012). The eggs and larvae of this species are pelagic (Sadovy 2003).

Life History. Wrasses are pelagic spawners, and schooling behavior is usually associated with reproduction. In tropical waters, spawning occurs year-round along the outer edge of the patch reef or along the outer slope of more extensive reefs. Many labrids migrate to prominent coral or rock outcrops to spawn. Wrasses may spawn in large aggregations or in pairs depending on the maturity of the individuals (Western Pacific Regional Fishery Management Council 2001). Typically, labrids reproduce via protogynous hermaphroditism; multiple species have been found to reach maturity as sexually active initial phase females, later changing to a terminal phase male (Morton et al. 2008).

It has been confirmed that protogynous hermaphroditism is characteristic of the humphead wrasse; one study determined that the minimum total length for sexual maturation was 650 mm for females, versus 845 mm for males (de Mitcheson, Liu, and Suharti 2010). The humphead wrasse may spawn in small or large groupings, and spawning coincides with certain phases of the tidal cycle. This species is a daily spawner that does not migrate far from its spawning area (resident spawner) (Sadovy 2003). A study on the Palau barrier reef documented spawning aggregations daily after high tide at specific locations on the seaward edge of the reef, with a consistently high female-to-male ratio between 6:1 and 10:1 (Colin 2010). Humpheads may spawn during several or all months of the year associated with a range of different reef habitats (Sadovy 2003).

EFH Designations

Eggs, Larvae, Juvenile, and Adult – The water column and all bottom habitats extending from the shoreline to the outer boundary of the U.S. EEZ to a depth of 100 m (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

10.5.4.9 Mullidae (Goatfishes)

Status. Thirteen species of the family Mullidae are managed in Micronesia as part of the CHCRT by the WPRFMC (2001); of these, 11 occur in CNMI and Guam (Myers and Donaldson 2003). All 11 have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). Insufficient data are available to determine if goatfishes of the CHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). However, decreasing fish length for Mullidae (and six other families) in response to increasing catch rates or fishing pressure contributed to the classification of certain sites in Pacific island countries and territories as under potentially high finfishing pressure risk (Kronen et al. 2010). A number of goatfish are commercially important in the western Pacific, and most of the catch is marketed fresh (Randall 2001c). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Goatfish are found in tropical, subtropical, and temperate regions of the Atlantic, Indian, and Pacific Oceans (Froese and Pauly 2012; Uiblein 2007). The majority of species in this family can be found in the Indo-West Pacific region (Allen and Steene 1987).

Habitat Preferences. Different species and life stages of goatfish vary significantly in habitat use, ranging from the upper littoral down to the upper slope (Uiblein 2007). Generally, goatfish are found over sandy areas in shallow waters adjacent to reefs at depths of about 10 m (Allen and Steene 1987; Western Pacific Regional Fishery Management Council 2001). However, some species have been reported as deep as 140 m (Western Pacific Regional Fishery Management Council 2001). Goatfish eggs and larvae are pelagic, and adults and juveniles are found in demersal habitats associated with coral reefs, rocks, sand, mud, crevices, and ledges (Western Pacific Regional Fishery Management Council 2001).

Life History. Goatfish are commonly found schooling and may spawn either in groups or pairs (Western Pacific Regional Fishery Management Council 2001). Goatfish are pelagic spawners, and aggregations of 300 to 400 individuals are common for certain species (Allen and Steene 1987). In the post-larval stage, during which the characteristic barbels are developed, goatfish prefer sand-associated bottoms (Uiblein 2007). Goatfish use their mouths and barbels vigorously while foraging, stirring up sediments and detritus into the water column (Uiblein 2007)

EFH Designations

Eggs and Larvae – The water column extending from the shoreline to the outer boundary of the U.S. EEZ to a depth of 100 m (Figure 10-11) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

Juvenile and Adult – All rocky/coral and sand-bottom habitat and the adjacent water column from 0 to 100 m (Figures 10-12, 10-15, and 10-18) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

10.5.4.10 Mugilidae (Mullets)

Status. Three species of the family Mugilidae (Mullets) are managed in Micronesia as part of the CHCRT by the WPRFMC (2001), and occur in CNMI and Guam (Myers and Donaldson 2003). All three have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if mullets of the CHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Several species of mullets are of moderate to major importance to fisheries in the western Pacific, and smallscale, subsistence fisheries are probably also relatively prominent (Harrison and Senou 1999); for example, Mugilidae species are targeted primarily by indigenous Melanese fishers for subsistence

purposes (Guillemot et al. 2009). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. The family Mugilidae can be found in all tropical and temperate seas but are most speciose in the Indo-West Pacific region (Froese and Pauly 2012; Harrison and Senou 1999). The kanda (*Valamugil engeli*) is found in the Indo-Pacific region from East Africa to the Marquesan and Tuamoto islands and north to the Yaeyamas (Froese and Pauly 2012). The acute-jawed mullet (*Neomyxus leuciscus*) is found in the Pacific Ocean around southern Japan and the Mariana Islands, and Bonin Islands east to the Hawaiian, Line, and Ducie Islands. In Micronesia, this species is found around the Ifaluk, Mariana, and Marshall Islands (Froese and Pauly 2012).

The fringelip mullet (*Crenimugil crenilabis*) is found in the Indo-Pacific region from the Red Sea and East Africa to the Line and Tuamoto islands, north to southern Japan, and south to Lord Howe Island (Harrison and Senou 1999).

Habitat Preferences. Most species of mullet are euryhaline and occupy diverse habitats including marine, brackish lagoons, estuaries, and freshwater environments (Harrison and Senou 1999). Some species more typically inhabit brackish waters. Mullets are generally found feeding over reefs or sandy bottoms at depths around 20 m (Harrison and Senou 1999; Western Pacific Regional Fishery Management Council 2001). Juveniles of some mullet species have been found in abundance over mud stratum in non-estuarine mangrove creeks (Mwandya et al. 2010) and in treeless mudflats of mangrove estuaries (Wang et al. 2009). The kanda is found in tropical waters from 25° N to 24° S usually associated with coral reefs. Adults usually inhabit sandy to muddy areas of reef flats and shallow lagoons, while juveniles are generally found in tide pools (Froese and Pauly 2012). The acute-jawed mullet is found in tropical waters between 30° N and 30° S at depths from 0 to 4 m. This species inhabits sandy shores, tide pools, and rocky surge areas. The acute-jawed mullet tends to move inshore to surface waters at night (Froese and Pauly 2012). The fringelip mullet inhabits tropical waters from 32° N to 32° S at depths from 0 to 20 m. This species is found in coastal waters, over sandy or muddy areas of lagoons, reef flats, and tide pools (Froese and Pauly 2012).

Life History. Very little information concerning the spawning and migration of these species is available. Presumably, the eggs and larvae are dispersed by advection. The acute-jawed mullet is a schooling species. The fringelip mullet forms large schools before spawning. Spawning occurs in June over the shallow, open areas of the lagoon slope, and spawning events usually take place after dark in large aggregations (Froese and Pauly 2012).

EFH Designations

Eggs/Larvae – The water column from the shoreline to the outer limits of the U.S. EEZ to a depth of 100 m (Figure 10-11) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

Juvenile/Adult – All sand and mud bottoms and the adjacent water column from 0 to 46 m (Figures 10-13, 10-16, and 10-19) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

10.5.4.11 Muraenidae (Moray Eels)

Status. Three species of the family Muraenidae (Moray eels) are managed in Micronesia as part of the CHCRT by the WPRFMC (2001) and occur in the CNMI and Guam (Myers and Donaldson 2003). All three species have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries

Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if moray eels of the CHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). No commercial fishery exists for morays, and most are taken as incidental catch; but they are sold in fish markets and readily eaten in the western Pacific (Bohkle, McCosker, and Smith 2001). These species are also targets of the aquarium trade. None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Morays are found worldwide in tropical and subtropical waters (Froese and Pauly 2012). Gymnothorax species or moray eels are distributed ocean-wide biogeographically and at different depths (Reece et al. 2011). The central Indonesian Seas appear to be a biodiversity hotspot for many species of eel, including *Muraenidae* (Wouthuyzen et al. 2005).

The yellow-edged moray (*Gymnothorax flavimarginatus*) ranges throughout the Indo-Pacific from the Red Sea and South Africa eastward to the Tuamoto and Austral islands, north to the Ryukyu and Hawaiian Islands and south to New Caledonia (Froese and Pauly 2012).

The giant moray (*G. javanicus*) can be found throughout the Indo-Pacific from the Red Sea and East Africa to the Marquesas and Oeno Atoll (Pitcairn Group), north to the Ryukyu and Hawaiian Islands, south to New Caledonia and the Austral Islands (Froese and Pauly 2012).

The undulated moray (*G. undulatus*) is distributed throughout the Indo-Pacific from the Red Sea and East Africa, including Walter Shoal, to French Polynesia, north to southern Japan and the Hawaiian Islands, south to the southern Great Barrier Reef (Froese and Pauly 2012).

Habitat Preferences. Most species of moray are benthic and can be found in shallow waters around rocks or reefs. Some species are associated with sand or mud bottoms and have been caught as deep as 500 m (Bohkle, McCosker, and Smith 2001). Juvenile and adult morays lurk in holes and crevices during the day and emerge at night to search the reef for food (Waikiki Aquarium 1999c). They are apex predators on coral reefs (Reece et al. 2010). Moray eggs are pelagic, and the leptocephalic larvae are epipelagic (Froese and Pauly 2012; Western Pacific Regional Fishery Management Council 2001).

The yellow-edged moray inhabits tropical waters between 30° N and 24° S at depths from 1 to 150 m. This species can be found along drop-offs and in coral or rocky areas of reef flats and protected fishshorelines to seaward reefs (Froese and Pauly 2012).

The giant moray inhabits tropical waters between 30° N and 25° S at depths from 0 to 50 m. This species is found in lagoons and seaward reefs and is frequently found along drop-offs and slopes in Indonesian waters. Juveniles tend to inhabit intertidal reef flats (Froese and Pauly 2012).

The undulated moray inhabits tropical waters from 32° N to 28° S at depths from 0 to 30 m. This species is common on reef flats among rocks rubble or debris and in lagoons and seaward reefs to depths greater than 26 m (Froese and Pauly 2012).

Life History. Information is lacking on the life history of this family (Western Pacific Regional Fishery Management Council 2001). Migration has been observed in some species of morays, but most tropical species remain in their home territories or congregate in small groups in certain areas (Debelius 2002). Morays typically have a long pelagic larval stage, which results in wide dispersal among different reef habitats (Reece et al. 2011).

EFH Designations

Eggs and Larvae – The water column from the shoreline to the outer boundary of the U.S. EEZ to a depth of 100 m (Figure 10-11) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

Juvenile and Adult – All rocky coral areas and the adjacent water column and the adjacent water column from 0 to 100 m (Figures 10-12, 10-15, and 10-18) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

10.5.4.12 Polynemidae (Threadfins)

Status. One species, the sixfeeler threadfin (*Polydactylus sexfilis*) of the family Polynemidae, is managed in Micronesia as part of the CHCRT by the WPRFMC (2001); the species has been reported as occurring in CNMI and Guam (Myers and Donaldson 2003). EFH has been designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001) for this species. No data are available to determine if the sixfeeler threadfin of the CHCRT is approaching an overfished situation (National Marine Fisheries Service 2011). This species is highly valued as food-fish (Western Pacific Regional Fishery Management Council 2001). This species is not listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. The sixfeeler threadfin is found throughout the tropical waters of the Atlantic and Indo-Pacific Oceans from 30° N to 0° N (Western Pacific Regional Fishery Management Council 2001); (Froese and Pauly 2012). In the Indo-Pacific, this species ranges from India to the Hawaiian, Marquesan, and Pitcairn Islands, north to the Yaeyama and Bonin Island, and throughout Micronesia (Myers 1999).

Habitat Preferences. Adult sixfeeler threadfin are found near reef areas and inhabit turbid waters along sandy shorelines and over sandy lagoon bottoms usually associated with high-energy surf zones (Feltes 2001; Myers 1999; Western Pacific Regional Fishery Management Council 2001). This species is most common at depths from 20 to 50 m (Feltes 2001). Sixfeeler threadfin eggs and larvae are pelagic, but after larval metamorphosis they enter nearshore habitats such as surf zones, reefs, and stream entrances (Western Pacific Regional Fishery Management Council 2001). Juvenile sixgill threadfin are found from the shoreline breaker to 100 m depth (Western Pacific Regional Fishery Management Council 2001).

Life History. Spawning occurs close to shore for 3 to 6 days per month, and is associated with the lunar cycle (Myers 1999; Western Pacific Regional Fishery Management Council 2001). The sixfeeler threadfin spawns from June to September, with a peak in July and August (Western Pacific Regional Fishery Management Council 2001). Spawning may occur year-round in tropical locations (Western Pacific Regional Fishery Management Council 2001). Both eggs and larvae are subject to advection by ocean currents (Western Pacific Regional Fishery Management Council 2001). Sixfeeler threadfin consume a diet of primarily crustaceans, with smaller prey such as amphipods becoming less common and larger prey such as crabs and fishes becoming increasingly common with successively larger threadfin size classes (Ogawa, Ziemann, and Bloom 2008).

EFH Designations

Eggs and Larvae – The water column extending from the shoreline to the outer boundary of the U.S. EEZ to a depth of 100 m (Figure 10-11) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

Juvenile and Adult – All rocky/coral and sand-bottom habitat and the adjacent water column from 0 to 100 m (Figures 10-12, 10-15, and 10-18) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

10.5.4.13 Priacanthidae (Bigeyes)

Status. Two species of the family Priacanthidae (Bigeyes) are managed in Micronesia as part of the CHCRT by the WPRFMC (2001); both species are reported as occurring in CNMI and Guam (Myers and Donaldson 2003). Both species have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if bigeyes of the CHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). These species are excellent food-fish but are not important in most fishery areas (Amesbury and Myers 2001; Starnes 1999). These two species are not listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Priacanthids can be found in the tropical and subtropical waters of the Atlantic, Indian, and Pacific Oceans (Froese and Pauly 2012).

The glasseye (*Heteropriacanthus cruentatus*) is located circumtropically north to Ryukyu, Bonin, and Hawaiian Islands, and south to Lord Howe and Easter Island. This species is located throughout Micronesia (Myers 1999).

The moontail bullseye (*Priacanthus hamrur*) can be found in the Indo-Pacific from the Red Sea and southern Africa to southern Japan and Australia, and throughout the central Pacific to French Polynesia (Froese and Pauly 2012).

Habitat Preferences. Bigeyes are typically epibenthic and are usually associated with rock formations or coral reefs. This family prefers shaded overhangs, caves, and crevices near the reef during the daytime (Western Pacific Regional Fishery Management Council 2001). Occasionally, bigeyes may be associated with more open areas at depths of 5 to 400 m (Starnes 1999). Eggs, larvae, and early juvenile stages are pelagic (Froese and Pauly 2012).

The glasseye is a subtropical species that ranges from 33° N to 32° S at depths from 3 to 300 m (Froese and Pauly 2012). This species is commonly associated with lagoons or seaward reefs below the surge zone, generally around islands (Froese and Pauly 2012; Myers 1999). Glasseyes are found singly or in small groups under or near ledges during the day, forming larger groups at dusk to forage. Juveniles of this species are pelagic (Froese and Pauly 2012).

The moontail bullseye is a tropical species ranging from 32° N to 24° S at depths from 8 to 250 m (Froese and Pauly 2012). This is a relatively uncommon species that inhabits the outer reef slopes and deep lagoons at depths from 8 m to greater than 80 m, and is probably most common from 30 to 50 m (Froese and Pauly 2012; Starnes 1999).

Life History. Spawning for this species has not been observed (Western Pacific Regional Fishery Management Council 2001). Daily migrations usually occur above and away from the reef in search of food (Myers 1999). The moontail bullseye is heavily preyed upon by yellowfin tuna in the Indian Ocean (Rohit, Rao, and Rammohan 2010).

EFH Designations

Eggs and Larvae – The water column extending from the shoreline to the outer boundary of the U.S. EEZ to a depth of 100 m (Figure 10-11) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

Juvenile and Adult – All rocky/coral and sand-bottom habitat and the adjacent water column from 0 to 9100 m (Figures 10-12, 10-15, and 10-18) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

10.5.4.14 Scaridae (Parrotfishes)

Status. Four species of the family Scaridae are managed in Micronesia as part of the CHCRT by the WPRFMC (2001); all four are reported as occurring in CNMI and Guam (Myers and Donaldson 2003). Each species has EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if parrotfishes of the CHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Parrotfish are not a major commercial catch, but they are an important food-fish and are frequently found in fish markets (Froese and Pauly 2012; Westneat 2001).

Parrotfishes are heavily targeted in coral reef fisheries, which has led to a shift in abundances from large to smaller sizes in most parrotfish species throughout the South Pacific (Clua and Legendre 2008). This trend has followed a shift from more traditional and sustainable fishing practices using fish traps, to more selective modern techniques (de Loma et al. 2009).

No species of parrotfish is listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011), however; the bumphead parrotfish is a National Marine Fisheries Service species of concern (National Oceanic and Atmospheric Administration 2010).

Distribution. Parrotfishes are mainly tropical species occurring in the Atlantic, Indian, and Pacific Oceans (Froese and Pauly 2012). The majority of these species are found inhabiting the coral reefs of the Indian and western Pacific Oceans.

Habitat Preferences. Parrotfishes are commonly found around coral reefs, and are usually most abundant in shallow waters to a depth of 30 m (Westneat 2001). These species occupy a variety of coral reef habitats including seagrass beds, coral-rich areas, sand patches, rubble or pavement fields, lagoons, reef flats, and upper reef slopes (Myers 1999). Parrotfishes sleep under ledges or wedged against coral or rock at night (Myers 1999).

Life History. Parrotfishes spawn in pairs and groups, with group spawning frequently occurring on reef slopes associated with high current speeds. Paired spawning has been observed at the reef crest or reef slope during peak or falling tides. Parrotfishes may migrate into lagoons or to the outer reef slope in order to spawn. Some parrotfishes are diandric, forming schools and spawning groups often after migration to specific sites, while others are monandric and are strongly site-specific and practice haremic, pair spawning. The eggs and larvae of these species are pelagic and subject to dispersal by ocean currents (Western Pacific Regional Fishery Management Council 2001). No reliable data are available on the spawning and migration of the bumphead parrotfish (Froese and Pauly 2012; Myers 1999; Western Pacific Regional Fishery Management Council 2001).

EFH Designations

Eggs and Larvae – The water column from the shoreline to the outer limit of the U.S. EEZ to a depth of 100 m (Figure 10-11) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

Juvenile and Adult – All bottom habitat and the adjacent water column from 0 to 100 m (Figures 10-12, 10-15, and 10-18) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

10.5.4.15 Scombridae (Mackerels and Tunas)

Status. One mackerel species, the dogtooth tuna (*Gymnosarda unicolor*), is managed in Micronesia as part of the CHCRT by the WPRFMC (2001); the species has been reported as occurring in CNMI and Guam (Myers and Donaldson 2003). EFH has been designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004b; Western Pacific Regional Fishery Management Council 2001) for this species. No data are available to determine if the dogtooth tuna of the CHCRT is approaching an overfished situation (National Marine Fisheries Service 2011). The dogtooth tuna is not listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. The dogtooth tuna is widely distributed throughout much of the Indo-Pacific faunal region from the Red Sea eastward to French Polynesia (Collette and Nauen 1983).

Habitat Preferences. The dogtooth tuna is an offshore species mainly found around coral reefs. This species may be found in deep lagoons and passes, shallow pinnacles, and off outer reef slopes occurring in mid-water, from the surface to depths of approximately 100 m (Collette and Nauen 1983). Dogtooth tuna prefer water temperatures ranging from 20 to 28°C (Western Pacific Regional Fishery Management Council 2001). Dogtooth tuna larvae are found in surface and subsurface tows, generally concentrated at depths from 20 to 30 m (Western Pacific Regional Fishery Management Council 2001).

Life History. Spawning activities for dogtooth tuna have been observed during the summer months in Fiji and Papua New Guinea. Various authors have noted evidence of summer spawning events for this species (Western Pacific Regional Fishery Management Council 2001). Diurnal migrations have been observed in older larvae, which make their way to the surface at night (Western Pacific Regional Fishery Management Council 2001). Spawning is believed to occur year-round in tropical locations (Western Pacific Regional Fishery Management Council 2001). Dogtooth tuna are generally solitary species but may occur is small schools of six or less (Froese and Pauly 2012).

EFH Designations

Eggs, Larvae, Juvenile, and Adult – The water column from the shoreline to the outer boundary of the U.S. EEZ to a depth of 100 m (Figures 10-11, 10-12, 10-15, and 10-18) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

10.5.4.16 Siganidae (Rabbitfish)

Status. Six species of the family Siganidae are managed in Micronesia as part of the CHCRT by the WPRFMC (2001). All six occur in CNMI and Guam (Myers and Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if rabbitfishes of the CHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Rabbitfish are a highly esteemed food-fish and may make up a large portion of marketable reef fish in some areas of the

western Pacific (Myers 1999). The more colorful the species in this family, the more popular they are in the aquarium trade (Froese and Pauly 2012). No species of rabbitfish located within the MRA Study Area is listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Rabbitfish are found throughout the Indo-Pacific and eastern Mediterranean (Froese and Pauly 2012). More specifically, their distribution includes the South Pacific islands of New Caledonia and French Polynesia, the West Pacific Ocean, Indian Ocean, West Indian Ocean, and the Red Sea (Borsa, Lemer, and Aurelle 2007).

Habitat Preferences. Rabbitfish are usually associated with shallow coastal waters to a depth of approximately 50 m. Some species live in pairs among corals, while others live in schools around rock and coral reefs, mangroves, estuaries, and brackish lagoons (Woodland 2001). Rabbitfish are common on reef flats, around small, scattered coral heads, and near grass flats at depths less than 15 m. Juveniles of certain species are estuarine, and larvae are pelagic (Western Pacific Regional Fishery Management Council 2001). Eggs are usually adhesive and demersal, but at least one species, the schooling or forktail rabbitfish (*Siganus aregenteus*), is known to have pelagic eggs (Western Pacific Regional Fishery Management Council 2001). This is also the only species of the family known to go through a pelagic, prejuvenile stage. *S. woodlandi*, a newly described species, is morphologically close to *S. argenteus*, and the two are grouped as a distinct ecological type among rabbitfish (Borsa, Lemer, and Aurelle 2007).

Other rabbitfishes can be divided into schooling species and pairing species. Schooling species of rabbitfishes tend to occupy a wide range of habitats, whereas pairing species tend to remain in one area—usually among branches of hard corals (Western Pacific Regional Fishery Management Council 2001). Habitat selection is influenced by behavior and body type: fusiform species (e.g., *S. spinus*) live in schools on the inshore reef flats and deep-bodied species that live in small schools (e.g., *S. guttatus, S. randalli,* and *S. vermiculatus*) are found in mangroves, estuaries, and estuarine lakes (Borsa, Lemer, and Aurelle 2007).

Life History. Rabbitfish spawning typically corresponds to a lunar cycle, with peak activity in the spring and early summer (May to June). The timing of the spawning may be influenced by variation of environmental factors including water temperature, photoperiod, and food abundance (Takemura et al. 2004). Spawning may occur in pairs or groups on outgoing tides either at night or early in the morning. Spawning rabbitfish generally migrate to specific spawning sites such as mangrove stands, shallow reef flats, the outer reef crest, or the deeper reef (Western Pacific Regional Fishery Management Council 2001). Rabbitfishes are herbivorous with disparate diets that vary between species; studies of foraging behavior have documented *S. doliatus* as a primary consumer of red thallate algae and red and green filamentous algae (i.e., reef turf algae), the diet of *S. lineatus* consists almost entirely of off-reef detrital aggregates (Fox et al. 2009), and the diet of *Siganus canaliculatus* (not part of the CHCRT) is dominated by *Sargassum* (Fox and Bellwood 2008).

EFH Designations

Eggs and Larvae – The water column from the shoreline to the outer boundary of the U.S. EEZ to a depth of 100 m (Figure 10-11) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

Juvenile and Adult – All bottom habitat and the adjacent water column from 0 to 100 m (Figures 10-12, 10-15, and 10-18) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

10.5.4.17 Sphyraenidae (Barracudas)

Status. Two species of the family Sphyraenidae are managed in Micronesia as part of the CHCRT by the WPRFMC (2001). Both species are reported as occurring in CNMI and Guam (Myers and Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if barracudas of the CHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). In the western Pacific, barracudas are marketed fresh, frozen, dried, salted, or smoked (Senou 2001). No species of barracuda is listed on the IUCN Red List of threatened species located within the MRA Study Area (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Barracudas can be found in tropical and subtropical waters in the Atlantic, Indian, and Pacific Oceans (Froese and Pauly 2012).

Heller's barracuda (*Sphyraena helleri*) can be found from southern Japan south to the Coral Sea and east to French Polynesia. This species is common around the oceanic islands of the Pacific (Froese and Pauly 2012).

The great barracuda (*S. barracuda*) is found in the Indo-Pacific from the Red Sea and east coast of Africa to the Hawaiian, Marquesan, and Tuamoto Islands. This species is found throughout Micronesia (Froese and Pauly 2012).

Habitat Preferences. Barracudas are pelagic to demersal fish, most of which inhabit shallow coastal waters such as bays, estuaries, or the vicinity of coral reefs. This family may also be found at the surface of open oceans down to depths greater than 100 m (Senou 2001). Barracudas may be found within lagoons and mangrove areas, over coral reefs or sand or mud bottoms, or off of deep outer reef slopes (Senou 2001). Juveniles and subadults utilize a wide range of embayment habitats, although small-sized individuals have shown preference for shallow and turbid mangrove areas, whereas large-sized individuals have been observed in deeper and less turbid seagrass beds (Lugendo et al. 2005).

Heller's barracuda is a subtropical species found from 30° N to 25° S at depths from 15 to 60 m (Froese and Pauly 2012). This species occurs in lagoons and over seaward reefs (Myers 1999).

The great barracuda is a subtropical species found from 30° N to 30° S at depths from 0 to 100 m. Adults occur from murky inner harbors to open seas, usually at or near the surface (Froese and Pauly 2012). Juveniles occur among mangroves and in shallow sheltered inner reefs (Western Pacific Regional Fishery Management Council 2001).

Life History. Barracuda migrate in very large numbers to specific spawning areas at reef edges or in deeper water. Eggs, larvae, and juveniles are pelagic and may be carried long distances by ocean currents (Western Pacific Regional Fishery Management Council 2001). Heller's barracuda can be found in large schools during the day, whereas the great barracuda is diurnal and solitary (Froese and Pauly 2012). Barracuda are piscivorous, and exhibit different hunting behavior in different environments. On reef slopes, barracuda stalk prey (e.g., tilefish) near their benthic burrows, and they also attack by diving suddenly from higher in the water column (Baird and Baird 2006).

EFH Designations

<u>Eggs, Larvae, Juvenile, and Adult</u> – The water column from the shoreline to the outer boundary of the U.S. EEZ to a depth of 100 m (Figures 10-11, 10-12, 10-15, and 10-18) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

10.5.4.18 Octopodidae (Octopuses)

Status. Two species of octopus are managed in Micronesia as part of the CHCRT by the WPRFMC (2001) and are reported as occurring in CNMI and Guam (Ward 2003). Both species have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if octopuses of the CHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). These species are primarily harvested for human consumption but are also used as bait in other fisheries (Norman 1998). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Members of the family Octopodidae occur in all the oceans of the world from the equator to polar latitudes (Norman 1998; Waikiki Aquarium 1998b). The day octopus (*Octopus cyanea*) and the night octopus (*O. ornatus*) are found widely throughout the shallow waters of the Indo-West Pacific from Hawai‘i in the east to the east African coast in the west. This species has been reported as far north as Japan and as far south as New South Wales, Australia (Norman 1998).

Habitat Preferences. Reef-associated octopuses are bottom-dwelling species that usually occupy holes and crevices or coral areas. These species are found from the shallowest part of the reef down to approximately 50 m (Western Pacific Regional Fishery Management Council 2001). Octopuses occur on a wide range of substrates including coral and rock reefs, seagrass beds, sand, and mud. Octopus eggs are demersal and typically attached in clusters within the rocky depths of the reef (Western Pacific Regional Fishery Management Council 2001).

The day octopus and night octopus are found from intertidal reefs, shallow reef flats, and reef slopes to depths of at least 25 m and are associated with both live and dead corals. As the name implies, the day octopus is more active throughout day with peak activities at dusk and dawn (Norman 1998). The night octopus is nocturnal, resting by day and foraging at night (Waikiki Aquarium 1998b).

Life History. Life history information is lacking for these species of octopus (Western Pacific Regional Fishery Management Council 2001). However, two major life history strategies have been documented among benthic octopuses: (1) production of relatively few, large eggs resulting in well-developed hatchlings that resemble the adults and rapidly adopt the benthic habit of their parents; and (2) production of numerous small eggs that hatch into planktonic, free-swimming paralarvae that differ from adults in their morphology, physiology, ecology and behavior (Villanueva and Norman 2008). Eggs are demersal, and females tend the eggs until they hatch. Octopuses may migrate up to 100 m in search of food (Norman 1998; Waikiki Aquarium 1998b); conversely, they may stay in small home ranges for long periods of time if a constant food source is present (Rigby and Sakurai 2005).

EFH Designations

<u>Eggs, Juvenile, and Adult</u> – EFH for the adult, juvenile phase, and demersal eggs is defined as all coral, rocky, and sand-bottom areas from 0 to 100 m (Figures 10-11, 10-12, 10-15, and 10-18) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

10.5.4.19 Turbinidae (Turban shells/green snails)

Status. The family Turbinidae is managed in Micronesia as part of the CHCRT by the WPRFMC (2001), and occurs in CNMI and Guam (Smith 2003). All species within this family have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). The main species of turban shells harvested in the MRA Study Area are the rough turban (*T. setosus*), and the silver-mouth turban (*T. argyrostomus*) (Smith 2003). No other data are available to determine if turban shells of the CHCRT are approaching an overfished situation

(National Marine Fisheries Service 2011). No species of turban shells located within the MRA Study Area is listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. The Turbinidae family includes both predominantly shallow and deep-water clades, as well as genera that are distributed across the globe from the poles to the tropics (Williams, Karube, and Ozawa 2008). Turban shells (of the subfamily Turbininae) are distributed throughout the Indo-Pacific region extending into the South Pacific (Western Pacific Regional Fishery Management Council 2001).

Habitat Preferences. Turbanidae shells are found in shallow waters of warm temperate and tropical seas (Poutiers 1998). These species prefer healthy coral reef habitats that receive a constant flow of oceanic water. Juveniles can be found on shallow reef crests, while adults prefer deeper habitats (Western Pacific Regional Fishery Management Council 2001).

Life History. Very little information is available about the reproduction of these species. Eggs and larvae are dispersed by ocean currents, while juveniles and adults are demersal (Western Pacific Regional Fishery Management Council 2001). Some species of Turbinidae have been documented to prey on shark eggs (Powter and Gladstone 2008).

EFH Designations

Eggs and Larvae – The water column from the shoreline to the outer boundary of the U.S. EEZ to a depth of 100 m (Figure 10-11) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

Juvenile and Adult – All bottom habitat and the adjacent water column from 0 of 100 m (Figures 10-12, 10-15, and 10-18) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

10.5.5 Coral Reef Ecosystem Management Unit – Currently Harvested Aquarium Taxa/Species

Fish species harvested for the aquarium trade are managed as part of CHCRT by the WPRFMC (2001) and occur in CNMI and Guam (Myers and Donaldson 2003). All taxa within the CRE management unit have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). All aquarium species are managed as a unit, and the EFH designations for the lifestages of each species are identical and listed below. Limited harvest of aquaria species occurs within the MRA Study Area because commercial export of live aquarium fishes is prohibited in the Mariana Islands. Guam allows export of aquarium species but has only one commercial operation at this time (Western Pacific Regional Fishery Management Council 2001). Table 10-6 lists EFH designations for the CRE currently harvested aquarium management unit species.

EFH Designations

Eggs and Larvae – All waters from 0 to 100 m from the shoreline to the limits of the U.S. EEZ (Figure 10-11) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

Juvenile and Adult – All coral, rubble, or other hard-bottom features and the adjacent water column from 0 to 100 m (Figures 10-12, 10-15, and 10-18) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

Table 10-6: Coral Reef Ecosystem Currently Harvested Aquarium Management Unit Species Essential Fish Habitat Designations

Management Unit Species/Taxa	Habitat Type										Known Depth Range
	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	
Currently Harveseted Coral Reef Taxa – Aquarium Species (fish)											
Surgeonfishes (Acanthuridae)	J	A,J,S	A,J,S	J	A,J,S	A,J,S	A,J,S		A,J,S	E,L	Adult depth of 1–113 meters
Moorish Idols (Zanclidae)		A,J				A,J	A,J			E,L	Adult depth of 3–182 m
Angelfishes (Pomacanthidae)	J	A,J,S	J	J		A,J,S	A,J,S		A,S	E,L	Adult depth of 2–100 m
Hawkfishes (Cirrhitidae)		A,J,S				A,J,S	A,J,S		A,J,S	All	Adult depth of 0–30 m
Butterflyfishes (Chaetodontidae)	J	A,J,S	J	J		A,J,S	A,J,S		A,S	E,L	Adult depth of 0–30 m
Damselfishes (Pomacentridae)	J	A,J,S	J	J		A,J,S	A,J,S		A,S	E,L	Adult depth of 1–55 m
Scorpionfishes (Scorpaenidae)	J	A,J,S	A,J,S	J		A,J,S	A,J,S			E,L	Adult depth of 10–50 m
Currently Harveseted Coral Reef Taxa – Aquarium Species (invertebrates)											
Feather–duster Worms (Sabellidae)	A,J,S	A,J,S	A,J,S		A,J,S	A,J,S	A,J,S		A,J,S	E,L	Adult depth of 0–30 m

Sources: Colin and Arneson (1995); Myers (1999); Western Pacific Regional Fishery Management Council (2001).
Notes on habitat type: Mangrove (Ma), Lagoon (La), Estuarine (Es), Seagrass Beds (SB), Soft Substrate (Ss), Coral Reef/Hard Substrate (Cr/Hs), Patch Reefs (Pr), Surge Zone (Sz), Deep-slope Terraces (DST), Pelagic/Open Ocean (Pe).
Life History Stage: Egg (E), Larvae (L), Juvenile (J), Adult (A), Spawners (S).

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10.5.5.1 Acanthuridae (Surgeonfishes)

A complete summary of the family Acanthuridae, including EFH and HAPC designations, appears earlier in the CHCRT section. The following three examples (yellow tang, yellow-eyed surgeon fish, and achilles tang) are addressed individually.

Yellow Tang (*Zebrasoma flavescens*)

Status. The yellow tang is managed in Micronesia as part of the CHCRT by the WPRFMC (2001), has been reported as occurring in CNMI and Guam (Myers and Donaldson 2003), and has EFH designation within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). This species is heavily exploited in Hawaiʻi, as the primary species targeted for the live aquarium trade, with hundreds of thousands of juveniles caught every year (Claisse et al. 2009; Claisse, McTee, and Parrish 2009). Nonetheless, no data are available to determine if the yellow tang is approaching an overfished situation (National Marine Fisheries Service 2011). This species is not listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. The yellow tang can be found in the Pacific Ocean associated with Ryukyu, Mariana, Marshall, Marcus, Wake, and Hawaiian Islands (Froese and Pauly 2012).

Habitat Preferences. Yellow tangs inhabit coral-rich areas of lagoons and seaward reefs from below the surge to approximately 46 m. This species can be found in tropical waters from 30° N to 15° N with water temperatures ranging from 24 to 28°C at depths between 2 and 46 m (Froese and Pauly 2012). With increasing age and size, yellow tangs transition between deeper coral-rich habitats and shallow turf-dominated habitats (Claisse et al. 2009). Individual yellow tangs return each day to forage over the same few hundred square meters of shallow, turf-algae-dominated boulder and reef flat habitat (Claisse et al. 2011).

Life History. The yellow tang may spawn in groups or pairs (Myers 1999). Yellow tangs are multiple spawners with reproductive peaks coinciding with the full moon each month, and reproductive effort peaking in the late spring and summer (Bushnell, Claisse, and Laidley 2010). Sexual differences in patterns of habitat use, growth rate, and size dimorphism have been observed (Claisse et al. 2009). A study in Hawaiʻi revealed larval dispersal distances ranging from 15 to 184 km (Christie et al. 2010). Yellow tang adults make daily migrations of up to 600 m between foraging and spawning or sheltering sites at consistent times relative to sunset and sunrise, moving consistently from south to north at sunset (Claisse et al. 2011).

Yellow-eyed Surgeon Fish (*Ctenochaetus strigosus*)

Status. The yellow-eyed surgeonfish is managed in Micronesia as part of the CHCRT by the WPRFMC (2001), has been reported as occurring in CNMI and Guam (Myers and Donaldson 2003), and has EFH designation within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if the yelloweyed surgeonfish of the CHCRT is approaching an overfished situation (National Marine Fisheries Service 2011). This species is not listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. The yellow-eyed surgeonfish can be found in the Indo-Pacific region from east Africa to the Hawaiian, Marquesan, and Ducie Islands. Its range is bounded to the north by the Bonin Islands and to the south by the Great Barrier Reef and New Caledonia. This species can be found throughout Micronesia (Myers 1999).

Habitat Preferences. The yellow-eyed surgeonfish inhabit coral-rich areas of lagoons and seaward reefs. This species can be found in tropical waters from 30° N to 30° S with water temperatures ranging from 21 to 27°C at depths between 1 and 113 m (Froese and Pauly 2012).

Life History. Very little information is available on the life history of the yellow-eyed surgeonfish. This species has been observed spawning in pairs (Myers 1999).

Achilles Tang (*Ancanthurus achilles*)

Status. The Achilles tang is managed in Micronesia as part of the CHCRT by the WPRFMC (2001), has been reported as occurring in CNMI and Guam (Myers and Donaldson 2003), and has EFH designation within the boundaries of the MRA Study Area (Western Pacific Regional Fishery Management Council 2001). No data are available to determine if the Achilles tang of the CHCRT is approaching an overfished situation (National Marine Fisheries Service 2011). This species is not listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. The Achilles tang can be found distributed throughout the tropical Indo-Pacific from the western Caroline Islands, Parece Vela, and the Torres Strait east to the Hawaiian, Marquesan, and Ducie Islands. This species ranges as far north as the Marcus Islands and south to New Caledonia. The Achilles tang can be found throughout Micronesia including the Caroline, Mariana, and Marshall Islands (Myers 1999).

Habitat Preferences. The Achilles tang inhabits clear seaward reefs from the surge zone to a depth of 4 m (Myers 1999). This species can be found in tropical waters from 28° N to 26° S with water temperatures ranging from 26 to 28°C at depths between 0 and 10 m (Froese and Pauly 2012).

Life History. Very little information is available on the life history of the Achilles tang (Western Pacific Regional Fishery Management Council 2001).

10.5.5.2 Zanclidae (Moorish Idol)

Status. The Moorish idol (*Zanclus cornutus*), a sole member of this monotypic family, is an aquarium taxa managed in Micronesia as part of the CHCRT by the WPRFMC (2001), has been reported as occurring in CNMI and Guam (Myers and Donaldson 2003), and has EFH designation within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if the Moorish idol of the CHCRT is approaching an overfished situation (National Marine Fisheries Service 2011). This species is not listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. The Moorish idol can be found distributed throughout the Indo-pan-Pacific from the Gulf of Aden and eastern Africa east to Mexico. This species ranges as far north as southern Japan and the Hawaiian Islands and south to Lord Howe, the Kermadecs, Rapa, and Ducie Islands. The Moorish idol can be found throughout Micronesia (Myers 1999).

Habitat Preferences. The Moorish idol inhabits areas of hard substrates from turbid inner harbors and reef flats to clear seaward reefs as deep as 182 m (Myers 1999). This species can be found in tropical waters from 30° N to 35° S with water temperatures ranging from 24° to 28°C at depths between 3 and 182 m (Froese and Pauly 2012).

Life History. The Moorish idol is usually found in small groups but may occur in schools numbering over 100 individuals (Myers 1999).

10.5.5.3 Pomacanthidae (Angelfishes)

Status. Two species of aquarium taxa in the family Pomacanthidae are managed in Micronesia as part of the CHCRT by the WPRFMC (2001) and occur in CNMI and Guam (Myers and Donaldson 2003). Both species have EFH designation within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if angelfishes of the CHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Although harvested as food-fish, the primary value of angelfish is through the ornamental marine aquarium trade, where they are the second most-frequently exported fish by number and highest in total value of all families of aquarium fishes in trade (Pyle 2001). These species are not listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. The angelfish can be found throughout the tropical waters of the Atlantic, Indian, and Pacific Oceans (Froese and Pauly 2012).

The mango angelfish (*Centropyge shepardi*) is found only around the Marianas, Bonins, and Palau (Myers 1999).

The lemonpeel angelfish (*C. flavissima*) is found in the Indo-Pacific from Cocos-Keeling Atoll in the west, east to the Line, Marquesan, and Ducie Islands. This species ranges north to the Ryukyu Islands and south to New Caledonia and Rapa. The lemonpeel angelfish is found throughout Micronesia (Froese and Pauly 2012).

Habitat Preferences. Angelfish are usually found near coral reefs in shallow waters less than 20 m deep (Myers 1999).

The mango angelfish is found on outer reef slopes and occasionally in clear lagoon reefs (Froese and Pauly 2012). This species prefers areas of mixed living and dead coral with numerous shelter holes and passages. The mango angelfish can be found in tropical waters from 28° N to 15° N at depths from 1 to 56 m (Froese and Pauly 2012). In the Mariana Islands, this is the most common species of angelfish between 18 and 56 m (Myers 1999).

The lemonpeel angelfish is found in coral-rich areas of shallow lagoons and exposed seaward reefs from the lower surge zone to depths greater than 25 m (Myers 1999). This species can be found in tropical waters from 35° N to 30° S at depths from 3 to 50 m (Froese and Pauly 2012). In the Mariana Islands, this is the most common species of angelfish from 0 to 20 m (Myers 1999).

Life History. Angelfish exhibit paired spawning in pelagic waters typically around sunset (Myers 1999); (Froese and Pauly 2012). Genetic studies in conjunction with larval distribution data indicate that *Centropyge* species disperse widely (Schultz et al. 2007).

10.5.5.4 Cirrhitidae (Hawkfishes)

Status. Two species of aquarium taxa in the family Cirrhitidae are managed in Micronesia as part of the CHCRT by the WPRFMC (2001) and occur in CNMI and Guam (Myers and Donaldson 2003). Both species have EFH designation within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if hawkfishes of the CHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Some hawkfishes are occasionally used as food and are valued aquarium fishes (Randall 2001c). These species are not listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Hawkfishes can be found within the tropical western and eastern Atlantic, Indian, and Pacific Oceans (Froese and Pauly 2012).

The longnose hawkfish (*Oxycirrhites typus*) can be found from the Red Sea in the west to Panama in the east. This species ranges from southern Japan and Hawai'i in the north to New Caledonia in the south and throughout Micronesia (Myers 1999).

The flame hawkfish (*Neocirrhites armatus*) can be found from the Ryukyu Islands in the east to the Line Islands in the west. This species ranges from the Pitcairn group in the north to the Great Barrier Reef and Australs in the south. In Micronesia, the flame hawkfish can be found in the Carolines, Marianas, and Wake Islands (Myers 1999).

Habitat Preferences. Hawkfishes are generally found associated with rocks and corals (Randall 2001b). In one study, Pocillopora coral, in particular, was the most preferred habitat of all hawkfish species, and abundance of Pocillopora correlated directly with spatial variation in hawkfish abundance (Kane et al. 2009).

The longnose hawkfish prefers steep outer reef slopes exposed to strong currents. This species is found associated with large gorgonians and black corals. In Micronesia, it is confined to depths below 30 m (Myers 1999).

The flame hawkfish is found along surge swept reef fronts and submarine terraces to a depth of about 11 m. This species is most often associated with coral such as *Stylophora mordax*, *Pociiopora elegans*, *P. eydouxi*, or *P. verrucosa* (Myers 1999).

Life History. Previously believed to be protygynous (changing from female to male), one haremic hawkfish species, *Cirrhitichthys falco*, was found to change sex in both directions, reversing back from male to female as a tactic to regain reproductive status (Kadota et al. 2012). Spawning occurs throughout the year in tropical waters and only during warmer months in temperate areas. These species usually spawn at dusk or during early nighttime (Myers 1999). In addition to this diel timing, spawning has been documented to occur prior to the full and new moon, with semi-lunar spawning peak periodicity (Kadota et al. 2010).

10.5.5.5 Chaetodontidae (Butterflyfishes)

Status. Four aquarium species in the family Chaetodontidae are managed in Micronesia as part of the CHCRT by the WPRFMC (2001) and occur in CNMI and Guam (Myers and Donaldson 2003). Each species has EFH designation within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if butterflyfishes of the CHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Although harvested as food-fish, the primary value of butterflyfishes is through the ornamental marine aquarium trade, where they are the third most-frequently exported fish by number and second highest in total value of all families of aquarium fishes in trade (Pyle 2001). None of the aquarium species is listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Chaetodontids can be found in the tropical to temperate waters of the Atlantic, Indian, and Pacific Oceans, but are most abundant in the Indo-West Pacific region (Froese and Pauly 2012).

The threadfin butterflyfish (*Chaetodon auriga*) can be found from the west Red Sea and east Africa to the Hawaiian, Marquesan, and Ducie Islands in the west. This species ranges from southern Japan in the north to Lord Howe and Rapa Islands in the south and throughout Micronesia (Froese and Pauly 2012).

The raccoon butterflyfish (*C. lunula*) can be found in the Indo-Pacific from east Africa in the west to the Hawaiian, Marquesan, and Ducie Islands in the east. This species ranges from southern Japan south to Lord Howe and Rapa Islands and throughout Micronesia (Froese and Pauly 2012).

The black-backed butterflyfish (*C. melannotus*) can be found from the Red Sea in the west to Samoa in the east. This species ranges from Japan, south to Lord Howe Island and throughout Micronesia (Myers 1999).

The saddled butterflyfish (*C. ephippium*) can be found distributed throughout the tropical Indo-Pacific from the Cocos-Keeling Islands in the west to the Hawaiian, Marquesan, and Tuamoto Islands in the east. This species ranges as far north as the southern Japan and south to Rowley Shoals and New South Wales, Australia (Froese and Pauly 2012).

Habitat Preferences. Butterflyfish are diurnal species generally found near coral reefs (Froese and Pauly 2012). They are coral feeders, with trophic specialization on hard corals (Raymundo et al. 2009). Some butterflyfishes are obligate coral feeders, while others are more versatile feeders (Graham et al. 2009). Juveniles tend to occupy shallower, more sheltered habitats than adults. Butterflyfish eggs are planktonic (Western Pacific Regional Fishery Management Council 2001). A study at Ishigaki Island, Japan, found that Chaetodontae larvae exhibited high habitat selectivity, with post-settlement individuals restricted to coral (Nakamura, Shibuno, et al. 2009).

The threadfin butterflyfish can be found in a variety of habitats from rich coral reefs to weedy and rubble covered areas. They may be found on seaward reefs at depths greater than 30 m (Myers 1999). This species inhabits tropical waters from 30° N to 20° S at depths between 1 and 35 m (Froese and Pauly 2012).

The raccoon butterflyfish inhabits shallow reef flats of lagoons and seaward reefs to depths of over 30 m (Froese and Pauly 2012). This species is common in exposed rocky areas of high vertical relief (Myers 1999). The raccoon butterflyfish can be found in tropical waters from 30° N to 32° S at depths between 0 and 30 m (Froese and Pauly 2012). Juveniles prefer rocks of inner reef flats and tide pools (Froese and Pauly 2012). This is the only nocturnally active butterflyfish, spending its days hovering inactively in aggregations between boulders (Myers 1999).

The black-backed butterflyfish inhabits coral-rich areas of reef flats, lagoons, and seaward reefs to a depth of over 15 m (Myers 1999). This species can be found in tropical waters from 30° N to 30° S at depths between 4 and 20 m (Froese and Pauly 2012).

The saddled butterflyfish inhabits lagoons and seaward reefs to a depth of 30 m and prefers areas of rich coral growth and clear water (Myers 1999). This species can be found in tropical waters from 30° N to 30° S at depths between 0 and 30 m (Froese and Pauly 2012).

Life History. The threadfin butterflyfish may be found singly or in pairs and forms aggregations that roam long distances in search of food (Froese and Pauly 2012). The black-backed butterflyfish does not form pairs at maturation, but adults may be found singly or in pairs; same-sex pairs are common, which suggests that pair-forming may be used for non-reproductive purposes, such as predator vigilance (Pratchett, Pradjakusuma, and Jones 2006). Very little information is known about the spawning and migration of the other two butterflyfishes (Froese and Pauly 2012; Myers 1999; Western Pacific Regional Fishery Management Council 2001).

10.5.5.6 Pomacentridae (Damselfishes)

Status. Three aquarium species in the family Pomacentridae are managed in Micronesia as part of the CHCRT by the WPRFMC (2001) and occur in CNMI and Guam (Myers and Donaldson 2003). All three species have EFH designation within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if damselfishes of the CHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Their most important commercial use is as aquarium fishes, especially the anemone fish (Allen 2001). None of these aquarium species is listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Damselfish can be found in all tropical seas but are most abundant in the Indo-West Pacific region (Froese and Pauly 2012).

The blue-green chromis (*Chromis viridis*) can be found distributed throughout the tropical Indo-Pacific from the Red Sea in the west to the Line, Marquesan, and Tuamoto Islands in the east. This species ranges as far north as the Ryukyu Islands and south to New Caledonia (Froese and Pauly 2012).

The humbug dascyllus (*Dascyllus aruanus*) can be found distributed throughout the tropical Indo-West Pacific from the Red Sea and east Africa in the west to the Line, Marquesan, and Tuamoto Islands in the east. This species ranges as far north as southern Japan and south to Sydney, Australia (Froese and Pauly 2012).

The threespot dascyllus (*D. trimaculatus*) can be found distributed throughout the tropical IndoWest Pacific from the Red Sea and east Africa in the west to the islands of Oceania in the east excluding the Hawaiian and Marquesan Islands. This species ranges as far north as southern Japan and south to Sydney, Australia (Froese and Pauly 2012).

Habitat Preferences. Damselfish typically occur in shallow water or coral or rock substrata associated with shelter (Myers 1999). On coral reefs, damselfish defend their territories from invading herbivores and maintain algal turfs, from which they harvest filamentous algae (Hata, Watanabe, and Kato 2010). Some pomacentrid species assemble over tabular coral, while others preferentially select branching corals (Shibuno et al. 2008).

Blue-green chromis juveniles can be found in inshore and offshore islets in coral reef lagoons (Mellin et al. 2009). Adults of the species are found above thickets of branching coral in sheltered areas such as subtidal reef flats and lagoons. This species can be found in subtropical waters from 35° N to 35° S at depths between 10 and 12 m (Froese and Pauly 2012).

The humbug dascyllus inhabits shallow lagoons and subtidal reef flats. This species can be found in large aggregations above staghorn, *Acropora*, and in smaller groups above isolated coral heads (Froese and Pauly 2012). This species can be found in tropical waters from 30° N to 30° S at depths from 0 and 20 m. The larvae of this species are pelagic (Froese and Pauly 2012).

The threespot dascyllus inhabits lagoon and seaward reefs at depths of 1 to > 55 m. This species typically occurs in small groups around pronounced coral mounds or large isolated rocks (Myers 1999). It is a pelagic feeder, subsiding primarily on planktonic copepods (Frederich et al. 2009). The threespot dascyllus is found in tropical waters from 30° N to 30° S at depths from 1 to 55 m. Juveniles are associated with sea anemones, sea urchins, or small coral heads (Froese and Pauly 2012).

Life History. The blue-green chromis is non-migratory, and spawning occurs on sand and rubble (Froese and Pauly 2012). The humbug dascyllus is a benthic spawner (Juncker, Wantiez, and Ponton 2006). Very

little information is known about spawning of the threespot dascyllus, and about migration of either the humbug or threespot dascyllus (Froese and Pauly 2012; Myers 1999; Western Pacific Regional Fishery Management Council 2001).

10.5.5.7 Scorpaenidae (Scorpionfishes)

Status. Thirty species of the family Scorpaenidae are managed as aquarium taxa in Micronesia as part of the CHCRT by the WPRFMC (2001). Twenty-five of these species occur in CNMI and Guam (Myers and Donaldson 2003), and have EFH designation within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if scorpionfishes of CHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Most species in the Western Central Pacific are small and dangerous to handle, and do not form the basis of large fisheries (Poss 1999b). These species are not listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Scorpaenids can be found in all tropical and temperate seas (Froese and Pauly 2012). In the Sea of Japan, the larval and juvenile stages of the Japanese-named rockfish "ezo-mebaru" (*Sebastes taczanowskii*) have been described (Nagasawa, Ishida, and Sasaki 2008).

Habitat Preferences. Scorpionfish and lionfish may be found swimming well above the bottom, but smaller, more cryptic species of the subfamily Scorpaeninae are typically found on the bottom—usually associated with rubble areas in shallow water. Scorpaenids are commonly found in shallow waters but may be found at depths greater than 50 m (Western Pacific Regional Fishery Management Council 2001). Rockfish associate with higher seafloor relief, and select corals and sponges rather than inert substrata (Du Preez and Tunnicliffe 2011). The eggs are pelagic, and larvae of this family are planktonic (Froese and Pauly 2012).

The ezo-mebaru's larval and juvenile stages occur in both near-shore and relatively offshore water around Shakotan Peninsula-Ishikari Bay, Hokkaidō in June and July (Nagasawa, Ishida, and Sasaki 2008).

Life History. Most scorpionfishes are ovoviparous, producing between a few hundred and a few thousand eggs, although, some are viviparous (Poss 1999b).

10.5.5.8 Sabellidae (Feather-duster Worms)

Status. The family Sabellidae is managed as aquarium taxa in Micronesia as part of the CHCRT by the WPRFMC (2001). Four species occur in CNMI and Guam (Bailey-Brock 2003) and have EFH designation within the boundaries of the MRA Study Area (Western Pacific Regional Fishery Management Council 2001). These species are not listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Feather-duster worms are common throughout the world in shallow-water (Waikiki Aquarium 1998a).

Habitat Preferences. In the western Pacific, feather-duster worms are common on reef flats and in quiet bays and harbors where they are associated with hard surfaces to which they attach (Bailey-Brock 2003; Hoover 1998; Waikiki Aquarium 1998a). Likewise, in the central Pacific, they are common in bays and harbors (Bybee, Bailey-Brock, and Tamaru 2006). Feather-duster worms prefer turbid water (Hoover 1998). They are occasionally found in high energy environments and clear water, usually at depths greater than 30 m (Hoover 1998; Western Pacific Regional Fishery Management Council 2001).

Life History. Feather-duster worms are dioecious (separate sexes), and fertilization of eggs is external (Hawaii Biological Survey 2001a). One sabellid polychaete (*Sabella pavonina*) has an annual reproductive cycle during which eggs develop over a long period from September until the spawning period in May/June (Murray et al. 2011). Fertilized eggs develop into trochophore larvae (type of larva with several bands of cilia) that are planktonic for a short time before settling on the reef substrate to mature (primarily a complex reef habitat) (Bailey-Brock 2003). A study of the larval development of the sabellid polychaete *Sabellastorie spectabilis* in Hawai‘i observed the larvae from spawning to settlement (days 6–7) to metamorphosis (days 6–8) (Bybee, Bailey-Brock, and Tamaru 2006). Feather-duster worms can also propagate by fragmentation. They can also regenerate body parts (Hawaii Biological Survey 2001b).

10.5.6 Coral Reef Ecosystem Management Unit – Potentially Harvested Coral Reef Taxa

The Potentially Harvested Coral Reef taxa (PHCRT) are managed under the CRE FMP by the WPRFMC (2001). Taxa included under PHCRT consist of thousands of coral reef-associated species, families, or subfamilies that encompass fish, invertebrate, and sessile benthos Management Unit Species (MUS) (Western Pacific Regional Fishery Management Council 2001). These MUS are limited to those families/species known or believed to occur in association with coral reefs during some phase of their life cycle (Western Pacific Regional Fishery Management Council 2001). Because little information is available about life histories and habitat of this biota beyond general taxonomic and distributional descriptions, WPRFMC has adopted a precautionary approach in designating EFH for PHCRT.

EFH for all life stages of PHCRT is designated as the water column and bottom habitat from the shoreline to the outer boundary of the U.S. EEZ to a depth of 100 m (Figure 10-21) (National Oceanic and Atmospheric Administration 2012a; Western Pacific Regional Fishery Management Council 2001).

A complete list of the PHCRT occurring in the MRA Study Area is found in Table 10-5. All of the families, subfamilies, or species listed in the CHCRT also occur on the PHCRT list. Descriptions of these taxa are presented only in the CHCRT sections above (Sections 10.5.4 and 10.5.5, Coral Reef Ecosystem Management Unit). Descriptions of the individual families, subfamilies, or species of fish, invertebrates, and sessile benthos organisms that are not currently harvested (i.e., not in the CHCRT) are described in the following subsections. EFH for potentially harvested coral reef taxa in the Mariana Archipelago are shown in Figure 10-21.

Table 10-7: Coral Reef Ecosystem Potentially Harvested Management Unit Species Essential Fish Habitat Designations

Management Unit Species/Taxa	Habitat Type										Known Depth Range
	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	
Potentially Harvested Coral Reef Taxa – Fish											
Hammerhead Sharks (Sphyrnidae)	A,J	A,J	A,J		A,J	A,J	A,J		A,J	A,J	Adult depth of 1–275 meters (m)
Whiptail Stingrays, Eagle Rays, and Manta Rays (Dasyatidae, Myliobatidae, and Mobulidae)	A,J	A,J	A,J		A,J	A,J	A,J		A,J	A,J	Adult depth of 0–100 m
Groupers (Serranidae)	J	A,J		J	A,J,S	A,J,S	A,J,S		A,S	E,L	Adult depth of 0–400 m
Emperor Fishes (Lethrinidae)	J	A,J,S	J	J	A,J,S	A,J,S	A,J,S		A,S	E,L	Adult depth of 0–350 m
False Moray Eels, Conger and Garden Eels, and Snake Eels (Chlopsidae, Congridae, and Ophichthidae)	A,J,S	A,J,S	A,J,S	A,J	A,J,S	A,J,S	A,J,S		A,J,S	E,L	Adult depth of 0–105 m
Cardinalfishes (Apogonidae)	A,J,S	A,J,S	A,J,S	A,J,S		A,J,S	A,J,S		A,J,S	E,L	Adult depth of 0–80 m
Blennies (Blenniidae)		A,J,S	A,J,S		A,J,S	A,J,S	A,J,S		A,J,S	E,L	Adult depth of 1–40 m
Sandperches (Pinguipedidae)				A,J	A,J	A,J	A,J		A	E,L	Adult depth of 1–50 m
Flounders and Soles (Bothidae, Pleuronectidae, and Soleidae)		A,J				A,J	A,J		A,J	L	Adult depth of 1–100 m
Trunkfishes (Ostraciidae)		A	A	J	A,J	A			A	E,L	Adult depth of 1–100 m
Pufferfishes and Porcupinefishes (Tetradontidae and Diodontidae)	A,J	A,J	A,J		A,J	A,J	A,J		A,J	E,L	Adult depth of 0–100 m
Spadefishes and Batfishes (Ephippidae)	J	A,J,S	J		A,S	A,J,S	A,J,S		A,S	All	Adult depth of 20–30 m
Monofishess (Monodactylidae)	A,J,S	A,J,S	A,J,S			A,J,S	A,J,S			E,L	Adult depth of 1–10 m
Grunts and Sweetlips (Haemulidae)	J	A,J,S	A,J,S	J		A,J,S	A,J,S			E,L	Adult depth of 1–100 m
Remoras (Echeneidae)						A,J,S	A,J,S		A,J,S	E,L	Adult depth of 0–50 m
Tilefishes (Malacanthidae)		A,J,S			A,J,S	A,J,S	A,J,S			E,L	Adult depth of 6–115 m
Dottybacks (Pseudochromidae)	J	J		J		A,J,S	A,J,S			E,L	Adult depth of 0–100 m
Prettyfins (Plesiopidae)	J	A,J,S				A,J,S	A,J,S			E,L	Adult depth of 3–45 m
Coral Crouchers (Caracanthidae)						A,J,S	A,J,S			E,L	Adult depth of 0–10 m
Soapfishes (Grammistidae)						A,J,S	A,J,S			E,L	Adult depth of 0–150 m
Trumpetfishes (Aulostomidae)	J	A,J,S		A,J	A	A,J,S	A,J,S			E,L	Adult depth of 0–122 m
Cornetfishes (Fistularidae)	J	A,J,S		A,J		A,J,S	A,J,S			E,L	Adult depth of 0–122 m
Flashlightfishes (Anomalopidae)						J	J		A,J,S	E,L	Adult depth of 2–400 m
Herrings, Sprats, and Sardines (Clupeidae)	A,J,S	A,J,S	A,J,S			A,J,S	A,J,S		A,S	All	Adult depth of 0–20 m
Anchovies (Engraulidae)	A,J,S	A,J,S	A,J,S			A,J,S	A,J,S		A,S	All	No data

Table 10-7: Coral Reef Ecosystem Potentially Harvested Management Unit Species Essential Fish Habitat Designations

Management Unit Species/Taxa	Habitat Type										Known Depth Range
	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	
Gobies (Gobiidae)	All	All	All	All	All	All	All		All	All	Adult depth of 1–48 m
Snappers (Lutjanidae)	A,J,S	A,J,S	A,J,S	J		A,J,S	A,J,S		A,S	E,L	Adult depth of 0–400 m
Filefishes (Monocanthidae)	J	A,J,S	J	J		A,J,S	A,J,S		A,S	E,L	Adult depth of 2–200 m
Fusiliers (Caesionidae)	J	A,J,S			A,S	A,J,S	A,J,S		A,S	All	Adult depth of 0–60 m
Hawkfishes (Cirrhitidae)		A,J,S				A,J,S	A,J,S		A,J,S	All	Adult depth of 0–30 m
Frogfishes (Antennariidae)		All		All		All	All			L	Adult depth of 0–20 m
Pipefishes and Seahorses (Syngnathidae)	All	All		All		All	All			L	Adult depth of 0–400 m
Potentially Harvested Coral Reef Taxa – Invertebrates											
Mollusks (Mollusca)											
Gastropods	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S		A,J,S	E,L	Adult depth of 1–24 m
Sea Snails (Prosobranchs)	A,J	A,J,S		A,J,S	A,J,S	A,J,S	A,J,S		A,J	E,L	Adult depth of 2–30 m
Trochus (*Trochus* spp.)		A,J,S				A,J,S	A,J,S			E,L	Adult depth of 7–25 m
Sea Slugs (Opisthobranchs)	A,J	A,J,S				A,J,S	A,J,S		A,J,S	E,L	Adult depth of 2–30 m
Bivalves (Oysters and Clams)											
Black-lipped pearl oyster (*Pinctada margartifera*)	A,J	A,J,S				A,J,S	A,J,S		A,J,S	E,L	Depth Distribution: littoral/subtidal to 40 m
Giant clams (Tridacnidae)		A,J,S			A,J,S	A,J,S	A,J,S			E,L	Depth Distribution: 2–20 m
Other bivalves	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S		A,J,S	E,L	Depth Distribution: 1–27 m
Cephalopods											
Nautiluses, cuttlefishes, and squids		All	A,J,S	All	All	All	All		All	E,L	Adult depth from surface to 500 m
Octopuses (Octopodidae)	A,J,S	All	A,J,S	All	All	All	All		All	L	Adult depth of 1–1,000 m
Moss Animals (Bryozoans)	A,J,S	A,J,S	A,J,S	A,J		A,J,S	A.J,S		A,J,S	E,L	Adult depth of 20–80 m
Crustaceans (Crustacea)											
Lobsters: Spiny (*Panulirus* spp.) and Slipper (*Parribacus antarticus*)		All			A,J	All	All		All	L	Adult depth of 20–55 m
Shrimps and Mantis Shrimps		All	A,J	A,J	A,J	All	All		All	L	Adult depth of 3–70 m
Crabs: True and Hermit	A,J	All	A,J	A,J	A,J	All	All		All	L	Adult depth of 0–115 m

Table 10-7: Coral Reef Ecosystem Potentially Harvested Management Unit Species Essential Fish Habitat Designations

Management Unit Species/Taxa	Habitat Type										Known Depth Range
	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	
Sea Cucumbers and Sea Urchins (Echinoderms)	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S		A,J,S	E,L	Adult depth of 0–2,000 m
Segmented Worms (Annelids)	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S		A,J,S	E,L	Adult depth of 30–70 cm to 20 m
Potentially Harvested Coral Reef Taxa – Sessile Benthos											
Seaweeds (Algae)	All	All	All	All	All	All	All		All		Distribution: exposed shoreline, lagoon, bommies, inner/outer reef flat, reef crest, outer reef slope
Sponges (Porifera)	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S		A,J,S	E,L	Adult depth from intertidal to 50 m
Corals (Cnidaria)											
Hydrozoans											
Stinging or fire corals (Millepora)		A,J,S				A,J,S	A,J,S		A,J,S	E,L	Depth distribution: 0–10 m reef edge, reef flat, outer reef slope
Lace corals (Stylasteridae)	A,J,S	A,J,S	A,J,S			A,J,S	A,J,S		A,J,S	E,L	Depth Distribution: 10–20 m
Hydroid Fans (Solanderidae)	A,J,S	A,J,S	A,J,S			A,J,S	A,J,S		A,J,S	E,L	Depth Distribution: 0–100 m
Scleractinian Anthozoans											
Stony Corals (Scleractinia)		A,J,S	A,J,S			A,J,S	A,J,S		A,J,S	E,L	Depth Distribution: 0–60 m
Ahermatypic Corals (Azooxanthellate)		A,J,S	A,J,S			A,J,S	A,J,S		A,J,S	E,L	Depth Distribution: shallow water
Ahermatypic Corals (Azooxanthellate)		A,J,S	A,J,S		A,J,S	A,J,S	A,J,S		A,J,S	E,L	Depth Distribution: 44–1,761 m
Non-Scleractinian Anthozoans											
Anemones (Actinaria)	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S		A,J,S	E,L	Depth Distribution: 0–40 m
Colonial Anemones or Soft Zoanthid Corals (Zoanthidae)	A,J,S	A,J,S	A,J,S		A,J,S	A,J,S	A,J,S		A,J,S	E,L	Distribution: lagoon floors, back reef flats, reef crests, shallow sub-littoral zone

Table 10-7: Coral Reef Ecosystem Potentially Harvested Management Unit Species Essential Fish Habitat Designations

Management Unit Species/Taxa	Habitat Type										Known Depth Range
	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	
Soft Corals and Gorgonians (Alcyonaria)		A,J,S			A,J,S	A,J,S	A,J,S		A,J,S	E,L	Depth Distribution – soft corals: 3–30 m and gorgonians: <30–400 m
Blue coral (*Heliopora coerulea*)		A,J,S	A,J,S			A,J,S	A,J,S		A,J,S	E,L	Depth Distribution: < 1 m to > 30 m
Organ-pipe corals or star polyps (*Tubipora musica*)						A,J	A,J				Distribution: shallow lagoons, reef flats, reef slopes
Live Rocks		A,J	A,J			A,J	A,J		A,J	E,L	

Sources: Colin and Arneson (1995); Myers (1999); Western Pacific Regional Fishery Management Council (2001).
Notes on habitat types: Mangrove (Ma), Lagoon (La), Estuarine (Es), Seagrass Beds (SB), Soft Substrate (Ss), Coral Reef/Hard Substrate (Cr/Hs), Patch Reefs (Pr), Surge Zone (Sz), Deep-slope Terraces (DST), Pelagic/Open Ocean (Pe).
Life History Stage: Egg (E), Larvae (L), Juvenile (J), Adult (A), Spawners (S).

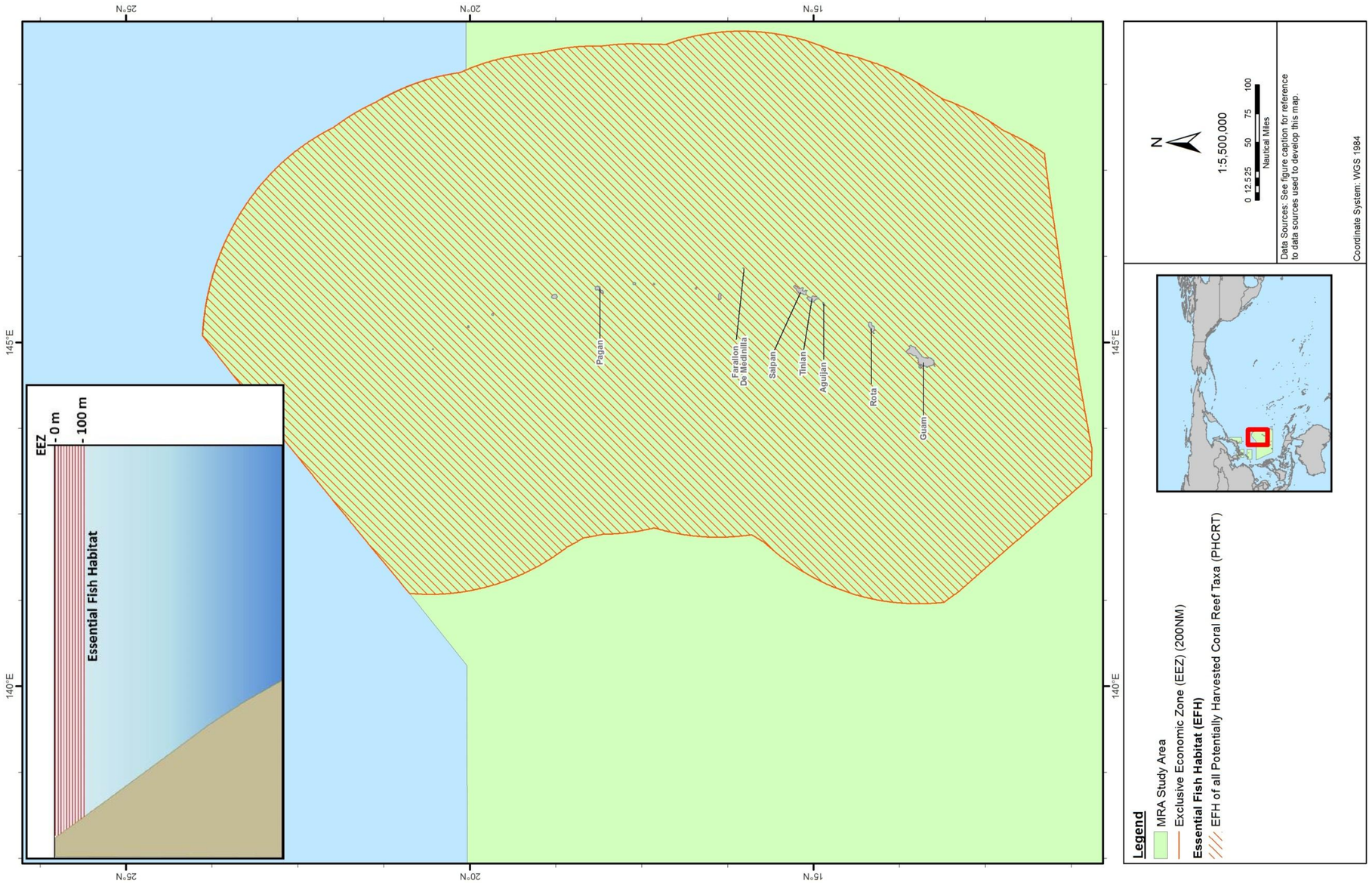

Figure 10-21: Essential Fish Habitat for Lifestages of the Potentially Harvested Coral Reef Taxa Designated for the Mariana Archipelago

Sources: National Oceanic and Atmospheric Administration (2012b) and Western Pacific Regional Fishery Management Council (2013).

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10.5.6.1 Sphyrnidae (Hammerhead Sharks)

Status. Two species of hammerhead sharks are managed in Micronesia as part of PHCRT by the WPRFMC (2001). Only the scalloped hammerhead (*Sphyrna lewini*) has been reported from the CNMI and Guam (Myers and Donaldson 2003) and has EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004b; Western Pacific Regional Fishery Management Council 2001). Currently, no data are available to determine if the scalloped hammerhead of the PHCRT is approaching an overfished situation (National Marine Fisheries Service 2011). Hammerhead sharks are generally caught in low numbers as part of longline fishery (National Marine Fisheries Service 2001), and are readily available to inshore primitive and small commercial fisheries (Compagno and Niem 1998).

Refer to Chapter 9 (Fish), Section 9.3 for a full species profile of the scalloped hammerhead shark. The IUCN lists the scalloped hammerhead as endangered (Baum et al. 2007) and the squat-headed hammerhead shark (*Sphyrna mokarran)* as endangered (Denham et al. 2007).

Distribution. Hammerheads are wide-ranging, coastal-pelagic, and semi-oceanic sharks that inhabit tropical and warm temperate waters which occur over continental and insular shelves (Compagno 1984; Compagno and Niem 1998).

Habitat Preferences. Hammerhead sharks are found in a wide variety of coral reef habitats (Hennemann 2001). They are very active swimmers, occurring in pairs, in schools, or solitary, and ranging from the surface, surfline, and intertidal region to depths of at least 275 m (Compagno 1984). Juveniles often occur in schools, frequently inhabiting inshore areas such as bays, seagrass beds, and lagoon flats for foraging near the bottom before moving into deeper waters as adults (Western Pacific Regional Fishery Management Council 2001). As adults, they can be found in shallow inshore areas during mating or birthing events (Compagno 1984).

Life History. Hammerhead sharks make long seasonal, north-south migrations to warmer waters in the winter and cooler waters in the summer (Hennemann 2001). They are viviparous, having a gestation period of about 12 months (Western Pacific Regional Fishery Management Council 2001). The scalloped hammerhead produces an offspring of 15 to 31 pups per liter and utilizes shallow, turbid coastal waters (e.g., Guam's inner Apra Harbor) as nursery areas (Compagno 1984; Myers 1999).

10.5.6.2 Dasyatididae, Myliobatidae, and Mobulidae (Whiptail Stingrays, Eagle Rays, and Manta Rays)

Status. Six species of rays (four stingrays, the spotted eagle ray [*Aetobatis narinari*] and the manta ray [*Manta birostris*]) are managed in Micronesia as part of PHCRT by the WPRFMC (2001). All six species occur in the CNMI and Guam (Myers and Donaldson 2003) and have EFH designated within the boundaries of the MRA Study Area (Western Pacific Regional Fishery Management Council 2001). No data are available to determine if rays of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). The white-spotted eagle ray is taken as a by-catch, while the manta ray is neither a fisheries nor a by-catch species (Cavanagh et al. 2003). A 2009 study raised new questions about the conservation status of the manta ray: a new, smaller, more tropical species, *Manta alfredi*, was distinguished in Indonesia, and it was suggested that targeted fishing, bycatch fisheries, boat strikes, and habitat degradation could pose threats to the manta species (Marshall, Compagno, and Bennett 2009). Eagle rays and devil rays are attractive and desirable as captives in large aquaria and oceanaria (Compagno and Last 1999a, b). Both of the above species are listed on the IUCN Red List of threatened species as data deficient (Kyne et al. 2006; Marshall et al. 2011). The porcupine stingray (*Urogymnus asperrimus*) is listed as vulnerable on the IUCN Red List (Compagno and Musick 2000).

Distribution. Stingrays range throughout the Indo-Pacific region, while the spotted eagle and manta rays are worldwide, occurring in tropical and subtropical seas and warm temperate and tropical oceans, respectively (Hennemann 2001; Myers 1999).

Habitat Preferences. Habitat preferences for most rays include sand and mud bottoms of continental shelves, with a few species occurring on coral reefs (Myers 1999). Juveniles inhabit a variety of habitats from shallow clear lagoons to outer reef slopes. Nursery areas are associated with seagrass beds, mangroves, and shallow sand flats (Western Pacific Regional Fishery Management Council 2001). Adults utilize shallow clear lagoons to outer reef slopes at depths ranging from 0 to 100 m (Myers 1999) or deeper (e.g., eagle rays: 527 m; sting rays: 480 m) (Compagno and Last 1999b; Last and Compagno 1999). In winter, manta rays annually occupy areas characterized by a coastal front and consequent plankton enrichment, which are probably motivated by the feeding opportunity (Luiz et al. 2009).

Life History. Stingrays found in the MRA study area are primarily viviparous (Last and Compagno 1999), whereas eagle rays and manta rays are ovoviviparous (Western Pacific Regional Fishery Management Council 2001). Stingrays produce a litter with two to six young with a 12- month gestation period (Last and Compagno 1999). Some species of eagle rays breed in shallow bays and lagoons (Compagno and Last 1999b). One study of eagle rays documented a breeding period of August to September, and suggested that reproduction occurs in alternate years (Capape et al. 2007). The spotted eagle ray produces an average of four pups per litter after a gestation period of about 12 months (Bester 2010). The manta ray may give birth to one pup during a breeding season (Passarelli and Piercy 2010). During the winter, manta rays migrate to warmer areas, deeper waters, or disperse offshore (Passarelli and Piercy 2010).

10.5.6.3 Serranidae (Groupers)

Status. More than 40 species of groupers are managed in Micronesia as part of Bottomfish Management Unit Species (BMUS) and PHCRT by the WPRFMC (1998, 2001). All 40 species occur in the CNMI and Guam (Myers and Donaldson 2003) and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). Data from fish market surveys and analysis of management practices in Pohnpei, Micronesia, and Hong Kong, China, strongly indicate that groupers (particularly *Epinephelus* spp.) are highly susceptible to overfishing (Rhodes and Tupper 2007; To and de Mitcheson 2009). Declining long-term landings, increased targeting of juveniles, and absence of reproductive-size individuals signal the need for comprehensive management. Furthermore, grouper density across all lightly or heavily fished sites in an Indonesian study decreased drastically over a 5-year period; this is believed to result from unsustainable and exponential increases in fishing efficiency (Unsworth et al. 2007). Groupers are the most highly priced food fishes and are actively caught by commercial and sport fishermen (Heemstra and Randall 1999). The following groupers within the MRA Study Area have been listed on the IUCN Red List of threatened species: giant grouper (*Epinephelus lanceolatus*) as vulnerable (Shuk Man and Chuen 2006); humpback grouper (*Cromileptes atliyelis*) as vulnerable (Sadovy et al. 2008). The following groupers within the MRA Study Area have been listed as endangered on the IUCN Red List: the Hong Kong grouper (*Epinephelus akaara*) (Cornish 2003) and the Nassau grouper (*Epinephelus striatus*) (Cornish and Eklund 2003).

Distribution. Groupers are robust-bodied, long-lived, benthic fishes with a worldwide distribution and occur in tropical and semitropical seas of the Indo-Pacific region (Debelius 2002). Their wide geographic distribution is thought to result from the relatively long pelagic phase as larvae (Allen et al. 2003).

Habitat Preferences. Serranids inhabit a wide variety of habitats (Myers 1999). Larvae tend to be more abundant over the continental shelf than oceanic waters, avoid surface waters during the day, are evenly distributed vertically in the surface water column at night, and may be influenced by oceanic currents (Leis 1987; Rivera, Kelley, and Roderick 2004). A study in Palau of early juvenile stage nursery habitat found that the squaretail coralgrouper (*Plectropomus areolatus*) selects coral rubble habitats on the slopes of tidal channels, at a narrow depth range of 5 to 7 m, while the camouflage grouper (*Epinephelus polyphekadion*) is a habitat generalist for which no specific nursery habitat could be identified (Tupper 2007). Juveniles are found in shallow-water reef areas (seagrass beds and tide pools) and estuarine habitats (Western Pacific Regional Fishery Management Council 2001). Seagrasses provide protection to juveniles against predators (Nuraini et al. 2007). Adults utilize shallow coastal coral reef areas to deep slope rocky habitats from 0 to 400 m (Heemstra and Randall 1999). They are active and feed by day and by twilight, but are generally stationary and quiescent at night (Gibran 2007). Regardless of size, groupers are typically ambush predators, hiding in crevices and among coral and rocks (Western Pacific Regional Fishery Management Council 2001). Most species of groupers are solitary fishes with a limited home range (Heemstra and Randall 1999).

Life History. Spawning in groupers is typically seasonal and synchronized by lunar phase (Grimes 1987), with some species of groupers migrating several kilometers to spawn (Heemstra and Randall 1999); (Hutchinson and Rhodes 2010; Nakamura et al. 2008). Groupers tend to spawn in predictable, dense aggregations (some species spawn in pairs) with individual males spawning multiple times during the breeding season ((Myers 1999); (Rivera, Kelley, and Roderick 2004). In Palau, areas where spawning aggregations occur are protected from fishing, primarily benefitting the three grouper species (*Plectropomus areolatus, Epinephelus polyphekadion,* and *Epinephelus fuscoguttatus*) that account for most of the grouper abundance (Golbuu and Friedlander 2011). A life history study of the white-streaked grouper (*Epinephelus ongus*)in Okinawa, Japan, found fish ranging in age from 1 to 20 years had diets consistent with other serranids (e.g., crabs, shrimps, octopi, and fishes), and suggested that the white-streaked grouper may be a protogynous hermaphrodite (Craig 2007).

10.5.6.4 Lethrinidae (Emperors)

Status. Lethrinids are managed in Micronesia as part of BMUS and PHCRT by the WPRFMC (1998, 2001). the CNMI and Guam exhibit a large diversity of emporer species (Myers and Donaldson 2003), which have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). Emperors are commonly taken by bottom handline fishing in Guam (Amesbury and Myers 2001) and are of moderate to significant importance in commercial, recreational, and artisanal fisheries throughout the tropical Pacific (Western Pacific Regional Fishery Management Council 1998). No data are available to determine if emperor fishes of the PHCRT are approaching an overfished situation in the MRA Study Area (National Marine Fisheries Service 2011). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. The emperor fish is widely distributed over the Indo-Pacific in tropical and subtropical waters, with a few species ranging into warm-temperate waters (Debelius 2002). The spotcheek emperor (*Lethrinus rubrioperculatus*) occurs in the southern islands of the CNMI (Trianni 2011).

Habitat Preferences. Little is known about the biology of the emperor fish (Western Pacific Regional Fishery Management Council 2001). Emperors are known to occur in the deeper waters of coral reefs and adjacent sandy areas from 0 to 350 m (Western Pacific Regional Fishery Management Council 2001). Some lethrinid species are found inhabiting coastal waters, including coral and rocky reefs, sand flats,

seagrass beds, and mangrove swamps (Debelius 2002). Juvenile emperors near the southern Ryukyu Islands (Okinawa), Japan, occupy not only seagrass beds that are adjacent to adult coral habitats, but also isolated seagrass beds (Nakamura, Horinouchi, et al. 2009). Most species occur either singly or in schools to feed primarily at night on or near reefs (Myers 1999). Lethrinids are carnivores that feed on other reef fishes (McClanahan 2011).

Life History. Spawning behavior of lethrinids is poorly documented (Western Pacific Regional Fishery Management Council 1998). Based on available data, spawning occurs throughout the year and is preceded by localized migrations during crepuscular periods (Carpenter 2001c). Peak spawning events occur on or near the new moon. Spawning occurs near the surface, as well as near the bottom of reef slopes (Western Pacific Regional Fishery Management Council 2001). Settlement-stage emperor larvae are attracted to higher-frequency, invertebrate-generated audible reef noise, which may help guide them to their settlement destinations on coral reefs (Simpson et al. 2008).

The spotcheek emperor is a hermaphroditic species that reaches maturity at 1 year of age, and transitions to the male phase at 3–4 years; the maximum age observed was 8 years. The species is characterized by a high initial growth rate at age 0 (Trianni 2011).

10.5.6.5 Chlopsidae, Congridae, Moringuidae, and Ophichthidae (False Morays, Conger and Garden Eels, Spaghetti Eels, and Snake Eels)

Status. Forty species of eels are managed in Micronesia as part of PHCRT by the WPRFMC (2001). More than half of the managed eel species (60%) occur in the CNMI and Guam (Myers and Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if eels of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Eels are distributed worldwide in tropical and temperate seas (Allen and Steene 1987). Leptocephali of the widely tropically distributed false moray eels of the genus *Kaupichthys* were collected around Sulawesi Island during a sampling survey in the Indonesian Seas; they were present in Makassar Strait and the Celebes Sea, but were most abundant in Tomini Bay to the northeast (Lee et al. 2008). Garden eel leptocephali are widely distributed off of west Sumatra (Miller et al. 2011).

Habitat Preferences. Chlopsidae, Moringuidae, Muraenidae, and Ophichthidae are generally shallow-water eels that tend to live around islands and spawn nearby (Miller et al. 2006). Both juvenile and adult eels inhabit cryptic locations in the framework of coral reefs (e.g., false moray) or softbottom habitats (e.g., spaghetti, snake, and conger/garden eels) (Myers 1999). Habitats vary among the different families from the false moray (secretive indwellers of coral heads, seaward reefs, and seagrass beds at depths of 0 to 56 m); conger/garden eels—solitary or large colonies on sand patches/flats or slopes away from reefs at depths of 7 to 53 m with strong currents; spaghetti eels—shallow sandy areas, remaining hidden beneath the surface of the sediment at depths of 36 to 105 m; and snake eels—indwellers that stay buried in the sand or mud, with a few occasionally emerging to traverse sand, rubble, or seagrass habitats at depths of 16 to 68 m (Allen and Adrim 2003; Debelius 2002; Myers 1999; Smith 1999).

Life History. Most eel species are known to migrate for spawning (Western Pacific Regional Fishery Management Council 2001). Individual spawning characteristics vary among the different families. False morays are known to migrate off the reef to spawn, and spaghetti eels migrate to the surface to spawn

with males that are pelagic (Myers 1999). Snake eels appear to be nocturnal, with some species also coming to the surface to spawn (Myers 1999). Group spawning of eels has also been documented, with large numbers of adults congregating at the water surface at night (Western Pacific Regional Fishery Management Council 2001).

10.5.6.6 Apogonidae (Cardinalfishes)

Status. Fifty-eight cardinalfish species are managed in Micronesia as part of PHCRT by the WPRFMC (2001). All of these managed species occur in the CNMI and Guam (Myers and Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if cardinalfish of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Generally, this species is not important economically, but a few species are seen in the aquarium trade or used as tuna bait (Allen 2001). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011). Four new Indo-Pacific species (*Nectamia ignitops, N. luxuria, N. similis, and N. viria*) were described in 2008 (Fraser 2008). However, these species have not yet been accounted for in the PHCRT.

Distribution. Apogonids are a very large family of small reef fishes distributed in shallow coastal waters of the Atlantic, Pacific, and Indian Oceans (Debelius 2002). Recent distinctions have been made in the distributions of apogonid species of the genus *Foa*: *F. brachygramma* was previously believed to be widely distributed throughout the Indo-Pacific, but is restricted to the Hawaiian Islands; *F. fo* of the locality Phillipines has an apparent Indo-Pacific distribution but is not found in the Hawaiian Islands; *F. leisi* is a newly described species from French Polynesia; and *F. nivosa* is a newly described species from Palau, Marshall Islands, and Fiji (Fraser and Randall 2011).

Habitat Preferences. Cardinalfishes are found at water depths ranging from 0 to 80 m and are typically nocturnal, remaining hidden under coral reef ledges, holes, flats, and rubble even among the spines of sea urchins (*Diadema*) or crown-of-thorns starfish (*Acanthaster*) during the day, and then emerging at night to feed on the reef (Allen 2001; Amesbury and Myers 2001; Debelius 2002). Although cardinalfishes are typically solitary, a few species in pairs or loose clusters (e.g., *Apogon fragilis*) form dense aggregations immediately above mounds of branching corals (Allen et al. 2003). Members of the genera *Apogonichthys*, *Foa*, and *Fowleria* are typically secretive, cryptic inhabitants of seagrasses, algal beds, or rubble of sheltered reefs and reef flats (Western Pacific Regional Fishery Management Council 2001).

Life History. Apogonid species display a variety of different spawning patterns including year-round, spring and fall peaks, and phases of the moon (Western Pacific Regional Fishery Management Council 2001). Courtship and spawning in cardinalfishes are always paired rather than group activities (Debelius 2002). Cardinalfishes are also among the few marine fishes with oral brooding with the male carrying the eggs in his mouth until they hatch (Allen et al. 2003). Males of the cardinalfish species *Apogon doederleini* sometimes cannibalize their entire broods; this appears to be a conditional strategy affected by male status, such as age, somatic condition, and mate availability (Takeyama, Okuda, and Yanagisawa 2007).

10.5.6.7 Blenniidae (Blennies)

Status. Fifty-three species of blennies are managed in Micronesia as part of PHCRT by the WPRFMC (2001). At least 80 percent of these managed species occur in the CNMI and Guam (Myers and

Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if blennies of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). They have very little commercial importance because of their small size (Springer 2001). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Blennies have a worldwide distribution, occurring in tropical and temperate seas. The Indo-Pacific population consists of two subfamilies distinguished by dentition and diet: sabretooth (Salariinae) and combtooth (Blenniinae) (Myers 1999).

Habitat Preferences. Blennies are bottom-dwelling fishes that tend to shelter in small holes in the rocky, oyster, or coral reefs or sand substrate in tidepools (Debelius 2002; Springer 2001). This group exhibits complex color patterns that enable them to be well camouflaged to the surrounding habitat (Western Pacific Regional Fishery Management Council 2001). Most of the combtooth blennies are sedentary inhabitants of rocky shorelines, reef flats, or shallow seaward reefs at depths of 1 to 30 m (Myers 1999). Some combtooth blennies (e.g., *Alticus*, *Istiblennius*, and *Entomacrodus*)—called rockskippers—inhabit intertidal zones where they can leap between tide pools; others in the genus *Escenius* generally occupy coral-rich areas (Allen and Adrim 2003). Sabretooth blennies utilize empty worm tubes or shells when not actively swimming above the seafloor, mimicking (e.g., bluestreak cleaner wrasse, *Labroides dimidiatus*) or pursuing other fishes at depths from 1 to 40 m (Allen and Adrim 2003). Some species of sabretooth blennies, however, inhabit much deeper waters than their counterparts; for example, *Petroscirtes pylei* has been observed at a deep-water reef and collected at a depth of 110 m (Smith-Vaniz 2005).

Life History. The reproductive biology of blennies has been studied extensively. Despite many variations, most are demersal territorial fishes that deposit adhesive eggs guarded by the male in or near a shelter hole (Amesbury and Myers 2001). Spawning occurs throughout the year, with a peak from January to April (Western Pacific Regional Fishery Management Council 2001). Blenniidae larvae are found in abundance inshore (Muhling et al. 2008), where they move vertically over a range of depths consistent with the halocline (Irisson et al. 2010).

10.5.6.8 Pinguipedidae (Sandperches)

Status. Four shallow-water sandperch species are managed in Micronesia as part of PHCRT by the WPRFMC (2001). All managed species occur in the CNMI and Guam (Myers and Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if sandperches of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). A few species are large enough to be of commercial importance as food, but are of limited value (Randall 2001d). None of the species found in the MRA Study Area are listed on the IUCN Red List (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Only the genus *Parapercis* occurs in the Indo-Pacific region (Myers 1999). Evidence suggests that the blue cod (*Parapercis colias*) forms discrete subpopulations at the mesoscale in nearshore waters (10 to 20 km) (Beer, Wing, and Swearer 2011).

Habitat Preferences. This genus typically occurs on sandy bottoms near rubble, rock, or coral reefs, where they typically rest on the bottom using well-separated pectoral fins (Western Pacific Regional

Fishery Management Council 2001). Adults are found at depths ranging from 1 to 50 m, with some species occurring in deeper waters (100 to 300 m) (Myers 1999).

Life History. Sandperches live in small harems with a single dominant, territorial male (Allen et al. 2003). Some are unisexual (Randall 2001d). Courtship and spawning occur just before sunset year-round (Myers 1999). No evidence of spawning migrations has been reported (Western Pacific Regional Fishery Management Council 2001).

10.5.6.9 Bothidae/Pleuronectidae/Soleidae (Flounders and Soles)

Status. Nine shallow-reef flatfish species are managed in Micronesia as part of PHCRT by the WPRFMC (2001). Four left-eyed flounders and two soles occur in the CNMI and Guam (Myers and Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). Although flatfishes are among the world's important food fishes, no data are available to determine if flatfishes of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Flatfishes are distributed on tropical and temperate continental shelves worldwide. Some species are associated with coral reefs in the Indo-Pacific (Myers 1999). Two patterns of distribution have been identified for species of the genus *Asterorhombus* (family Bothidae): *A. intermedius* and *A. cocosensis* are distributed from the Indian Ocean to the western Pacific, not occurring nonmarginally on the Pacific Plate, whereas *A. filifer* is distributed from the Indian Ocean to nonmarginal localities on the Pacific Plate (Hensley 2005). Deepsea sole (*Embassichthys bathybius*), Korean flounder (*Glyptocephalus stelleri*), rex sole (*G. zachirtis*) and slime flounder (*Microstomus achne*) are rare flatfishes found off the Northern Kuril Islands and Southeastern Kamchatka (Orlov and Tokranov 2007).

Habitat Preferences. Habitat for most flatfish consist of softbottoms such as sand, mud, silt, or gravel often associated with coral reefs (Myers 1999). Some species occur directly on the reef or within the reef framework (Western Pacific Regional Fishery Management Council 2001). Juveniles and adults are often found in lagoons, caves, flats, and reefs (Western Pacific Regional Fishery Management Council 2001). Flatfishes exhibit adaptive camouflage to closely match the surrounding bottom habitat (Allen and Adrim 2003). Some flatfishes are found in water deeper than 100 m (e.g., panther flounder [*Bothus pantheinus*]), and some species are common in shallower habitats (1 to 73 m) (Myers 1999). The Pacific halibut (*Hippoglossus stenolepis*) (family Pleuronectidae) occupies a deep, remote environment during the spawning season (Seitz et al. 2005). Larvae are often found in the upper 100 m of the water column (Western Pacific Regional Fishery Management Council 2001).

Life History. Eggs of the flounder and sole are pelagic. As larvae metamorphose into juveniles and adults, they become demersal. Information is lacking on the reproductive process and the extent of spawning aggregations in the Indo-Pacific species (Western Pacific Regional Fishery Management Council 2001). However, the lefteye flounder (*Engyprosopon grandisquama*), southwest of Kyūshū Island, Japan, was observed to have a spawning season June to September, with a peak in June–July; males that retain their mating territories long-term (i.e., between spawning seasons) have greater success at acquiring mates (Manabe et al. 2005). Spawning success of the Japanese flounder (*Paralichthys olivaceus*), offshore from the Pacific coast of northern Honshū, Japan, was found to significantly correlate to the water temperature at 50 m depth in the coastal region off northern Iwate Prefecture in July (Goto 2006).

10.5.6.10 Ostraciidae (Trunkfishes)

Status. Six trunkfish species are managed in Micronesia as part of PHCRT by the WPRFMC (2001); all occur in the CNMI and Guam (Myers and Donaldson 2003), and all have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if trunkfishes of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Trunkfish or boxfish are distributed in both the Indo-Pacific and Indo-pan-Pacific regions of Micronesia (Amesbury and Myers 2001; Myers 1999).

Habitat Preferences. Ostraciids are solitary, slow-swimming, diurnal predators that inhabit a variety of sand and rubble bottom areas (e.g., subtidal reef flats, lagoons, bays, channels, seaward reefs) covered with moderate to heavy algae or coral growth (Matsuura 2001; Myers 1999). These fish have been reported at depths from 1 to 100 m (Amesbury and Myers 2001). Postlarvae and juveniles commonly collect in grassbeds and other shallow areas (Western Pacific Regional Fishery Management Council 2001).

Life History. Trunkfish are sexually dimorphic. The species of trunkfish studied so far are haremic, and males defend a large territory with non-territorial females and subordinate males. Trunkfish spawning occurs in pairs at dusk, usually above a structure (Western Pacific Regional Fishery Management Council 2001).

10.5.6.11 Tetradontidae/Diodontidae (Pufferfishes and Porcupinefishes)

Status. Seventeen pufferfish and three porcupinefish species are managed in Micronesia as part of PHCRT by the WPRFMC (2001). All of these species occur in the CNMI and Guam (Myers and Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if pufferfishes or porcupinefishes of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Some porcupine fishes are inflated, dried, and sold as curios (Leis 2001). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Pufferfish and porcupinefish are distributed worldwide throughout tropical and temperate waters, including brackish and some freshwater habitats (Matsuura 2001; Waikiki Aquarium 1999d).

Habitat Preferences. Both groups have reef-associated and pelagic forms utilizing bottom types of sand, rubble, silt, coral, or rock in estuarine, mangrove, lagoon, and coral reef (e.g., reef flats, seaward reefs, patch reefs) habitats from the shoreline to 100 m (Myers 1999; Western Pacific Regional Fishery Management Council 2001). Pufferfishes feed in the quiet, shallow waters of the reef during the day and rest in caves or crevices at night. Porcupinefishes also occur close to the reef in quiet waters during the day, often in caves or under ledges, but emerge at night to feed (Waikiki Aquarium 1999d). Most puffers are solitary, but a few form small aggregations (Western Pacific Regional Fishery Management Council 2001). Larval forms are pelagic and occur from 0 to 100 m (Western Pacific Regional Fishery Management Council 2001).

Life History. Most information on pufferfish reproduction has been obtained in temperate locations; however, some assumptions about tropical species are plausible (Western Pacific Regional Fishery Management Council 2001). All species lay demersal adhesive eggs, although the courtship often occurs near the surface (Myers 1999). At least one species, the sharpnose puffer (*Canthigaster valentini*), is haremic, with males spawning at midmorning with a different female each day. Females then deposit the eggs in tufts of algae (Myers 1999). Porcupinefish may spawn pelagic or demersal eggs, depending on species. As observed in one species, the spiny balloonfish (*Diodon holacanthus*), spawning takes place at the surface near dawn or dusk and involves pairs or groups of males and a single female. In Hawai‘i, porcupinefish have a spawning peak in late spring, with some spawning also occurring from January to September (Western Pacific Regional Fishery Management Council 2001). The spiny puffer (*Diodon holocanthus*) displays an irregular oocyte development schedule, which means this species can spawn multiple times a year, with peaks in June, and September through December (Lucano-Ramirez et al. 2011).

10.5.6.12 Ephippidae (Spadefishes and Batfishes)

Status. Three species of batfish are managed in Micronesia as part of PHCRT by the WPRFMC (2001), two of which occur in the CNMI and Guam (Myers and Donaldson 2003). All species have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if the batfishes of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Batfishes occur in tropical temperate seas worldwide, with only the genus *Platax* found in the Indo-west Pacific region of Micronesia (Debelius 2002).

Habitat Preferences. Batfishes are schooling, semi-pelagic fishes that occur over muddy, silty, and/or sandy bottoms and coral reefs (Western Pacific Regional Fishery Management Council 2001). Juveniles occur singly or in small groups among mangroves and in inner sheltered lagoons or reefs (Kuiter and Debelius 2001). Adults migrate to deeper channels and lagoons, and along deep outer reef walls where they aggregate in large schools or occur singly or in pairs to depths ranging from 20 to 30 m (Debelius 2001; Myers 1999). Juvenile *Platax* species often mimic floating leaves or crinoids, whereas adult species of *Platax* travel through open water in tightly-knit schools (Kuiter and Debelius 2001). Studies of the reefs off Kuchierabu-jima Island, Japan, showed that juvenile batfish (*Platax orbicularis*) change swimming and feeding patterns according to the time of day. During the day, the juveniles drift, mimicking floating leaves, while picking at algae-covered materials on the surface. However, at night the juveniles actively swim and feed in a ram and suction manner on zooplankton (Barros et al. 2008).

Life History. Little information is known about the spawning or egg characteristics of Indo-Pacific ephippids (Leis, Trnski, and Bruce 1989). However, observations of the Atlantic spadefish (*Chaetodipterus faber*) suggest that members of this family may migrate offshore to spawn, which could explain the formation of large schools (Kuiter and Debelius 2001).

10.5.6.13 Monodactylidae (Monofishes)

Status. Only one species of this family, the diamondfish (*Monodactylus argenteus*), is managed in Micronesia as part of PHCRT by the WPRFMC (2001). The diamondfish has been reported as occurring in the CNMI and Guam (Myers and Donaldson 2003), and has EFH designated within the boundaries of the MRA Study Area (Western Pacific Regional Fishery Management Council 2001). No data are available to

determine if the diamondfish of the PHCRT is approaching an overfished situation (National Marine Fisheries Service 2011). It is of minor commercial importance, occasionally sold fresh in markets or caught for the aquarium-fish trade (Kottelat 2001). This species is not listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. The diamondfish ranges from the Red Sea to Samoa, north to the Yaeyamas, south to New Caledonia, and from Palau to the east Carolines and Mariana Islands in Micronesia (Allen and Adrim 2003).

Habitat Preferences. Diamondfish are active schoolers that occur in freshwater, brackish estuaries, and harbors but may venture over silty coastal reefs to depths of 10 m (Allen et al. 2003; Myers 1999). Juveniles and adults of this species can be found over silt, mud, sand, or coral bottoms (Western Pacific Regional Fishery Management Council 2001). This species feeds in open water during the day and night (Debelius 2001). Mangrove communities are important to some monodactylid species at early stage: juveniles begin life in nursery estuary areas, first feeding on zooplankton and later shifting to periphyton and plant material around mangrove prop roots (Gning, Vidy, and Thiaw 2008).

Life History. Diamondfish eggs are demersal and adhesive in freshwater, and probably pelagic in seawater (Western Pacific Regional Fishery Management Council 2001).

10.5.6.14 Haemulidae (Grunts and Sweetlips)

Status. Eleven grunt (sweetlips) species are managed in Micronesia as part of PHCRT by the WPRFMC (2001). Six of these species occur in the CNMI and Guam (Myers and Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). Although NMFS does not have sufficient current data to determine if grunt stocks of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011), the family had become scarce by the late 1990's in the heavily fished waters of Guam (Myers 1999). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Grunts are distributed in tropical and temperate seas and in marine and brackish waters worldwide. All 11 species have been recorded within Micronesian waters (Western Pacific Regional Fishery Management Council 2001).

Habitat Preferences. Grunts are mostly reef dwellers that shelter in caves and shipwrecks (Debelius 2001, 2002). These nocturnal predators school during the day under or near overhangs or tabular corals on sandy to muddy bottoms at depths from 1 to 100 m (Western Pacific Regional Fishery Management Council 2001). Juveniles are commonly found in small groups on grass flats, near mangroves, and in other sheltered inshore areas (e.g., lagoons, estuaries; (McKay 2001)). Adults generally frequent patch reefs, lagoons, channels, inshore and seaward reefs, and outer reef slopes (Myers 1999). The ritualized evening feeding migrations of grunts are important in moving nutrients and organic matter across habitat boundaries, with reef margins determining the direction of ontogentic habitat shifts (Appeldoorn et al. 2009).

Life History. Little information is available on grunt reproduction in Indo-Pacific locations. Given their similarity to other roving predators (e.g., groupers or snappers), they probably migrate to spawning sites on the outer reef slope for group spawning at dusk (Western Pacific Regional Fishery Management

Council 2001). Studies of reproduction of white grunt (*Haemulidae plumieri*) show that females are mature at total lengths around 213 mm and males around 271 mm. Fecundity is proportional to size and range—between 19,873 and 535,039 eggs per female (Palazon-Fernandez 2007).

10.5.6.15 Echeneidae (Remoras)

Status. Three remora species are managed in Micronesia as part of PHCRT by the WPRFMC (2001), two of which are reported as occurring in the CNMI and Guam (Myers and Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if remoras of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Remoras are not considered of any commercial importance (Collette 1999). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Remoras are circumglobal in their distribution and are found throughout Micronesia (Western Pacific Regional Fishery Management Council 2001).

Habitat Preferences. Remoras occur in coastal and pelagic waters, and utilize a wide variety of hosts (to which they cling using a sucking disc and act as cleaners)—including fishes, marine mammals, and ships/boats (Debelius 2001; Myers 1999). Species associated with coral reef dwellers are found near reefs at depths up to 50 m (Allen and Adrim 2003).

Life History. Information is lacking on the spawning techniques and/or locations of remoras (Western Pacific Regional Fishery Management Council 2001). Eggs of the sharksucker (*Echeneis naucrates*) and remora (*Remora remora*) are pelagic and spherical (Leis and Trnski 1989).

10.5.6.16 Malacanthidae (Tilefishes)

Status. Five tilefish species are managed in Micronesia as part of PHCRT by the WPRFMC (2001). Two of these species occur in the CNMI and Guam (Myers and Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (Western Pacific Regional Fishery Management Council 2001). No data are available to determine if tilefishes of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Tilefishes are very high quality food fishes, and several species are commercially important (Dooley 1999). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. This family is distributed worldwide in tropical and temperate seas, and is represented by three genera in the Indo-Pacific region (Western Pacific Regional Fishery Management Council 2001).

Habitat Preferences. Tilefish usually occur singly or in pairs on outer slope reefs (Myers 1999). They can be found in depths ranging from 6 to 115 m in mud, sand, or rubble areas of barren seaward slopes (Western Pacific Regional Fishery Management Council 2001). Tilefish frequently build mounds under rocks in the sand or excavate burrows when facing a potential threat (Debelius 2002). A study in Western Wakasa Bay and Maizuru Bay, Japan, showed a clear diel movement pattern of the red tilefish (*Branchiostegus japonicas*) from the shallower Wakasa Bay to deeper waters; the tilefish in the deeper Maizuru Bay showed burrow fidelity inside the bay up to 1 month after release (Mitamura et al. 2005).

Life History. Few accounts of spawning are known, but it appears that adult pairs of tilefish make a short spawning ascent to release pelagic, spheroid eggs (Leis, Trnski, and Bruce 1989). Research suggests that female sand tilefish living different habitats display significantly different spawning patterns due to variable risk of predation from barracuda. Deep channel inhabiting sand tilefish have a predation mortality rate over nine times higher than reef-slope inhabiting females. Deep channel sand tilefish spawn more frequently and dedicate less energy to growth than reef slope tilefish, indicating that behavioral and life-history traits show phenotypic plasticity depending on the nature and intensity of predation risk (Baird and Baird 2006).

10.5.6.17 Pseudochromidae (Dottybacks)

Status. Ten dottyback species are managed in Micronesia as part of PHCRT by the WPRFMC (2001). Five of these species occur in the CNMI and Guam (Myers and Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if dottybacks of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Some species are of commercial importance in the aquarium fish trade (Gill 1999). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Dottybacks are distributed in the tropical Indo-Pacific, and are represented by two genera in Micronesian waters (Nelson 2006).

Habitat Preferences. Dottybacks are cryptic diurnal inhabitants of coral reefs and rock bottoms in shallow intertidal areas of depths of about 100 m (Gill 1999). They commonly utilize numerous small hiding places such as cracks in rock faces, boulders, small caves, or dead corals overgrown by new; they occur in mixed algae, sponge, and coral habitats (Debelius 2002). Dottybacks usually occur singly or in pairs. Some species live in small aggregations of mixed sizes and utilize large caves as a territory (Debelius 2002).

Life History. Dottybacks are demersal spawners, with some species brooding eggs in the mouth of the male, while others lay adhesive egg masses guarded by the male (Allen and Adrim 2003; Western Pacific Regional Fishery Management Council 2001). Hatching typically occurs at night, shortly after sunset (Western Pacific Regional Fishery Management Council 2001).

10.5.6.18 Plesiopidae (Prettyfins)

Status. Three species of prettyfins are managed in Micronesia as part of PHCRT by the WPRFMC (2001). All three species occur in the CNMI and Guam (Myers and Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if prettyfins of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Some species are popular in the aquarium trade (Mooi 1999). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Prettyfins are distributed in the tropical Indo-Pacific (Nelson 2006).

Habitat Preferences. Juvenile and adult prettyfins inhabit outer reef slopes and flats, hiding in holes and crevices at depths ranging from 3 to 45 m (Western Pacific Regional Fishery Management Council 2001).

Most species are secretive by day but venture out at night to feed (Myers 1999). *Notographus sp.* is an acanthoclinine plesiopid often found near the benthos feeding on alpheid shrimp (Mooi and Gill 2004). Prettyfins school in caves or overhangs, loosely aggregate or school around coral heads, or are solitary (Mooi and Gill 2004).

Life History. Prettyfin reproduction is similar to the closely related dottybacks (Western Pacific Regional Fishery Management Council 2001). They produce demersal eggs with hair-like filaments that either entangle with one another to form a mass or adhere the eggs to a hard surface (Mooi and Gill 2004). Eggs are guarded by the male in a crevice or cave, and males are known to mouthbrood the eggs (Mooi and Gill 2004; Myers 1999).

10.5.6.19 Caracanthidae (Coral crouchers)

Status. Two coral croucher species are managed in Micronesia as part of PHCRT by the WPRFMC (2001). Both species occur in the CNMI and Guam (Myers and Donaldson 2003) and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if coral crouchers of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Coral crouchers are distributed in the Indian and Pacific Oceans (Nelson 2006).

Habitat Preferences. Coral crouchers inhabit branches of certain *Stylophora*, *Pociiopora*, and *Acropora* corals at depths from 0 to 10 m, where they tightly wedge themselves into the coral branches when disturbed (Myers 1999). Other than their close association with corals, little is known of their biology (Poss 1999a).

Life History. The spawning mode and development at hatching of coral crouchers is not known (Western Pacific Regional Fishery Management Council 2001). Pygmy coral crouchers display mating system plasticity in response to coral patch size, with monogamy occurring on small corals and harem polygyny on large corals (Wong, Munday, and Jones 2005).

10.5.6.20 Grammistidae (Soapfishes)

Status. Six species of soapfish are managed in Micronesia as part of PHCRT by the WPRFMC (2001). All six species occur in the CNMI and Guam (Myers and Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if soapfishes of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Soapfishes are distributed in the Atlantic, Pacific, and Indian Ocean, represented by five genera in the Indo-Pacific region of Micronesia (Myers 1999; Western Pacific Regional Fishery Management Council 2001).

Habitat Preferences. Soapfishes are small, grouper-like, secretive fishes that occur in shallow lagoons and on reef flats, outer reef slopes, and wave-washed seaward reefs (Western Pacific Regional Fishery

Management Council 2001). They often hide in small caves, under ledges, or in holes at depths up to 150 m (Myers 1999).

Life History. The soapfish, like the grouper, are generally unisex. All species are solitary and territorial. The genus *Liopropoma* has pelagic eggs, whereas the genus *Pseudogramma* has large demersal eggs (Western Pacific Regional Fishery Management Council 2001).

10.5.6.21 Aulostomidae (Trumpetfishes)

Status. One trumpetfish species, *Aulostomus chinensis*, is managed in Micronesia as part of PHCRT by the WPRFMC (2001). This species occurs in the CNMI and Guam (Myers and Donaldson 2003), and has EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if the trumpetfish of the PHCRT is approaching an overfished situation (National Marine Fisheries Service 2011). It has no commercial importance, but is occasionally taken as by-catch in artisanal fisheries (Fritzsche and Thiesfeld 1999a). This species is not listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. The trumpetfish is distributed in the tropical Atlantic and Indo-Pacific region, occurring in Hawai‘i, Micronesia, and American Samoa (Nelson 2006; Western Pacific Regional Fishery Management Council 2001).

Habitat Preferences. Trumpetfish occur in virtually all reef habitats except areas of heavy surge to a depth of 122 m (Myers 1999). These fish are solitary ambush predators that hover vertically among branches of corals and seagrasses, hide within schools of surgeonfishes, or use the body of a large parrotfish as cover to approach unsuspecting prey (Waikiki Aquarium 1999e).

Life History. Spawning of trumpetfishes has been reported occurring at dusk when individual males and females ascend to a depth of 5 to 8 m to release gametes before returning to the bottom (Western Pacific Regional Fishery Management Council 2001).

10.5.6.22 Fistularidae (Cornetfishes)

Status. One cornetfish species, *Fistularia commersonnii*, is managed in Micronesia as part of PHCRT by the WPRFMC (2001). This species occurs in the CNMI and Guam (Myers and Donaldson 2003), and has EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if the cornetfish of the PHCRT is approaching an overfished situation (National Marine Fisheries Service 2011). Although not important in commercial fisheries, they are frequently taken in trawls and by various types of artisanal gear, and may appear in local food markets (Fritzsche and Thiesfeld 1999b). This species is not listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. The cornetfish is distributed in the tropical Atlantic, Pacific, and Indian Oceans, and is represented by a shallow-water and deepwater species in Indo-Pacific region (Nelson 2006; Western Pacific Regional Fishery Management Council 2001). Rising ocean temperature is thought to have changed the range of cornetfishes in the Gulf of Mexico (Fodrie et al. 2010), but not necessarily within the Study Area. *F. commersonii* is an Indo-Pacific species that has recently invaded areas in the eastern Mediterranean (Kalogirou et al. 2007).

Habitat Preferences. A shallow-water species, the cornetfish occurs in virtually all reef habitats except in areas of heavy surge to a depth of 122 m (Allen and Adrim 2003; Myers 1999). They are usually seen in relatively open sandy areas within schools of similarly sized individuals (Western Pacific Regional Fishery Management Council 2001), and occasionally occur in mid-water, above steep dropoffs (Myers 1999). Habitat type greatly affects the feeding mode of *F. commersonii,* which stalks fish on the reef and will actively chase pelagic species in open water (Takeuchi 2009).

Life History. Cornetfish eggs are large, pelagic, and subject to advection by ocean currents (Western Pacific Regional Fishery Management Council 2001).

10.5.6.23 Anomalopidae (Flashlight Fishes)

Status. Two flashlight fish species are managed in Micronesia as part of PHCRT by the WPRFMC (2001). Both species occur in the CNMI and Guam (Myers and Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (Western Pacific Regional Fishery Management Council 2001). No data are available to determine if flashlight fishes of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Flashlight fishes are popular species in public aquariums, and are also targeted by fisherman for use as bait (Paxton and Johnson 1999). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Flashlight fishes are scattered in warm-water localities, primarily the Indo-Pacific region (Nelson 2006).

Habitat Preferences. Flashlight fishes utilize caves and/or crevices within the coral reef habitat, ranging at depths from 30 to 400 m and as shallow as 2 m (Myers 1999). Flashlight fishes are nocturnal, remaining hidden during the day and venturing out into the water column at night to feed (Western Pacific Regional Fishery Management Council 2001). They occur in large aggregations on outer reef slopes on dark, moonless nights where they probably utilize their light organs for feeding, defense, schooling, or mating (Allen and Adrim 2003; Waikiki Aquarium 1999a).

Life History. The eggs of flashlight fishes are pelagic, positively buoyant, and subject to advection by ocean currents (Western Pacific Regional Fishery Management Council 2001).

10.5.6.24 Clupeidae (Herrings, Sprats, and Sardines)

Status. Six clupeid species are managed in Micronesia as part of PHCRT by the WPRFMC (2001). Two species of sprat occur in the CNMI and Guam (Myers and Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if sprat of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). In the Mariana Islands, the blue sprat (*Spratelloides delicatulus*) is caught by butterfly (lift) nets and used as bait or food (Myers 1999). None of these species found in the MRA Study Area is listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Clupeids are distributed worldwide in freshwater and marine systems, and are represented by four genera in Micronesia and the Indo-Pacific region (Myers 1999; Nelson 2006).

Habitat Preferences. Represented by the subfamily Dussumierinae, both tropical sprat species occur in coastal water habitats over sand, mud, rock, and coral reefs from the surface down to 20 m (Western

Pacific Regional Fishery Management Council 2001). The blue sprat schools near the surface of clear coastal waters, lagoons, and reef margins during feeding, whereas the sharp-nosed sprat inhabits deep lagoons and the outer reef slopes (Myers 1999).

Life History. Clupeid eggs are spherical and thought to be pelagic in all tropical taxa except Spratelloides, which has demersal eggs (Leis, Trnski, and Bruce 1989). Blue spat (*Spratelloides gracilis*) release on average 1.2 million eggs, and sexual maturity is reached at 54 mm flork length (Weng et al. 2005). Counts of daily otolith rings on blue sprat off central Japan showed that most are born between April and November in that region, with a shorter spawning window in colder southern waters (Shirafuji et al. 2007).

10.5.6.25 Engraulidae (Anchovies)

Status. Seven anchovy species are managed in Micronesia as part of PHCRT by the WPRFMC (2001). Four of these species occur in the CNMI and Guam (Myers and Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (Western Pacific Regional Fishery Management Council 2001). No data are available to determine if anchovies of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Anchovies are commercially important, utilized as live bait for pole and line tuna fisheries ((Myers 1999). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Anchovies are distributed in the Atlantic, Indian, and Pacific Oceans represented by three genera in Micronesia of the Indo-Pacific region (Myers 1999; Nelson 2006).

Habitat Preferences. Anchovies typically inhabit estuaries and turbid coastal waters, but some occur over inner protected reefs, and at least one species, the oceanic or buccaneer anchovy (*Encrasicholina punctifer*) is found in large atoll lagoons or deep, clear bays (Western Pacific Regional Fishery Management Council 2001). Juvenile and adult anchovies are planktivores, utilizing the surface waters over sand, mud, rock, or coral reef habitats (Myers 1999). The little priest (*Thryssa baelama*) anchovy occurs in large schools in turbid waters of river mouths and inner bays (Western Pacific Regional Fishery Management Council 2001).

Life History. Anchovy eggs are pelagic and subject to advection by ocean currents (Western Pacific Regional Fishery Management Council 2001). In the genus *Thryssa*, eggs are spherical and small to moderate in size, whereas in the genera *Encrasicholina* and *Stolephorus*, eggs are ovate to elliptical and vary from small to large (Leis, Trnski, and Bruce 1989). The ontogeny of swimming speed, schooling behavior, and predator avoidance of Japanese anchovies (*Engraulis japonicus*) show that swimming speed more than doubles between early larval and metamorphosing stage, and schooling behavior is much greater than that of other pelagic species. Predator avoidance remains limited throughout life stages, and is offset by high fecundity and early maturation (Masuda 2011).

10.5.6.26 Gobiidae (Gobies)

Status. In Micronesia, 159 gobies are managed as part of PHCRT by the WPRFMC (2001). At least 122 goby species occur in the CNMI and Guam (Myers and Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (Western Pacific Regional Fishery Management Council 2001). No data are available to determine if gobies of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Most gobies have no commercial or recreational importance other than food for larger fishes (Larson and Murdy 2001). None of the species found in the

MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Gobies are distributed worldwide in temperate and tropical seas represented by 212 genera in the Indo-Pacific region (Allen and Adrim 2003; Western Pacific Regional Fishery Management Council 2001).

Habitat Preferences. Gobies occur in a variety of habitats such as rocky shorelines, coral reefs, reef flats, shallow seaward reefs, sand flats, and seagrass beds (Myers 1999). The majority of gobies utilize the coral reef habitat, where they exhibit high diversity and abundance, but may occur in adjacent coastal and estuarine waters (Larson and Murdy 2001). Many gobies also occupy a wide variety of substrata ranging from mud to rock or coral, or live in close association with other marine organisms such as sponges, gorgonians, or snapping shrimps at depths from 1 to 48 m (Debelius 2002). Various gobies (e.g., *Bryaninops*, *Paragobiodon*, *Gobiodon*) live within or occur in groups hovering above the branches of various coral species (*Millepora* spp., *Porites cylindrica*, *P. lutea*, *Acropora*, and *Cirrhipathes anguina*) (Western Pacific Regional Fishery Management Council 2001). Several genera (*Amblyeleotris*, *Cryptocentrus*, *Ctenogobiops*, *Vanderhorstia*, *Lotilia*, and *Mahidolia*) have a symbiotic relationship with one or more species of alpheid prawns, in which the gobies occupy and/or share a burrow (Allen and Adrim 2003). The gobies, either singly or in pairs, act as sentinels for the snapping shrimp (Alpheus spp.), which maintains the burrow (Western Pacific Regional Fishery Management Council 2001). Studies analyzing the effects of reef noise show that settlement stage Gobiidae often are encountered more often in high-frequency areas rather than in silent or low-frequency areas. High frequency noise is most often produced by marine invertebrates (Simpson et al. 2008). Coral dwelling gobies have a peripheral olfactory organ that develops at an early life stage and assists with navigation to suitable habitat (Arvedlund, Munday, and Takemura 2007).

Life History. Gobies appear to spawn promiscuously, with many individuals loosely organized into a social hierarchy or with individuals maintaining small contiguous territories (Western Pacific Regional Fishery Management Council 2001). Pairing and apparent monogamy is also documented for a number of goby species (Debelius 2002). *Valenciennea strigata* form pairs after sexual maturity, suggesting pair formation was for breeding rather than protection; however, studies also show that solitary individuals are also capable of breeding (Pratchett, Pradjakusuma, and Jones 2006). Female gobies lay a small mass of eggs in burrows, on the underside of rocks or shells, or in cavities within the body of sponges (Larson and Murdy 2001). Males guard the nesting site and eggs, which are attached to the substrate at one end by a tuft of adhesive filaments (Western Pacific Regional Fishery Management Council 2001).

10.5.6.27 Lutjanidae (Snappers)

Status. Snapper species are managed in Micronesia as part of the BMUS and PHCRT by the WPRFMC (1998, 2001). Twenty-three lutjanid species occur in the CNMI and Guam (Myers and Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if snappers of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Snappers are important to artisanal fisheries, where they are caught with handlines, traps, a variety of nets, and trawls (Anderson and Allen 2001). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Snappers occur in the subtropical and tropical waters of the Atlantic, Indian, and Pacific Oceans, and are represented by eight genera in the Indo-Pacific region of Micronesia (Nelson 2006); (Myers 1999).

Habitat Preferences. Snappers are slow growing, long-lived fish that inhabit shallow coastal coral reef areas to deep (0 to 400 m) slope rocky habitats (Allen and Adrim 2003; Amesbury and Myers 2001). Snapper larvae tend to be more abundant in water over the continental shelf than the open ocean waters, are absent from surface waters during the day, and conduct nighttime vertical migrations (Leis 1987). Juveniles utilize a wide variety of shallow-water reef and estuarine habitats, whereas adults primarily utilize shallow to deep reef and rocky substrate (Western Pacific Regional Fishery Management Council 2001). Juveniles use seagrass bed to avoid predators and display a high affinity to complex, mixed microhabitats (Nuraini et al. 2007). Some snapper species exhibit higher densities on the upcurrent side versus the downcurrent side of islands, banks, and atolls—probably due to the increased availability of allochthonous planktonic prey (Moffitt 1993). Many snappers exhibit high site fidelity and a positive correlation between total length and home range size (Nanami and Yamada 2008). Mangrove snapper (*Lutjanus argentimaculatus*) in Japan gradually move from river habitat to marine areas between the ages of 1 and 3 years; otolith examination showed individuals with a fast growth rate migrate sooner than slower growing individuals (Yamada 2010).

Life History. Snappers are batch or serial spawners, spawning multiple times over the course of the spawning season; they may exhibit a shorter, more well-defined spawning period, or have a protracted spawning period (Allen 1985; Moffitt 1993; Parrish 1987). They form large aggregations near areas of prominent relief, and spawn with lunar periodicity coinciding with new/full moon events (Grimes 1987). The spawning season in coastal Okinawa waters is between May and October for humpback red snappers (*Lutjanus johnii*) (Nanami et al. 2010), and April to July for blackspot snappers (*Lutjanus fulviflammus*) (Shimose and Tachihara 2005). Indonesian red snapper (*Lutjanus erythropterus*) have a maximum fecundity of 997,000 eggs, and spawn between September and March (Fry et al. 2009).

10.5.6.28 Monacanthidae (Filefishes)

Status. Seventeen filefish species are managed in Micronesia as part of PHCRT by the WPRFMC (2001). Eleven of these species occur in the CNMI and Guam (Myers and Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if filefishes of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Filefishes occur in tropical and temperate waters of the Atlantic, Indian, and Pacific Oceans (Nelson 2006).

Habitat Preferences. Filefishes are found in lagoons, shallow coral and rocky reefs, seaward reefs with steeply sloping areas, and seagrass beds at depths ranging from 10 to over 220 m (Hutchins 2001; Myers 1999). Adults are solitary or occur in pairs, while some juvenile species form schools (Debelius 2001). Sargassum also provides important nursery habitat for some species of filefish such as the planehead filefish (Casazza and Ross 2008). Some Monacanthidae species are coralivores, preferring coral reef habitats, and therefore serve important ecological functions to the reef (Cole, Pratchett, and Jones 2008). Laboratory studies manipulating water pressures on larval filefish indicated their barokinetic

behaviors as they actively swam up or down to their preferred depths and pressure levels (Huebert 2008).

Life History. Little is known of the reproduction of most filefish species (Debelius 2002). Some species are sexually dimorphic (Western Pacific Regional Fishery Management Council 2001) and lay demersal eggs in nests near the base of dead corals that may be guarded by at least one of the parents (Myers 1999).

10.5.6.29 Caesionidae (Fusiliers)

Status. Ten fusilier species are managed in Micronesia as part of PHCRT by the WPRFMC (2001). Four species occur in the CNMI and Guam (Myers and Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (Western Pacific Regional Fishery Management Council 2001). No data are available to determine if fusiliers of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Fusiliers are important in coral-reef fisheries, where they are utilized as bait fish for tuna fisheries (Carpenter 2001a). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Fusiliers occur in the tropical waters of the Indo-Pacific region (Allen and Adrim 2003).

Habitat Preferences. Fusiliers are schooling, planktivorous fishes that are close relatives of the lutjanid snappers (Debelius 2002). They are abundant along steep outer reef slopes and around deep lagoon pinnacles over softbottoms (Myers 1999). During the day, fusiliers typically congregate in large, fast swimming, zooplankton-feeding, mixed aggregations in mid-water around reefs (Allen and Adrim 2003). At night, fusiliers shelter in crevices and under coral heads (Western Pacific Regional Fishery Management Council 2001). Studies have shown that larval Caesionidae abundance correlates positively to chlorophyll-a density in the water and negatively to water depth (Kaunda-Arara et al. 2009).

Life History. Fusiliers have a prolonged spawning season, with recruitment peaks occurring once or twice a year (Western Pacific Regional Fishery Management Council 2001). The yellowback fusilier (*Casio teres*) has been observed spawning in large schools around a full moon. This species migrates at dusk in large groups during slack tide. During spawning, fusiliers stay near the surface, subgroup within a mass swirl that rapidly circles, and release gametes (Carpenter 1988).

10.5.6.30 Cirrhitidae (Surgeonfishes)

A complete summary of the family Cirrhitidae, including EFH and HAPC designations, appears earlier in the CHCRT section, under the Aquarium Species.

10.5.6.31 Antennariidae (Frogfishes)

Status. Twelve frogfish species are managed in Micronesia as part of PHCRT by the WPRFMC (2001). Nine of these species occur in the CNMI and Guam (Myers and Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if frogfishes of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Aside from their value in the aquarium trade, frogfishes are of no significant economic interest in the western central Pacific (Pietsch 1999). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Distribution. Frogfishes occur in all subtropical and tropical waters of the Indo-Pacific region, and occasionally in temperate waters (Nelson 2006).

Habitat Preferences. Frogfishes are found in estuaries and turbid coastal waters, but occur in low number and are rare in most coral reef areas (Western Pacific Regional Fishery Management Council 2001). Habitats include seagrass beds, algae, sponge, seaward reefs, and rock or corals within tidepools and lagoons (Waikiki Aquarium 1999b).

Life History. Spawning female frogfishes lay thousands of tiny eggs within large, raft-shaped gelatinous masses at 3- to 4-day intervals (Myers 1999).

10.5.6.32 Syngnathidae (Pipefishes and Seahorses)

Status. In Micronesia, 37 pipefish and seahorse species are managed as part of PHCRT by the WPRFMC (2001). Twenty pipefish species and the thorny seahorse (*Hippocampus histrix*) occur in the CNMI and Guam (Myers and Donaldson 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if pipefishes or seahorses of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Some species regularly appear in the aquarium trade (Paulus 1999). The alligator pipefish (*Syngnathoides biaculeatus*), banded pipefish (*Doryrhamphus dactyliophorous*), and the thorny seahorse have been listed on the IUCN Red List of threatened species as data deficient in the MRA Study Area (Bartnik et al. 2008; Lourie and Vincent 2004; Morgan 2006).

Distribution. Pipefishes and seahorses are circumtropical and temperate in their distribution, occurring in the Atlantic, Indian, and Pacific Oceans in fresh, brackish, and marine waters (Nelson 2006).

Habitat Preferences. Syngnathids are small, inconspicuous bottom dwellers that occur in a wide variety of shallow habitats from estuaries and shallow sheltered reefs to seaward reef slopes (Western Pacific Regional Fishery Management Council 2001). Habitats include seagrasses, floating weeds, algae, corals, mud bottoms, and sand, rubble, or mixed reef substrate from tidepools to lagoons and seaward reefs (Myers 1999). Demersal syngnathid populations occur singly or in pairs at depths ranging from a few cm to more than 400 m, although they are generally limited to water shallower than 50 m (Allen and Adrim 2003). Juveniles are occasionally found in the open sea in association with floating debris (Western Pacific Regional Fishery Management Council 2001).

Life History. Spawning by pipefishes and seahorses involves the female depositing her eggs into a ventral pouch on the male, which carries the egg until hatching at intervals of 3 to 4 days (Western Pacific Regional Fishery Management Council 2001). Breeding populations occur throughout the salinity range from fresh to hypersaline waters (Dawson 1985). Studies on the alligator pipefish showed male individuals carrying eggs throughout the year, with brood sizes of approximately 350 eggs. Males are typically significantly longer than females, and achieve sexual maturity at lengths between 148 and 278 mm (Barrows, Martin-Smith, and Baine 2009). Most species of syngnathids are monogamous and maintain a bond through daily greetings and ritual dances (Sogabe and Yanagisawa 2007).

10.5.6.33 Gastropods (Sea Snails and Sea Slugs)

Status. Gastropods consisting of sea snails (prosobranchs, snails of the subclass Prosobranchia) and sea slugs (opisthobranchs, sea slugs of the subclass Opistobranchia) are managed in Micronesia as part of the PHCRT by the WPRFMC (2001). Over 1,300 gastropod species (895 prosobranchs and

485 opisthobranchs) occur in CNMI and Guam (Carlson and Hoff 2003; Smith 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001).

Additional information on this group is included in Chapter 8 (Marine Invertebrates).

10.5.6.34 Bivalves (Oysters and Clams)

Status. Bivalves, consisting of oysters and clams, are managed in Micronesia as part of the PHCRT by the WPRFMC (2001). At least 339 bivalve species occur in CNMI and Guam (Paulay 2003c), and have EFH designated within the boundaries of the MRA Study Area (Western Pacific Regional Fishery Management Council 2001). Both the commercially harvested black-lipped pearl oyster (*Pinctada margaritifera*) and giant clams (Tridacnidae) occur on Guam (Paulay 2003b). About 15 bivalve species (three of which are tridacnid clams) are harvested on Guam (Hensley and Sherwood 1993), and at least one of the giant clams (*Hippopus hippopus*) was extirpated (Paulay 2003c). Overfishing, habitat destruction, pollution, and rising sea temperatures are all causes of the decline in giant clam populations (bin Othman, Goh, and Todd 2010).

Additional information on this group is included in Chapter 8 (Marine Invertebrates).

10.5.6.35 Cephalopods (Nautiluses, Cuttlefishes, Squids, and Octopuses)

Status. Cephalopods are managed in Micronesia as part of PHCRT by the WPRFMC (2001). Twenty-four species—including 1 cuttlefish, 1 squid, and 22 octopuses—have been reported from the CNMI and Guam (Ward 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if cephalopods of the PHCRT are approaching an overfished situation (National Marine Fisheries Service 2011). Cephalopods are of considerable ecological and commercial importance to fisheries in the Western Central Pacific, where the squid, cuttlefish, and octopus are harvested for food items in the subsistence fishery (Western Pacific Regional Fishery Management Council 2001), and shells of nautiloids are used for ornamental purposes in the shell curio trade (Dunning 1998). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Additional information on this group is included in Chapter 8 (Marine Invertebrates).

10.5.6.36 Ascidians (Tunicates)

Status. Tunicates (sea squirts) are managed in Micronesia as part of PHCRT by the WPRFMC (2001). At least 117 species (87 colonial and 30 solitary) have been reported from Guam (Lambert 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). Ascidians are of economic importance for bio-prospecting, and are problematic as marine fouling organisms that clog cooling water intakes and interfere with boat operations (Western Pacific Regional Fishery Management Council 2001).

Additional information on this group is included in Chapter 8 (Marine Invertebrates).

10.5.6.37 Bryozoans (Moss Animals)

Status. Bryozoans are managed in Micronesia as part of PHCRT, and have EFH designated within the boundaries of the MRA Study Area (Western Pacific Regional Fishery Management Council 2001). While

bryozoans are probably very diverse in the MRA Study Area (e.g., (Tilbrook 2001)), only one species (*Penetrantia clinoidales*) is described on Guam (Paulay 2003d). Bryozoans are economically important for bio-prospecting and as marine fouling organisms that interfere with boat operations and clog industrial water intakes and conduits (Western Pacific Regional Fishery Management Council 2001).

Additional information on this group is included in Chapter 8 (Marine Invertebrates).

10.5.6.38 Crustaceans (Mantis Shrimps, Lobsters, Crabs, and Shrimps)

Status. Crustaceans of the Orders Stomatopoda (mantis shrimp) and Decapoda (shrimps, lobsters, and crabs) are managed in Micronesia as part of CMUS and PHCRT by the WPRFMC (1998, 2001). More than 839 crustacean species (36 stomatopods and 672 decapods) have been reported from the CNMI and Guam (Western Pacific Regional Fishery Management Council 2001); (Paulay 2003b), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). No data are available to determine if all crustaceans of the PHCRT are approaching an overfished situation, but lobsters are probably overfished (National Marine Fisheries Service 2011). Stomatopods are of little economic importance due to their limited use in subsistence fisheries and ornamental trade. However, decapods are very important in commercial, recreational, and artisanal fisheries, with limited use in the ornamental trade (except shrimp) throughout the tropical Pacific (Western Pacific Regional Fishery Management Council 2001). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Additional information on this group is included in Chapter 8 (Marine Invertebrates).

10.5.6.39 Echinoderms (Sea Cucumbers and Sea Urchins)

Status. Echinoderms include sea cucumbers (holothuroids), sea urchins (echinoids), brittle and basket stars (ophuiroids), sea stars (asteroids), and feather stars/sea lilies (crinoids). This group is managed in Micronesia as part of PHCRT (Western Pacific Regional Fishery Management Council 2001). More than 200 echinoderm species (47 holothuroids, 53 echinoids, 47 ophuiroids, 35 asteroids, and 21 crinoids) have been reported from CNMI and Guam (Kirkendale and Messing 2003; Paulay 2003a; Starmer 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). At least 196 of these species are known from Guam (Paulay 2003a). Some echinoderms have economic importance, particularly the sea cucumbers, which are prized for the dried muscular body wall. Gonads of some species of sea urchins are edible (Conand 1998). However, outbreaks of the crown-of-thorns starfish (*Acanthaster planci*) since 1967 have had negative economic impacts; an *Acanthaster* outbreak devastated Guam's reefs in 1967 (Colgan 1987) and Tinian's reefs in 1969–1970 (Grigg 1997).

Additional information on this group is included in Chapter 8 (Marine Invertebrates).

10.5.6.40 Annelids (Segmented Worms)

Status. Segmented worms or polychaetes are managed in Micronesia as part of PHCRT (Western Pacific Regional Fishery Management Council 2001). At least 76 genera and more than 100 species of polychaetes have been reported from Guam (Bailey-Brock 2003), and have EFH designated within the boundaries of the MRA Study Area (Western Pacific Regional Fishery Management Council 2001). Polychaetes are important food resources of reef fishes and invertebrates, and some species are indicators of environmental perturbation and reef condition (Bailey-Brock 2003).

Additional information on this group is included in Chapter 8 (Marine Invertebrates).

10.5.6.41 Algae (Seaweeds)

Status. All algae (blue-green, green, brown, and red) are managed in Micronesia as part of the PHCRT by the WPRFMC (2001). Over 370 species of algae occur in CNMI (137 species; (Western Pacific Regional Fishery Management Council 2001) and Guam (237 species; (Lobban and Tsuda 2003)), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). Algae are classified as EFH because they are direct contributors to the well-being and protection of fish species, as a source of food and protection to both larvae and small fish species (Western Pacific Regional Fishery Management Council 2001). Currently, no fishery for algal species exists in Guam and the CNMI (Western Pacific Regional Fishery Management Council 2001). Green, brown, and red algae are commonly harvested for sale at local markets or used as bait for rod and reel fishing on Guam (Hensley and Sherwood 1993). None of the species found in the MRA Study Area are listed on the IUCN Red List of threatened species (International Union for Conservation of Nature and Natural Resources 2011).

Additional information on this group is included in Chapter 11 (Marine Habitats).

10.5.6.42 Porifera (Sponges)

Status. Sponges are managed in Micronesia as part of the PHCRT by the WPRFMC (2001). More than 120 sponge species (124 siliceous and 4 calcareous sponges) have been reported from CNMI and Guam (Kelly et al. 2003), and have EFH designated within the boundaries of the MRA Study Area (Western Pacific Regional Fishery Management Council 2001). Sponges are found throughout the MRA Study Area (Kelly et al. 2003).

Additional information on this group is included in Chapter 8 (Marine Invertebrates).

10.5.6.43 Corals (Hydrozoans)

Status. Hydrozoans (stinging or fire corals, lace corals, and hydroids) are managed in Micronesia as part of the PHCRT by the WPRFMC (2001). Over 60 hydrozoan species (5 *Millepora* spp., 21 stylasterids, and 42 hydroids [80% leptothecates]) have been reported from CNMI and Guam (Kirkendale and Calder 2003), and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). Within the MRA Study Area, hydroids are an important component of marine fouling assemblages and may be transported via ship hulls (e.g., Apra Harbor) (Kirkendale and Calder 2003). In CNMI, coral collecting is banned under regulations prohibiting collection of stony hydrozoans (Green 1997). On Guam, coral harvesting (dead or alive) is no longer allowed without a permit (except for educational or research purposes), and is enforced by strict regulations (Hensley and Sherwood 1993).

Additional information on this group is included in Chapter 8 (Marine Invertebrates).

10.5.6.44 Corals (Scleractinian Anthozoans)

Status. Stony corals are managed in Micronesia as part of the PHCRT by the WPRFMC (2001). At least 377 scleractinian species (377 stony corals) have been reported from CNMI and Guam, and have EFH designated within the boundaries of the MRA Study Area (National Marine Fisheries Service 2004a; Western Pacific Regional Fishery Management Council 2001). Major and minor coral (curio trade) fisheries exist within the western central Pacific (Hodgson 1998). Within the MRA Study Area,

regulations in CNMI prohibit collection of hermatypic corals (Green 1997), and on Guam, strict laws regulate harvesting dead or live corals except for educational or research purposes (Hensley and Sherwood 1993). Many ongoing disturbances are preventing scleractinian rebound in the Pacific—including crown of thorn sea star invasions, increasing ocean temperatures, and fierce weather. Along with increased and ongoing reef distrubances, the impact of coralivores is more complicated than previously considered, and they likely have caused more damage after these disturbances than they had before these disturbances (Rotjan and Lewis 2008).

Additional information on this group is included in Chapter 8 (Marine Invertebrates).

10.5.6.45 Corals (Non-Scleractinian Anthozoans)

Status. Non-scleractinian anthozoans are managed in Micronesia as part of the PHCRT by the WPRFMC (2001). Over 120 non-scleractinian anthozoan species (including 79 octocorals and 37 anemones, 6 zoanthids, and 10 black corals) have been reported from CNMI and Guam (Paulay 2003b), and have EFH designated within the boundaries of the MRA Study Area (Western Pacific Regional Fishery Management Council 2001). Collection of non-scleractinian anthozoans is banned in the CNMI (Green 1997).

Additional information on this group is included in Chapter 8 (Marine Invertebrates).

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11.0 MARINE HABITATS

11.1 INTRODUCTION

The MRA Study Area for the Japan and Mariana Archipelagos (the MRA Study Area) covers a range of marine habitats (Table 11-1), each supporting a community of organisms that varies by season and location. Coastal marine habitats occur from the high-tide line to the edge of the continental shelf Levinton (2009). Open ocean and deep sea habitats are those beyond the edge of continental shelf. Coastal marine habitats are described at the archipelago, island, and site levels given the availability of information and where applicable.

Table 11-1: Types of Marine Habitats in the MRA Study Area

Coastal Habitats	Open Ocean/Deep Sea Habitats
• Estuaries • Mangroves and salt marshes • Intertidal shores (rocky, sandy, mudflat) • Seagrass beds • Kelp beds • Coral reefs • Artificial habitats • Submarine canyons • Chemosynthetic communities	• Deepwater coral communities • Seamounts • Deep ocean trenches • Abyssal plains and other deep softbottom habitat • Artificial habitats • Chemosynthetic communities

Most coastal habitats worldwide are under increasing pressure from human development and expansion (Butchart et al. 2010; Crain et al. 2009). Measures of coastal condition include water quality, habitat integrity, nonnative species, climate change, recreational and commercial fishing, and human health (National Oceanic and Atmospheric Administration 2010a). Habitats can be evaluated in terms of the functions and the services they provide. Habitat functions are processes that occur as a result of the chemical or physical structure of the area, independent of human interaction. Habitat services are benefits that humans derive from habitat functions. For example, seagrass habitat functions as a sea turtle nursery and dampens waves that would otherwise cause coastal erosion. Impacts on functions and services are important to consider when describing the overall condition of a habitat (Granek et al. 2010). Even more importantly, the tradeoffs between one habitat service and another must be understood and evaluated so that sustainable management decisions can be made (Bennett, Peterson, and Gordon 2009).

Coastal habitats are the most productive habitats in the ocean. The major coastal habitat types discussed in this section are listed in Table 11-1. They generally occur above the continental shelf and roughly encompass the top 200 meters (m) of the ocean, known as the euphotic zone, where sunlight can penetrate and photosynthesis can occur (Karleskint, Turner, and Small 2006). Photosynthesis is the conversion of energy from the sun by plants, algae, and some bacteria. Coastal water is distinguished from deeper oceanic waters by presence of more nutrients, higher light levels, more dynamic wave energy, and direct terrestrial influences.

The intertidal zone, in which the substrate is alternately inundated and exposed, extends from the high tide to the low tide line. Intertidal habitats include estuaries, mangroves and salt marshes, intertidal shorelines (rocky, sandy, mudflat). Below the low tide line, the subtidal zone extends to about 80 m from shore. The upper portion of the subtidal may be exposed briefly during the lowest tides of the year, but is generally submersed. Subtidal habitats include seagrass beds, kelp forests, coral reefs, and live hardbottom. Artificial reefs are commonly placed in the subtidal zone to attract fishes. Other types of artificial habitat such as shipwrecks occur in the lower neritic and deepsea zones. The lower neritic zone reaches to the edge of the continental shelf, in water depths of about 200 m. The most distinct benthic habitats in the lower neritic zone are formed by submarine canyons that incise the continental shelf and slope. Chemosynthetic communities may occur in the coastal or deepsea zone. In the Pacific Islands, the best known chemosynthetic communities occur at hydrothermal vents near mid-oceanic ridges; these habitats are discussed in the deep sea section.

Open ocean habitats generally occur beyond the continental slope areas. About 99 percent (%) of the biosphere, by volume, is open ocean, making the open ocean the largest habitat on earth (Game et al. 2009). Worldwide, open ocean habitat produces more than 80% of the fish that people eat, and accounts for about 50% of the primary productivity on the planet (Game et al. 2009).

The open ocean is inhabited by the slowest (drifting plankton) and the fastest (bluefin tuna) creatures in the sea (Game et al. 2009). True open ocean organisms (also known as “pelagic” organisms) drift or swim in the water column, only rarely contacting the ocean floor. Phytoplankton include the one-celled photosynthetic bacteria and protists. Zooplankton include one-celled animals, as well as multicellular organisms ranging in length from inches to over 3 feet (ft.) (such as jellyfish) (Johnson and Allen 2005). The plankton community consists of both permanent members and transient larval forms of organisms that become bottom dwellers or free swimmers as adults, including fish and benthic invertebrates (Johnson and Allen 2005). In addition to the relatively passive planktonic members of the open ocean, some strong vertebrate swimmers (fish, sea turtles, and marine mammals) and some macroinvertebrates (squid) are also associated with open water habitats. Prominent fishes of the open ocean include tuna, swordfish, sardines, herring, and many species of sharks (Allen and Cross 2006).

Very little sunlight penetrates habitats below about 200 m, and waters become dim. This zone is known as the “twilight zone.” No sunlight at all penetrates ocean waters below about 800 m; this zone is lit only by bioluminescent organisms whose bodies make chemicals that glow in the dark (Neighbors and Wilson 2006). In the deepest ocean waters, near the bottom of the sea (3,500 to 6,500 m), water is dark, cold (near freezing), and under extreme pressure (Neighbors and Wilson 2006). Fishes, squid, and other small invertebrates are known to occur within this region, but are not well described (Western Pacific Regional Fishery Management Council 2009a). The dark ocean waters contain the largest reservoir of active organic carbon in the living world, chiefly as dissolved organic carbon derived from organisms in the upper, sunlit zone (Aristegui et al. 2009).

The deep sea includes hard, soft, and biogenic benthic habitats. The specific habitats discussed in this section are deepwater coral communities, abyssal plains (flat, featureless expanses of seafloor), and other deep softbottom, deep ocean trenches, artificial habitats, and chemosynthetic communities. No physical break or obvious habitat shift occurs in deep ocean waters, yet numerous studies have reported that diversity and abundance of organisms decrease dramatically at a depth of about 4,000 m (Rex et al. 2005). Beyond the deep soft sediment plains lie oceanic trenches that cut into the seafloor at depths greater than 6,500 m. Although long thought to be stagnant backwaters, water in deep ocean trenches is now known to be subject to currents like other deep ocean habitats (Jamieson et al. 2010).

Seamount habitats discussed in this section do not fall easily into depth zones. Deepwater hardbottom can occur at any depth below 200 m, even as patches within the vast soft-bottomed plains (Smith et al. 2008). Seamounts can rise from the ocean floor at any depth; some are rooted in the deep plains, while others emerge from the slightly shallower seafloor. The discussion of seamounts is further complicated by the extreme vertical extent of habitat they provide, which may extend several kilometers (km) from the seafloor to near the surface of the sea. Organisms can live on the entire vertical extent of the seamount, so it is difficult to strictly categorize as being of the open ocean or of the seafloor.

11.2 ESTUARIES

11.2.1 Description

Estuaries form where freshwater streams or rivers meet the high-salinity waters of the ocean. The relative influence of freshwater input from the land controls the shape and size of the estuary. Typical estuaries are semi-enclosed, slightly saline, and connected to the open sea; however, many variations on the typical features are demonstrated by Pacific estuaries (Emmett et al. 2000). Bays, sounds, lagoons, and inlets that receive fresh water inputs from the land are estuaries. An estuary receives water and sediment from the sea, the land, and its own internal processes. The proportions of these inputs vary among estuaries, as well as throughout time at a given location.

Estuaries around the world have been classified in numerous ways, most recently by the type of filtering processes that occur as freshwater drains to the sea (Durr et al. 2011). Estuaries that actively filter sediment and water from terrestrial stream sources include (1) small deltas, (2) tidal systems, (3) lagoons, and (4) fjords. Large rivers discharge so much water that the filtering process is overwhelmed, and freshwater is delivered directly to coastal waters with little modification. Some coastlines are best described as arheic, meaning that very little fresh water flows from the land to coastal habitats. On a global scale, small deltas make up about 32% of all coastlines, followed by fjords (26%) and tidal systems (22%). In the MRA Study Area, however, small deltas and arheic coastlines are most common (Durr et al. 2011). No major riverine deltaic estuaries occur in the MRA Study Area.

Estuaries exist on Pacific islands principally where perennial stream runoff is captured in natural basins near shore. If the grade is flat enough to allow sediment to accumulate, halophytic plants such as pickleweeds and mangroves become established in tropical and subtropical Pacific estuaries. Unvegetated areas of mudflat provide important habitat for invertebrates and their predators, especially migratory shorebirds (Engilis and Naughton 2004).

The dominant feature of the estuarine environment is fluctuating salinity. By definition, a salinity gradient (from fresh to saline) exists at some time in an estuary (Nybakken 1997). The gradation of fresh to salt water provides intermediate salinity zones where a unique mix of species occurs. The young of many oceanic species spend their early developmental stages in estuaries, where the high primary productivity and structural protection from large predators is thought to offer enhanced nursery grounds. Juvenile reef fishes often rear in more saline lower parts of estuaries before moving onto coral reefs as older juveniles or adults. Many fishes and shrimps that live in fresh water streams or rivers as adults are spawned in the sea and pass through the estuary as larvae or young juveniles as they move up rivers to adult habitats (Western Pacific Regional Fishery Management Council 2009a). Other crustaceans and fishes live their entire lives in estuaries; for example, mangrove crabs complete their life cycles in burrows among the roots of trees in estuaries.

Many of the functional features of estuarine habitats derive from the vegetation that grows on the estuarine shorelines. In the tropical and subtropical regions of the MRA Study Area, mangrove forests are the dominant estuarine vegetation. In parts of Honshū (notably, Tōkyō Bay), mangroves give way to salt marsh vegetation. Vegetation characteristics of estuaries are described in Section 11.3 (Mangroves and Salt Marshes).

11.2.2 Distribution

JAPAN ARCHIPELAGO. The Pacific coast of central and southern Honshū is characterized by dramatic indentations and peninsulas created by bays along the coast, including Tōkyō Bay bordered by Tōkyō and Yokohama, Ise Bay near Nagoya, and Ōsaka Bay bordered by the Kobe-Ōsaka metropolis. Tōkyō Bay is a highly modified estuarine habitat fed by the Tone River, which drains the largest area of Japan (16,840 square kilometers [km^2]). The Tone River is dammed and diverted for human use and consumption throughout its course (UNESCO-IHP Regional Steering Committee for Southeast Asia and the Pacific 2002). Concurrent with water withdrawals from the Tone River, water from neighboring catchments has been diverted to Tōkyō Bay, freshening it and reducing the residency time of salt water in the bay (Okada et al. 2011).

Of greater ecological importance are the numerous smaller estuaries fed by streams throughout central and southern Japan (Islam, Yamashita, and Tanaka 2011). The small estuarine deltas provide a patchwork of rearing habitats for fishes and invertebrates that rely on the nutrient-rich, relatively protected estuarine environment to protect larval and juvenile stages. For example, 22 small estuaries south of Tōkyō Bay are known to support the economically and recreationally important Japanese sea bass, *Lateolabrax japonicus*, a typical estuarine-dependent temperate fish that spawns on the continental shelf and rears in coastal embayments and estuaries (Islam, Yamashita, and Tanaka 2011).

Kyūshū. Ariake Bay in southeastern Kyūshū is the largest bay on the island; it is fed by numerous rivers including the Chikugo, Rokkaku, Kase, and Yabe Rivers. The upper reaches of Ariake Bay provide highly turbid brackish waters with high tidal velocities favored as nursery grounds by at least 15 species of fishes from 12 families, including Japanese sea bass, javeline goby (*Acanthogobius hasta*), mudskipper (*Boleophthalmus pectinirostris*), grenadier anchovy (*Coilia nasus*), roughskin sculpin (*Trachidermus fasciatus*), and Shokihaze goby (*Tridentiger barbatus*) (Islam, Hibino, and Tanaka 2007; Yagi et al. 2011). Portions of the estuary have been severely impaired by reclamation projects that reduced tidal flow, converting mudflat habitat to dry land unsuitable for estuarine organisms (Sato 2006).

Okinawa. Important estuaries on Okinawa Island (Manko and Okukubi) are recognized and protected as reserves for birds and other wildlife (see discussion of Manko in Section 11.3). The Kokuba, Nagado, and Noha Rivers flow through Naha City before discharging into the Manko Estuary. Rivers on Okinawa that form small deltas include the Manna and Kouchi Rivers that flow through farmland and areas of low population in the northwest; and the Hija, Makiminato, and Aja Rivers that have more urban drainages in central Okinawa.

The Ōura Bay is characterized by deep waters extending from the inner bay to some distance off shore. The Teima and Oura Rivers that flow into Oura Bay support almost 200 species of fishes (World Wildlife Fund Japan 2010). A 10-day survey of Oura Bay yielded 496 species of decapod crustaceans in 62 families; 36 of the species collected were new to science, and 25 species were newly recorded in Japan (World Wildlife Fund Japan 2010).

Ōsumi Islands. The major islands of the Ōsumi Islands include Yakushima, Tanegashima, and Kuchinoerabujima. The rivers of Yakushima are typically steep with no estuarine basin to hold brackish water; these rivers drain directly to the sea without forming intertidal habitat (World Wildlife Fund Japan 2010). Conversely, several rivers on Tanegashima have gentler slopes and substantial brackish estuarine areas that support mangroves and associated fish and wildlife species. This island contains the southernmost population of the yellowfin goby (*Acanthogobius flavimanus*), *Gymnogobius breunigii*, and other temperate gobies that are transported from the south on the Kuroshio Current. Estuaries on Tanegashima also support more common fishes, including the northern mud gudgeon (*Ophiocara porocephala*) and golden goby (*Glossogobius aureus*) World Wildlife Fund Japan (2010).

MARIANA ARCHIPELAGO. Steep slopes and complex shorelines of the Mariana Islands (U.S. Territory of Guam [Guam] to Farallon de Medinilla [FDM]) form relatively sheltered coastal bays characterized by silty sediments and turbid waters. Often, these bays are associated with riverine freshwater discharge that form estuaries. While estuarine habitats in the Commonwealth of the Northern Mariana Islands (CNMI) are not as widely studied, a number of bays and lagoons probably function as estuarine habitats. Brackish estuarine waters support palm (*Nypa fruticans)* and bulrushes (*Scirpus littoralis*), which provide habitat for freshwater and marine coastal species (Guam Department of Agriculture 2005).

Pagan and FDM. The lack of permanent rivers or streams on Pagan (Sukhraj et al. 2010a, b) and FDM (Smith and Marx Jr. 2010) eliminates the possibility of estuary development in these areas.

Saipan. Saipan has no large estuaries, but small coastal streams provide limited intertidal brackish habitat during seasons of high freshwater input. Laolao Bay receives freshwater through groundwater, as well as surface runoff (Commonwealth of the Northern Mariana Islands 2011; Houk et al. 2011).

Guam. Estuarine habitats on Guam include lagoons, embayments, and river mouths. Estuarine habitats are typically vegetated by mangroves, especially in the lower channels of rivers that are inundated by tides ranging in amplitude from 75 to 90 centimeter (cm) (Scott 1993). Nine of Guam's 46 rivers that empty into the ocean have true estuarine habitats, with elevated salinity levels extending upstream as far as 1.6 km (Scott 1993). Some of these rivers are only 5 to 20 m wide and 1 to 4 m deep. Estuarine communities also exist in Apra Harbor and the artificial San Luis Ponds (Guam Department of Agriculture 2005).

Estuarine habitats were described in detail in the recent Final Environmental Impact Statement (FEIS) for Guam and CNMI (Naval Facilities Engineering Command 2010), and are not repeated here. Virtually all of inner and outer Apra Harbor provides estuarine habitat for a diverse assemblage of species. A portion of the estuary known as Sasa Bay has been designated as a preserve, and the entire bay is considered essential fish habitat by the National Oceanic and Atmospheric Administration (NOAA) (Naval Facilities Engineering Command 2010). Rich estuarine habitats such as Sasa Bay are especially valuable to hermit crabs and the increasingly rare coconut crabs, which hatch from eggs released in the ocean that are subsequently transported by tides and currents into estuarine habitats.

CAROLINE ISLANDS.

Yap. True estuarine habitat is limited on Yap. Several high-turbidity nearshore regions where freshwater drains from the land to the sea attract common fish species such as mullets (Family Mugilidae). These stream mouths are small and barely form deltas, but are still distinguishable from rocky shores where no freshwater input occurs. The seagrass *Enhalus acoroides* and the algae *Halimeda* sp. may also occur near

stream mouths, providing important nursery and feeding grounds for fishes and invertebrates (Edward 2002).

Palau. The largest estuary in Republic of Palau (Palau), and indeed in Micronesia, is the 1,450 hectares (ha) Ngaremeduu Bay, a shallow estuary on the west coast of the Babeldaob Island, the largest island of Palau (Ewel et al. 2009). Ngaremeduu Bay is the center of a United Nations Educational, Scientific, and Cultural Organization (UNESCO)Biosphere Reserve. The estuary is fed by three rivers: Ngermeskang, Ngatpang (also known as the Ngetpang or Ngchelotel), and Nekkeng (also called Tabecheding) (Ewel et al. 2009). The mangrove habitat that lines the estuary creates a diverse array of microhabitats that support several endangered and threatened species such as the dugong, salt-water crocodile, and green and hawksbill sea turtles (United Nations Educational 2010, 2012). The estuary also provides essential habitat for at least one species of the economically and ecologically important mangrove crabs (*Scylla* spp.).

11.2.3 Conditions and Stressors

Estuaries are subject to degradation from both human development on the landward side and oceanic processes on the seaward side. The rise in relative sea level may drown some estuarine habitats, which cannot retreat landward because human developments have left little space along the coast (Hoegh-Guldberg and Bruno 2010; Nicholls and Cazenave 2010). Human activities that threaten estuaries include (1) filling to create upland, (2) restricting tidal flow with roads, (3) introducing invasive species, (4) replacing plants with hard structures that prevent vegetation growth, and (5) increasing runoff of freshwater and pollutants.

In Japan, many estuaries have been purposefully filled, or “reclaimed” to increase useable land area. In Okinawa, the Kokuba, Nagado, and Noha Rivers rivers carry urban contaminants including bisphenol A, pesticides, and antifoulants into estuaries and coastal waters (Kitada et al. 2008; Sheikh et al. 2009). The sediments in the Manko estuary are also contaminated with tributyltin, thought to have originated from shipping, domestic wastewater, and other human activities (Sheikh et al. 2007). Because rivers on the Ōsumi Islands have not been significantly diverted or dammed, the estuarine ecosystems are relatively healthy (World Wildlife Fund Japan 2010).

Threats to estuaries on Palau include accidental releases of oil and fuel from boat engines, sewage, and overfishing (Hinchley et al. 2007). In addition, estuaries are silting in due to increased sedimentation from road construction (Ewel et al. 2009; Hinchley et al. 2007; Victor et al. 2004). The Ngaremeduu Bay estuary receives heavy loads of sediment resulting from land use practices in the watershed—about 216 tons per km^2 each year. Removal of estuarine vegetation causes secondary impacts to estuaries, as the shoreline becomes vulnerable to storm surge and other erosive forces.

11.3 MANGROVES AND SALT MARSHES

11.3.1 Description

Mangroves and salt marshes provide similar ecological and physical services, including capturing and holding sediment with their roots, adding nutrients to the sediment and water though vegetative growth, and providing structural habitat for terrestrial and marine organisms (Barbier et al. 2011). In temperate latitudes, salt marshes typically give way to mangroves, the subtropical equivalent intertidal habitat (Nybakken 1997). Each of these intertidal vegetation types are described below.

About 50 to 75 species of trees are commonly known as “mangroves,” which refers to both the trees and the ecosystems they support (Barbier et al. 2011). They are variously known as coastal woodlands, tidal forests, and mangrove forests. Mature sizes range from trees 40 m tall to small shrubs. Mangroves derive from terrestrial vegetation, and grow best in freshwater conditions typical of other shrubs and trees. Like other trees, they produce fragrant flowers pollinated by insects and bats. However, special adaptations to high salinity environments have released mangroves from competition with more dominant terrestrial plants, allowing them to colonize coasts throughout the tropics. Their salt-tolerant roots facilitate growth along the margins of bays, estuaries, and inlets (Barbier et al. 2011). Elaborate roots anchor them in unstable muds and sands; aboveground root structures called prop roots allow gas exchange in anoxic sediments. All mangroves exclude salt from their tissues, and some can live in salinities well above seawater. Most produce buoyant seeds that float some distance before settling in habitat suitable for germination. Some species produce seeds that germinate during the journey, ready to set down roots upon arrival.

Mangroves often grow in patches to form mangrove forests that are essential habitat for many fishes and animals, including mangrove crabs (*Scylla* spp.), clams, shrimps, fishes, and the endangered saltwater crocodile (*Crocodylus porosus*) (Hinchley et al. 2007). Mangrove forests are the tropical equivalent of salt marshes; they line the shores of coastal embayments and the banks of rivers to the upper tidal limits (Nagelkerken et al. 2008). The extensive network of below-ground roots and prop roots consolidates sediments efficiently, and may eventually transform surrounding mudflats into dry land (Nagelkerken et al. 2008). Coastal mangrove habitats may protect adjacent seagrass and coral habitats from excessive sedimentation from terrestrial sources (Nybakken 1997; Thurman 1997; Victor et al. 2004).

Mangrove forests add nutrients to the surrounding ecosystem, making them among the richest nursery grounds for marine life (Feller et al. 2010; Nagelkerken et al. 2008). Nutrients derive directly from the trees, in the form of leaf litter, as well as from the wastes and remains of animals associated with mangroves (Sharma et al. 2012).

At more temperate latitudes, mangroves are limited by the cold, and salt marshes become the dominant habitat type in coastal embayments and estuaries. Like mangroves, salt marsh vegetation is characterized by tolerance for inundation and fluctuating salinity (Kennish 2001; Mitsch et al. 2009). Salt marsh vegetation varies with elevation, with more salt-tolerant species occurring nearer the sea (Carlisle et al. 2002). Within the MRA Study Area, salt marsh habitat occurs only in the temperate areas of central Japan.

Like mangroves, salt marshes are widely used by both terrestrial organisms, which move into the area during low tide, and marine organisms, which enter during high tides to feed. Rooted plants and attached invertebrates cannot move so they must be able to withstand the repeated flooding, extreme temperature fluctuations, and drying out. The salinity and tidal regimes of salt marshes create an extreme environment that most plants cannot tolerate, so species richness of salt marsh plants is low (Traut 2005). Like mangroves, salt marshes provide habitat for many organisms and protect the coast from erosion (Allen et al. 2006; Bromberg Gedan, Silliman, and Bertness 2009; Takekawa et al. 2006). In addition, salt marshes act as an important interface and natural filter between land and the open ocean as they take up nutrients and break down or bind a variety of organic and inorganic pollutants before these can reach the open sea (Mitsch et al. 2009).

Benthic fauna are present in high abundances and diversities in salt marsh habitats (Furota 1981). Similar to vegetation zonation, occurrence of macrobenthic fauna in salt marshes is governed by tidal fluctuations. The abundance and distribution of macrobenthic fauna are affected by interstitial water level, predation, and interspecific competition (Furota 1981). In general, salt marsh benthic fauna are characterized by polychaetes, crustaceans, bivalves, and gastropods (Furota 1981). Grapsoid crabs are common in the middle marsh zone in bays and estuaries (Kuroda, Wada, and Kamada 2005).

11.3.2 Distribution

Mangroves occur in Japan, Guam, Saipan, Palau, and Yap. Salt marshes occur in the MRA Study Area only in Japan.

JAPAN ARCHIPELAGO. Mangroves are mainly restricted to the tropics, but some mangroves are found in subtropical areas of Japan, mostly on the small southern islands of Okinawa Prefecture (Sharma et al. 2012). Japan is one of the few regions that support both the tropical mangrove habitat and temperate salt marshes.

Salt marsh occurs on Japan on the edges of Tōkyō Bay, where *Phragmites australis*, *Carex pumila*, and *Suaeda maritima* communities make up the low marsh. The middle marsh elevations are dominated by *Phacelurus latifolus* (Nohara, Yabe, and Kaneko 2004). In Yoshino River Estuary on Shikoku Island, *Phragmites australis* occupies the low marsh (Kuroda, Wada, and Kamada 2005).

Kyūshū. Mangroves reach their northernmost limit in Japan at Kiire, Kyūshū (31°22'N) (Spalding, Kainuma, and Collins 2010).

Okinawa. Iriomote Island at the southern end of Japan has the greatest number of mangrove species (10): *Kandelia candel (obovata), Avicennia marina, Sonneratia alba, Rhizophora stylosa, Bruguiera gymnorrhiza, Lumnitzera racemosa, Heritiera littoralis, Excoecaria agallocha, Nypa fruticans,* and *Acrostichum aureum* (Suzuki and Saenger 1996). Populations of the common *K. candel* in Japan were recently determined to be a separate species that occurs only in more northern latitudes. Previous reports of *K. candel* are now known as *K. obovata*, which reaches the northernmost limit of its distribution in southern Japan (Sheue, Liu, and Yong 2003).

The current distribution of mangroves is largely concentrated on the islands of Ishigaki and Iriomote at the extreme southern end of the Okinawa Prefecture (United Nations Environment Programme 2012). The Ministry of the Environment (2002j) identified numerous important wetland habitats throughout Japan, many of which include mangrove forests. The estuaries of southwestern Iriomote Island have been identified as valuable wetlands containing high diversity of endemic mangrove forest ecosystems with unique geographic distribution; species include *Kandelia candel* (*K. obovata*) *, Bruguiera gymnorhiza, Avicennia marina,* and *Lunmitzrea racemosa* (Ministry of the Environment 2002d). *B. gymnorhiza*, *R. stylosa*, and *K. candel (obovata)* were reported to occur throughout the intertidal area of the Nakara River on Iriomote Island (Enoki et al. 2009).

Near Taketomi Town, the estuaries of Nakama-gawa, Shiira-gawa, and Maira-gawa support some of the most extensive mangrove habitat in Japan, with high benthic species diversity (Ministry of the Environment 2002h, j). The mangrove areas of both these estuaries, as well as Aira-gawa, support populations of intertidal crabs such as *Uca* spp., *Scopimera* spp., *Mictyris* spp., grapsids, portunids, xanthids, as well as diogenids and upogebiids. At low tide, large aggregations of *Uca vocans vocans* and *Mictyris brevidactylus* are typically found on the outer tidal flats at the mouth of the estuary. The crabs

are important culturally as well as ecologically. It was here that the Komi community created a folk song about crabs, the"Yakujama-bushi."

The Miyara-wan and Miyara-gawa Estuary near Ishigaki City is an important riverine estuary that supports several species of mangrove in an area designated as a National Natural Monument; species include *Kandelia candel (obovata), Bruguiera gymnorhiza,* and *Rhizophora mucronata* the southern shore of Apra Harbor (Ministry of the Environment 2002f).

Mangroves also occur on the shore of Obama-jima from Kuba-zaki to Akaya-zaki. Species include *Kandelia candel (obovata), Bruguiera gymnorhiza, Rhizophora mucronata, Avicennia marina, Lunmitzrea racemosa,* and *Sonneratia alba* (Ministry of the Environment 2002i). Yubu-jima supports mangroves, as well as tidal flats (Ministry of the Environment 2002o). The estuary of Urauchi-gawa is the only location in Japan where the crab *Macrophthalmus (Venitus) latreillei* occurs in the intertidal zone. This estuary also supports numerous benthic species that are tightly linked to mangrove habitat (Ministry of the Environment 2002m). The inlets of Irabu-jima are considered an important mangrove area supporting three species (*Kandelia candel* [*obovata*]*, Bruguiera gymnorhiza,* and *Rhizophora mucronata*) (Ministry of the Environment 2002c). Generally, the smaller islands of the Okinawa portion of the MRA Study Area do not have the extensive estuaries necessary to support mangrove forests (Simard 1995).

The height of mangroves trees in Japan varies by dominant species, as follows:

Dominant Mangrove Species	**Typical Tree Height**
Kandelia candel (obovata)	1.0–6.0 m
Bruguiera gymnorrhiza	1.5–10.0 m
Sonneratia alba	2.0– 8 m
Rhizophora stylosa	2.8–7.0 m
Avicennia marina	1.0–2.5 m
Lumnitzera racemosa	2.0–5.0 m
Myporum bontioides	1.3–2.0 m
Excoecaria agallocha	3.0–4.0 m

Source: Suzuki and Saenger (1996).

Many mangrove forests have been destroyed for urban development. However, a large portion of the remaining high-quality mangrove habitat is protected as National Natural Reserve, as described above, and a small amount is included in Ramsar sites designated as wetlands of international importance (principally for birds). Man-ko is one of two Ramsar sites in Japan that support mangroves. It is an estuarine tidal flat that supports 11 ha of mangroves on the southern side of Okinawa (Ministry of the Environment 2008b). The other Ramsar site that includes mangrove habitat is at Nagura Amparu, which is outside the MRA Study Area (Ministry of the Environment 2008a). Prefectural governments, academic researchers, and NGOs have also focused on protecting mangroves as essential intertidal habitats in Japan. Mangroves in Japan support endemic species such as the Ryukyu crab (*Ryukyum yaeyamense*) (Spalding, Kainuma, and Collins 2010).

Ōsumi Islands. Tanegashima Island has two extensive mangrove forests where *Kandelia obovata* dominates: one in the Minato River estuary near Nishino-omote City and one at the mouth of the Ōura River near Minamitane Town (World Wildlife Fund Japan 2010).

Daito Islands. The Daito Islands do not have any estuaries or intertidal areas that support mangroves. They are completely surrounded by rocky reefs (World Wildlife Fund Japan 2010).

MARIANA ARCHIPELAGO. Mangrove forests are native to the Mariana Islands, but are present only around the islands of Saipan and Guam (Figure 11-1 and Figure 11-2). No salt marshes occur in the Mariana Archipelago.

Saipan. Mangroves in Saipan, although once more broadly distributed around Saipan Lagoon on the western side of the island, today only two areas remain. The largest remaining mangrove forest encompasses about 12 ha in the American Memorial Park; a smaller area occurs north of the park at the mouth a small stream, the Sadog Tasi.

The highly fragmented mangrove forest on Saipan is dominated by a single species (*Bruguiera gymnorhiza*) although several other species co-occur in some locations. The mangroves of Saipan support the federally endangered nightingale reed warbler (*Acrocephalus luscinia*), as well as other important bird species, including the endemic and common bridled white-eye (*Zosterops conspicillatus*) and the indigenous Micronesian honeyeater (*Myzomela rubratra*) (Williams et al. (2007). In addition to birds, mangroves on Saipan support bats, mangrove crabs, and juvenile fishes (Berger, Gourley, and Schroer 2005).

Guam. The mangroves of Guam are the most extensive and diverse in the Mariana Archipelago. About a decade ago, researchers estimated presence of approximately 70 ha of mangroves on Guam (Scott 1993), but a recent Landsat survey documented only 34.2 ha (Bhattarai and Giri 2011). Guam has 10 species of mangrove, the greatest species diversity in the Mariana Archipelago (Spalding, Kainuma, and Collins 2010). Species include *Rhizophora mucronata*, *R. apiculata*, *Bruguiera gymnorrhiza*, *Avicennia marina*, *Lumnitzera littorea*, *N. fruticans*, *Xylocarpus moluccensis*, *Heritiera littoralis*, *H. tiliaceus,* and *Acrostichum aureum* (Guam Department of Agriculture 2005). Mangroves grow in estuarine habitats at the mouths of rivers on the southern half of Guam, where the tides may vary by almost 1 m each day. Mangrove forests occur on the eastern shores of Outer and Inner Apra Harbor—the greatest density of mangroves on Guam (Smith et al. 2009).

Sasa Bay, in the outer portion of Apra Harbor, is a shallow estuarine lagoon protected by the government of Guam as a marine preserve. The highly turbid waters of Sasa Bay support one of the healthiest remaining mangrove habitats on Guam. The mangroves of Sasa Bay provide habitat for many species and serve as nursery grounds for fishes such as jacks (Carangidae), barracudas (Sphyraenidae), snappers (Lutjanidae), and groupers (Serranidae), as well as numerous burrowing invertebrates including bivalves, small crabs, and worms (Naval Facilities Engineering Command 2010).

The Navy mapped the mangrove habitat in Apra Harbor for a recent EIS regarding activities on Guam (Naval Facilities Engineering Command 2010). Approximately 125.3 acres (50.7 ha) of mangrove forests exists at 10 locations on Navy lands on Guam. As mentioned above, a large tract of mangroves exists on the eastern shoreline of the Inner Apra Harbor. Four areas of mangrove forest occur near Abo Cove at the southern tip of Inner Apra Harbor, two near Dry Dock Island, two near Polaris Point, and one along the southern shore of Apra Harbor.

CAROLINE ISLANDS.

Yap. About 15 species of mangrove trees occur in the Federated States of Micronesia (FSM); nine of them, including the palm *Nypa fruticans,* are known from Yap (Cole, Ewel, and Devoe 1999; Ellison 2008). On Yap, most mangroves occur on the fringes of the island on former reef flats and coral sands, where they are inundated during high tides (Kauffman et al. 2011). The most common mangrove species on Yap are *Bruguiera gymnorhiza, Sonneratia alba,* and *Rhizophora apiculata.* Tree density in healthy mangrove forested areas averages about 780 trees per ha (Kauffman et al. 2011).

Palau. Palau is one of the few islands of Micronesia that supports extensive stands of mangroves (Ewel et al. 2009). Recent Landsat surveys estimated about 5,666 ha of mangroves on Palau, covering about 12% of the nation (Bhattarai and Giri 2011). The assemblage of mangroves on Palau is similar to that on other islands of the FSM, comprising up to 18 or 19 species (Cole, Ewel, and Devoe 1999; Hinchley et al. 2007). Ngaremeduu Bay has almost half (44%) of the mangrove habitat in Palau, with 18 different mangrove species (United Nations Educational 2010, 2012). Individual trees tend to be smaller in the western islands than in the eastern islands where rainfall is greater. The most common mangrove species on Palau are *Rhizophora apiculata, Bruguiera gymnorhiza,* and *Sonneratia alba* (Kauffman et al. 2011). In the Ngaremeduu estuary, *Xylocarpus granatum, Ceriops tagal, Lumnitzera littoralis, Nypa fruticans,* and *R. stylosa* are also common (Ewel et al. 2009).

Most mangroves on Palau grow either atop old reef flats and coral sands that fringe the island or within estuary habitats (Kauffman et al. 2011). Daily tidal inundation is the norm. Dense stands of mixed *Rhizophora* species occur on Palau, with more than 2400 trees per ha in some areas; however, individual trees on Palau are smaller than those on Yap (Kauffman et al. 2011). The elevation that supports mangroves on Palau is restricted to about 1.5 m, representing 9.4% of the land mass of Palau.

Almost half (44%) of the mangrove acreage on Palau has been designated as a Biosphere Reserve, which may offer long-term protection from development. This reserve, in the Ngaremeduu estuary, includes 18 species of mangrove, as well as numerous other plants and animals (United Nations Educational 2010).

Mangroves on Palau support numerous invertebrates on which people rely for subsistence, as well as commercial harvest—including mangrove clams (*Anodonita edulenta*, *A. alba*, *Polymededa luhuana* and *Terebralia semestriata*) that live deep in the mud surrounding the mangrove roots. The mangroves in Ngardmau and Ngeremlengui States support the greatest abundance of clams. These clams are important to people in the northern barrier reef area (Ngatpang, Ngeremlengui and Peleliu) (Secretariat of the Pacific Regional Environment Programme 2007).

11.3.3 Condition and Stressors

About half of the global acreage of mangrove habitat has been lost since 1900, about a third of that within the past 20 years (Gilman et al. 2006). Because the role of mangroves in providing environmental services is often not well understood by local people, mangroves are under intense pressure from coastal populations throughout the world. Wherever mangroves and human populations co-occur, mangroves are used as firewood and building materials, stressed by pollutants, and adversely affected by changes to freshwater and marine hydrology (Duke et al. 2007; Nagelkerken et al. 2008). Systemic threats to mangroves across the MRA Study Area stem from population increases, economic trends, climate change, and modifications of upstream habitats (Gilman et al. 2006; Spalding, Kainuma, and Collins 2010). Direct threats to mangrove habitats include clear-cutting for aquaculture (prawn and fish),

collection of wood for fuel and charcoal, smothering by dredge spoils, and drowning by impoundments resulting from water diversions upstream. Indirect effects include pollution, invasive species, excessive harvesting of key fauna, and habitat modification leading to changes in salinity and hydrographic regimes (Polidoro et al. 2010; Todd, Ong, and Chou 2010). Many exploited fish and invertebrate species move among mangroves, seagrasses, and coral reefs as they grow. Loss of any one of the key habitats can disrupt the sustainable harvest of these species (Feller et al. 2010).

The remaining mangrove habitat in Japan may be threatened by sedimentation from poor land use practices and erosion from tourist boats, as well as from direct cutting and filling for urban development (Spalding, Kainuma, and Collins 2010).

The small area of remaining mangrove on Saipan in the American Memorial Park is threatened by invasive vines that smother and kill the trees (Williams et al. 2007). This highly disturbed remnant mangrove forest requires active management to persist. In addition, the mangroves on Saipan represent highly disturbed habitat in a commercially active area where they are believed to be adversely affected by dredging, a contaminated landfill, and a power plant (Ridolfi Inc. and National Oceanic and Atmospheric Administration 2007; Williams et al. 2007).

Mangroves often occur on the fringes of islands within relatively narrow elevation bands. Mangroves are threatened by sea level rise because they can exist only at the land-water interface (Gilman et al. 2006). On Yap and Palau, it has been estimated that a 1-m rise in sea level would eliminate a substantial portion of the currently existing mangrove habitat (Kauffman et al. 2011). The coastal margins of Yap are becoming more saline with frequent overwash by ocean waters; mangroves along the shoreline are prone to erosive forces of strong storm surges (Fletcher and Richmond 2010).

About 44% of Palau's mangroves are protected from development in the Ngaremeduu UNESCO Biosphere Reserve (United Nations Educational 2010, 2012); however, reserve status cannot protect the mangroves from sea level rise and other adverse effects of climate change.

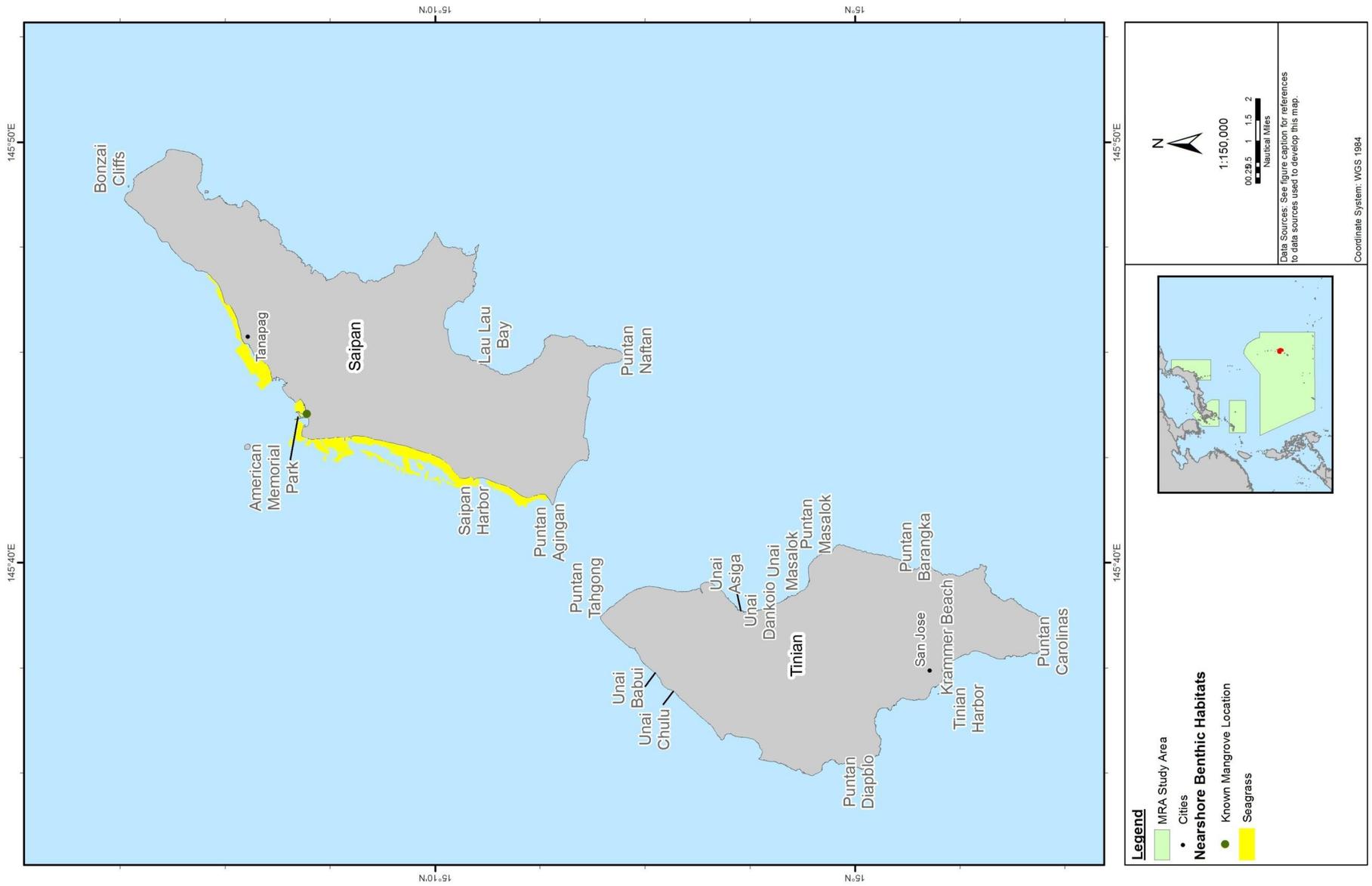

Figure 11-1: Distribution of Mangrove and Seagrass Communities in Saipan and Tinian
Sources: National Oceanic and Atmospheric Administration (2005b) and U.S. Department of the Navy (2005b).

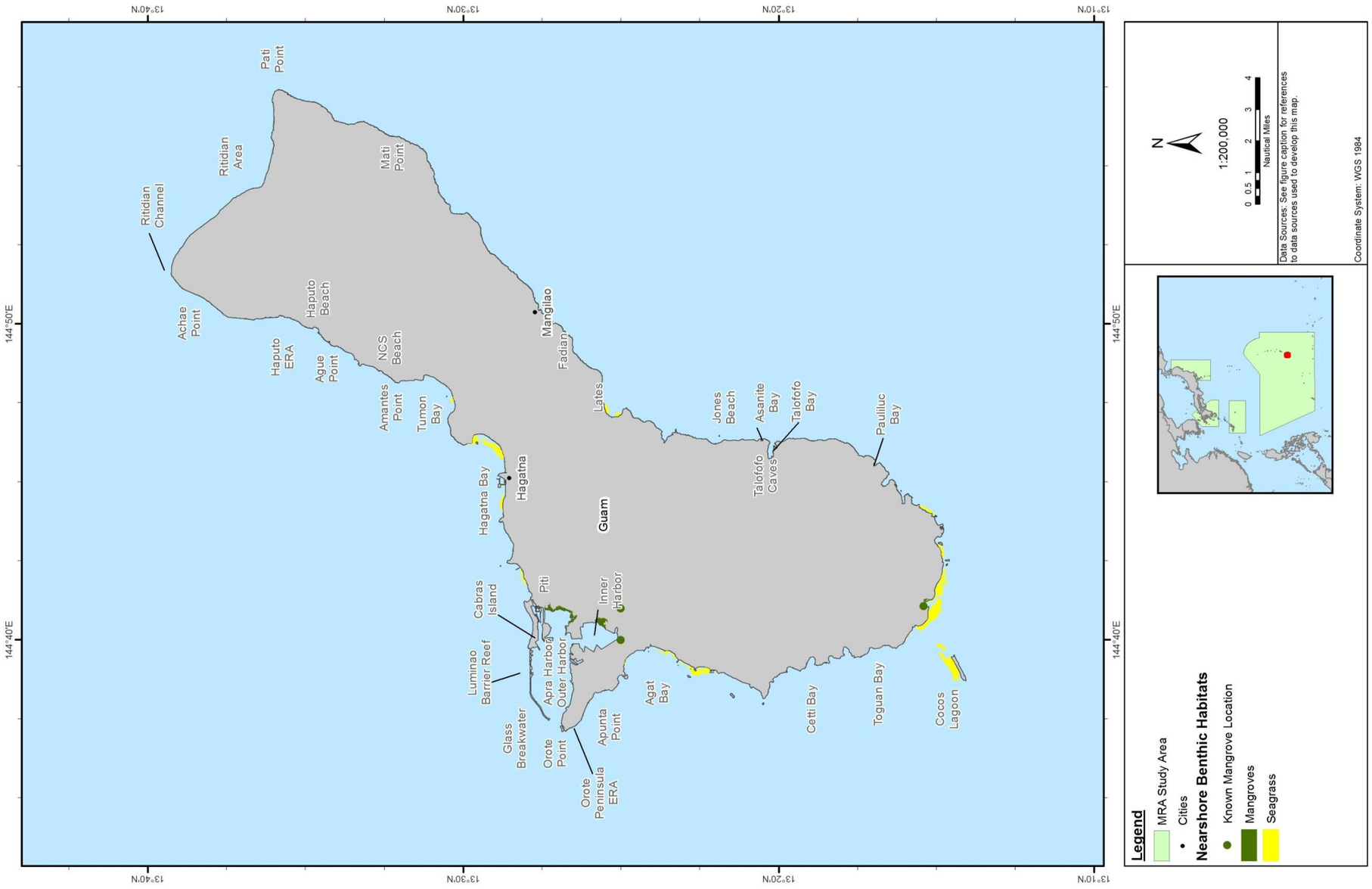

Figure 11-2: Distribution of Mangrove and Seagrass Communities in Guam
Sources: National Oceanic and Atmospheric Administration (2005b);
U.S. Department of the Navy (2005b); and Water and Environmental Research Institute of the Western Pacific (2011).

11.4 INTERTIDAL HABITATS (MUDFLATS, ROCKY SHORES, AND SANDY BEACHES)

The size of the intertidal zone varies by location, depending on the slope of the land. Many Pacific Islands have steep sides that drop quickly to deep water, providing only vertical rocky intertidal habitat. On more gradual shorelines, the intertidal zone may be characterized by the type of sediment trapped there and the vegetation it supports. Heavily vegetated intertidal habitats, mangroves, and salt marshes, are discussed above. Relatively unvegetated intertidal habitats include mudflats, rocky shores, and sandy beaches. The intertidal zone provides a substantial amount of easily harvested food, especially mollusks and crustacenas, for people throughout the Pacific Islands (Western Pacific Regional Fishery Management Council 2009a).

11.4.1 Description

Intertidal flats, also known as tidal flats or mudflats, are unvegetated areas consisting of loose mud, silt, and fine sand with organic-mineral mixtures that are regularly exposed and flooded by the tides. Muddy fine sediment is deposited in sheltered inlets and estuaries where wave energy is low (Holland and Elmore 2008). Mudflats are typically unvegetated but may be covered with mats of green algae and benthic diatoms (single-celled algae), or sparsely vegetated with low-growing aquatic species. Filter feeding invertebrates thrive in the nutrient-rich habitat, and soft-bodied invertebrates live well below the sediment surface in burrows. Some mollusks and crustaceans feed on organic particles in the sediment itself. In addition to such invertebrates as these, tidal flats provide habitat for a variety of fishes (Allen et al. 2006; Carlisle and Starr 2009; Onuf 1987), and shorebirds depend on tidal flats as feeding grounds.

By definition, sand becomes mud when the grain size drops to 1/16 millimeter (mm); however, hydrodynamic processes result in heterogeneous sediments in mudflats. Analysis of actual grain size distribution in intertidal habitats around the world suggests sediment is strongly heterogeneous in up to 80% of coastal regions (Holland and Elmore 2008). In fact, the proportion of sand increases from the shoreline to the subtidal portions of tidal flats. Although tidal flats may seem to consist of uniformly fine-grained particles, tides, waves, and currents continually rearrange the sediment, creating mosaics of mixed grain types and sizes, sometimes in discrete patches (Holland and Elmore 2008).

The tidal flat community is largely determined by the salinity of the water, the wave energy, and the latitude where the mudflat occurs. Tidal flats are typically anaerobic, stable, nutrient-rich, and unvegetated; however, flats may be covered with mats of green algae and benthic diatoms, or sparsely vegetated with low-growing aquatic species. Intertidal flats occur most often within a mosaic of habitats that includes rocky shores, tidal streams, sandy beaches, salt marshes, and mangroves.

Although tidal flats are not as productive as salt marshes, they perform an important role in transferring energy from the water column (phytoplankton) to the benthic food chain. Filter feeding invertebrates thrive in the nutrient-rich habitat during high tides, then burrow or close their valves (in the case of clams and mussels) during low tides to prevent desiccation. Many soft-bodied invertebrates live well below the sediment surface in burrows, extending tubes or siphons into the overlying water to feed. The burrows provide conduits for oxygen to penetrate more deeply into the sediment, which enhances the habitat for other animals (Shull et al. 2009). Some mollusks and crustaceans feed on organic particles in the sediment itself, and deposit fecal material that stabilizes the substrate.

Rocky shores are areas of bedrock that alternate between marine and terrestrial habitats, depending on whether the tide is high or low. Bedrock outcrops may persist where wave energy is extreme, but in

lower energy areas, a mixture of rock sizes provides a wide variety of habitats (Horn and Martin 2006). Some rocky intertidal shores are protected by offshore rocks, reefs, or islands; others are on headlands where they take the full brunt of offshore wave action (Airamé, Gaines, and Caldow 2003). Exposed conditions on rocky shores generally benefit stationary suspension feeders, such as mussels and barnacles, as well as mobile predators, such as crabs and fish that can move in and out with the tides (Ellis et al. 2007; Horn and Martin 2006). Extensive rocky shorelines can be intermixed with sandy areas, estuaries, or river mouths.

Wave action influences the physical characteristics of rocky shores. Only rock outcrops may persist where wave energy is extreme. In lower energy areas, a mixture of rock sizes will form the intertidal zone. Boulders scattered in the intertidal and subtidal areas provide places to hide and escape the waves for both benthic and pelagic organisms (Horn and Martin 2006) .

In general, intertidal organisms exhibit strong vertical zonation on rocky shores, influenced by desiccation, predation, competition, and grazing (Airamé, Gaines, and Caldow 2003; Lubchenco 1980; Tyrrell 2005). Species assemblages cluster into four zones, defined by tidal elevations: splash zone, upper intertidal, mid intertidal, and low intertidal. The splash zone is at the highest elevation and is rarely, if ever, submerged. The upper intertidal zone, just below the splash zone, is exposed to air more often than to water, leaving organisms vulnerable to extreme temperatures and desiccation. The mid intertidal zone is inundated during high tides, and the low intertidal zone is submerged more often than not (Airamé, Gaines, and Caldow 2003).

One special feature of the rocky intertidal is anchialine ponds. Anchialine ponds are marine or brackish pools of water along the coasts of younger volcanic islands and where coral reefs have been uplifted (Maragos 2000) and connected to the sea through underground caves, tunnels, or fissures (Frankel 2004). They are typically found along rocky coasts up to several hundred meters inland. Depending on the distance from the sea and the extent of groundwater input, pools range in salinity and water quality. Subsurface water exchange occurs through the porous rock walls. Anchialine pools in basalt rock are generally found where the lava rock is porous and creates broad shallow shelves near the coast. Limestone anchialine pools are found in karstic formations that consist of fossilized coral reefs; these formations have undergone extensive weathering and dissolution (Meier, Laurel, and Maragos 1993). Lava rock depressions that have subsided to sea level become flooded with seawater during tidal flow, and anchialine pools are created; eventually these anchialine pools are eroded to form tide pools (Juvik and Juvik 1998).

Sandy beaches form through interaction of waves and tides, as particles are sorted by size and deposited along the shoreline (Karleskint, Turner, and Small 2006). Wide flat beaches occur where wave energy and tidal ranges are high and sands are fine grained. This type of beach tends to support higher productivity, especially dense populations of filter feeders (Defeo and McLachlan 2005). Narrow steep beaches of coarser sand form where energy is limited (Speybroeck et al. 2008).

Four kinds of beaches have been recognized. White sand beaches are the most common, formed from breakdown of coralline algae and corals, producing white carbonate sand; black sand beaches derive from recent lava flows, when molten lava flows into the sea and tiny tephra particles are formed; pink sand beaches result from breakdown of iron-rich coastal cinder cones; and green sand beaches consist of olivine crystals that have eroded from lava rock (Juvik and Juvik 1998; Maragos 2000).

White sand beaches are generally associated with adjacent coral reefs, and are composed mainly of carbonate sediments. Carbonate sediments support diverse invertebrate assemblages; the specific assemblage structure is based upon the mean grain size and wave exposure of the site (DeFelice and Parrish 2001). In general, the number of individuals and diversity increases with increased mean grain size and decreased wave exposure (DeFelice and Parrish 2001). Beach sand tends to be coarser off wave-exposed and windy reaches of islands, and finer within lagoons, embayments, mangroves, and harbors (Maragos 2000); wave action and biological and chemical erosion determine the composition and longevity of beaches (Juvik and Juvik 1998).

Beaches provide extensive benthic habitat for sand-dwelling crustaceans, mollusks, and fish; they also supply resting and nesting sites for seabirds, sea turtles, and some marine mammals. Beaches and their associated tidal flats support a rich ecosystem in three beach zones. Nesting shorebirds and crabs dominate the highest reaches; in the middle reaches, the wrack line (where kelp is deposited along the mean high tide line) creates shelter and forage for small crustaceans; in the surf zone, (the area between the breaking waves and the shore) filter-feeding crabs and clams burrow into the sand (McLachlan et al. 1996). Many important fish species forage in the surf zone along beachfronts (Allen and Pondella 2006; Britton and Morton 1989). Shorebirds feed on the invertebrates when the tide retreats (Airamé, Gaines, and Caldow 2003). Sandy beaches also provide nesting sites for sea turtles (see Chapter 6 for details on important beach habitat for sea turtles).

11.4.2 Distribution

JAPAN ARCHIPELAGO. Intertidal flats, white and black sand beaches, and areas of large pebbles are intermixed throughout the islands of Japan (Simard 1995). More than 30 mudflats larger than 1 ha occur througthout the islands of Japan (Fujikura et al. 2010). The largest area of tidal flats with the highest tidal range in Japan is at Ariake Bay in southeastern Kyūshū (Fujikura et al. 2010). This expanse of tidal mudflats covers more than 15,000 ha and undergoes tidal extremes of about 7 m. The mudflats are critical feeding grounds for breeding populations of egrets, herons, and plovers, as well as a variety of migratory birds (Wild Bird Society of Japan 2009). Nearshore fishes endemic or restricted to the area forage over the mudflats at high tide; species include the javeline goby (*Acanthogobius hasta*), mudskipper (*Boleophthalmus pectinirostris*), grenadier anchovy (*Coilia nasus*), roughskin sculpin (*Trachidermus fasciatus*), and Shokihaze goby (*Tridentiger barbatus*) (Yagi et al. 2011). In the late 1990s, a land reclamation project cut off the inner estuary of the Honmyo River (at the Isahaya inlet), which greatly reduced tidal exchange and degraded water quality in the area. However, other portions of the bay and estuary are still functional and heavily used by fish and wildlife (Islam, Hibino, and Tanaka 2007; Islam, Yamashita, and Tanaka 2011; Yagi et al. 2011).

Intertidal mudflats have largely been filled in for development on the northern islands, but still exist at the Manko Ramsar site on southern Okinawa. The mudflats there are considered one of the 12 most important staging areas for migratory shorebirds in Japan, especially the black-faced spoonbill (Ministry of the Environment 2002e).

A large tidal flat at the head of Ise Bay near Nagoya City, Fujimae-higata, traps sediment discharged by the Shonai and Nikko Rivers; it was named a Ramsar site in 2002. This expansive unvegetated mudflat supports a rich benthic fauna of worms and mollusks that attract more than 20,000 migratory shorebirds between their breeding grounds in Siberia and their wintering grounds in Oceania (The Ramsar Convention on Wetlands 2008). Another tidal mudflat designated as a Ramsar site is in the heart of Tōkyō Bay, surrounded by urban development. Two channels allow tidal exchange between this 40-ha

(1000-acre) flat and the ocean. The accessibility of this extensive mudflat, which supports more than 100 types of birds, makes it an important cultural and educational resource; it is included in the East Asian and Australian Shorebird Reserve Network (Yatsuhigata Nature Observation Center 2007).

Rocky intertidal habitat is common throughout the islands of Japan (Simard 1995), with highly complex shorelines composed of sedimentary, metamorphic, and igneous rock (Ohgaki 2011). The type of rock in a given location, combined with currents and other physical processes, influences the biological community. For example, on the Bōsō Peninsula of central Japan, mudstone shorelines are dominated by herbivorous mollusks while sessile filter feeding mollusks are more common on metamorphic rocky shores (Ohgaki 2011).

Rocky shores provide habitat for both marine and terrestrial organisms. On the rocky shoreline of Yonoha-wan (bay), between Yonamine-wan and Kurima-jima, the mangrove skink (lizard) (*Emoia atrocostata atrocostata*) inhabits the intertidal zone and feeds on invertebrates at low tide (Ministry of the Environment 2002n) throughout the Ryukyu Islands.

Anchialine pools (or ponds) dot the intertidal zone of many islands, especially in the southern islands. Anchialine ponds on Kuro-shima, Okinawa, are best known for their unique community assemblages. Rare anchialine pool shrimp (*Antecaridina lauensis*) occur on Ryukyu Islands and Daito Islands (Center for Biological Diversity 2004). A new species of crab (*Orcovita miruku*) was recently discovered in anchialine ponds on Ishigaki Island in the southern Ryukyu Islands (Naruse and Tamura 2006).

Ōsumi Islands. Sandy beaches suitable for sea turtle nesting occur on the Ōsumi Islands of Yakushima and Tanegashima. Mudflats and sandy beaches occur near the mouth of the Ōura River on Kumano, where several species of estuarine mollusks occur (World Wildlife Fund Japan 2010).

Tokara Islands. Some of the Tokara Islands have sandy beaches where sea turtles nest. The coconut crab (*Birgus latro*) and the unilobed porcelain crab (*Petrolisthes unilobatus*) are also known to inhabit beaches on these relatively undisturbed islands (World Wildlife Fund Japan 2010).

Okinawa, Kerama, Kume, and Daito Islands. Okinawa and several of the smaller islands have sandy beaches and tidal mudflats scattered along the shoreline. These habitats provide important foraging and breeding grounds for terns and wintering grounds for migratory birds such as snipes and plovers. Loggerhead turtles nest on the sandy beaches of northern Okinawa Island, Kudakajima, and the islands of Kerama. Green turtles nest on Yakabijima and other islands of Kerama (World Wildlife Fund Japan 2010). The Daito Islands are completely surrounded by rocky shores and reefs, with no sandy beaches or mudflats (World Wildlife Fund Japan 2010).

MARIANA ARCHIPELAGO. Most of the Mariana Islands have steep rocky shores and relatively narrow intertidal zones without extensive mudflats. The northern islands in the Mariana Archipelago (Pagan, FDM) have mostly rocky shoreline and scarce beaches, reflecting their volcanic origin (U.S. Fish and Wildlife Service 2009; World Wildlife Fund Japan 2010). Small areas of mudflat or sand beach may be interspersed among the rocks. Guam and Saipan have the most intertidal habitat, including beaches and mudflats (Engilis and Naughton 2004; Stinson, Wiles, and Reichel 1997b).

Pagan. Most of the intertidal zone on Pagan is rocky, but several sandy beaches are interspersed around the shoreline. Three small beaches protected by embayments are on the northwestern shore of Pagan, in Laguna Bay, Bandeera Bay, and Katchu Bay. The basaltic rock in the area creates black sandy substate offshore. On the eastern shore south of Mount Pagan, two relatively wide beaches (called Long Beach

and Map Area B) are protected by fringing reef but are not part of embayments. The intertidal zone remains exposed during extended periods at low tide. The green sea turtle is known to frequent the waters of these beach areas (Sukhraj et al. 2010a, b).

Farallon de Medinilla. The coastal area of FDM contains two small intertidal beaches that are inundated by high tide on the northeastern and western coastlines. The shoreline of FDM surrounded by steep, unstable sea cliffs that are heavily eroded (Smith and Marx Jr. 2010).

Saipan. Intertidal habits on Saipan varies from sandy beaches on the western and southern coasts to rocky shores and steep cliffs on the north and east shores. The west coast of Saipan contains well developed fine-sand beaches protected by the Saigon and Tanapag Lagoons (Scott 1993). All other beaches of Saipan consist of coral-algal-mollusk rubble. Obyan Beach, located on the southern coast of Saipan, provides important habitat for the green sea turtle, and is also popular with divers and residents; this area has been recommended for protection under the Coastal and Estuarine Land Conservation Program (Stevens 2008). The Puerto Rico and Tanapag mudflats of Saipan provide important habitat for migratory shorebirds (Engilis and Naughton 2004; Stinson, Wiles, and Reichel 1997b).

Tinian and Aguijan. The submarine topography surrounding Tinian and Aguijan is limestone pavement with interspersed coral colonies and submarine boulders (Kolinski et al. 2001). While no beaches exist on Aguijan (Kolinski et al. 2001), the island of Tinian has 13 small beaches (10 on the west coast and 3 on the east coast). These beaches are not well developed (except Tinian Harbor on the southwest coast and Unai Dankulu along the east coast and are composed mainly of medium- to coarse-grain calcareous sands, gravel, and coral rubble ("coral-algal-mollusk rubble") (Eldredge 1983; Kolinski et al. 2001). Sea turtles are known to nest on Tinian's sandy beaches (Western Pacific Regional Fishery Management Council 2009b).

Rota. On Rota, the rare beaches are found scattered among limestone patches and are composed of rubble and sand (Eldredge 1983). Some sea turtle nesting is known to occur on Rota's sandy beaches (Western Pacific Regional Fishery Management Council 2009b). The tide pool skink (also known as the mangrove skink in Japan) that occupies the narrow rocky shore on Rota and possibly some of the other Mariana Islands is considered a species of special conservations need (Commonwealth of the Northern Mariana Islands Division of Fish and Wildlife 2005).

Guam. On Guam, most of the coastline is composed of rocky intertidal regions. Interspersed among this rocky shoreline are 58 beaches composed of calcareous or volcanic sands (Eldredge 1983). The shoreline of Inner Apra Harbor is fine-grained, sticky mud that is easily suspended (Smith et al. 2009). A channel of unconsolidated mud enters Talofofo Bay on the southeastern side of the island (Burdick 2006). The Dungcas flats and beach and mudflats in and around the Apra Harbor mangrove system are important migratory shorebird habitat (Scott 1993; Stinson, Wiles, and Reichel 1997a, b). Surveys at the Orote Ecological Reserve Area documented only a narrow intertidal zone almost exclusively restricted to the near-vertical cliff face. Occasional large limestone boulders add hard substrate to this high-energy intertidal zone, which is sparsely colonized by endemic limpets and other mollusks (chitons and cowries), decapod crustaceans (lobsters, crabs, and shrimp), and sea urchins (Helber Hastert & Fee 2007b).

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Yap. Most of the islands of Yap are high volcanic peaks that have limited areas of sandy beach or mudflat. A small area of sandy beach surrounding the lagoon provides intertidal habitat for small decapod crustaceans and copepods that support higher trophic levels (Edward 2002). The rocky shores on the high-energy side of the islands serve as attachment points for brown algae such as *Ectocarpus* sp. that can withstand exposure at low tide. When the tide comes in, fishes and other animals forage on the algae (Edward 2002).

Palau. Rocky shores on Palau provide sheltering habitat for small invertebrates such as shore crabs, as well as the endangered saltwater crocodile (Hinchley et al. 2007). Extensive intertidal and subtidal mudflats exist in shallow Ngaremeduu Bay (Ewel et al. 2009).

11.4.3 Conditions and Stressors

Threats to intertidal habitats stem from both overuse, as in the case of desirable beaches, and neglect, as in the case of release of pollutants and contaminants to coastal wetland habitats (Engilis and Naughton 2004). Intertidal habitats in the MRA Study Area have been historically threatened by direct development. More recently, sensitive habitats have been nominally protected, but regional and global threats persist. Sea level rise can adversely affect organisms living in narrow intertidal strands far from direct human impacts. Fuel spills offshore can contaminate shorelines, and increasing human populations associated with military activities and tourism threaten intertidal habits on Guam and Saipan, respectively (Engilis and Naughton 2004).

The Saipan Mudflats have historically been used as dumping grounds, but recent research has led to an appreciation of the habitat value of mudflats (Teck et al. 2010). In Japan, the threat of conversion of local mudflats to a landfill prompted a citizen action that resulted in designation of a Ramsar site (Fujimae-higata).

Sandy beach habitats are under almost constant pressure from recreation and tourism. Human activity can affect the quality of beach habitat by crushing fragile burrows of sand-dwelling organisms, creating physical and acoustic disturbances that cause animals to relocate, and introducing debris and contaminants. Rocky shorelnies are somewhat protected because they are more difficult to convert to other uses. Natural resources of rocky intertidal, such as crabs and mollusks, are vulnerable to overharvest, as well as to adverse effects of climate change and local pollution.

The low islands of Yap are vulnerable to increasing storm surges and overwash, which erode the shorelines (Fletcher and Richmond 2010).

11.5 SEAGRASS BEDS

11.5.1 Description

Seagrasses are submerged aquatic vegetation that form extensive underwater beds (or meadows) which create important habitats. Twelve genera and about 60 species of seagrass are found in shallow-water depths within various temperature and salinity ranges throughout many parts of the world (Phillips and Meñez 1988). The greatest number of seagrass species is in Indonesia and New Guinea (13 species) Ellison (2008).

Seagrasses are unique among the angiosperms (flowering plants) in their ability to grow submerged in shallow marine environments. Some species occur in the rocky intertidal zone, but most grow in shallow intertidal or subtidal unconsolidated sediments. A small group of plants can extend over a large area to form seagrass beds, because seagrasses can reproduce asexually by spreading rhizomes and leaf shoots, as well as sexually through seed production (Coyer et al. 2008). Most seagrasses have similar morphologies, including a creeping horizontal rhizome and erect stems that produce the flowers and leaves. Leaves may be wide and flat or narrow and thin. Most seagrasses have flattened leaves that help them adjust to light restrictions and slow rates of gas diffusion within the water column (Thayer, Kenworthy, and Fonseca 1984). Their extensive rhizome (root) system forms dense and tough belowground mats that anchor plants to the seafloor and absorb nutrients from the sediments. The leaves are capable of transporting oxygen to the rhizomes, allowing seagrasses to grow in anoxic sediments (Thayer, Kenworthy, and Fonseca 1984).

Seagrasses grow in a range of salinities, from fresh water to salinities of up to 42 parts per thousand (ppt), but thrive in a range of 10–30 ppt and temperatures from -6 to 40.5 degrees Celcius (°C) (Dawes, Phillips, and Morrison 2004; Phillips and Meñez 1988). Seagrasses occur as one element of a complex patchwork of coastal habitats, including estuaries, rocky reefs, coral reefs, mangroves, and bare sediments (Tuya et al. 2010). Seagrasses contribute substantially to primary productivity (the energy that is produced by plants from the sun's energy), growing up to 10 mm/day (Spalding et al. 2003). In addition, the blades of most seagrasses are colonized by epiphytic algae that add significant productivity to the system (Roberts, Johnston, and Poore 2008).

Seagrasses play an important role in nutrient regeneration and recycling, water quality, primary production, and carbon sequestration. They also sustain ecosystem productivity by trapping detrital material and sustaining detrital-feeding pathways (Nybakken 1997; Phillips and Meñez 1988). The physical structure of seagrass beds protects coastlines from erosion and promotes nutrient cycling through breakdown of debris, and improves water quality (Allen and Cross 2006). Accumulation of sediment around seagrasses promotes nutrient cycling through decomposition of detritus, and improves water quality (Allen et al. 2006). In addition, seagrass meadows improve water quality by filtering sediments and sediment-borne pollutants, excess nutrients, and dissolved and particulate pollutants from terrestrial runoff (Short et al. 2011; Waycott et al. 2009). As perennial structures, seagrasses are one of the few marine ecosystems that store carbon for relatively long periods. This carbon can be bound into sediments or transported to the deep ocean, and can play an important role in long-term carbon sequestration (Mcleod et al. 2011).

Seagrass beds provide complex, three-dimensional structures that other organisms use to feed, spawn, and hide (Unsworth and Cullen 2010). Seagrass beds are known as nursery habitat for commercially important crustaceans, finfish, and shellfish, and are consumed directly by turtles, dugongs, and some invertebrates (Heck, Hays, and Orth 2003; Hughes et al. 2009; National Oceanic and Atmospheric Administration 2001; Russell and Balazs 2009; Waycott et al. 2009).

In the Pacific islands, people use seagrasses directly as food and burn it to obtain salt. They use seagrasses to make baskets, thatch for roofs, bedding, packing material, and insulation, as well as for fertilizer (Ellison 2008). Throughout the Pacific Islands, people rely indirectly on seagrass habitats for a substantial proportion of their food resources (Unsworth and Cullen 2010; Unsworth et al. 2010).

11.5.2 Distribution

Geographic distributions of seagrasses are based upon individual species tolerances to hydrological and atmospheric conditions—for example, water temperature, salinity, irradiance, depth, substrate, and exposure (Phillips and Meñez 1988).

JAPAN ARCHIPELAGO. About 15.7% of all seaweed acreage in Japan consists of seagrasses. Both temperate and tropical species of seagrasses are known to occur in the country, including the following: *Zostera asiatica, Z. caulenscens, Z. caespitosa, Z. japonica; Phyllospadix iwatensis, P. japonicus; Cymodocea rotundata, C. serrulata; Syringodium isoetifolium; Halodule uninervis, H. pinifolia; Halophila ovalis, H. decipiens, H. minor, H. australis; Enhalus acoroides;* and *Thalassia hemprichii.*

Seagrasses are most abundant (and most endangered) in the northern part of the country. About 35% of all seagrass beds in Japan are in Hokkaidō, and about 15% in Aomori-prefecture in northern Honshū (Short et al. 2011; Sohma, Sekiguchi, and Nakata 2004). *Zostera* spp. and *Phyllospadix iwatensis* are more common in colder waters of northern Japan (Okuda 2008). Of the temperate species, *Zostera japonica* is the only one to extend south to the Ryukyu Islands (McKenzie, Yoshida, and Coles 2006-2012). Seagrass growth is seasonal, especially in temperate areas. In Atsumi Bay, Japan, the biomass of seagrass is highest in June (Sohma, Sekiguchi, and Nakata 2004).

Okinawa. Seagrasses are known at many locations on the shores of Okinawa Island: the region from Awase to Nansei Islands, the Katsuren Peninsula side of Nakagusuku Bay, both sides of Uruma City's bridge connecting its lesser islands to Okinawa Island, the east side of Miyagijima, the area from Kin to Teniya, the north sides of Yagajishima and Kourijima, the moat in Onna Village, the area from Naha Airport to Tomigusuku City, and the village of Kyan in Itoman City (World Wildlife Fund Japan 2010). About 14% of Japanese seagrass acreage is in Okinawa prefecture.

The tropical seagrasses are generally restricted to the southwestern Ryukyu and Amami Islands. Of the nine tropical seagrasses in Japan, only *Halophila ovalis* extends to the northern islands (McKenzie, Yoshida, and Coles 2006-2012). *Halophila* spp. and *Thalassia hemprichii* occur in the subtropical southern regions of the country (Okuda 2008).

In the Ryukyu Islands, the intertidal and higher subtidal zones are dominated by *Halodule pinifolia, Cymodocea rotundata,* and *Thalassia hemprichii.* The deeper subtidal area that are rarely exposed to air support *Cymodocea serrulata* and *Enhalus acoroides*. Both *E. acoroides* and *Halophila decipiens* have limited distributions in Japan and are listed as vulnerable in the Red Data Book of threatened Japanese plant species (McKenzie, Yoshida, and Coles 2006-2012).

In the northern part of Okinawa Island, near Bise on the northwest coast of the Motobu Peninsula, an extensive seagrass bed (about 1 km long by 100–200 m wide) occurs on the landward side of a well-developed fringing reef. *Thalassia hemprichii* dominates the seagrass assemblage there, which grows atop a substrate of coral rubble (Hiratsuka and Uehara 2007).

Seagrasses on the northeastern coast of Okinawa Island provide foraging habitat for the dugong. The Okinawan term for seagrasses in this area is "Jangusa," which means "dugong-grass"; the seagrass bed is called "Jangusanumi," or Sea of Jangusa (McKenzie, Yoshida, and Coles 2006-2012). Around Kayo, on the eastern side of Okinawa Island, dugong feeding trails were observed in relatively intact mixed-species beds of seagrasses. Seagrass abundance is greatest within 200 m of shore, dominated by *Thalassia hemprichii.* In contrast, *Syringodium isoetifolium* is restricted to nearshore shallows. *Halophila ovalis*

occurs in abundance from deeper waters to sandy intertidal areas (McKenzie, Yoshida, and Coles 2006-2012). Between Henoko and Kanna, on the eastern side of Okinawa, large communities of *S. isoetifolium, Cymodocea serrulata,* and *C. rotundata* occur several hundred meters offshore. Dugong and green sea turtles are known to feed in the seagrass beds (Ministry of the Environment 2002a). The large seagrass beds at Henoko are considered important not only to the dugong but to a diversity of invertebrate species as well (Japan for Sustainability 2011).

Burrowing sea urchins (*Echinometra* spp.) feed heavily on seagrasses around Okinawa, relying on fragments of seagrasses called "drift" in locations where seagrass beds are scarce. For example, on the northwest coast of the Katsuren Peninsula of Okinawa Island (around Yonishori), seagrass beds are interspersed with small, round, sandy flats (10–20 m in diameter) along a shallow reef slope that extends several km. Sea urchins that burrow in the sandy flats feed on fragments of seagrasses that drift into their habitat from adjacent seagrass beds (Hiratsuka and Uehara 2007).

The estuaries and nearshore habitats of southwestern Iriomote-jima have been identified as an important wetland area of Japan, containing pure communities of *Enhalus acoroides,* as well as stands of *Thalassia hemprichii* and *Cymodocea serrulata* (Ministry of the Environment 2002k). The seagrass beds were observed to extend along the coastline between 40 and 160 m from the shore (Nakamura and Sano 2004).

Near Ishigaki City, the nearshore waters of Shiraho-kaigan support several seagrasses, including *Halophila ovalis, Enhalus acoroides, Thalassia hemprichii, Cymodocea serrulata,* and *Syringodium isoetifolium* (Ministry of the Environment 2002l). On the northern side of Ishigaki Island, the seagrass bed was observed to extend along the coastline between 30 and 120 m from the shore; this bed is dominated by *Thalassia hemprichii* (Nakamura and Sano 2004).

Near Ishigaki city, the tropical Nagura-wan and Nagura-gawa watersheds support eight seagrass species in mixed seagrass beds, including *Thalassia hemprichii, Cymodocea serrulata, C. rotundata, Syringodium isoetifolium, Halophila ovalis, Halodule uninervis,* and *Halodule pinifolia*. This is habitat for *Enhalus acoroides* and communities of *Acetabularia ryukyuensis*. This well-studied estuarine region is known for high diversity and abundant invertebrates and fishes (Ministry of the Environment 2002g).

The seagrass *Enhalus acoroides* reaches its northernmost distribution in the nearshore waters of the Fukido-gawa estuary, where it occurs in mixed-species beds containing *Thalassia hemprichii, Cymodocea serrulata, Cymodocea rotundata, Syringodium isoetifolium, Halophila ovalis, Halodule uninervis,* and *Halodule pinifolia* (Ministry of the Environment 2002b).

The waters between Yonamine-wan and Kurima-jima support eight seagrass species in mixed beds, especially in Yonoha-wan (bay). This area is the northernmost distribution of *Caulerpa lentillifera,*an edible seaweed that occurs in mixed seagrass beds (Ministry of the Environment 2002n).

Kerama Islands. Few seagrass beds are known in the Kerama Islands; small areas of seagrass occur off Tokashikijima, Zamamijima, and Akajima (World Wildlife Fund Japan 2010).

MARIANA ARCHIPELAGO. In the Pacific Islands, excluding Japan, seagrass beds most commonly occur as components of habitat complexes that include mangroves, coral reefs, and other shallow or intertidal habitats. Twelve species occur in the Pacific Islands; except for one species endemic to Fiji, Tonga, and Samoa, all are widely distributed across the Pacific Islands (Ellison 2008).

Five species of seagrasses are widely distributed within the Mariana archipelago: *Enhalus acoroides, Halodule uninervis, Halodule pinifolia, Halophila minor*, and *Halophila ovalis* (Ellison 2008). The leaves of *E. acoroides*, also referred to as tape grass, can reach up to 150 cm long and 1 to 2 cm wide; this species has white flowers, forms clumps, and grows best on sheltered coastlines in sandy or muddy substrate in a range from the mean low water to 4 m deep (Daniel and Minton 2004; Phillips and Meñez 1988). *Halodule uninervis* has leaves ranging from 0.25 to 3.5 mm wide, grows from the intertidal zone to 30 m deep on firm sand and soft mud, and can survive in a range of environments including highly sheltered bays and along coral reefs. *Halophila minor* has small wide leaf blades (3 to 5 mm wide) and is found in sheltered areas on muddy or sandy substrate in the upper subtidal zone (Phillips and Meñez 1988). Both Saipan and Guam have extensive seagrass meadows surrounding the coastlines (National Oceanic and Atmospheric Administration 2005a) (Figure 11-1 and Figure 11-2).

Pagan. No seagrasses were reported from Pagan during a recent shoreline survey, although a wide variety of marine algae (at least 25 families) was documented in nearshore habitats around the island, including Laguna Bay, Bandeera Bay, near South Point, and Katchu Bay (Sukhraj et al. 2010a, b).

FDM. No seagrasses are known from FDM. Crustose coralline algae (Rhodophyta) and mixed species assemblages of turf algae dominated the substrate from the shoreline down to 30 m (Smith and Marx Jr. 2010).

Saipan. Saipan Lagoon has the greatest extent of uninterrupted shallow sandy seagrass meadows in the CNMI (Berger, Gourley, and Schroer 2005). Saipan Lagoon supports extensive beds of mixed seagrasses, including *Enhalus* and *Halodule* species, although relative abundances of species have shifted and overall densities have been greatly reduced since the late 1940s, particularly in the northern portion of the lagoon (Berger, Gourley, and Schroer 2005; Houk and van Woesik 2008). Saipan Lagoon supports a widely distributed population of *Halodule uninervis* whose abundance and overall quality vary from place to place in response to environmental factors. Large macroalgal blooms occur in Saipan Lagoon during fall and winter when the water cools to below 28°C. Under ideal conditions, with strong tidal exchanges and minimal input of pollutants, the macroalgae die and are washed out to sea during storms. When tidal exchange is limited, however, the macroalgae may overgrow the seagrass. Regular disturbances of storms favor the persistence of seagrasses in the lagoon even when pollutant loads are higher than desired (Houk and Camacho 2010; Houk et al. 2010). Seagrasses are scattered elsewhere around Saipan, including along Tanapag Beach (along the northwest coast) and in the Puerto Rico Mudflats (northwest shoreline, south of Tanapag Beach) (Scott 1993; Tsuda, Fosberg, and Sachet 1977).

Tinian. Tinian has seagrass beds along the northeastern, eastern, southwestern, and northwestern coastlines, although extents are limited (Kolinski 2001). Sea turtles have been observed feeding around Tinian, assumedly on seagrasses (Western Pacific Regional Fishery Management Council 2009b). Small areas of *Enhalus acoroides* were reported from Unai Chiget reef (and mapped also at Unai Masalok and Lamonibot Bay in the INRMP). *Halophila minor* and *Halodule uninervis* occur within Tinian Harbor (Naval Facilities Engineering Command 2010). A literature review in 2001 concluded that seagrasses were largely absent from Tinian's north and south coast nearshore areas (Kolinski 2001), based on studies cited within.

Rota. The coastline of Rota supports a fringing reef with associated patches of macroalgae and turf grass. Seagrass beds on Rota are limited but in good condition (Western Pacific Regional Fishery Management Council 2009a). Sea turtles have been observed feeding around Rota (Western Pacific

Regional Fishery Management Council 2009a). There is no record of seagrass beds occurring on the islands north of Saipan (Tsuda 2003).

Guam. Approximately 3.7 km^2 (917 acres) of reef flats support seagrass beds in coastal bays around Guam (Guam Department of Agriculture 2005); three of the five common species are known from Guam (*H. uninervis, E. acoroides,* and *H. minor*) (Lobban 2006). Extensive seagrass beds occur in Agat Bay (including the Agat Unit of the War in the Pacific National Historical Park) (Daniel and Minton 2004), south of Apra Harbor, and in Cocos Lagoon on Guam (U.S. Department of the Navy 2003). Beds range in size from several meters to almost 1.0 km^2. Reef flats along southern Guam (Cocos Lagoon and Achang Reef Flat Preserve) support the largest expanses of seagrass beds where green turtles (*Chelonia mydas*) forage. Smaller sea grass beds in East Agana Bay, Pago Bay, Piti Bomb Holes Marine Preserve, and Agat support seagrasses mixed with turf algae (Burdick 2006). These areas provide essential rearing and foraging grounds for reef fish such as emperors (Lethrinidae), wrasses (Labridae), and goatfish (Mullidae) (Guam Department of Agriculture 2005).

On Guam, three species of seagrass (*Halodule uninervis*, *Enhalus acoroides*, and *Halophila minor*) cover between 750 and about 900 acres of reef flats in several coastal bays (Guam Department of Agriculture 2005; Western Pacific Regional Fishery Management Council 2009b). Benthic habitat maps prepared in 2005 indicate that seagrasses cover about 2.8% of the reef flat (Burdick 2006). Sea turtles forage in the seagrasses, and economically important fishes such as emperors, scads, wrasses, and goatfish may rear in them (Guam Department of Agriculture 2005). Seagrass beds occur in patches within Outer and Inner Apra Harbor and other isolated areas around Guam (including Agat Bay, Piti Bombholes National Park, and Cocos Lagoon) Burdick (2006). The nearshore areas of Piti, Asan, and Agana Bays support a mixed habitat of seagrass, macroalgae, and coral (U.S. Department of the Navy 2005d). The seagrass *Halophila japonica* is seldom seen outside of Abo Cove (Smith et al. 2008). No seagrasses were reported in the 2005 coastal survey of Orote, Haputo, Ritidian, or Talofofo Bay (Burdick 2006).

Seagrasses also occur in the area around Anderson Air Force Base, where they are intermixed on a narrow fringing reef supporting coralline algae and corals. Macroalgae colonize the shallow parts of the reef flat, and seagrasses occur in the intertidal zone. The fringing reef is interspersed with patches of seagrass. Seagrasses are especially abundant in a small bed in the Ritidian area (Naval Facilities Engineering Command 2010).

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Yap. A survey of seagrasses in the late 1970s reported only seven species and suggested that seagrass communities were in early successional stages dominated by competition (Kock and Tsuda 1978). A more recent review identified three additional species of seagrass from Yap, based on surveys in 1986 by Bridges and McMillan (Ellison 2008). SeagrassWatch, a not-for-profit conservation group that monitors seagrasses throughout the Pacific Islands, reported healthy mixed-species seagrass beds around the Rock Islands containing *Enhalus acoroides, Thalassia hemprichii, Cymodocea rotundata,* and *Halophila ovalis*; the same suite of species occurs on Koror (McKenzie, Yoshida, and Coles 2006-2012).

Most of the seagrass occur in mixed species beds in shallow nearshore waters. The shallow-water species of seagrasses are part of an intertidal habitat mosaic that includes fringing reefs and mangroves (Ellison 2008). Near mangroves, channels, and interior harbors, all species other than *Enhalus acoroides* tend to become sparse (Kock and Tsuda 1978). Water depth, temperature, salinity, and other environmental factors influence the distribution of seagrasses around the islands of Yap. Species that

tolerate low salinity and high temperatures (*Cymodocea rotundata*, *Enhalus acoroides*, and *Thalassia hemprichii*) occur nearer shore, where water temperature reaches 40°C and riverine input creates areas of fresher water. During heavy rains at low tide, these species are exposed to salinities as low as 2 ppt (Bridges and McMillan 1986). These three species extend into deeper water also, where they may form stands that include *C. serrulata* and *Syringodium isoetifolium* down to 1 m (Kock and Tsuda 1978); these two latter species are restricted to deeper areas that are not so exposed at low tide (Bridges and McMillan 1986). *T. hemprichii* extends all the way to the margin of the barrier reef, at depths greater than 2.5 m (Kock and Tsuda 1978).

A survey of commercially important sea cucumbers indirectly reported on seagrasses that co-occurred with sea cucumbers. For example, a species of holothurian new to science was reported to occur in seagrass flats of the inner reef at a few localities around Yap; it is highly abundant at the southern end of Tomil (Kerr, Netchy, and Hoffman 2007). The Caroline Islands ghost goby (*Pleurosicya carolinensis*) is thought to be endemic to the seagrasses in lagoon reef flats of Yap (Edward 2002).

Palau. Seagrass beds occur in a variety of habitats of Palau, including the fringing reefs around the Rock Islands and interspersed with mangrove habitat at Ngesaol in Koror (Secretariat of the Pacific Regional Environment Programme 2007). In addition to the seven seagrasses known from Yap, two additional species were reported to occur on Palau in the 1970s: *Thalassodendron ciliatum* (only on Kayangel Atoll) and *Halodule uninervis* (Kock and Tsuda 1978). By 2008, one more species had been added: *H. pinifolia* (Ellison 2008). *Enhalus* and *Thalassia* are the dominant species in shallow seagrass habitats (less than 2 m deep); these areas are important for sea cucumbers, sea urchins, and sea turtles (Hinchley et al. 2007). In waters down to about 15 m, mixed-species of seagrasses form beds that support dugongs, especially north of Babeldaob and off Sar Passage and Malakal Harbor (Maragos and Cook 1995). Dugongs were also observed feeding in large seagrass beds off the islands of Ngerchur and Ngerkeklau, and on the west side of Ngerchelong peninsula. Other locations known to have adequate seagrass beds to attract dugongs include Ngerchelong, Ngiwal, Ngchesar, and eastern Airai (Secretariat of the Pacific Regional Environment Programme 2007). A survey in 1992 near Koror reported seagrass beds up to 10 m deep containing six species (*Enhalus acoroides*, *Thalassia hemprichii*, *Halodule uninervis*, *Halophila ovata*, *Cymodocea rotundata,* and *Syringodium isoetofolium*) that supported heavy feeding by dugongs (Secretariat of the Pacific Regional Environment Programme 2007). Palau was a leader in the 2011 Pacific Year of the Dugong, an international event focused on protecting this endangered marine mammal that feeds almost exclusively on seagrasses (Secretariat of the Pacific Regional Environment Programme 2011).

Other species locally important to the people of Palau feed or take shelter in seagrass beds, including spiny lobsters (*Panulirus* spp.), several species of clam, octopus, and numerous fishes (Secretariat of the Pacific Regional Environment Programme 2007). Shallow seagrass beds are important habitat for sea cucumbers and sea urchins. Hawksbill and green sea turtles forage in seagrass beds around Palau (Secretariat of the Pacific Regional Environment Programme 2007), especially at Helen Atoll, Anguar Island, Peleliu Island, and the southern lagoon, and at the major seagrass beds off Babeldaob, south of Orepr and Sar Passage (Hinchley et al. 2007; Maragos and Cook 1995).

In the northeastern region of Palau, the larger islands of Kayangel Atoll are surrounded by seagrass beds interspersed with sandy beaches. North of Babeldaob, seagrasses grow from the lagoon shorelines up to 2 km offshore. Expansive seagrass beds occur off Ngiwal, on Ngerechelong, and along the entire eastern coast. The large islands in the north (Koror, Malakal, and Ngerekebesang) all support healthy seagrass beds (Maragos and Cook 1995).

11.5.3 Conditions and Stressors

Seagrasses are under threat worldwide from directly and indirect results of human activity. Up to 93% of all seagrass species are at risk of adverse effect from coastal development and associated degradation of water quality (Short et al. 2011). Globally, nutrient enrichment, dredging/filling, commercial fishing (trawl fishing), boat propeller damage, climate change, and coastal development are the chief human-caused threats to seagrass (Short et al. 2011). The decline of seagrasses is largely reported to be the result of nutrient enrichment caused by nutrient inputs from human sources (sewage, agricultural runoff, industrial runoff). Coastal modifications causing shading, resuspension of sediment (via dredging, recreational watercraft, ferries, tankers, and freighters), deposition of upland soils, and oil spills may reduce the transmission of light to and/or bury seagrasses (Barbier et al. 2011; Short et al. 2011; Waycott et al. 2009).

Field studies in Saipan Lagoon suggest that human population density has a strong direct detrimental effect on seagrass abundance (Houk and Camacho 2010; Houk and van Woesik 2008). Seagrasses are physically damaged by people walking on them or driving personal watercraft and small boats on top of the delicate beds (Guam Department of Agriculture 2005).

Increased water temperatures due to climate change may also contribute to seagrass decline by increasing the intensity and frequency of storm events and disrupting important metabolic functions (Orth et al. 2006). The quantity and quality of most seagrass beds have been lowered by coastal development to such an extent that their existence is now threatened by natural events, such as major storms. When a typhoon completely eliminated a seagrass bed in the southern Ryukyu Islands, mean species rishness of seagras-assocaited fishes declined by up to 85%; 13 of the 21 dominant species of fish were absent from the area (Nakamura 2010).

A widespread decline of the seagrass *Zostera marina* on the south and southwest coasts of Kyūshū, Japan, has been attributed to rising sea temperatures since the 1980s (Kikuchi 1994). In Seto Inland Sea, water pollution and coastal development have caused dramatic declines in *Z. marina* acreage since the 1960s. A study of northern Hiroshima Bay in the Seto Inland Sea on the causes of decline indicated that the immediate mechanism for decline was sedimentation in the blades of seagrass and inadequate flow to remove the sediment once it had deposited (Tamaki et al. 2002). The loss of tidal flats has also been blamed for subsequent deterioration of both seagrass beds and kelp forests (Okuda 2008).

11.6 KELP BEDS

11.6.1 Description

Worldwide, the many species of kelp (primarily brown algae in the order Laminariales) form structural habitats that vary based on the length, branching pattern, and strength of their fronds. Kelp “forests” are the principal biogenic structure along subtidal rocky shores in cold marine waters (California Deparment of Fish and Game 2005; Steneck et al. 2002). Biogenic structures are habitat formations that are built by living organisms. Kelp provides physical habitat for associated species and increases the overall energy flow in the ecosystem by contributing to primary productivity (California Deparment of Fish and Game 2005). The association of fish and large invertebrates with kelp forests has long been recognized (Stephens, Larson, and Pondella II 2006).

Temperature, light, sedimentation, substrate, relief, wave exposure, and biological factors (i.e., grazing, competition with other species) determine the distribution and abundance of kelp. The highest densities

are found on low relief substrate (Deysher et al. 2002). The most persistent beds occur on solid rock substrate with moderately low relief and moderate sand coverage; very low relief and abundant sand has less persistent kelp (Deysher et al. 2002). Kelp attached to rocky substrate can grow up to 50 m in length in nearshore areas of 2 to 30 m depth (Rodriguez, Santiago, and Shenker 2001). Wave exposure and interspecific competition affect both the temporal and spatial variability of kelp (Foster and Schiel 1985; Graham 1997). Kelp are sensitive to light irradiance; because of this, they do not occur in waters less than 2 m deep (Graham 1997).

The stems and blades of kelp can form overlying canopies on the water's surface and provide unique habitat for plant and animal communities (Rodriguez, Santiago, and Shenker 2001). Kelp forests provide refuge, forage, and nursery areas for an abundance of animal and plant species in the Japanese Islands. In addition, kelp forests provide large quantities of drift kelp (detached kelp) to adjacent habitats; drift kelp provides an important resource to soft and rocky benthos, deep channel basins, sandy beaches, rocky shores, and coastal lagoons (Rodríguez 2003).

11.6.2 Distribution

JAPAN ARCHIPELAGO. Japan supports more species of kelp (38 species) than any other nation (Fujita 2011), and is believed to be the global center of biodiversity of true kelps (Bolton 2010). Three main groups of kelp beds are found in Japanese coastal waters: *Laminaria* beds, *Eisenia/Ecklonia* beds, and *Undaria* beds. *Laminaria* beds are dominant in northern Japan (SW Hokkaidō, 39 to 46°N), especially *Laminaria japonica* (Steneck et al. 2002). The commercially important *Saccharina* sp. (kombu) and *Undaria pinnatifida* (wakame) are also grown around Hokkaidō (Fujita 2011).

About 75% of the *Eisenia/Ecklonia* beds occur in temperate waters from Kyūshū to Honshū; this group makes up about 24% of all kelp beds in Japan. Southern kelp species include *Ecklonia cava, E. kurome, E. stolonifera; Eckloniopsis radicosa; Eisenia arborea, E. bicyclis; and Streptophyllopsis kuroshioensis* (Okuda 2008). Aquaculture of *Saccharina* sp. extends only to the northeastern coast of Honshū, where it is replaced by species more tolerant of warmer waters (the southern kelps) (Bolton 2010; Fujita 2011). Abundance of *Eisenia/Ecklonia* beds is greatest in Shizuoka prefecture (in mid-Honshū), which contains 18% of the nation's total. Other local abundances of *Eisenia/Ecklonia* occur in Yamaguchi and Nagasaki prefectures in western Japan (Okuda 2008).

In South Japan (West Honshū, 36-38°N), *Undaria pinnitifida*, *Eisenia bicyclis* (arame), and *Ecklonia cava* are the most common species of kelp (Steneck et al. 2002). Natural and commercially managed populations of kelp occur throughout Japan (Fujita 2011). In Tosa Bay (Shikoku Island), perennial stands of *Ecklonia cava* have historically been intermingled with *Sargassum* spp. (Serisawa et al. 1998). However, in recent years, the *Ecklonia* has failed to thrive, and has been implicated in a collapse of the abalone fishery in Tosa Bay. Causes for the decline are unknown but may include warmer sea temperatures (Serisawa et al. 2004).

Japanese marine ecologists often categorize a closely related group of brown algae with true kelp. These relatives of kelp make up the largest group of large brown algae in Japan, including more than 60 species of *Sargassum* and additional closely related and similar species. *Sargassum* beds are present between low tide and about 10 m in depth. All of these species are held in the water column by air bladders. *Sargassum* beds make up 27% of all seaweed beds in Japan, stretching across the Japanese coast except in Fukushima and Okinawa prefectures. Prefectures supporting at least 10% of the nation's total *Sargassum* area include Ishikawa (on the Sea of Japan), Nagasaki (on the East China Sea), and Shizuoka (on the Pacific Ocean) (Okuda 2008). In Shubushi Bay, Kagoshima, *S. yamamotoi* and *S. kushimotense*

were reported to occur on rocky shores in the upper subtidal zone at depths between 1.0 and 2.5 m. These species do not occur over sand or in the intertidal zone (Shimabukuro et al. 2007).

Kyūshū. On Kyūshū, the rocky reefs of smooth cobbles in sheltered sites of Kasasa, Minamisatsuma, Kagoshima Prefecture support dense mats of *Sargassum duplicatum.* These algae persist even though the area has relatively high sediment loads typically thought to reduce habitat suitability for macroalgae. The rare occurrence of sea urchins in this area may favor the growth of *Sargassum* (Kawamata et al. 2012).

MARIANA ARCHIPELAGO. No true kelp occurs in the Mariana Archipelago. Some species of *Sargassum* are known from Guam, Rota, Aguijan, Tinian, Saipan, and Pagan (Lobban and N'Yeurt 2006).

CAROLINE ISLANDS. No true kelp occurs in the Caroline Islands. Some species of *Sargassum* are known from Palau (Lobban and N'Yeurt 2006).

11.6.3 Condition and Stressors

The stressors that cause changes in kelp coverage are numerous but not completely understood. A study of *Eisenia/Ecklonia* off the Pacific Coast of Central Japan identified several stressors, including desiccation, rainfall, low salinity, low light intensity, turbidity, accumulation of suspended sediments, biofouling, wave and current action, and grazing pressure (Tamaki et al. 2002). Recent work in southern Japan (Kagoshima Prefecture) suggests that although too much sedimentation can harm *Sargassum* beds, a moderate amount of sedimentation can actually protect it from over-grazing by urchins (Kawamata et al. 2011). Rising sea temperature have also been implicated in the decline off Japan's southern coast (Shikoku Island) (Serisawa et al. 2004). Increasing sea temperatures may also play a role in restricting some kelps at the southern edge of their range in Japan (Kikuchi 1994). A process known as "isoyake," in Japanese, meaning "replacement of subtidal kelp beds on the rocky bottom by a crust of unsegmented coralline algae," has been widely reported in south and southwest Kyūshū (Kikuchi 1994).

Some causes of kelp damage are relatively simple to document, such as human development and storms. About 6400 ha of kelp, algae, and seagrass grass beds were lost from the coast of Japan between 1978 and 1992, largely due to land reclamation activities that filled in tidal flats (Kikuchi 1994). Estimates are that kelp forests declined by 36%, *Sargassum* beds by 22%, and seagrass beds by 20% during that time. Typhoons can damage the fronds and reduce the extent of kelp growth. Warmer ocean temperatures inhibit kelp growth by reducing availability of nutrients (California Department of Fish and Game 2010). Other causes contributing to the declines in coastal macrophytes include eutrophication (Okuda 2008) and commercial harvesting (Fujita 2011).

11.7 CORAL REEFS

11.7.1 Description

Coral reefs are produced by stony corals that create rich, three-dimensional habitat with their calcium carbonate skeletons (Spalding, Ravilious, and Green 2001). The complex structures serve as shelter sites and breeding areas for invertebrates and fishes. More groups of algae and animals are represented on coral reefs than in any other habitat on earth (Sheppard, Davy, and Pilling 2009). In addition to providing physical structure to the entire reef community, corals are eaten by other animals, including parrotfish, polychaetes, barnacles, crabs, and gastropods. Other deepwater corals are discussed in the habitat descriptions for Deepwater Coral Communities.

Coral reefs are ecosystems of several linked habitats, including unconsolidated sediment, hermatypic coral, colonized hardbottom, and submerged vegetation—organized around a framework of structural components such as the reef crest, lagoon, and fore reef. A functioning coral reef integrates processes and services from all of these components (Rohmann et al. 2005). The framework of coral reefs is composed of sessile, colonial invertebrates in the phylum Cnidaria, classes Hydrozoa and Anthozoa (subclasses Octocorallia and Hexacorallia) (Veron 2000). The most well-known corals are the stony corals (hermatypic hard corals) in the order Scleractinia (subclass Hexacorallia). Other common species associated with coral reefs include soft corals, sea whips, sea fans (octocorals), and fire and lace corals (Hydrozoans) (Spalding, Ravilious, and Green 2001).

The smallest functional unit of a coral reef is the coral polyp, groups of which collectively create coral colonies. Each polyp secretes a cup, or calyx, which surrounds its soft body. The polyp has a ring of tentacles around its mouth that are retracted into the calyx during the day and extended during the night to feed on zooplankton (Sheppard, Davy, and Pilling 2009). In addition to feeding, hermatypic corals derive nutrients from symbiotic microscopic algae (zooxanthellae) that live in their tissues. The photosynthetic zooxanthellate allow their coral hosts to survive in nutrient-poor waters that otherwise may not sustain them (National Oceanic and Atmospheric Administration 2010d). The photosynthetic pigments also protect the coral from harmful ultraviolet-B radiation (Salih et al. 2000; Sheppard, Davy, and Pilling 2009). Scleractinian corals reproduce both sexually in mass spawning events, and asexually by fragmentation (Sheppard, Davy, and Pilling 2009).

Corals are significant environmental engineers, creating rich, three-dimensional habitat with their calcium carbonate skeletons in otherwise low-relief hardbottom areas. The complex structures have tiny crevices and large holes that serve as shelter sites for invertebrates and fishes. The sharp edges of the reef are used as spawning platforms for animals that broadcast their gametes into the water column; the coral rubble around the perimeter serves as ancillary hardbottom for non-reef-building organisms that require a stable attachment point.

Coral reefs are important to humans ecologically and economically. They provide essential ecosystem services, as well as income from tourism, commercial fisheries, and recreational fisheries (Spalding, Ravilious, and Green 2001). Coral reefs also influence surrounding habitats by serving as wave breaks that protect shorelines, producing carbonate sands that provide softbottom habitat for other organisms, trapping suspended sediment, and mediating currents in the area. Humans benefit economically from the habitat-forming structures that corals build. People in tropical areas worldwide consume fish and invertebrates associated with coral reefs, as well as earn income from selling products of coral reefs or facilitating tourist experiences near coral reefs. Apart from gaining financially, people also benefit socially from the recreational and cultural riches that reefs provide (National Oceanic and Atmospheric Administration 2010c).

Advances in the depth of self contained underwater breathing apparatus (SCUBA) surveys and remote sensing (camera sleds and remotely operated vehicle dives) have yielded an increased appreciation of light-dependent (zooxanthellate) corals at depths from 100 to more than 490 ft. (30 to more than 150 m). These deeper subtidal reefs are known as “mesophotic coral ecosystems” to distinguish them from both the familiar shallow reefs and the cold-water corals of the aphotic deep sea (Hinderstein et al. 2010). Although mesophotic coral reefs are connected to shallow reefs ecologically, they harbor some unique species and are thought to be more vulnerable to impacts by human activities, especially those that cause decreases in light or increases in sedimentation.

11.7.2 Distribution

Corals occur throughout tropical and subtropical oceans between 30°S and 30°N latitudes (Freiwald et al. 2004; Rohmann et al. 2005). The distribution of scleractinian corals is roughly bounded by shallow tropical waters between the Tropics of Cancer and Capricorn (Schuhmacher and Zibrowius 1985; Sheppard, Davy, and Pilling 2009). Reefs occasionally occur beyond these boundaries in warm water currents in Bermuda, the Red Sea, southern Japan, South Africa, and Australia (Sheppard, Davy, and Pilling 2009). The assemblage of organisms that constitutes a coral reef community (corals, seagrasses, algae, sponges, and associated animals) is influenced by environmental conditions such as nutrient availability, salinity, light, substrate, wave forces, sediment, and temperature (20–29°C), as well as by biological interactions such as competition and predation. Light requirements limit most hermatypic corals to a maximum depth of 165 ft. (50 m) (Hinderstein et al. 2010; Rohmann et al. 2005), although exceptions are known, as discussed below. The area of global reef coverage is approximately 109,770 square miles (284,300 km^2), more than 90% of which is in the Indo-Pacific region (Spalding, Ravilious, and Green 2001).

JAPAN ARCHIPELAGO. Coral communities and reefs of Japan occur from sub-tropical to temperate areas (Iryu et al. 1995; Kimura et al. 2008; Ministry of the Environment and Japanese Coral Reef Society 2006; Tsuchiya 2006; Veron 2000; Yamano et al. 2001) (Figure 11-3). Coral reefs in the south around the Ryukyu Islands are well developed (Kimura et al. 2008). Coral communities are patchy and coexist with macroalge in northern areas of Japan.

Approximately 800 coral species have been documented in Japan (Ministry of the Environment and Japanese Coral Reef Society 2006). The most speciose stony coral genera in Japan are *Acropora* (82 species), *Montipora* (38), *Porites* (25), *Favia* (16), and *Fungia* (15). Three coral species are endemic: *Euphyllia paraglabrescens*, *Acropora tanegashimensis*, and *Porites okinawensis* (Tsuchiya 2006). The most diverse coral communities occur in the Yaeyama Archipelago (southern Ryukyu Islands) (Nishihira 2006).

Three different types of coral communities occur in the Japanese Islands: true coral reefs, non-reefal communities, and outlying communities. The main factor differentiating the three types of coral communities is the northward reduction in the number of tropical coral species (Veron 2000). True coral reefs (hermatypic coral reefs) occur from the southern Ryukyu Islands to the Amami Islands (Tsuchiya 2006; Veron 2000). Temperate non-reefal coral communities border the coastlines of Kyūshū and Shikoku Islands, Goto Islands (Sea of Japan), and Iki Islands (Sea of Japan). High-latitude outlying coral communities fringe the Izu and Bōsō peninsulas (Shimoike, Ueno, and Igarashi 2006; Veron 2000) (Figure 11-3). Further, a major difference between hermatypic reefs and non-reefal communities is the ability of the hermatypic reefs to outcompete macroalgae. Corals in non-reefal communities are less capable of developing habitats suited for diverse coral communities (Veron 2000).

The number of tropical coral species in Japan decreases with decreasing sea surface temperature (SST); SST decreases with the poleward direction of the Kuroshio Current. In contrast to subtropical and temperate regions, SST in the tropicals is typically greater than 18°C and is suitable for the mass accretion of reefs. The Kuroshio Current disperses coral planulae from the tropical reefs of Japan to higher latitudes. Larvae that settle at higher latitudes form coral colonies that are genetically connected to the tropical locations. These corals subsequently form subspecies to which tropical species are not connected. Okinotorishima Island is the southernmost Japanese island that supports coral reefs.

Minamitorishima Island is the easternmost and Yonaguni Island is the westernmost of Japanese Islands that support coral reefs (Kayanne, Hongo, and Yamano 2006).

True coral reefs of Japan are found between 24° and 33°N, and hermatypic corals are found down to a depth of 100 m (Kayanne, Hongo, and Yamano 2006; Yamano et al. 2001; Yamazato 1972). True coral reefs are particularly abundant and speciose in the southern Ryukyu Islands (Irimote Island, Sekisei Lagoon, Ishigaki Island, Miyako Island, and Tarama Island) (Nishihira 2006). The morphology of coral reefs changes with latitude from wide fringing reefs in the Ryukyu Islands (24° to 27°N) to patchy reefs and narrower reef flats farther north in the Ogasawara Islands (27° to 31°N) (Kan et al. 1995; Kayanne, Hongo, and Yamano 2006). Except for Iki Island, non-reefal communities are found north of Tanegashima Island and up to the Izu Peninsula (Tsuchiya 2006; Veron 2000; Yamano et al. 2001). High-latitude outlying communities occur from the Izu Peninsula to Tōkyō Bay (Tsuchiya 2006). The northernmost coral communities are found in Tōkyō Bay off the central Japanese mainland (Tsuchiya 2006).

Other factors influencing the regional distribution of corals of Japan include terrigenous runoff, the topography of coastal habitats, and seawater temperature (Nakano 2006a; Omija 2006; Veron 2000). The southern and central Ryukyu Islands (Yaeyama, Miyako, Okinawa, and Amami islands) are isolated from terrigenous runoff originating from mainland China, have diverse coastal habitats, and compared to other coral-bearing locations of Japan, are located within the warm waters of the Kuroshio Current (Nishihira 2006).

Bōsō Peninsula, Izu Peninsula, and Izu Islands. Coral reef habitat of the Bōsō Peninsula, Izu Peninsula, and Izu Islands occurs in high-latitude outlying waters with surface temperatures averaging about 20.5°C annually (Shimoike, Ueno, and Igarashi 2006). The total area of coral reef communities is approximately 425.3 ha. The stony corals of these communities accrete only minor amounts of calcium carbonate and do not form substantial reefs (Veron 2000).

Coral communities of the Bōsō Peninsula (Figure 11-4) include 32 species of stony corals (Shimoike, Ueno, and Igarashi 2006). In Tateyama Bay are 25 stony coral species at a water depth of 10 to 15 m. Stony corals in Tateyama Bay include *Acropora tumida*, *Favia* sp., and *Alveopora japonica* (Shimoike, Ueno, and Igarashi 2006).

Coral communities at the tip of Izu Peninsula include 42 stony coral species (Shimoike, Ueno, and Igarashi 2006) (Figure 11-4). Along the northwestern portion of the peninsula at Uchiura Bay are up to 60 stony coral species within a 5,000 square meters (m^2) area at depths of 5 to 10 m. The survival of this high-latitude coral community is governed by temperature. Most of this coral community was once composed of *Acropora tumida*. A prolonged exposure to cold water in 1996 and 1997 caused mass coral bleaching and mortality. As a result, live coral cover dropped from 85% to 40%. Grazing damage on corals caused by the sea urchin *Diadema setosum* in Uchiura Bay could further deplete live coral cover. Seasonal shading (December to June) caused by the large brown alga *Colpomenia sinuosa* could also contribute to the decrease in coral cover, although corals and large brown algae coexist along the Izu Sea coast (Shimoike, Ueno, and Igarashi 2006).

The Izu Islands are found along the 140°E meridian and between 35° and 33°N (Shimoike, Ueno, and Igarashi 2006) Figure 11-4. Coral communities are documented on Miyakejima Island and Hachijojima Island.

Kyūshū Island, Ōsumi Islands, and the Tokara Archipelago. The total area of coral reef communities around Kyūshū Island is approximately 581.8 ha (Nojima 2006). Average annual SST ranges from 20.9 to 22.9°C. Approximately 100 species of coral occur from Kyūshū Island to the Kii Pensinsula (Nishihira 2006). Coral communities on the west side of Kyūshū Island are mainly located around the Amakusa Islands, including Shimojima Island and Nagashima Island (Nojima 2006) (Figure 11-5); 98 stony coral species have been documented around the Amakusa Islands. The southern shores of Shimojima Island and those of neighboring small islands support relatively extensive coral communities. Dominant stony corals in this area are *Cyphastrea serailia*, *Acropora solitaryensis*, *Favia speciosa*, *Mycedium elephantotus*, *Favites abdita*, *Porites heronensis*, *Hydnophora exesa*, *Goniastrea australiensis*, and *Psammocora superficialis*. Tabular acroporids are found in water depths less than 10 m, and massive corals are found at water depths of 10 to 30 m. This area also contains a rare stony coral, *Acanthastrea amakusensis*.

Two main land features of the southern end of Kyūshū Island are the Satsuma and Ōsumi peninsulas. These peninsulas are separated by Kagoshima Bay (Nojima 2006) (Figure 11-5). In Kagoshima Bay, Sakurajima Island is the most active volcano of Japan. At the tips of the Satsuma and Ōsumi Peninsulas are 11 and 23 species of stony corals, respectively. Within Kagoshima Bay, 17 stony coral species were recorded off of Sakurajima Island. To the west of the Satsuma Peninsula are the Koshikijima and Uji Islands, where high cover of branching and tabulate acroporids (*Acropora hyacinthus*, *A. solitaryensis*, and *A. gemmifera)* was documented in 1990 along the wave-exposed coastlines.

Approximately 40 stony corals occur along the northeastern coastline of Kyūshū Island in the vicinity of Kamae Town (Nojima 2006). In this area, dominant coral species along the coastline are *Pavona decussata* and *A. tumida*. On Yakata Island, dominant corals are tabular forms of *A. hyachinthus* and *Monitpora* spp. (Nojima 2006). Farther south, in the area of the Shimaurajima Island, a 1991 survey documented some 22 coral species, including *A. solitaryensis*, *A. hyachinthus*, and *Turbinaria peltata,* and coral cover was estimated at 13% (Nojima 2006). At the southern end of eastern coast of Kyūshū Island along the Nichinan coast and Shibushi Bay, 52 stony corals were found in 1991. The reefscape in 1991 was dominated by tabular forms of *A. hyacinthus*, *A. solitaryensis*, and *A. gemmifera*. This area was also colonized by *T. peltata,* and could be the northern limit of the stony corals *Merulina ampliata* and *Echinopora lamellosa*.

True coral reefs are present along the southern end of the West Japan portion of the MRA Study Area in the Ōsumi Islands and Tokara Archipelago (Nakai and Nojima 2006). Tanegashima Island, within the Ōsumi Islands, marks the northern limit of true coral reefs. While the northernmost coral reef of Japan is located at Iki Island (Yamano et al. 2001), no true corals occur between Tanegashima Island and Iki Island (Nakai and Nojima 2006). Moreover, the composition of the reefs at Iki Island is very different from that found on reefs south of Tanegashima Island. Coral reefs of the Ōsumi Islands are mainly found in areas protected from high-energy, wave-exposed environments. On Tanegashima Island and on the north coast of Yakushima Island, well-developed reef flats and reef slopes are located on the east sides of the islands. In the Ōsumi Islands, 151 stony coral species occur at Tanegashima Island, 100 at Yakushima Island, and 68 at Kuchinoerabujima Island (Nakai and Nojima 2006).

The Tokara Archipelago is made up of 12 small islands scattered from north to south over 160 km (Nakai and Nojima 2006). Coral reefs are found on Kuchinoshima, Nakanoshima, Hirashima, Kogajyajima, Kodakarajima, and Takarajima Islands (Figure 11-5). Because of recent volcanic activity, the other islands of the Tokara Archipelago are not surrounded by reefs. In the Tokara Archipelago, preliminary surveys have listed 21 dominant species at Kodakarajima and Takarajima (Nakai and Nojima 2006).

Okinawa Island, Kerama Islands, Kume Island and Daito Islands. Okinawa Island has fringing and patch reefs close to shore except on the southeastern end of the island where patch reefs occur several km offshore (Sakai, Iwao, and Shimoike 2006). These offshore patch reefs form barrier-like reefs. More than 340 stony coral species and eight non-reef building species occur at Okinawa. A large coral lagoon known as the Oh-do Beach lagoon covers about 0.12 km^2 on the southern tip of Okinawa. A channel approximately 7 m wide by 2 m deep (at low tide) carries water and organisms between the inner and outer reefs on swift currents. Water depths in the lagoon are about 3.5 m at low tide, deepening to 35 m on the outer reef. This lagoon is considered essential nursery habitat for a variety of reef fishes, including cardinalfishes (apogonids), wrasses (labrids), parrotfishes (scarids), and triplefin blennies (tripterygiids) (Ishihara and Tachihara 2011).

Reefs of the Kerama Islands, 20 to 40 km west of the southern end of Okinawa Island (Figure 11-6), harbor 248 species of stony corals (Sakai, Iwao, and Shimoike 2006). These reefs are an important source of coral larvae for downstream reefs, including the heavily impacted reefs of Okinawa Island. In 2001, average coral cover on Akajima Island ranged from 30 to 53%. Coral reefs remain in good condition on the west coast of Tokashiki Island, where branching and tabular acroporids constitute more than 90% of the live coral cover. Coral development is restricted on the south and east coasts of Tokashiki Island due to strong wave action. Patch reefs made of acroporids and soft corals are found along northeastern coast of Tokashiki Island.

Other reefs within the Okinawa portion of the MRA Study Area are located off the northwestern end of Okinawa (Iheya Island, Gushikawa Island, and Izena Island) and to the northwest of the Kerama Islands (Aguni Island, Tonaki Island, and Kume Island; Figure 11-6). Aside from Aguni Island, reefs were surveyed at each of these islands in 1994 (Sakai, Iwao, and Shimoike 2006). Further reef assessments were conducted at Kume Island from 1999 to 2003, and in 2001 at Gushikawa Island (Sakai, Iwao, and Shimoike 2006).

In 1994 at Iheya Island, the coral cover ranged from less than 5% to more than 50% (Sakai, Iwao, and Shimoike 2006). Fringing reefs at Iheya Island contained substantial amounts of branching *Montipora* cover in the moat and tabular *Acropora* on the reef crest. In 2001, surveys of the northern coast of Gushikawa Island reported coral communities made of tabular and branching acroporids, with 64% cover in 2 to 3 m water depth, and 92% cover in 9 to 10 m water depth. On Tonaki Island, the coral cover of roughly two-thirds of the reefs surveyed ranged from 5 to 50%. Coral cover on the remaining third exceeded 50%. Branching colonies of *Porites* and *Montipora* were found in the moat. During the 1999 reef survey at Kume Island, patch reefs made of large tabular acroporids were found at the eastern end of the reef system. Reef slopes of these same reefs were in good condition. The reef slopes were primarily colonized by branching *Acropora formosa* and large colonies of *Favia*, *Pocillopora*, *Merulina ampliata*, and *Diploastrea heliopora* (Sakai, Iwao, and Shimoike 2006).

The Daito Islands (Kitadaito Island, Minamidaito Island, and Okidaito Island or Okino Daito Jiwa) are located 360 km west of the Ryukyu Islands and are part of the Okinawa portion of the MRA Study Area. Kitadaito Island (30.6 km^2) and Minamidaito Island (12.7 km^2) are the main islands, and are 7 km apart. Okidaito Island is located 150 km to the south of the main Daito Islands and is smaller than either Kitadaito or Minamidaito Island (Nonaka 2006). Poorly developed reefs are present around the main islands. In 2001, average coral cover was 10%. Sixty-two species of stony corals occurred within 10 to 20 m of water depth. Dominant stony corals were of the *Porites* and *Pocillopora* genera. All species observed at the Daito Islands occur on the Okinawa and Kerama Islands. Compared with the reefs of

Okinawa and Kerama Islands, the reefs of the Daito Islands harbored less acroporids and faviids and more *Astreopora* colonies.

Tori Shima is located 28 km north of Kume Island. No formal surveys of coral reefs have been conducted at Tori Shima. The structure of coral reefs around this island might be similar to the reefs at Kume Island. Quantitative surveys of coral reefs at Tori Shima are needed to assess their current status.

Idesuna Jima is located 4 km northeast of Tonaki Island. No formal surveys of coral reefs have been conducted at Idesuna Jima Island. Considering its proximity to Tonaki Island and not accounting for potential military training impacts on corals, coral cover on fringing reefs possibly ranges from 5 to 50%. Quantitative surveys of coral reefs at Idesuna Jima are needed to assess their current status.

Okino Daito Jiwa or Okidaito Island is located 150 km south of the main Daito Islands. No formal surveys of coral reefs have been conducted at this site. Considering their southerly location and relative proximity to the southern Ryukyu Islands, reefs of Okidaito Island are possibly similar to the stony coral species at the Miyako Archipelago (Kajiwara and Matsumoto 2006). Quantitative surveys of coral reefs of Okidaito Island are needed to assess their current status.

MARIANA ARCHIPELAGO. Coral reefs are found throughout the Mariana Archipelago (Bearden et al. 2005; Birkeland, Rowley, and Randall 1981; Eldredge 1983; Green 1997; Houk 2001; Paulay 2003; Paulay et al. 1997; Randall 1985; Randall and Siegrist 1988; Randall, Siegrist, and Siegrist 1984). Subtidal regions are characterized by limestone pavement interspersed with coral colonies and submerged boulders (Kolinski et al. 2001).The degree of reef development depends on a number of environmental controls including age of the islands, volcanic activity, availability of favorable substrates and habitats, weathering caused by groundwater discharge, sedimentation and runoff accentuated by land use practices, and varying levels of exposure to wave action, trade winds, and storms (Bearden et al. 2005; Eldredge 1983; Paulay 2003; Randall 1985, 1995; Randall, Siegrist, and Siegrist 1984). In the CNMI, coral growth was reported to be limited by wave energy and exposure to freshwater (Houk and Starmer 2010). Large corals were absent in areas of high wave energy and low salinity despite the presence of many coral recruits. The southern islands (FDM to Guam) are inactive volcanic islands that have subsided and are covered by massive limestone deposits dating back more than 40 million years (Randall 2003). The substrate of the younger islands to the north of FDM dates back to 1.3 million years and is not characterized by substantial limestone deposits (Randall 1995, 2003). In the southern islands, faulting and erosion caused by groundwater discharge have produced large, oblique, and shallow areas (lagoon, bays) favorable to extensive reef development. This contrasts with the vertical profile of the uplifted younger islands, where less favorable and fewer macrohabitats are available for reef development (Paulay 2003; Randall 1995).

Some of the reef-building corals found in the Mariana Islands probably originated from the nearest upstream reef ecosystems, the Marshall Islands, and were transported to the Mariana Islands as gametes and planulae by the North Equatorial Current (Randall 1995). Overall, the reefs of the Mariana Islands have a low coral diversity compared to other reefs in the northwestern Pacific (e.g., Palau, Philippines, Australian Great Barrier Reef, southern Japan, Marshall Islands) Randall (1995) but a higher diversity than the reefs of Hawaiʻi. There are 377 scleractinian species in the Mariana Islands (Randall 2003) versus 60 in Hawaiʻi (Maragos and Gulko 2002). Of the 377 scleractinian corals of the Mariana Islands, 276 species harbor zooxanthellae and 101 species do not (Randall 2003).

Fewer reef building species and genera occur in the northern islands than in the southern islands: 159 species and 43 genera in the northern islands versus 256 species and 56 genera in the southern islands (Randall 1995, 2003). The same is true for other reef dwelling organisms, where greater species diversity of fishes and mollusks is evident in the southern than in the northern islands. These estimates of numbers of species could increase as a function of sampling effort and percentage of reef habitats surveyed at each location. Coral habitats of the northern islands are less well sampled than those of the southern islands. In the northern islands, the most sampled coral reef habitats are at Pagan Island (20% of coral habitats) and Maug Islands (15% of coral habitats). At all other locations of the northern islands, less than 10% of the coral habitats have been sampled. In the southern islands, Guam and Saipan have the most sampled coral habitats (95% and 50% of coral habitats, respectively). Ten percent of the coral habitats have been sampled at Rota, 20% at Tinian, and 2% at FDM (Randall 2003). Corals are found on shallow reefs and upper fore reefs (<75 m water depth), and deeper fore reef habitats (>75 m water depth) (Randall 2003).

Most of the shorelines in the Mariana Archipelago are karstic and bordered by limestone cliffs (Amesbury et al. 2001; Eldredge 1983; Paulay et al. 2001; Paulay, Puglisi, and Starmer 2003; Randall 1979; Siegrist and Randall 1992). In a few areas, the shorelines consist of volcanic substrates (Paulay, Puglisi, and Starmer 2003; Randall 1979). On windward shores in the reefs are narrow and have steep fore reefs. Narrow reef flats or shallow fringing reefs (100 to 1,000 m wide) are characteristic of leeward and more protected coastlines. Reefs also occur in lagoonal habitats: Apra Harbor and Cocos Lagoon on Guam, and Tanapag-Garapan Lagoon on Saipan. Reef organisms also occur on eroded limestone substrates, including submerged caves and crevices, and large limestone blocks fallen from shoreline cliffs (Paulay, Puglisi, and Starmer 2003; Randall 1979).

The islands of Tinian and Rota lack complex lagoon systems. Saipan has five small lagoons located on the western side of the island and two lagoons along the eastern coastline (National Oceanic and Atmospheric Administration 2005a; Pacfic Basin Environmental Consultants 1985). On the island of Rota, a small “semi-lagoon” is located along the entire western coast, and the only true lagoon on Rota can be found at the extreme southern tip of the island (Pacfic Basin Environmental Consultants 1985).

NOAA’s Coral Reef Conservation Program, the Coral Reef Ecosystem Division, conducts assessments and mapping of benthic habitat, oceanography, coral, algae, reef fish, invertebrates, and marine debris to monitor the health of coral reef ecosystems of the Mariana Archipelago (Pacific Islands Fisheries Science Center 2008). Delineations by NOAA of shallow-water benthic habitats of Guam and the CNMI have supported of estimates of the overall distribution of reefs within the MRA Study Area (National Oceanic and Atmospheric Administration 2005a). Three depictions, the subtidal reef morphology, benthic substrate, and live cover of coral reef habitats are provided Figure 11-7 to Figure 11-27 for each island starting with Pagan in the north to Guam in the south. A detailed description of mapping methods is provided in the Atlas of the Shallow-Water Benthic Habitats of American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands (National Oceanic and Atmospheric Administration 2005a). Site-specific information on coral cover provided in this report is based on peer-reviewed publications and reports.

Pagan. Unlike the other southern Mariana Islands, Pagan does not include fringing or fore reefs(Figure 11-8). Benthic substratum features include boulders and and (Figure 11-8). Hard corals covered approximately 20% of the benthic habitat at Pagan (Starmer et al. 2008). Soft coral, macroalgae, and coralline algae covered 10%, 40%, and 30% of the remaining benthic habitat, respectively. Coral cover at Pagan ranged from 3.9 to 20.6%, with an island-wide mean of 10.6% based on surveys conducted at nine

sites during 2007 (Figure 11-9) (Pacific Islands Fisheries Science Center 2008). The highest coral cover observed in 2007, 50–70%, was similar to that recorded in 2003 in the same location. Dominant coral genera were *Pavona, Favia*, and *Astrepora*.

Farallon de Medinilla. Unlike the other southern Mariana Islands, FDM does not include fringing or fore reefs (Figure 11-10). The benthic substratum features include limestone pavement and sand (Figure 11-11). The island is surrounded by a relatively wide insular shelf (400 to 1,800 m wide) that supports limited coral cover along all sides except the western side of the island (National Oceanic and Atmospheric Administration 2005a). In 2004, 81 species of corals were observed on reefs at FDM (U.S. Department of the Navy 2005d). Overall, the northwestern nearshore area (eroded submerged cliff face and reef terrace) of the island supports the highest diversity of marine invertebrates and fishes on FDM (U.S. Department of the Navy 2005d). Most of the coastline of FDM is bordered by steep karstic cliffs that for the most part extend 6 to 9 m below the waterline (U.S. Department of the Navy 2005d). Cliffs on the western shoreline extend more than 20 m below the waterline. Numerous underwater caves are present along the FDM shoreline. Boulders dislodged from the cliffs border the base of the cliffs. Seaward of the cliff face is a reef terrace that is 30 to 50 m wide and 10 to 25 m deep, beyond which is a sandy slope zone (Figure 11-11). On parts of the western side of the island, a vertical wall undercut by caves and ledges delimits the seaward edge of the reef terrace and intersects with the sandy slope habitat. At the southern end of the island, a 2-m-deep “finger reef” extends 200 m southward. The edges of the finger reef are vertical walls that drop down to a 30 m depth. The reef terrace consists of a spur-and-groove system on the eastern (windward) side of the island, where the island forms an isthmus separating the lower narrow third of the island from the wider upper two-thirds of the island (U.S. Department of the Navy 2005d).

Near the cliff edge on the reef terrace of the eastern side of FDM is less than 5% coral cover (U.S. Department of the Navy 2005d). Farther offshore is 10 to 20% coral cover composed of encrusting *Porites* and head coral forming *Pocillopora*. Coral cover on the boulders is 25 to 30% and composed of *Pocillopora*, *Porites*, *Montipora*, and *Millepora*. Coral cover on the ridges of the spur-and-groove system off the island isthmus on the windward side ranges from 15 to 25% and is composed of *Porites* and *Pocillopora*. Large aggregations of the long-spined urchin *Echinotrix diadema* (hundreds to thousands of individuals) occur on both the eastern and western sides of the island, and high coral cover is found on boulders along the reef terrace on the leeward side of the island (50 to 70%, mostly *Pocillopora* coral heads). Most of the branching colonies of *Pocillopora* sp. on the leeward side have broken branches (U.S. Department of the Navy 2005d). Live cover of coral reef habitats around FDM is depicted in Figure 11-12.

Saipan. The subtidal reef morphology of Saipan is complex (Figure 11-13). Benthic substratum features include limestone pavement, spur and groove, sand, and rubble (Figure 11-14). Hard corals covered approximately 20% of the benthic habitat at Saipan (Starmer et al. 2008). Soft coral, macroalgae, and coralline algae covered approximately 5%, 65%, and 10% of the remaining benthic habitat, respectively. Coral cover at Saipan ranged from 2.0% to 33%, with an island-wide mean of 11.2% based on surveys conducted at seven sites during 2007 (Pacific Islands Fisheries Science Center 2008). The highest coral cover, observed in 2005 surveys along the west coast of Saipan, ranged from 20% to 75%. Dominant coral genera were *Favia*, *Porites, Leptasrea*, and *Montipora*. Coral cover ranged from 27% to 73% of the benthic habitat of seven marine protected areas in Saipan (National Oceanic and Atmospheric Administration 2009a). Living cover of coral reef habitats is depicted in Figure 11-15.

Tinian. The subtidal reef morphology is dominated by a reef crest and narrow reef flat (Figure 11-16). Benthic substratum features include limestone pavement and spur and groove (Figure 11-17). Hard corals cover approximately 12% of the benthic habitat at Tianian (Starmer et al. 2008). Soft coral, macroalgae, and coralline algae cover approximately 2%, 70%, and 8% of the remaining benthic habitat, respectively. Coral cover ranged from 5.9% to 31.4%, with an island-wide mean of 13.3% according to surveys at five sites in 2007 (Pacific Islands Fisheries Science Center 2008). High coral cover, 40% to 50%, was observed in localized areas. Dominant coral genera were *Porites*, *Favia*, *Astrepora, Montipora*, and *Goniastrea*. Live cover of coral reef habitats is depicted in Figure 11-18.

Barrier reefs, fringing reefs, and a broad shelf area (1,000 m wide) are found off the Tinian Harbor (Eldredge 1983; National Oceanic and Atmospheric Administration 2005a). Coral cover around Tinian is depicted in Figure 11-18. The largest amount of coral cover probably occurs along the outer edges of the reef (fore reef and terrace) (Bearden et al. 2005; Starmer, Trianni, and Houk 2002). Fringing and fore reefs (less than 200 m wide) occur immediately next to the western shoreline of Tinian (National Oceanic and Atmospheric Administration 2005a). Corals are found on the fore reef and insular shelf seaward of the fore reef. On the eastern side of the MRA Study Area, from Puntan Tahgong (the northeastern tip of the island) to north of Unai Asiga, coralline algae populate the fringing and fore reefs, and the insular shelf seaward of the fore reef. From Unai Asiga to south of Unai Masalok, coralline algae occupy the reef crest, and corals are found along the fore reef and a large portion of the seaward shelf.

From Unai Masalok to Puntan Masalok (the eastern Tinian coast), no fringing reefs are found, and the shelf is composed of coralline algae. Furthermore, no fringing reefs occur from Puntan Masalok to Puntan Carolinas (southernmost point of Tinian). Coralline algae occupy the entire shelf from Puntan Masalok to an area north of Puntan Barangka, where coral cover begins to dominate (Figure 11-18). Fringing reefs reoccur past Puntan Carolinas (National Oceanic and Atmospheric Administration 2005a). An oval-shaped, offshore, submerged reef (3.5 by 1 km) composed primarily of coralline algae is located approximately 2.7 km southeast off the southernmost point of Tinian (National Oceanic and Atmospheric Administration 2005a). The overall coral cover around Tinian ranges from 10 to 50%.

Coral cover ranges from 14 to 59% on coral reefs at Kammer Beach and Two Coral Head, respectively (Quinn and Kojis 2003). Dominant coral species in terms of cover are *Goniastrea retiformis* at Kammer Beach and *P. rus* at Two Coral Head. Coral cover is much higher at Two Coral Head than at Kammer Beach because the coral species at Two Coral Head are more resistant to predators (Quinn and Kojis 2003).

Unai Chulu and Unai Babui are located on the northwestern side of Tinian, and Unai Dangkolo is on the east side of the island, north of Puntan Masalok. A narrow fringing reef composed of coralline algae (50 to 90% cover) borders the carbonate sand beaches of Unai Chulu and Unai Babui (National Oceanic and Atmospheric Administration 2005a). Landward of the fringing reef is a reef flat in a water depth of 0.5 m (Marine Research Consultants 1999). At Unai Chulu, within 20 m seaward of the shoreline, the reef flat substrate includes sand, rubble, and outcrops of a fossil reef. Live cover in the inner reef flat is mostly composed of turf algae. The few coral specimens of the genus *Porites* located in this area of the reef form circular, flat-topped, and lobate colonies. In the middle of the reef flat, echinoids have bioeroded the reef substrate, and corals (small branching and encrusting colonies) are more abundant than on the inner reef flat. The fringing reef is exposed to wave action, resulting in few coral colonies. Seaward of the fringing reef, the reef front forms a spur-and-groove system (alternating channels and ridges that are perpendicular to the fringing reef). Spurs are 1 to 2 m wide, and the grooves are

approximately 5 m wide. Abundant coral cover was observed within the spurs. Seaward of the spur-and-groove system is a deep reef front terrace (Marine Research Consultants 1999). The reef morphology off Unai Babui is similar to that of Unai Chulu except that the spur-and-groove system was found more developed at Unai Babui.

A fringing reef borders the Unai Dangkolo white carbonate beach (National Oceanic and Atmospheric Administration 2005a). Macroalgae (10 to 50% cover) populate the reef flat, while the fringing reef is composed of coralline algae. Corals (10 to 50% cover) are a main constituent of the fore reef and insular shelf (National Oceanic and Atmospheric Administration 2005a). Surveys in 1994, however, reported that the inner reef flat supports an extensive (50 to 70% coral cover) and diverse reef community (25 coral species) (Marine Research Consultants 1999). On the reef front is a spur-and-groove system down to a depth of 10 m, seaward of which the benthos is composed of limestone pavement. Both the spur-and-groove system and the fore reef are densely populated by corals (36 species of corals).

Aguijan. The subtidal reef morphology of Aguijan has a reef crest and narrow reef flat (Figure 11-19). Benthic substratum features include limestone pavement, spur and groove, and sand (Figure 11-20). Hard corals covered approximately 25% of the benthic habitat at Aguijan (Starmer et al. 2008). Soft coral, macroalgae, and coralline algae covered 5%, 55%, and 15% of the remaining benthic habitat, respectively. Coral cover was 7.8%, based on one rapid ecological survey in 2007 (Pacific Islands Fisheries Science Center 2008). Localized high coral cover ranging from 30% to 75% was observed during benthic towed-diver surveys in 2005 (Pacific Islands Fisheries Science Center 2008). Dominant coral genera were *Leptastrea*, *Favia*, *Pavona*, *Pocillopora*, *Astrepora, Montipora*, *Goniastrea*, and *Porites*. Live cover of coral reef habitats is depicted in Figure 11-21.

Rota. The subtidal reef morphology of Rota is characterized by a reef crest and narrow reef flat (Figure 11-22). Benthic substratum features include limestone pavement, spur and grove, and sand (Figure 11-23). Hard corals covered approximately 10% of the benthic habitat at Rota (Starmer et al. 2008). Soft coral, macroalgae, and coralline algae covered 10%, 80%, and 10% of the remaining benthic habitat, respectively. At Sasanhaya Bay Fish Reserve on Rota, coral cover was 16% of the benthic habitat (National Oceanic and Atmospheric Administration 2009a). Coralline algae and marcroalgae covered 22% and 1%, of the benthic habitat, respectively. The remaining habitat was classified as uncolonized or unknown. Live cover of coral reef habitats is depicted in Figure 11-24.

Guam. Guam is almost entirely surrounded by fringing reefs, is entirely surrounded by fore reefs, and has barrier reefs at Apra Harbor (Luminao Barrier Reef at the western end of Guam) and Cocos Lagoon (southern end of Guam) (Eldredge 1983)(Figure 11-25). Benthic substratum features include limestone pavement, sand, and spur and groove (Figure 11-26). Apra Harbor, the only deep lagoon on Guam and the busiest port in the Mariana Islands, is enclosed by the Glass Breakwater. The Inner Apra Harbor is a lagoon created by dredging in the 1940s. Cocos Lagoon, a shallow lagoon (12 m water depth) located on the southern tip of the island is also encompassed by a series of barrier reefs (Paulay et al. 2002). Sasa Bay, also located on Guam, is a shallow coastal lagoon populated with patchy corals (Scott 1993). Embayments along the entire western coastline, except for the small regions spanning from Oca Point to Ypao Point and from Orote Point to Apuntua Point, have developed behind fringing reefs and may possess physical characteristics similar to a lagoon (Paulay et al. 2002).

Dominant coral genera were *Porites*, *Leptastrea*, *Astrepora Favia*, and *Montipora*. Reefs in the southern half of Guam have always been subject to more naturally occurring sedimentation than those in the northern half of the island because the erosional products differ (volcanic in the south versus limestone

in the north) (Richmond and Davis 2002). Coral cover and diversity were higher on reefs located along the northeastern coast of Guam (Richmond and Davis 2002).

Surveys of shallow-water benthic habitats of Guam found that the overall coral cover around Guam ranged from 10 to 90% (National Oceanic and Atmospheric Administration 2005a) Figure 11-27. Coral cover in specific sites around Guam ranged from 4.9% to 39.2%, with an island-wide mean of 16.2%, during surveys at 10 sites in 2007 (Pacific Islands Fisheries Science Center 2008). Average coral cover was lower in 2007 than the 26.1% observed in 2005 (Pacific Islands Fisheries Science Center 2008). Live cover of coral reef habitats is depicted in Figure 11-27.

The fringing reef is interrupted in several locations along the coastline by bays, channels, and areas where the insular shelf is colonized by seagrass. Along the northern coast of the island between Achae Point and the Ritidian Channel, the fringing reef and fore reef area transitions from a relatively wide swath of coral (less than 250 m wide) to an area populated by turf algae (200 to 500 m wide). Similarly, turf algae and macroalgae cover the insular shelf (up to a 500 m width) from Pati Point (northeastern tip of the island) to an area south of Mati Point on the eastern side of the island. Turf algae and macroalgae also cover the insular shelf from Fadian to Lates, Talofofo Caves to Paulicuc Bay, north of Toguan Bay to south of Cetti Bay, Apuntua Point to Orote Point, Amantes Point to NCS Beach, and Ague Point to Haputo Beach (National Oceanic and Atmospheric Administration 2005a). Small coral-populated reef areas (individual areas less than 1 ha) occur within large stretches of turf algae and macroalgae cover off of Jones Beach near Camp Dealy (eastern side of the island), at Asanite Bay (south of Jones Beach), and in two areas off Togcha on the western end of the island south of Agat Bay (National Oceanic and Atmospheric Administration 2005a).

***Apra Harbor*.** Apra Harbor is a deep lagoon located at the western end of Guam (Paulay et al. 1997); Before 1944, the lagoon of Apra Harbor was delimited to the north by Cabras Island, Luminao Reef, and Calalan Bank; to the east by the Piti area; and to the south by the Orote Peninsula (Paulay et al. 1997). In 1944, construction of the Glass Breakwater (limestone boulders) on Calalan Bank altered the barrier reef system and restricted water exchange between Apra Harbor and the open ocean. In addition, dredging of the Inner Apra Harbor (formerly a silty embayment of the lagoon) and fill operations to develop Dry Dock Island, Polaris Point, and artificial shorelines of the northeastern and southeastern boundaries, altered the lagoon (Paulay et al. 1997).

Because of its depth (37 m), the Apra Harbor lagoon is unique to the Mariana Archipelago portion of the MRA Study Area (Paulay et al. 1997). It provides habitat for unique and diverse benthic fauna; for example, most of the sponges and ascidians found in Apra Harbor—48 species of sponges and 52 species of ascidians—are unique to Apra Harbor. Many of these species unique to Apra Harbor are indigenous. Some of the species (1 sponge and 16 ascidians) were introduced via ship traffic. Indigenous species generally occupy natural substrates, while introduced and cryptogenic species (species whose origins cannot be verified) generally occupy artificial substrata (e.g., wharf walls, concrete revetments, moorings, and navigational buoys) (Paulay et al. 1997).

Corals are found in the Outer Apra Harbor where they thrive on shoals and fringing reefs (Department of Defense 1999; Paulay 2003; Paulay et al. 1997; U.S. Department of the Navy 2003). *Porites rus* is the dominant coral species on the shoals in the center of the harbor outside Sasa Bay (Western Shoals, Jade Shoals, and Middle Shoals) Paulay et al. (1997). Other coral species associated with these shoals include *Porites lobata*, *P. annae*, *P. cylindrica*, *Millepora dichotoma*, *Acropora formosa*, and *P. damicornis* (Paulay et al. 1997). Coral cover on the shoals ranges from 50 to 90% (National Oceanic and Atmospheric

Administration 2005a; Paulay 2003). Mounds at greater depths are present in the outer harbor. Paulay et al. (1997) surveyed Sponge Mound, located west-southwest of Western Shoals. They found that the top of the mound (within 20 m of the sea surface) supported the highest diversity of sponges in all of Guam.

Along the southern boundary of Apra Harbor between Orote Point and Gabgab Beach, including east and west of ammunition pier or "Kilo Wharf," coral cover on fringing reefs is high (Department of Defense 1999; National Oceanic and Atmospheric Administration 2005a; Smith 2004). The areas to the east and west of Kilo Wharf support high coral cover (close to 100% cover) consisting mainly of *P. rus* (>90% of the cover) and other stony corals including *P. lichen*, *P. lobata*, *Platygyra pini*, *Leptoseris* spp., *Lobophyllia corymbosa*, and *Acanthastrea echinata* (Smith 2004). Corals in the Inner Apra Harbor (including *P. rus* and *P. damicornis*) encrust sheet pilings, rocks, and concrete debris (Department of Defense 1999).

Corals also occur on reefs off the tip of the Orote Peninsula (Paulay et al. 2001). Paulay et al. (2001) described two macrohabitats in this area—the Orote Point reef slope and the Orote Point fringing reef. The Orote Point reef slope is at the tip of the peninsula and extends from Spanish Steps to the western end of Orote Island. This area supports higher coral and fish diversity and higher fish biomass than do other locations of Guam. The submerged terrace slopes gently down to a water depth of 12 to 15 m, followed by a steep fore reef slope that plunges down to more than 30 m. The area of reef that is contiguous with Apra Harbor is populated by the biota commonly found in the harbor (e.g., *P. rus* and sponges). The *P. rus*-dominated reef is limited to an area immediately adjacent to the harbor. Along the northern end of the Orote Peninsula west from the harbor, the coral community is more diverse. Paulay et al. (2001) observed 19 species of corals in this area and noted that this was the most diverse coral area of the coastline from Spanish Steps to Agat Bay. The diversity of fishes was also greatest in this area, with 53 species observed. In addition, within this diverse area, Paulay et al. (2001) may have found a new *Acropora* species record for Guam. The coral species appeared to be similar to *Acropora nasuta*.

The Orote Point fringing reef is located between the tip of the Orote Peninsula and Orote Island. It has a reef front facing the southern coast of the Orote Peninsula and another facing the southwestern end of Apra Harbor (Paulay et al. 2001), providing a connection between the north and south sides of the peninsula. Karstic shores flank the other two sides of the reef. Paulay et al. (2001) found a "strong gradient in species composition" on this reef. The middle and northern parts of the reef supported coral species typical of Apra Harbor (including *P. rus*, *P. cylindrica*, *Pavona venosa*, *Pavona divaricata*, *Psammocora contigua*, and *P. damicornis*). Corals found on the southern end of the reef were characteristic of an oceanic reef front community, with corals including *A. digitifera*, *Galaxea fascicularis*, and an *Acropora* species similar to *Acropora valida*.

On the northern side of the harbor, the fringing reefs on either side of the Glass Breakwater, Luminao Barrier Reef, the fore reef off Cabras Island, and the fore reef of Piti Reef have 10 to 50% coral cover (National Oceanic and Atmospheric Administration 2005a). Also, a narrow strip of seagrass borders the entire fore reef from the end of the breakwater to Piti Reef (National Oceanic and Atmospheric Administration 2005a). In addition to these data from the National Centers for Coastal Ocean Science (National Oceanic and Atmospheric Administration 2005a), Randall et al. (1982) surveyed three reef areas—the Luminao Barrier Reef on the seaward side of Glass Breakwater, the fringing reef on the seaward side of Cabras Island, and the Piti Reef (fringing reef east of Cabras Island). Randall et al. (1982) found corals concentrated in the reef flat and the reef front areas of the reefs.

Luminao Barrier Reef is approximately 50 to 200 m long and less than 1 to 2 m deep. Coral cover on the reef flat ranged from 7 to 31% (Randall et al. 1982). Corals making up most of the cover were of the following genera: *Porites*, *Pocillopora*, *Leptastrea*, *Montipora*, *Millepora*, *Acropora*, *Psammocora*, *Leptoria*, and *Goniastrea*. Coral cover on the reef front slope ranged from 18 to 25%, and was composed of the coral genera *Pocillopora*, *Acropora*, *Goniastrea*, and *Millepora*. The reef off Cabras Island consisted of a narrow and wave-exposed limestone pavement (0.6 m deep), a reef margin, and a reef slope. Very few corals and little coral cover were on the limestone pavement (less than 0.3% coral cover), and coral cover on the reef margin was minute (0 to 1.1% coral cover). Coral genera on the limestone pavement included *Porites* and *Pocillopora*. On the reef margin were more coral genera including *Goniastrea*, *Pocillopora*, *Acropora*, *Porites*, and *Favites*. Coral cover on the reef front (5 m water depth) ranged from 10 to 22%, and was mostly composed of *Pocillopora*, *Goniastrea*, *Acropora*, *Millepora*, and *Montipora*. The Piti Reef was located seaward of the Tepungan Channel along the Piti shoreline. Five physiographic zones were on the Piti Reef: the inner reef moat (approximately 50 m wide and 1 m deep), the outer reef moat (approximately 150 m wide and 1.3 m deep), the outer reef flat (approximately 60 m wide and less than 1 m deep), the reef margin (approximately 50 m wide and exposed at low tide), and the reef front slope (approximately 50 m wide and 5 m deep). Coral cover at Piti Reef ranged from 0.2 to 20%, with coral cover greatest on the outer reef flat (20%) and the reef margin (12%). The exposed outer reef flat and the inner reef flat had the least amount of coral cover (0.2% and 0.4%, respectively). Corals on the outer reef flat were of the genera *Porites*, *Acropora*, *Pocillopora*, and *Millepora*. On the reef margin and reef front, the predominant coral genera were *Pocillopora*, *Acropora*, and *Montipora*. The little coral cover on the inner reef flat was composed of *Porites*, *Pocillopora*, and *Leptastrea,* and on the outer reef flat, coral cover was composed of *Porites* and *Goniastrea* corals (Randall et al. 1982). As mentioned earlier, many environmental changes have occurred in Guam since the 1908-1981 Randall et al. survey. An update is needed on the status of the coral populations of the Luminao Barrier Reef on the seaward side of Glass Breakwater, the fringing reef on the seaward side of Cabras Island, and the fringing reef east of Cabras Island.

***Haputo Ecological Reserve Area*.** The Haputo Ecological Reserve Area is located along the northwestern karstic coast of Guam, between Haputo Beach and an area located approximately 840 m north of Double Reef (Pugua Patch Reef). The marine portion of the Haputo Ecological Reserve Area covers a 29-ha area (Pacific Division Naval Facilities Engineering Command 1986). Live coral covered 34% of the benthic habitat at Haputo Ecological Reserve Area (National Oceanic and Atmospheric Administration 2009b). Macroalgae and coralline algae covered 7% and 2% of the benthic habitat, respectively. The remaining benthic habitat was unclassified or uncolonized. The following information on the Haputo Ecological Reserve Area marine community is taken from Amesbury et al. (2001).

The Haputo Ecological Reserve Area coastline is characterized by narrow supratidal, exposed benches (less than 5 m wide, raised 0.5 to 1.5 m above sea level) alternating with vertical cliffs. Six main macrohabitats support corals in the Haputo Ecological Reserve Area within the 1- to 18-m water depth range: exposed benches, protected reef flats, Double Reef Top, the back reef, the shallow fore reef, and the deep fore reef. Macrohabitats on the fore reef (1 to 18 m in depth) support more diverse assemblages of corals, macroinvertebrates, and fish than do the three shallow macrohabitats. Corals, however, are most diverse in shallow water on Double Reef. Coral cover was found to range from 37 to 64% in the Haputo Ecological Reserve Area. Coral cover was higher along transects taken at an 8-m depth than along transects taken at 15 m; coral species with the highest coverage in the Haputo Ecological Reserve Area include *Porites* (deep area), *Montipora* (shallow area), and *Leptastrea*.

Amesbury et al. (2001) found 21% of the known marine fauna of Guam within the Haputo Ecological Reserve Area. These organisms consisted of 154 species of corals, 583 species of other macroinvertebrates (>1 cm), and 204 species of fish. The 154 coral species found in the Haputo Ecological Reserve Area correspond to approximately 60% of the coral species known on Guam, and the 204 fish species correspond to 22% of the fish known on Guam. The marine portion of the Haputo Ecological Reserve Area is therefore an area of relatively high biodiversity; yet, because of overfishing, the fishes in the Haputo Ecological Reserve Area are not very diverse or abundant.

Shallow splash pools found on the exposed benches support low diversities of corals, fishes, and cryptic organisms. Shoreward of the benches and at the base of the cliffs are erosional notches created by wave action on the rock face where habitat-specific species of limpets, chitons, slugs, and shore crabs can be found. The seaward edge of the benches is a steep subtidal face, typically burrowed by echinoids, that supports corals, macroinvertebrates, and fishes.

Protected reef flats (fringing reefs) off Haputo Beach and shoreward of Double Reef are intertidal habitats supporting few species of corals (including *Pavona divaricata*), hermit crabs, crabs, sea slugs, and sea cucumbers that can withstand the rigors of an exposed habitat. Corals and fishes are more common and diverse at the seaward margin of these reef flats.

The Double Reef Top is a reef front environment that supports healthy corals and high coral cover (>75%) consisting of *Acropora valida*, *A. digitifera*, and *Pocillopora* species. The exposed limestone pavement has been honeycombed by echinoids.

The shallow fore reef substrate within the Haputo Ecological Reserve Area includes a steep reef front and gently sloping fore reef starting at a 4- to 8-m water depth. Numerous cuts and channels normal to the shoreline run through the fore reef and create abundant structural complexity. The highest coral cover (54 coral species) within the Haputo Ecological Reserve Area is found between these cuts and channels. Amesbury et al. (2001) recorded three new sponges for Guam in this macrohabitat (*Neofibularia hartmani*, "yellow tough sponge," and "puff sponge"). Branching corals (*Acropora*, *Pocillopora*) dominate the 1- to 3-m depth range on the fore reef. Coral composition within the 4- to 9-m depth range varies within the Haputo Ecological Reserve Area, including several areas dominated by encrusting species of *Montipora,* while other areas are dominated by the massive *Porites*. The reef front off Haputo Beach contains very large corals of diverse faviid species (>0.5 m diameter)—distinguishing it from other locations of Guam where abundant large massive corals are largely *Porites*. Coral cover on this reef front exceeds 80%, consisting of faviid, mussid, and poritid species (*Leptoia phrygia*, *Goniastrea* spp., *Platygyra* spp., *Favia stelligera*, *Lobophyllia hemprichii*, and *Porites* spp.). Because this area contains slow growing coral heads that are healthy and large, Amesbury et al. (2001) believe that this site withstood the pressures of predation by *A. planci* and physical damage by storms.

On the deep fore reef (9- to 18-m depth range), Amesbury et al. (2001) found 52 species of corals, a species richness comparable to that found on the shallow fore reef. The coral community on the deep fore reef is healthy and *Porites*-dominated. Two faviids rare on Guam, *Favia helianthoides* and *Favia maritima*, are common along the deep fore reef. The soft corals *Sinularia leptoclados, S. racemosa, Lobophytum batarum,* and *Sarcophyton trocheliophorum* are also common on the reef slope.

The back reef to the east and south of Double Reef supports branching, platy, and massive corals, including *Acropora palifera*, *Acropora acuminata, P. rus*, and *Porites* spp. (>2 m diameter). The soft coral

Asterospicularia randalli is common and very abundant in this region of the reef. Dead coral skeleton is evidence of recent coral mortality that has affected the back reef (Amesbury et al. 2001).

***Guam National Wildlife Refuge: Ritidian Unit*.** The Ritidian unit on the northern shore of Guam between Tarague Cave and the Tarague Channel is bordered by a nearshore narrow fringing reef made of coralline algae (National Oceanic and Atmospheric Administration 2005a). Landward of the fringing reef are a reef flat primarily populated by macroalgae and an intertidal area colonized by seagrass. Seaward of the fringing reef is a fore reef colonized by corals (10 to 50% cover) (National Oceanic and Atmospheric Administration 2005a). Live coral covers 9% of the benthic habitat at Piti Bomb Holes Marine Preserve (National Oceanic and Atmospheric Administration 2009b). Macroalgae, coralline algae, and turf algae cover 19%, 19%, and 4% of the benthic habitat, respectively. The remaining benthic habitat was unclassified.

***Orote Peninsula Ecological Reserve Area*.** The Orote Peninsula Ecological Reserve Area is located at the western end of Guam (Figure 11-27). The benthic habitat was dominated by turf algae (National Oceanic and Atmospheric Administration 2009b). The following is a description of the coral and reef communities found within the Orote peninsula based on Paulay et al. (2001).

The Orote Peninsula Ecological Reserve Area is characterized by steep karstic cliffs plunging abruptly onto a steep fore reef macrohabitat. Erosional processes and seismic events detached large boulders from the karstic cliffs and land on the fore reef. Strong currents run along this area of the Guam coastline. Paulay et al. (2001) identified four macrohabitats in this area: the Orote Point fringing reef, the Orote cliff reef, the Orote reef slope, and the Orote dropoff.

The Orote Point fringing reef is located between the tip of the Orote peninsula and Orote Island. Two fringing reefs are present, one facing the southwestern tip of Apra Harbor and the other facing the southern coast of the Orote peninsula. Corals that populate these fringing reefs are more Apra Harbor-like to the north end of the reef and more Orote-like toward the southern end. The northern and middle parts of the reef support high coral cover composed mainly of *P. rus* and *P. cylindrica*. Corals on the southern end consist of *Acropora valida*, *A. digitifera*, and *Galaxea fascicularis*.

The Orote cliff reef was surveyed on the southern face of Orote peninsula. The fore reef slope of the cliff reef is the continuation of the cliff face. At sea level, wave action has undercut notches and caverns into the cliff, and at the base are accumulations of large boulders originating from the cliff. The cliff reef substrate is highly bioeroded by boring echinoids (*Echinometra*), and a low diversity of corals in this macrohabitat includes primarily *Montipora*, *Pocillopora*, and *Millepora platyphylla*.

The Orote Point reef slope (from Spanish Steps to western tip of Orote Island) is characterized by higher coral diversity and higher fish biomass and diversity than at most locations on Guam. The western tip of Orote Island has high wave energy. The eastern end of the Orote Point reef slope abuts the Apra Harbor southern reef slope. West of the *P. rus*-dominated Apra Harbor, the Orote Point reef slope is more diverse and includes 19 species of corals. The reef slope is heavily bioeroded ("deeply honeycombed") and supports a diverse cryptofauna (including shrimp, lobster, and crab) and abundant crinoids. Sharks, tuna, groupers, snappers, parrotfish, and emperors are abundant at this location. In total, 53 species of fishes were recorded on the Orote Point reef slope.

Paulay et al. (2001) defined the Orote reef slope as a depth zone between the Orote cliff reef and the Orote dropoff. This is the largest macrohabitat of the Orote Peninsula Ecological Reserve Area. The limestone pavement of Orote reef slope has a gentle slope, is barren, and supports a low diversity biota

including clumped macroalgae, corals (*Montipora foveolata*, *Leptastrea*, *Astreopora*, and *Pocillopora*), and the large boring sponge *Spirastrella vagabunda*. Yet, three microhabitats there support unusual biota: boulder fields, rubble fields, and the Blue Hole.

Boulders detached from and clustered along cliffs provide habitat for highly diverse reef communities. Individual boulders are up to 15 m in diameter. Large clusters of boulders located off Neye Island, Apuntua Point, and Barracuda Rock support higher coral diversity and higher fish diversity and biomass than do typical locations of Guam, and support many soft corals rarely observed on Guam. In this microhabitat, Paulay et al. (2001) found the largest population of *Plerogyra sinuosa* (bubble coral) on Guam, and recorded the only sighting of *Madracis kirbyi* on Guam.

The fore reef on the western half of the Orote peninsula is covered with large areas of rubble (10 to 100 cm in size). The rubble fields contain diverse cryptofauna including a new species of lobster (*Paraxiopsis* sp.), a new species of a swimming crab (*Carupa* sp.), a rare crab (*Aethra edentata*), the only reported occurrence of a spider crab (*Acheus lacertosus*), and many species of pagurid hermit crabs.

The other microhabitat on the reef slope is the Blue Hole, a cave formed during low sea stands. The bottom of the cave is 91 m deep, with a collapsed roof at 18 m and a “window” at 37 m. The Blue Hole is the most popular dive spot on Guam. This cave contains sessile species and fishes known only at this location on Guam. The cave contains the gorgonians *Viminella* sp., *Keroides* sp., *Heliania spiniescens*, and *Briareum excavatum,* which have been observed only around the lip of the cave and on the Orote dropoff (Paulay et al. 2001). Other significant observations include the undescribed minute false oyster (*Dimyella* sp.) and an undescribed hard coral (*Leptoseris* sp.).

The Orote dropoff on the southwestern margin of the Orote peninsula is a steep vertical face that begins at 25 to 35 m and extends down to >100 m. This region of the reef is exposed to strong currents, and large gorgonians and black corals can be found on the reef face (*Annella mollis*, *Annella reticulata*, *Astrogorgia* sp., *Subergorgia suberosa*, *Antipathes* sp., and *Cirripathes* sp.). The rare encrusting gorgonian *B. excavatum* and the hard coral *Favia rotumana* inhabit the dropoff.

***Agat Bay*.** Agat Bay is located at the western end of Guam. Paulay et al. (2001) recently surveyed coral reefs from Orote Point to the northern half of Agat Bay. This survey obtained information on the reefs specific to the MRA Study Area, i.e., the coastal area between Togcha Beach and Apuntua Point (Agat Bay area).

A silty sand plain in the middle of Agat Bay lies beneath water depths ranging from 5 to 30 m (National Oceanic and Atmospheric Administration 2005a; Paulay et al. 2001). Sand channels and reef substrate interdigitate with patch reefs and reef substrate rising more than 2 m above the sand channels. At depth of 30 m, few patch reefs are found on the dominant sand cover. The epifauna on the sand substrate has low diversity.

The reef flat from Tipalao Bay through Dadi Beach includes silty intertidal and nearshore areas covered with macroalgae and some seagrass. Paulay et al. (2001) found that the silt cover and macroalgae and seagrass cover decreased with increasing distance from shore. Meanwhile, the diversity of corals, macroinvertebrates, and fish increased directly with distance from shore. Corals along the inner reef flat include *Porites australiensis*, *Porites lutea*, and *Leptastrea purpurea*. The coral assemblage along the outer reef flat is more diverse than along the inner reef flat, and includes *Pocillopora damicornis*, *Acropora valida*, *Acropora abrotanoides*, *Pavona venosa*, and a new record for Guam, *Pavona bipartita*.

The reef flat between Neye Island and the main island is swept by strong currents and is less subject to siltation, making it suitable to support a high biodiversity of marine fauna. Coral cover is dominated by large *Porites* microatolls and 11 *Acropora* species. Algal cover is low, while coralline algae cover is high; 34 species of echinoderms have been identified.

CAROLINE ISLANDS

Yap. Coral reef areas of Yap are privately owned in a traditional marine tenurial system (George et al. 2008). Approximately 215 coral species have been recorded. Coral reef monitoring data are limited. *Porites lobata* occurs at 1.5 m depth off the eastern central shore of Yap near the Ruul Causeway at Tamil Harbor, to the north at Tamil and south of Ruul (Downs et al. 2006).

Palau. The Republic of Palau has some of the most biologically diverse and best-preserved coral reefs in the Indo-Pacific (Golbuu et al. 2005; Maragos and Cook 1995; Poonian, Davis, and McNaughton 2010). The most diverse coral assemblages and most popular dive sites are in the Rock Islands–Southern Lagoon Area (centered on 7.2 degrees N latitude) (Poonian, Davis, and McNaughton 2010).

Coral cover surveyed in four habitat types in Palau ranged from 20% to over 60% in 2005 (Golbuu et al. 2005). *Acropora digitifera* occurs at Lukes Reef and Porites cylindrica at Lighthouse Reef, both on the southeastern side of the main island (Golbuu et al. 2011). The distribution of coral on the western side of the island off the Ngermeduu estuary was shown to be greatly influenced by suspended solids concentrations, as coral abundance and diversity increased with distance from shore (Golbuu et al. 2011).

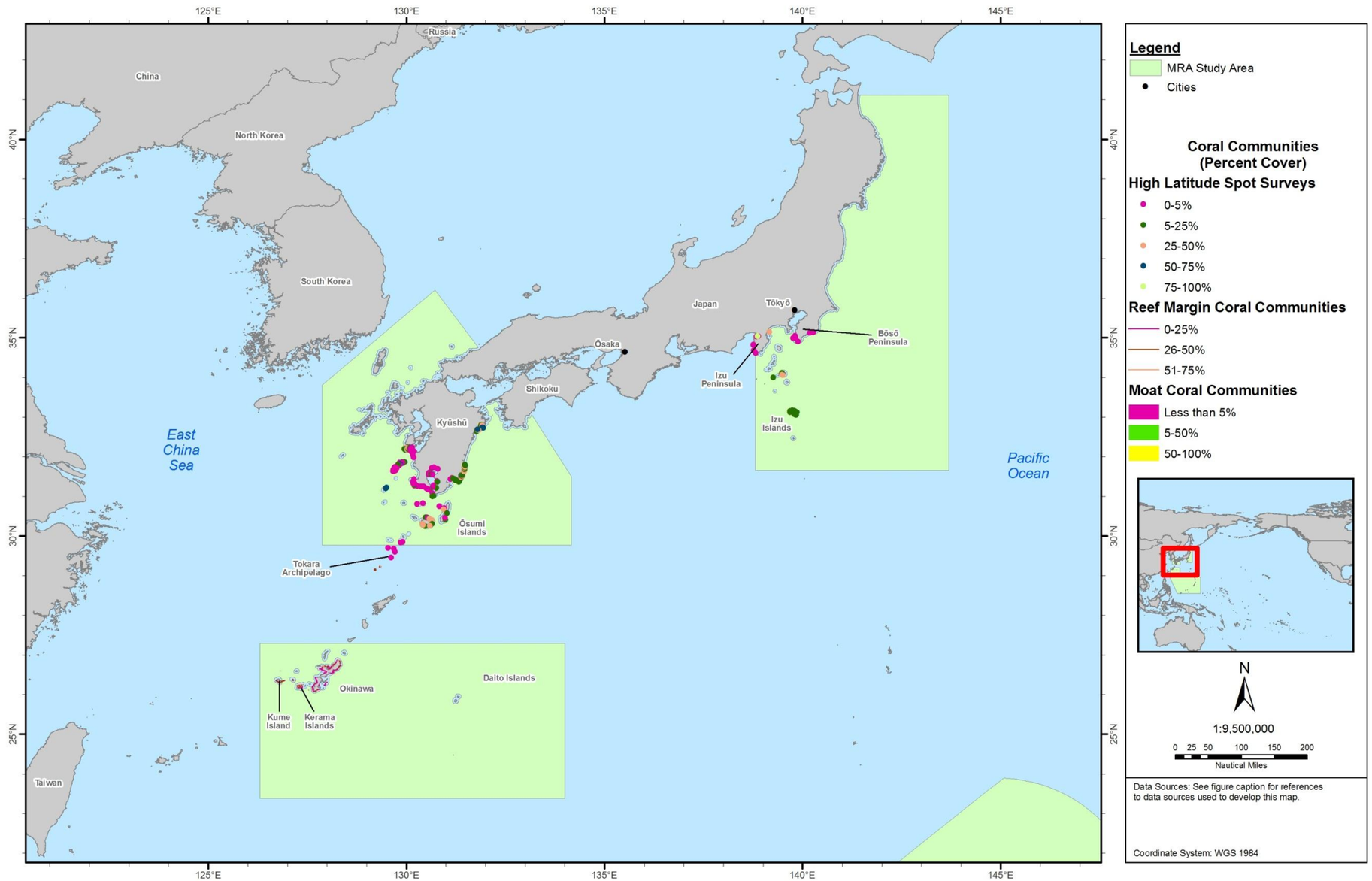

Figure 11-3: Live Cover of Coral Reef Habitats Around the Japan Archipelago
Source: U.S. Department of the Navy (2005a).

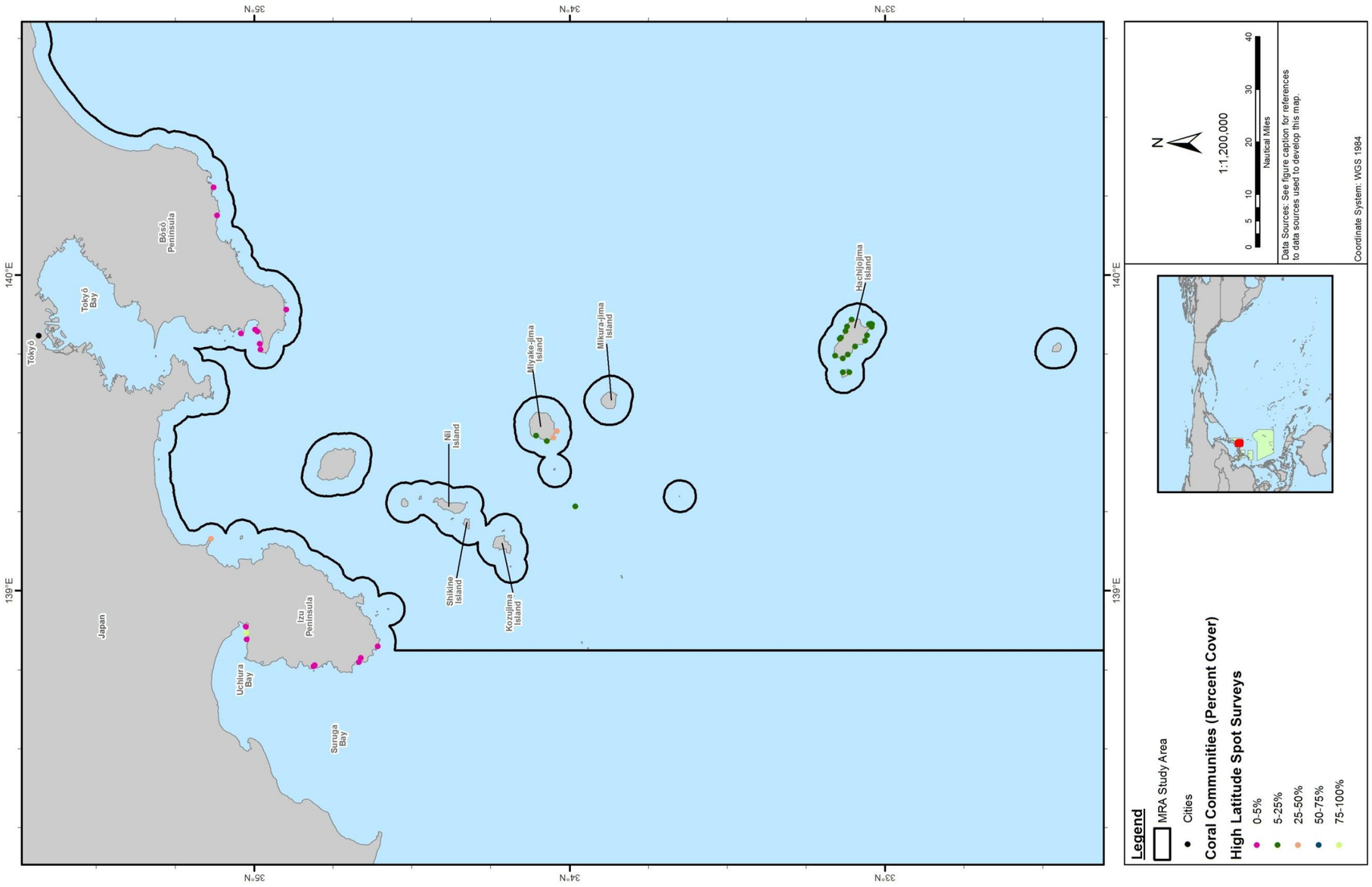

Figure 11-4: Live Cover of Coral Reef Habitats of the Izu Islands, Bōsō Peninsula, and Izu Peninsula
Source: U.S. Department of the Navy (2005a).

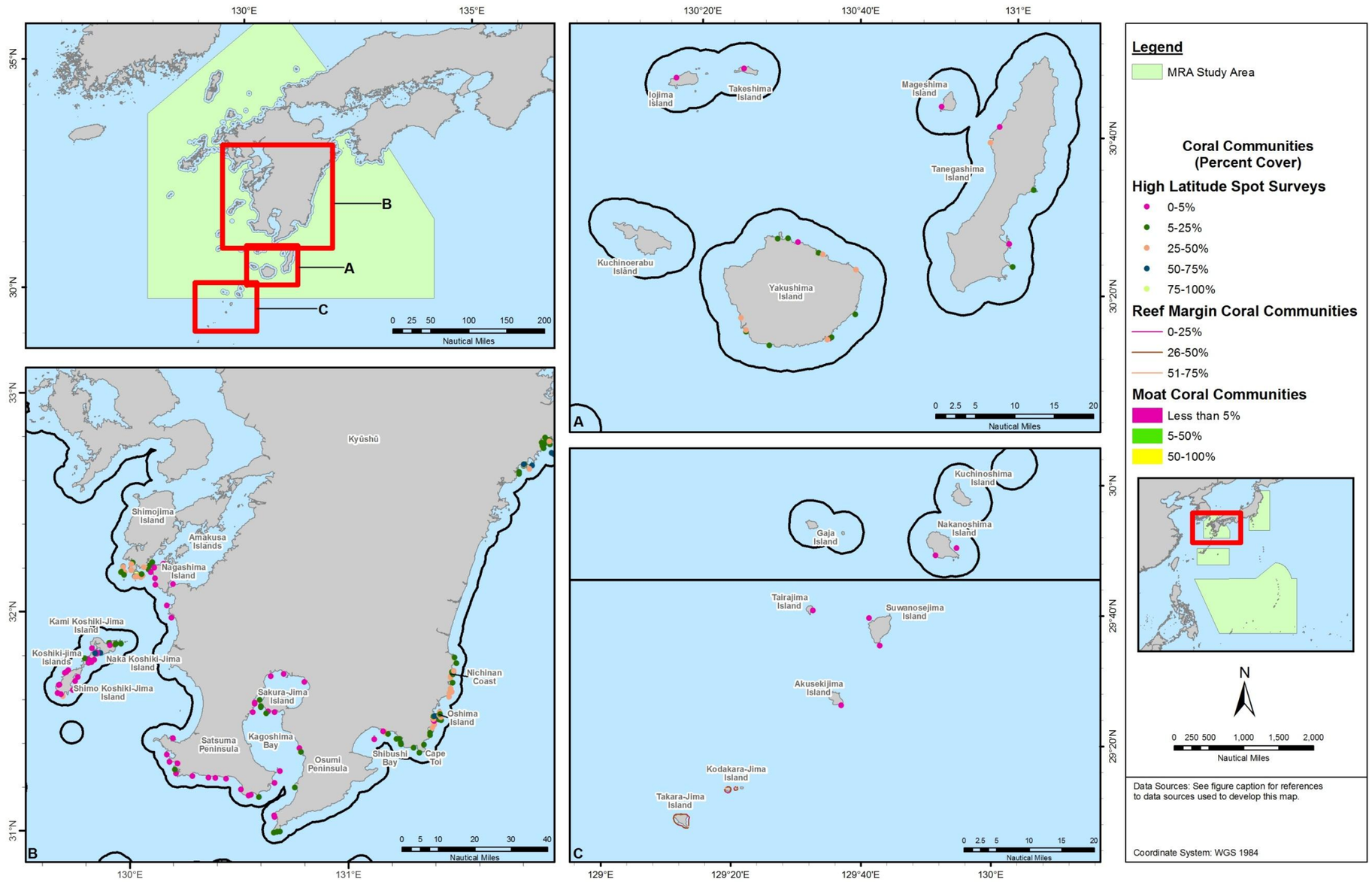

Figure 11-5: Live Cover of Coral Reef Habitats of the (A) Osumi Islands, (B) Kyūshū, and (C) the Tokara Islands
Source: U.S. Department of the Navy (2005a).

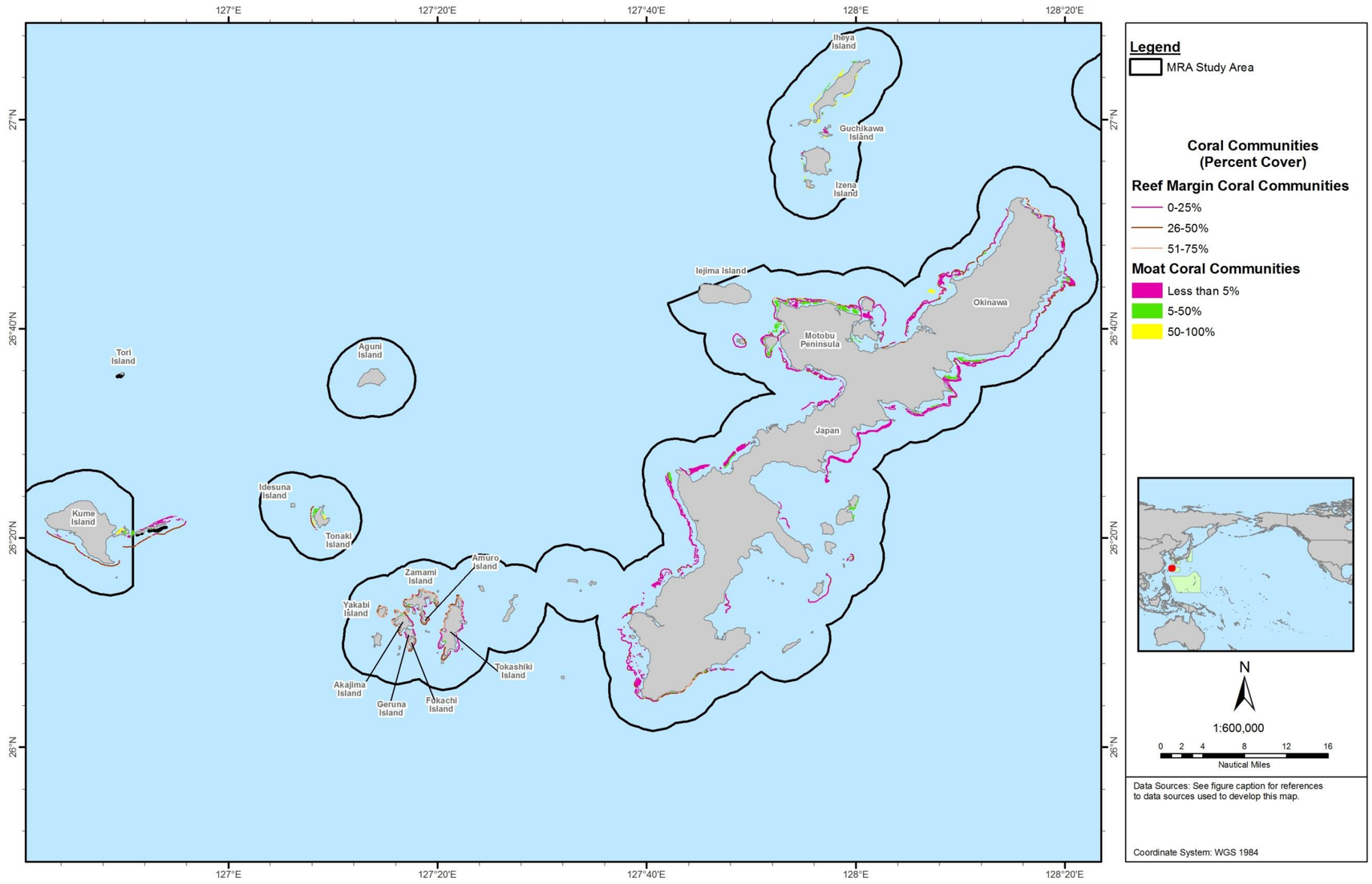

Figure 11-6: Live Cover of Coral Reef Habitats of the Okinawa Islands
Source: U.S. Department of the Navy (2005a).

Figure 11-7: Subtidal Reef Morphology of Pagan
Source: National Oceanic and Atmospheric Administration (2005b).

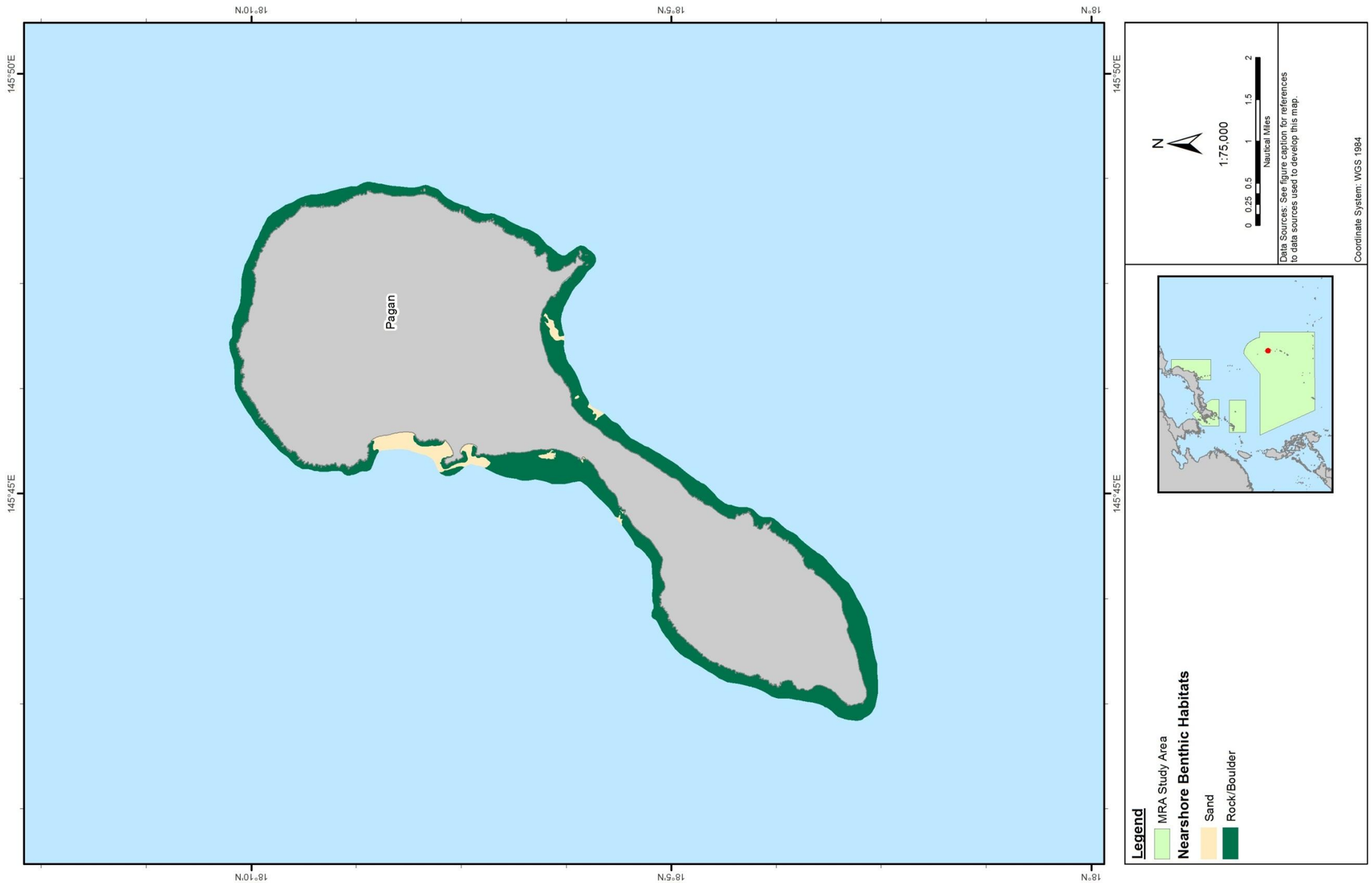

Figure 11-8: Benthic Substratum of Pagan
Source: National Oceanic and Atmospheric Administration (2005b).

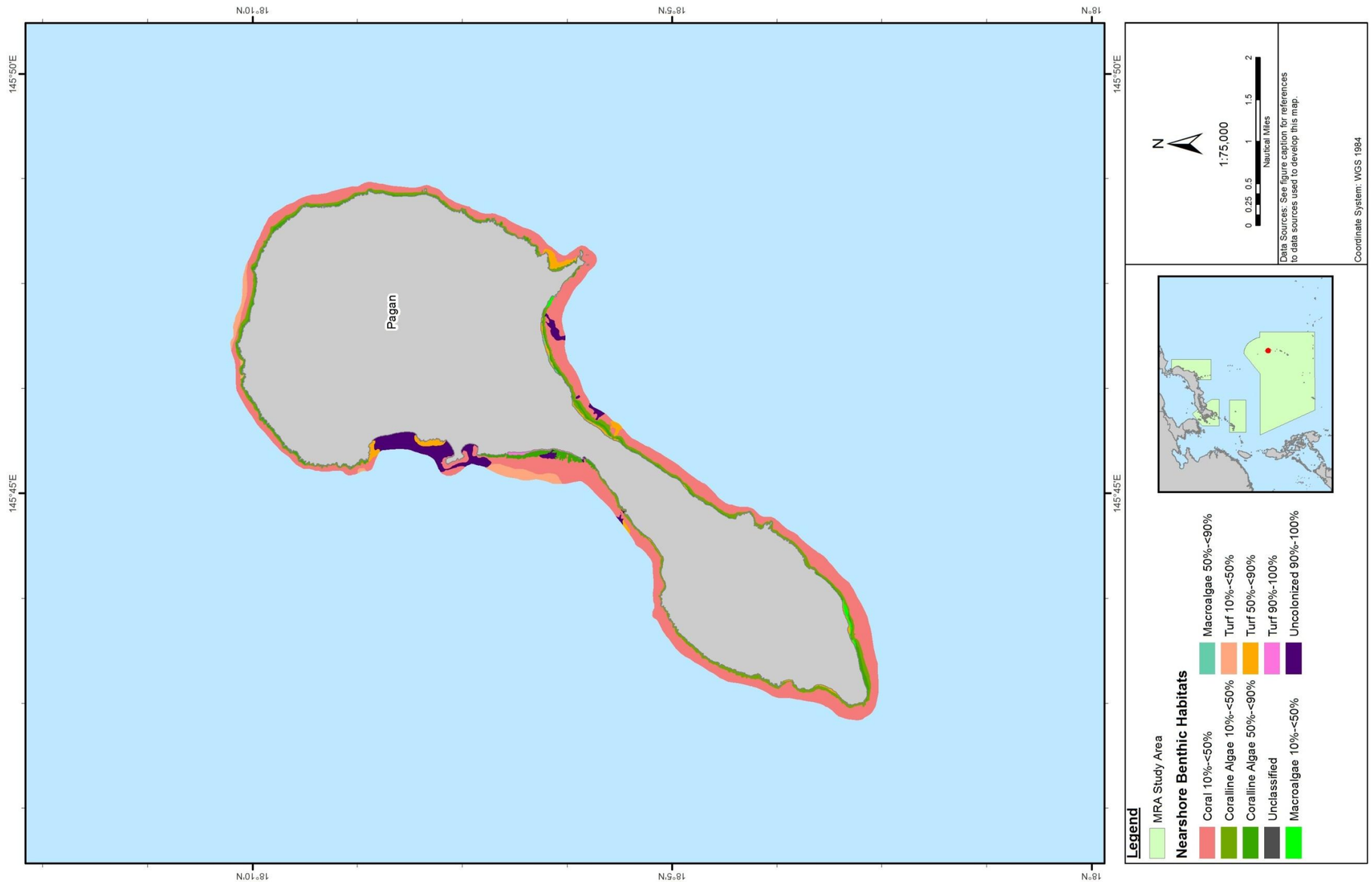

Figure 11-9: Live Cover of Coral Reef Habitats of Pagan
Source: National Oceanic and Atmospheric Administration (2005b).

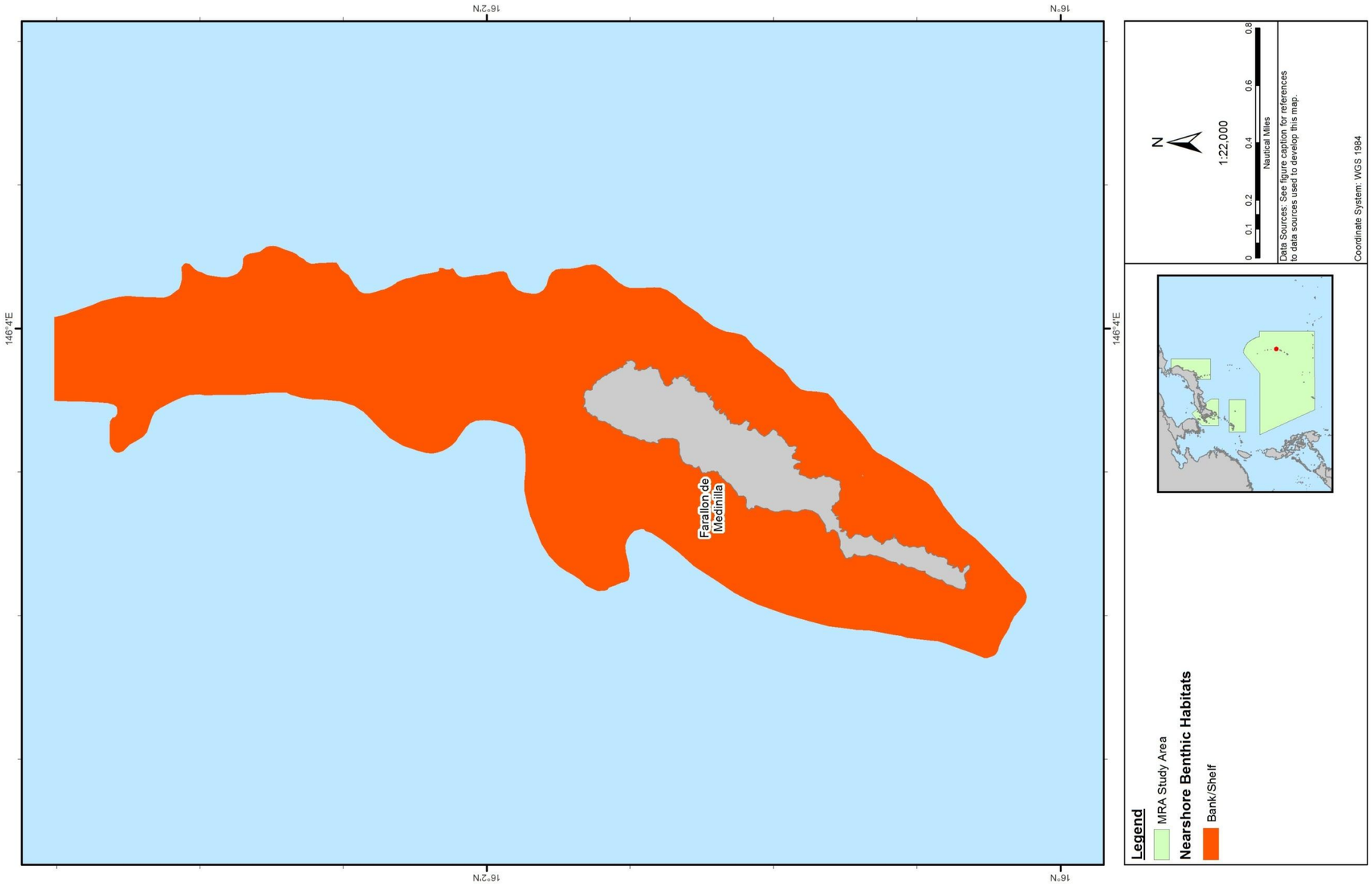

Figure 11-10: Subtidal Reef Morphology of Farallon de Medinilla
Source: National Oceanic and Atmospheric Administration (2005b).

Figure 11-11: Benthic Substratum of Farallon de Medinilla
Source: National Oceanic and Atmospheric Administration (2005b).

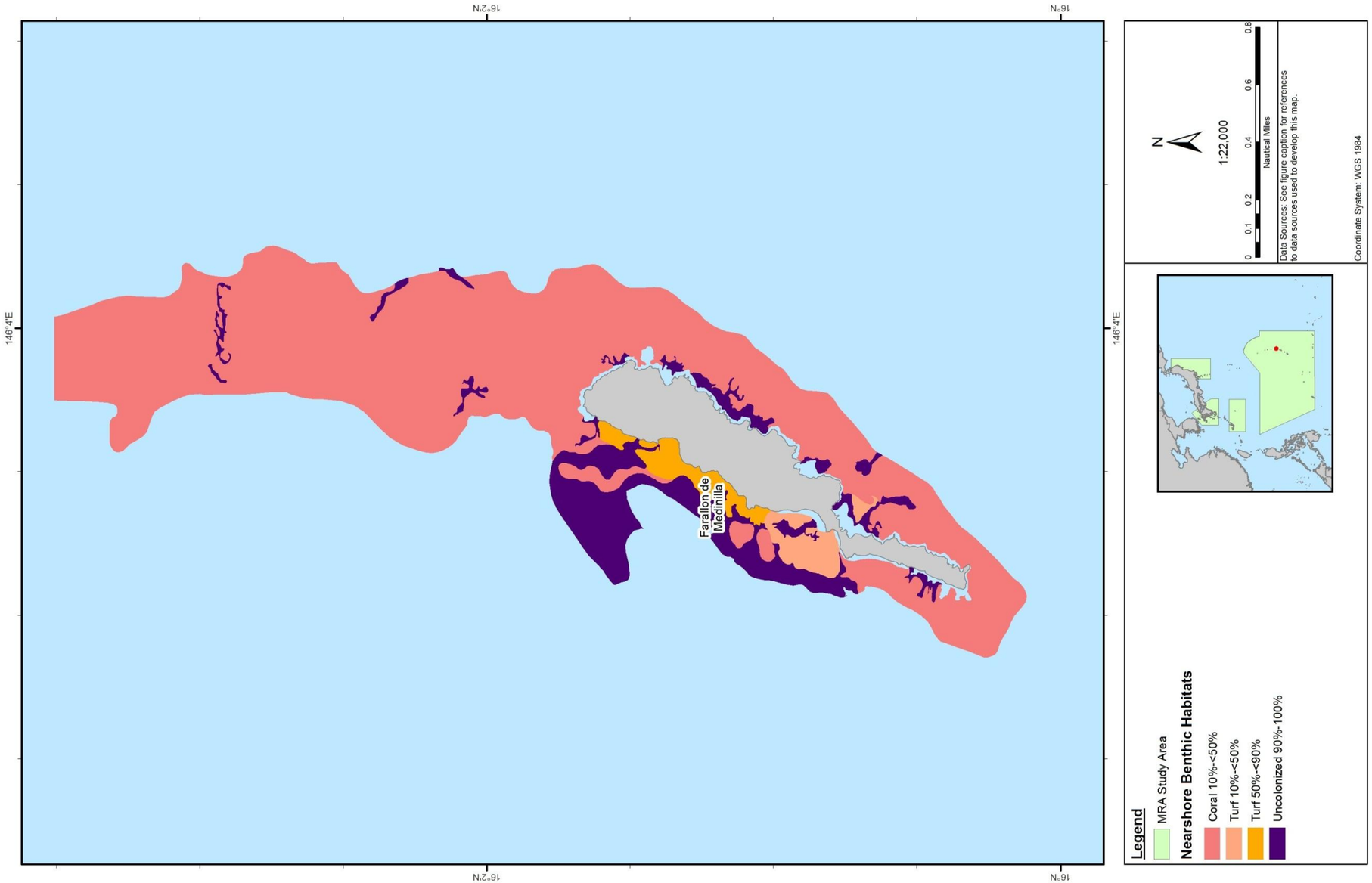

Figure 11-12: Live Cover of Coral Reef Habitats of Farallon de Medinilla
Source: National Oceanic and Atmospheric Administration (2005b).

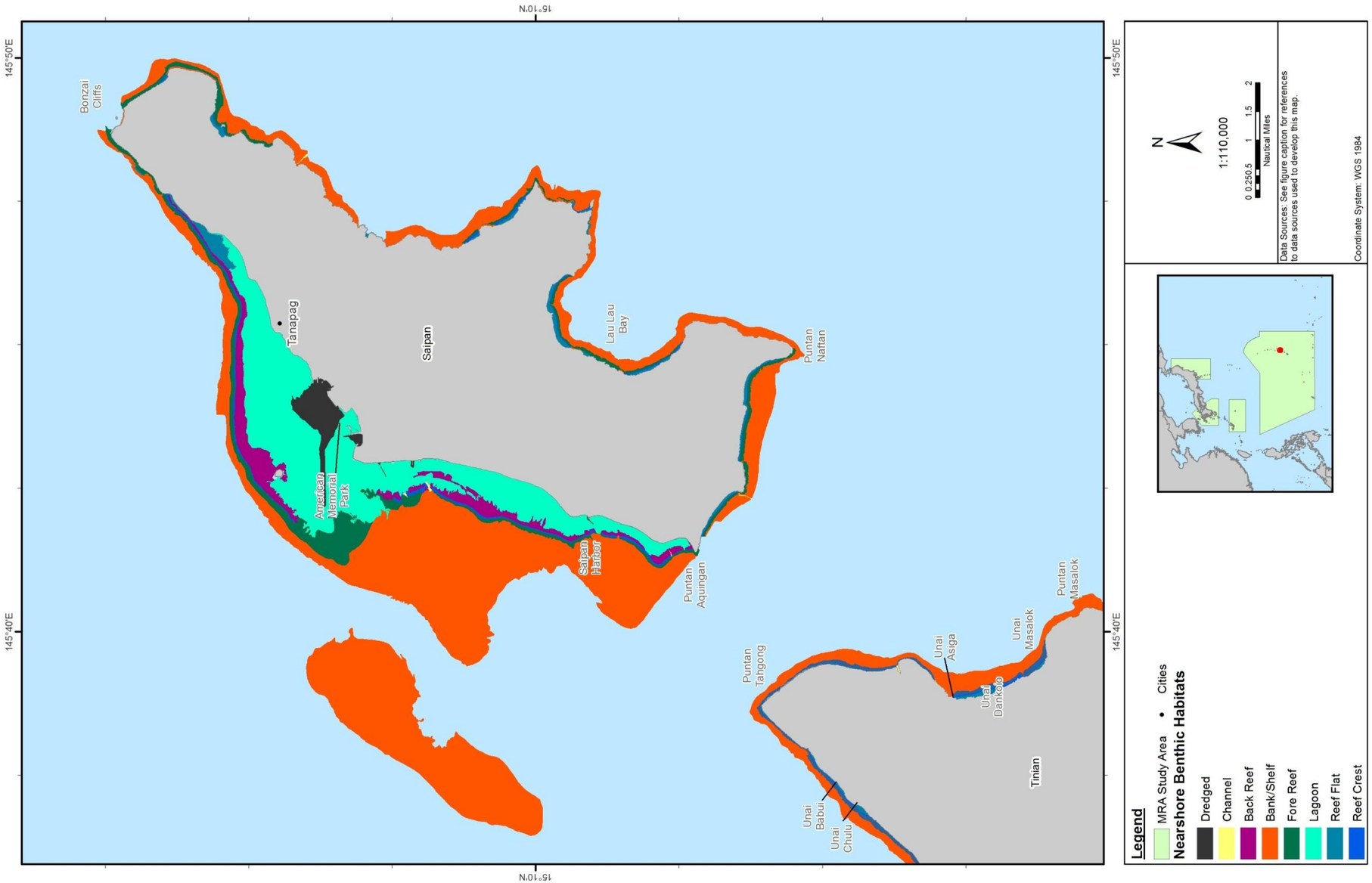

Figure 11-13: Subtidal Reef Morphology of Saipan and Northern Tinian
Source: National Oceanic and Atmospheric Administration (2005b).

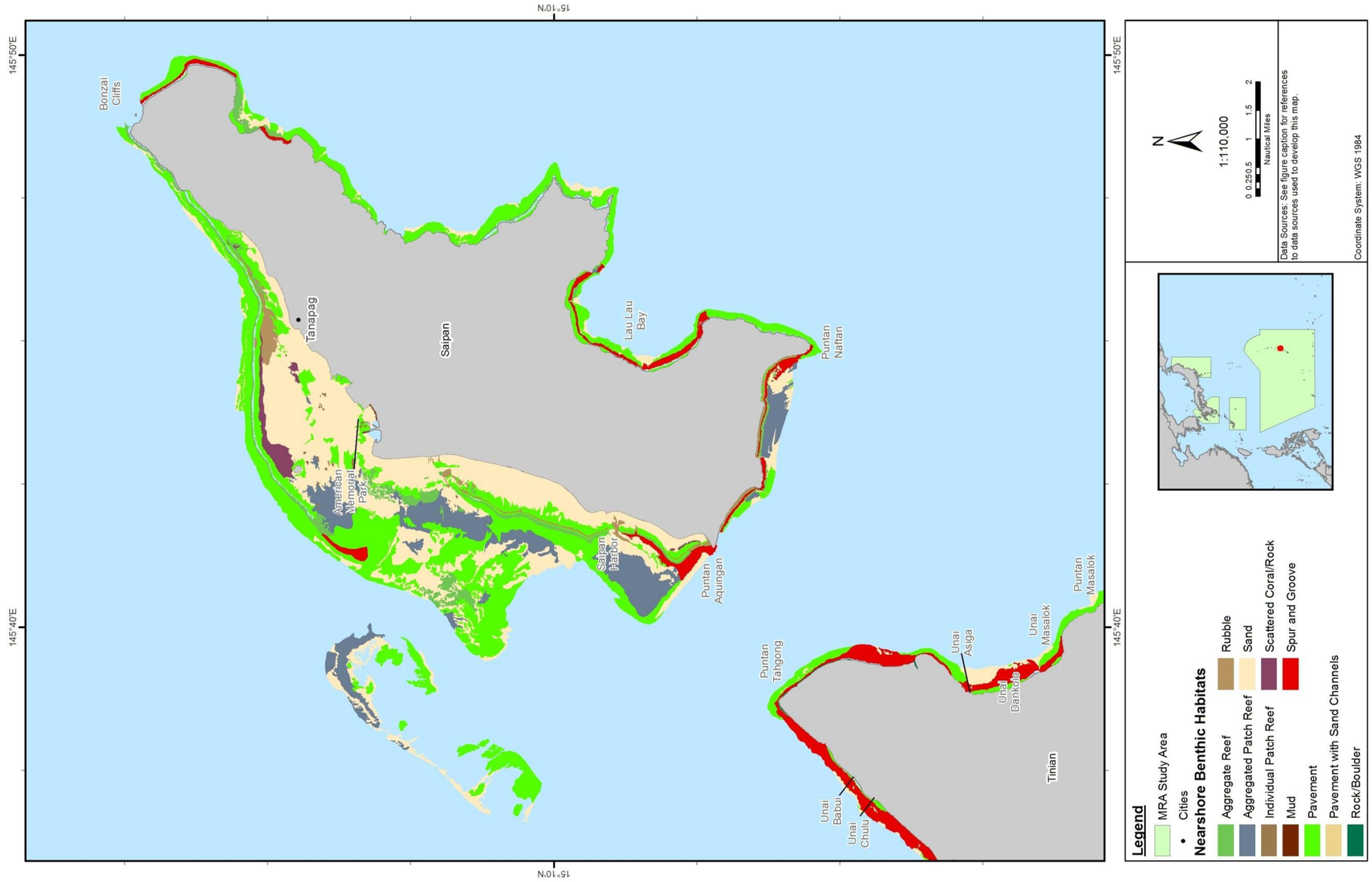

Figure 11-14: Benthic Substratum of Saipan and Northern Tinian
Source: National Oceanic and Atmospheric Administration (2005b).

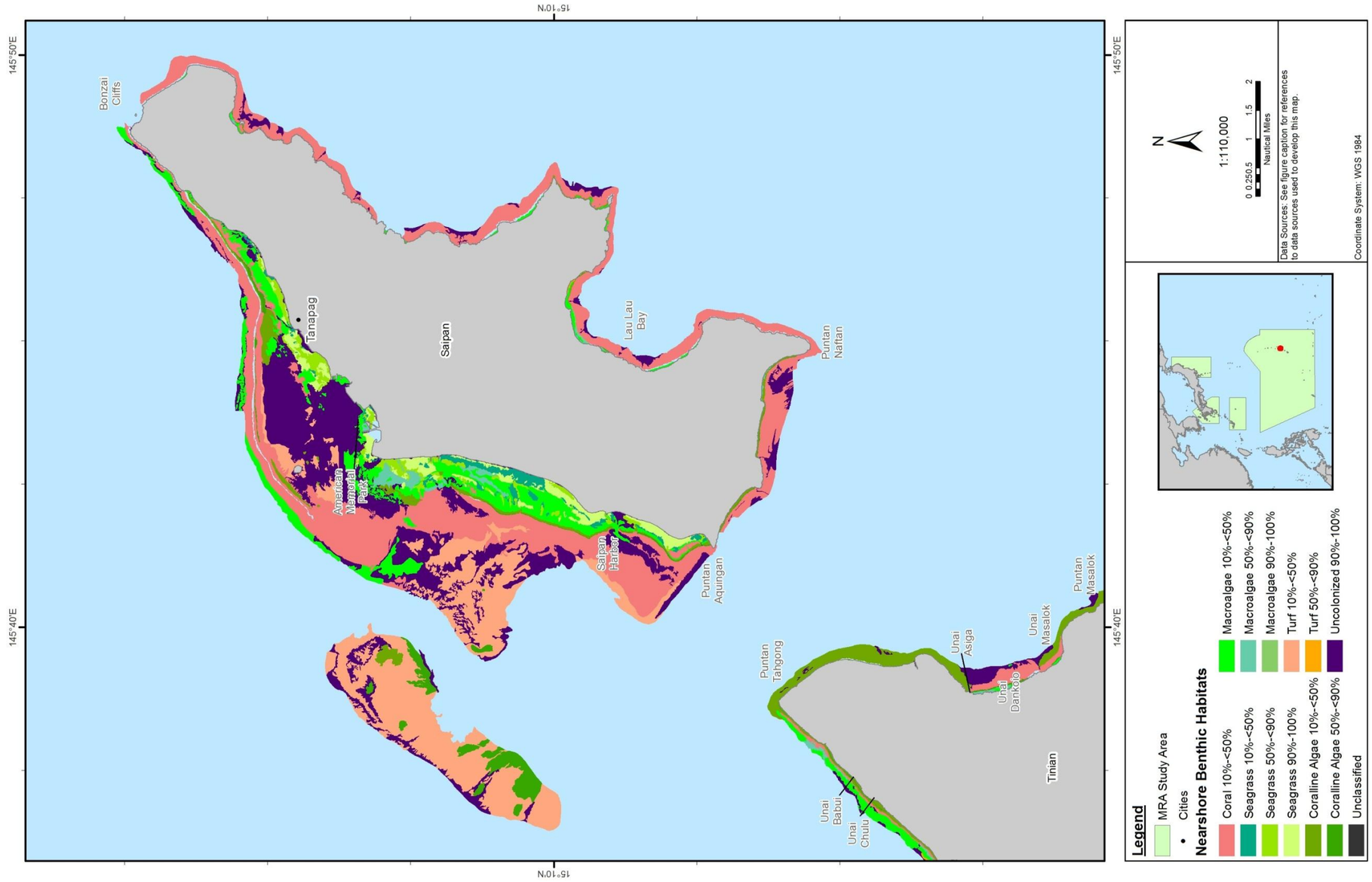

Figure 11-15: Live Cover of Coral Reef Habitats of Saipan and Northern Tinian
Source: National Oceanic and Atmospheric Administration (2005b).

Figure 11-16: Subtidal Reef Morphology of Tinian
Source: National Oceanic and Atmospheric Administration (2005b).

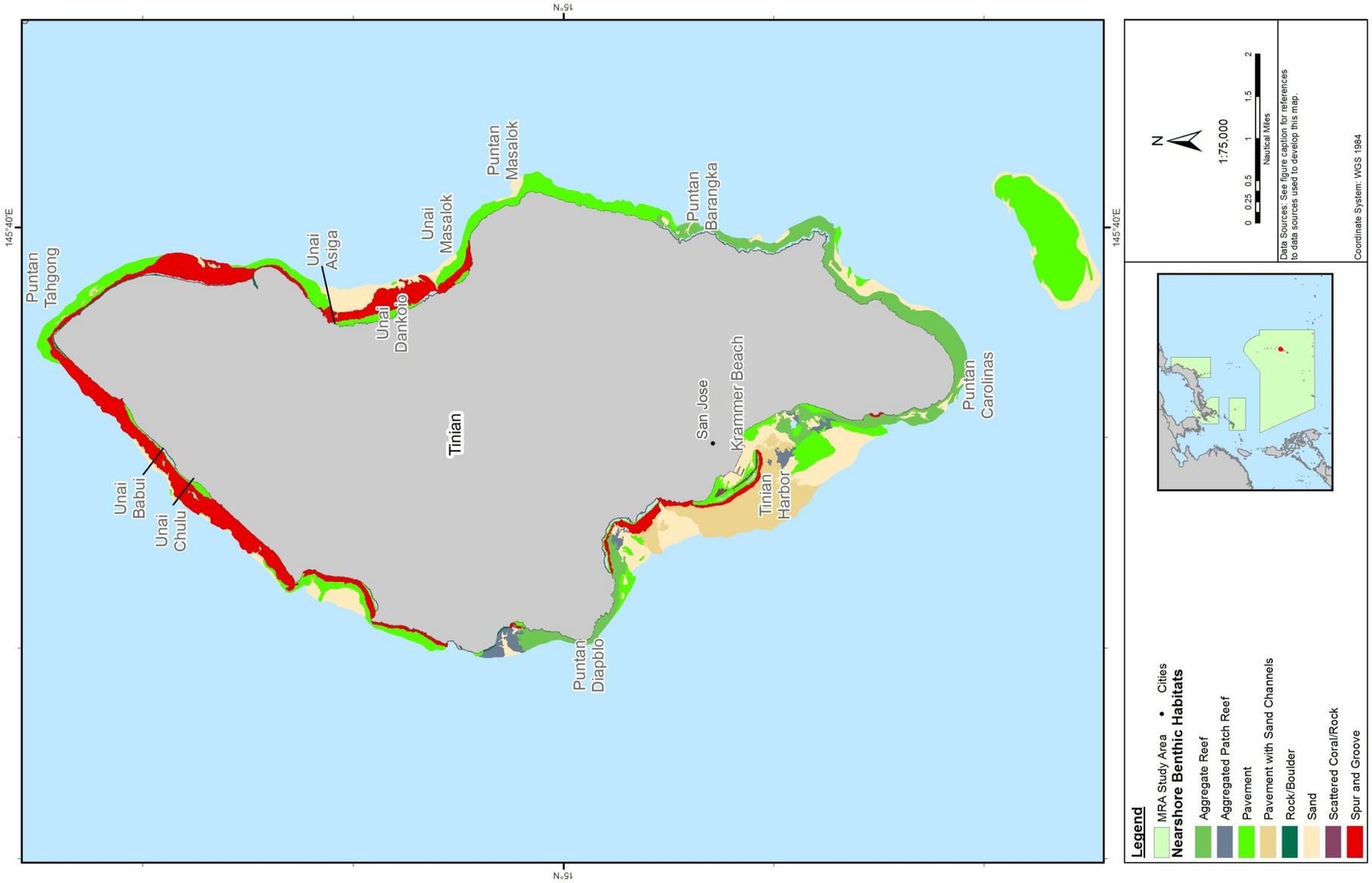

Figure 11-17: Benthic Substratum of Tinian
Source: National Oceanic and Atmospheric Administration (2005b).

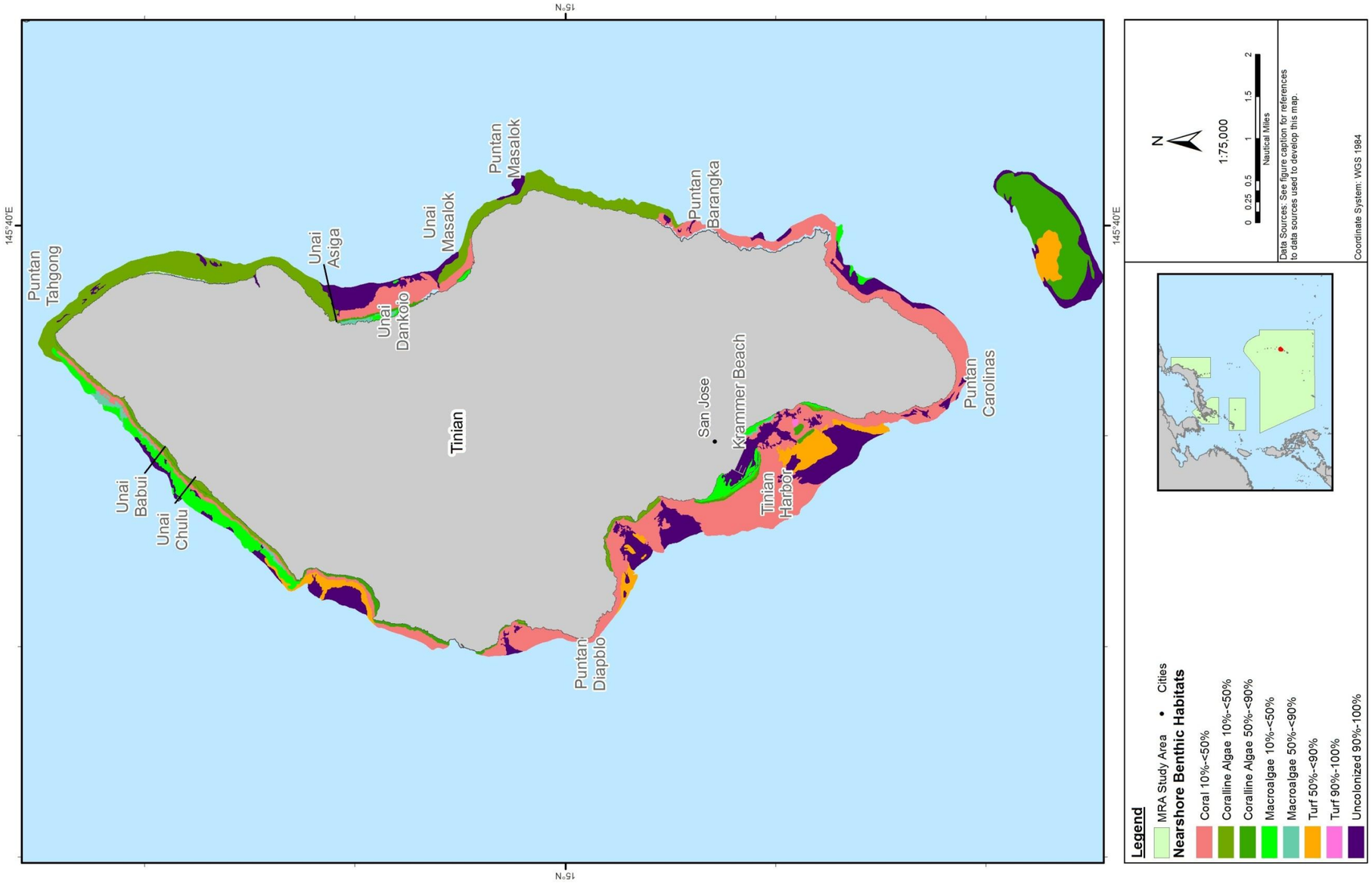

Figure 11-18: Live Cover of Coral Reef Habitats of Tinian
Source: National Oceanic and Atmospheric Administration (2005b).

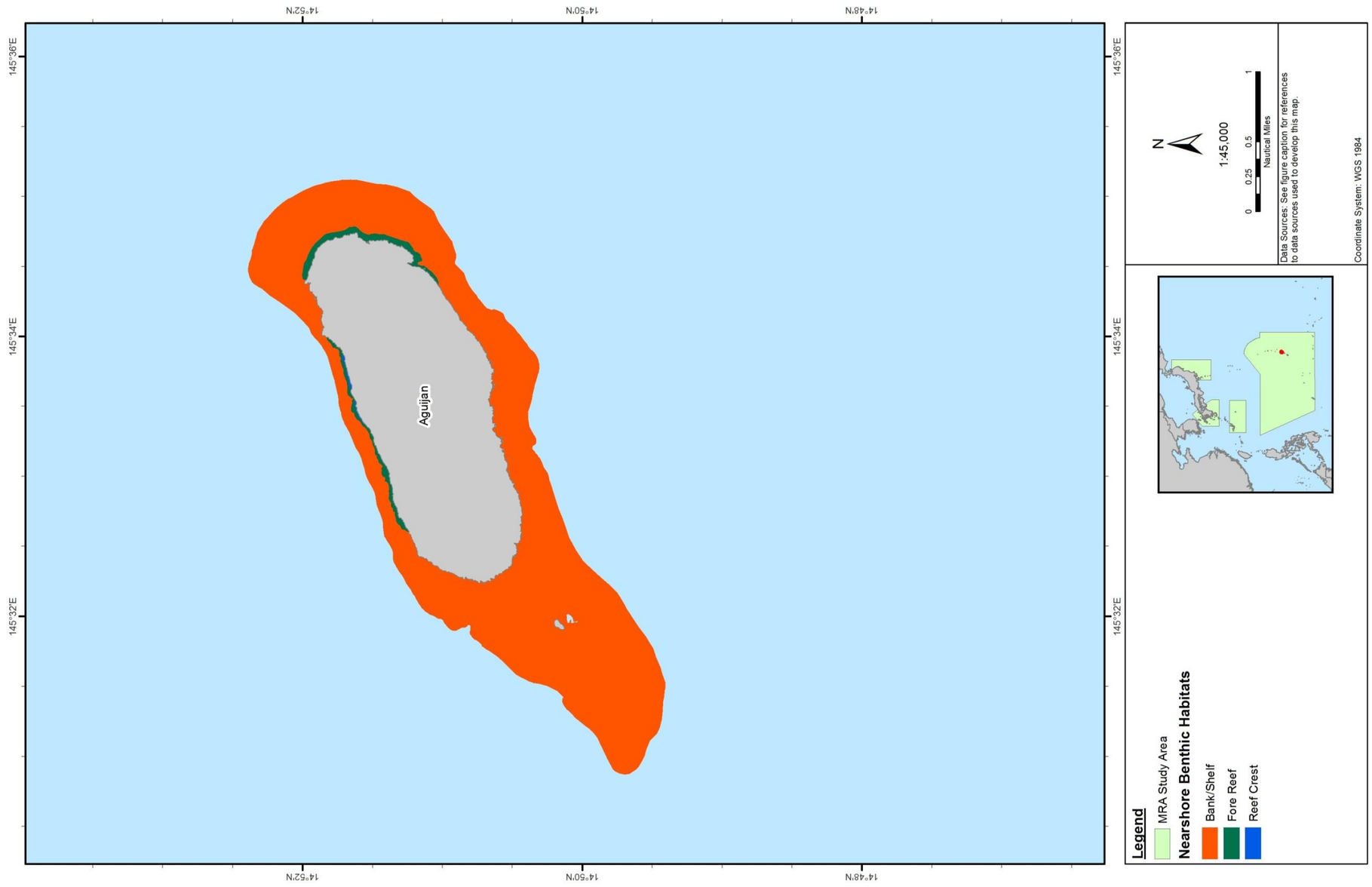

Figure 11-19: Subtidal Reef Morphology of Aguijan
Source: National Oceanic and Atmospheric Administration (2005b).

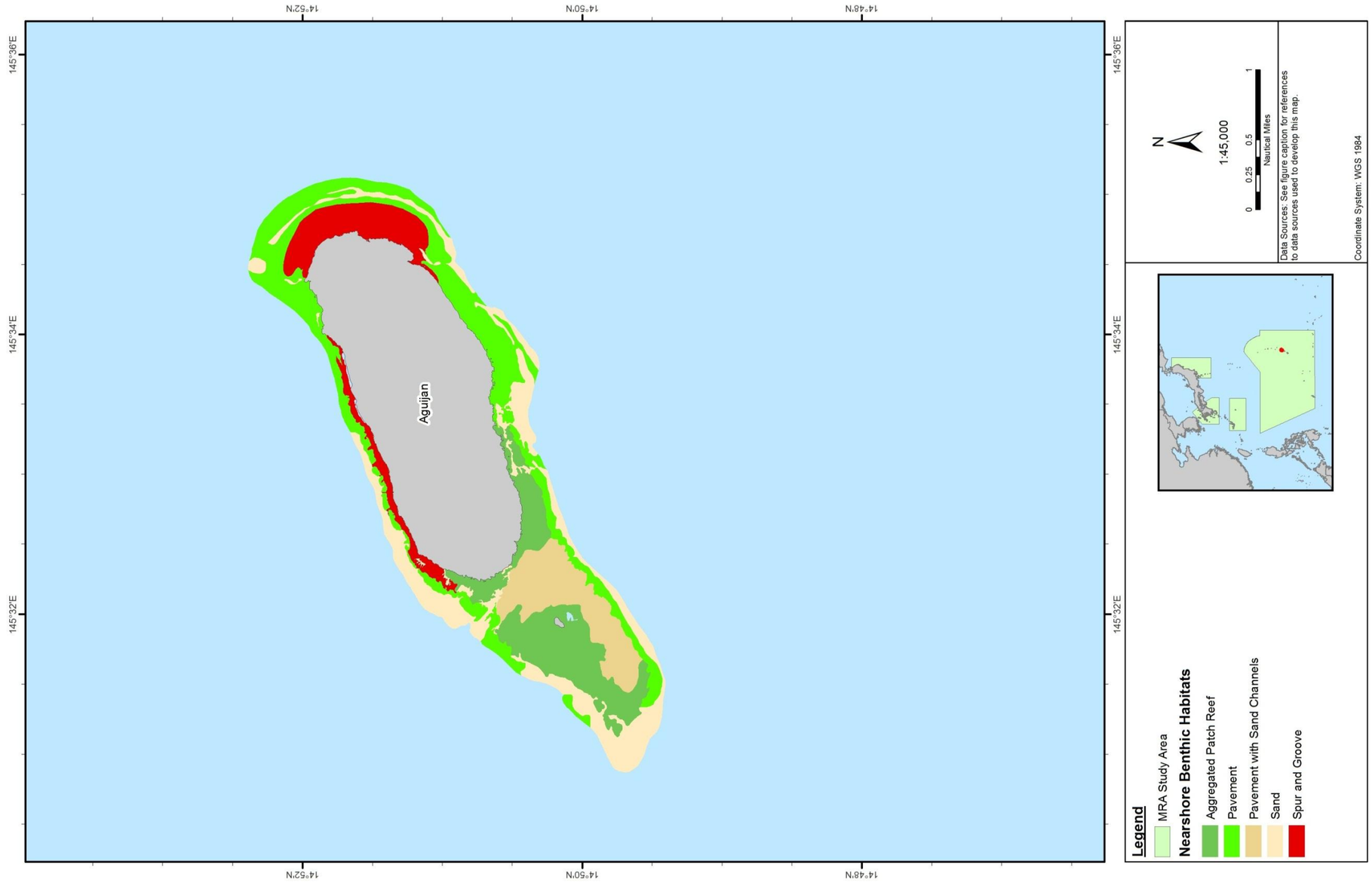

Figure 11-20: Benthic Substratum of Aguijan
Source: National Oceanic and Atmospheric Administration (2005b).

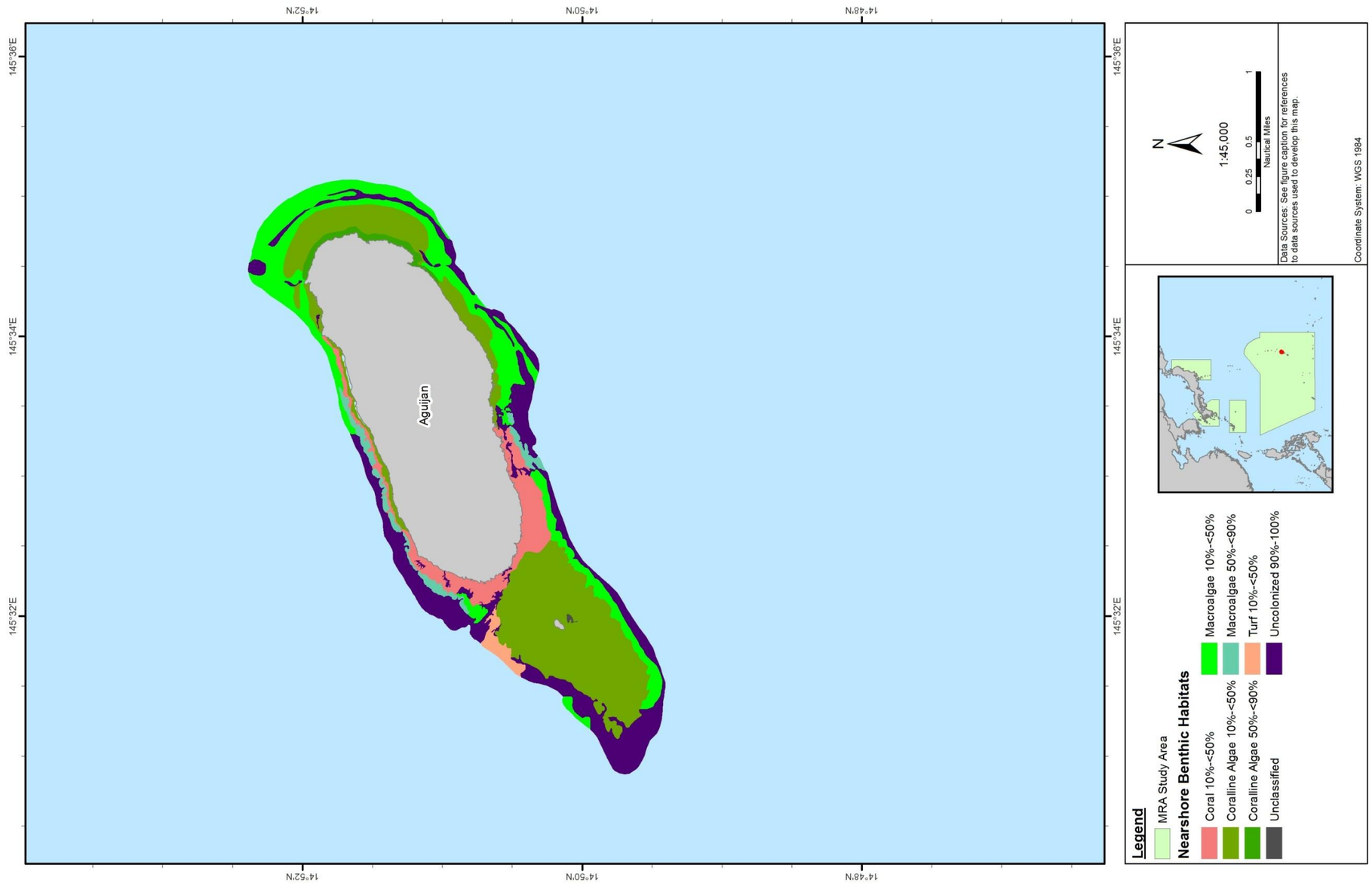

Figure 11-21: Live Cover of Coral Reef Habitats of Agujan
Source: National Oceanic and Atmospheric Administration (2005b).

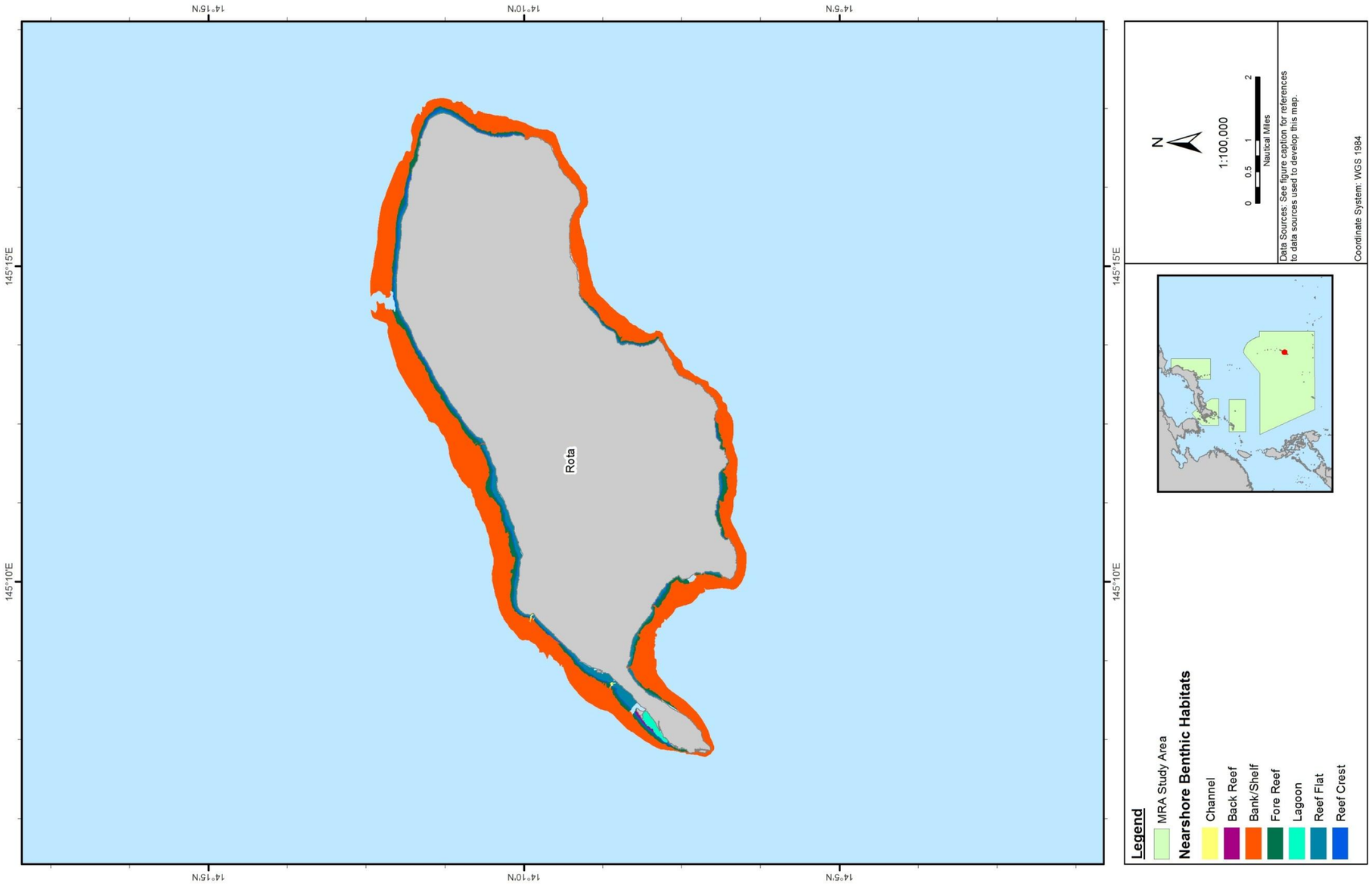

Figure 11-22: Reef Morphology of Rota
Source: National Oceanic and Atmospheric Administration (2005b).

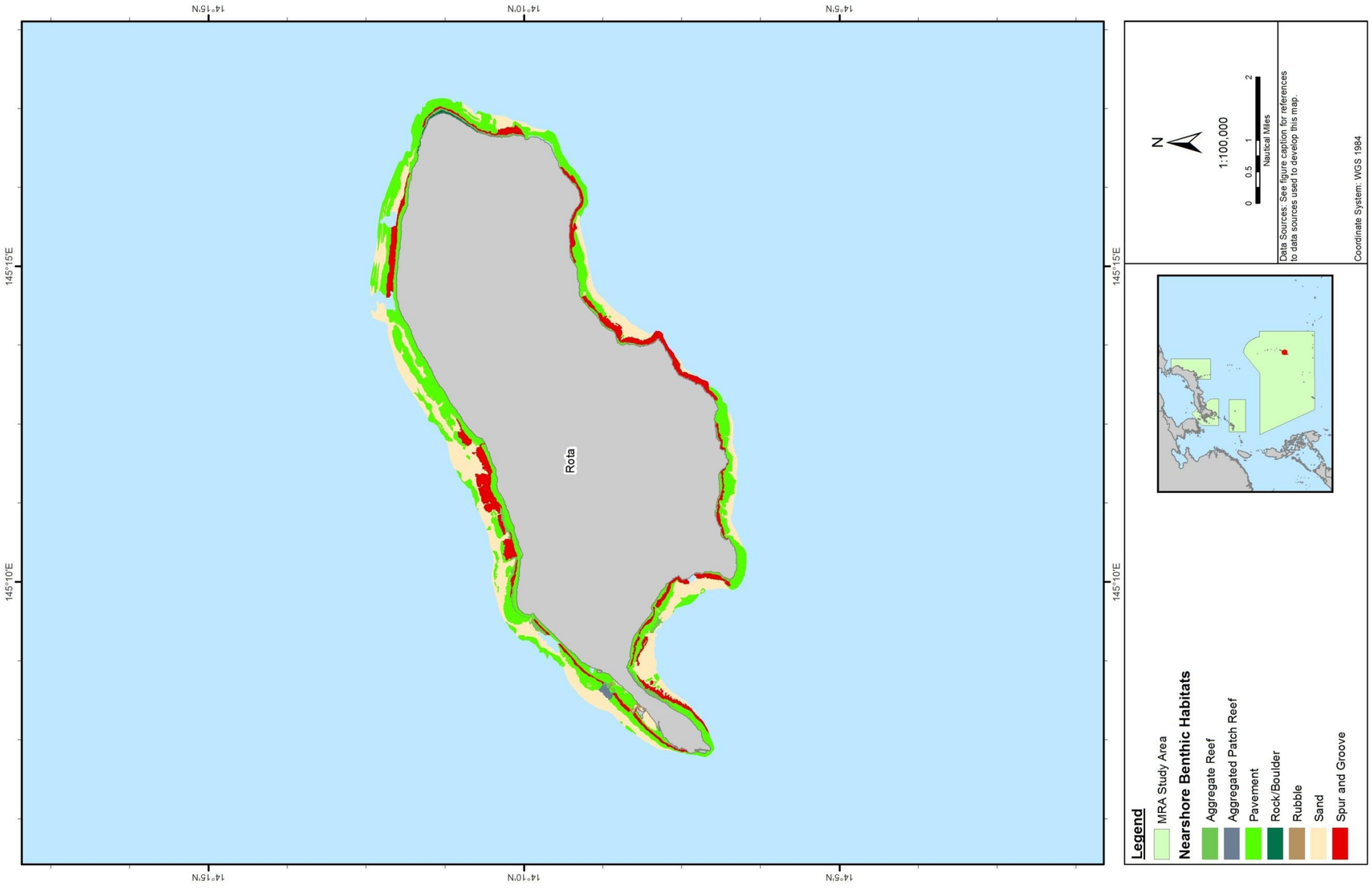

Figure 11-23: Benthic Substratum of Rota
Source: National Oceanic and Atmospheric Administration (2005b).

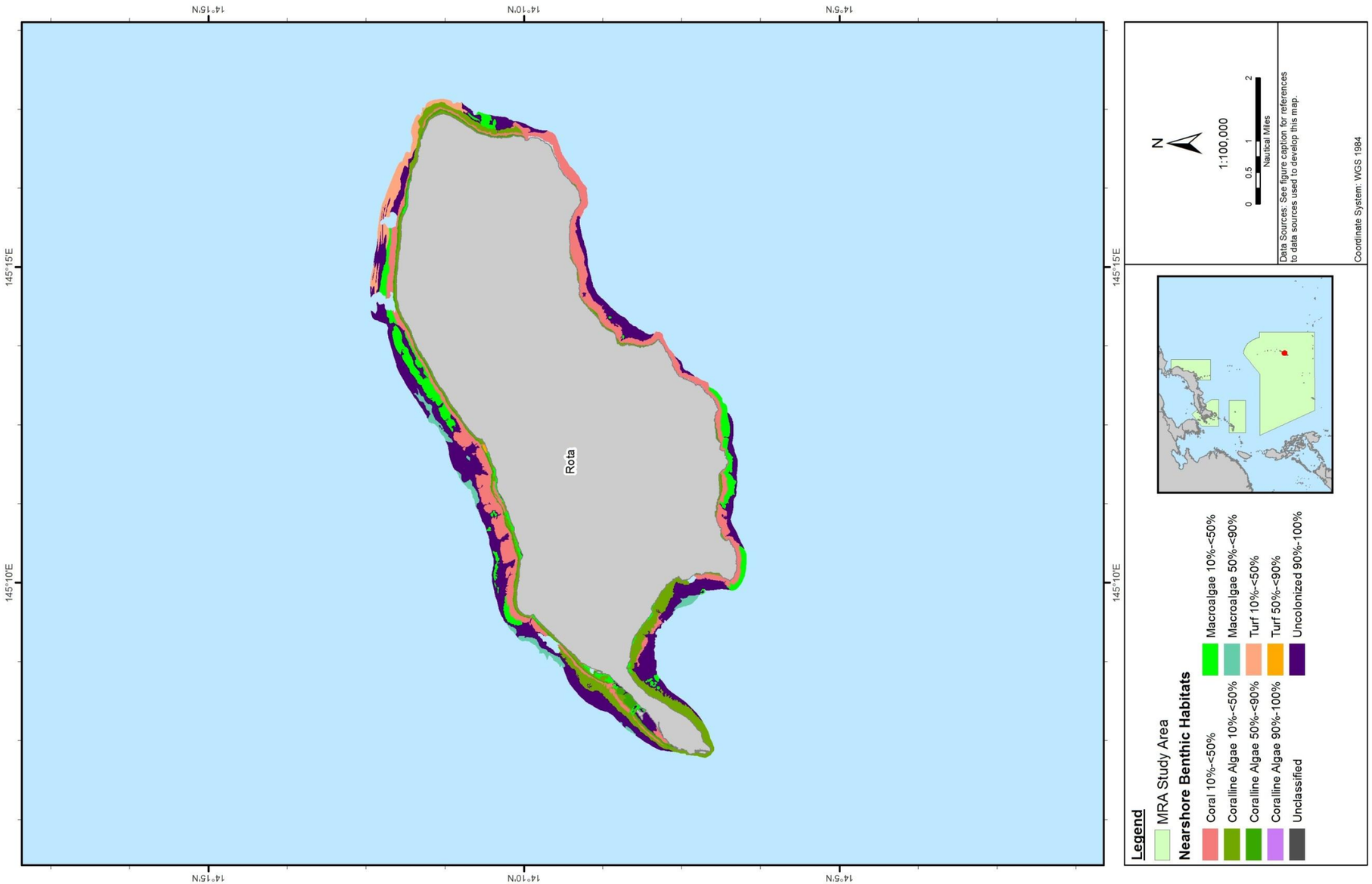

Figure 11-24: Live Cover of Coral Reef Habitats in Rota
Source: National Oceanic and Atmospheric Administration (2005b).

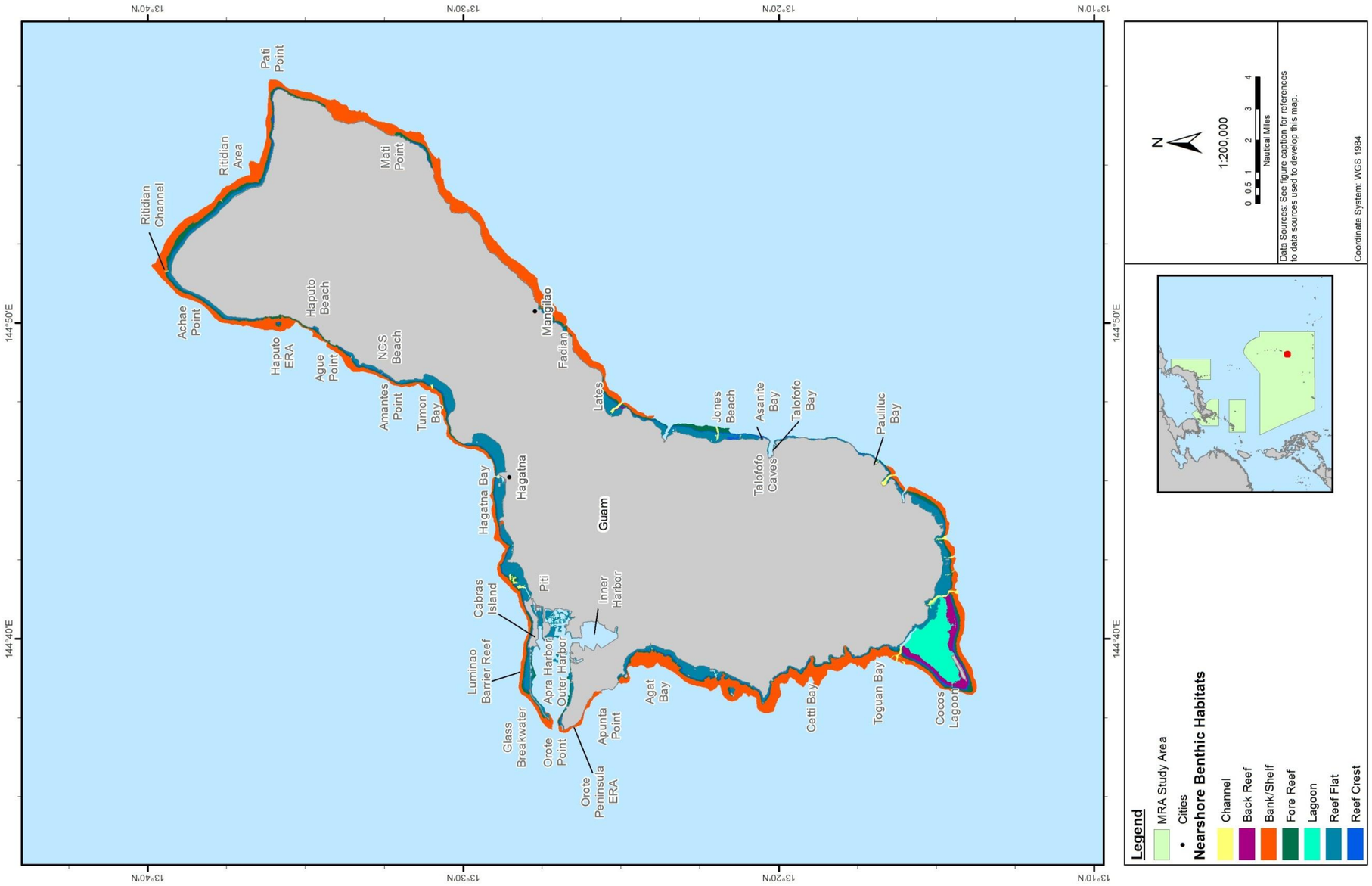

Figure 11-25: Subtidal Reef Morphology of Guam
Source: National Oceanic and Atmospheric Administration (2005b).

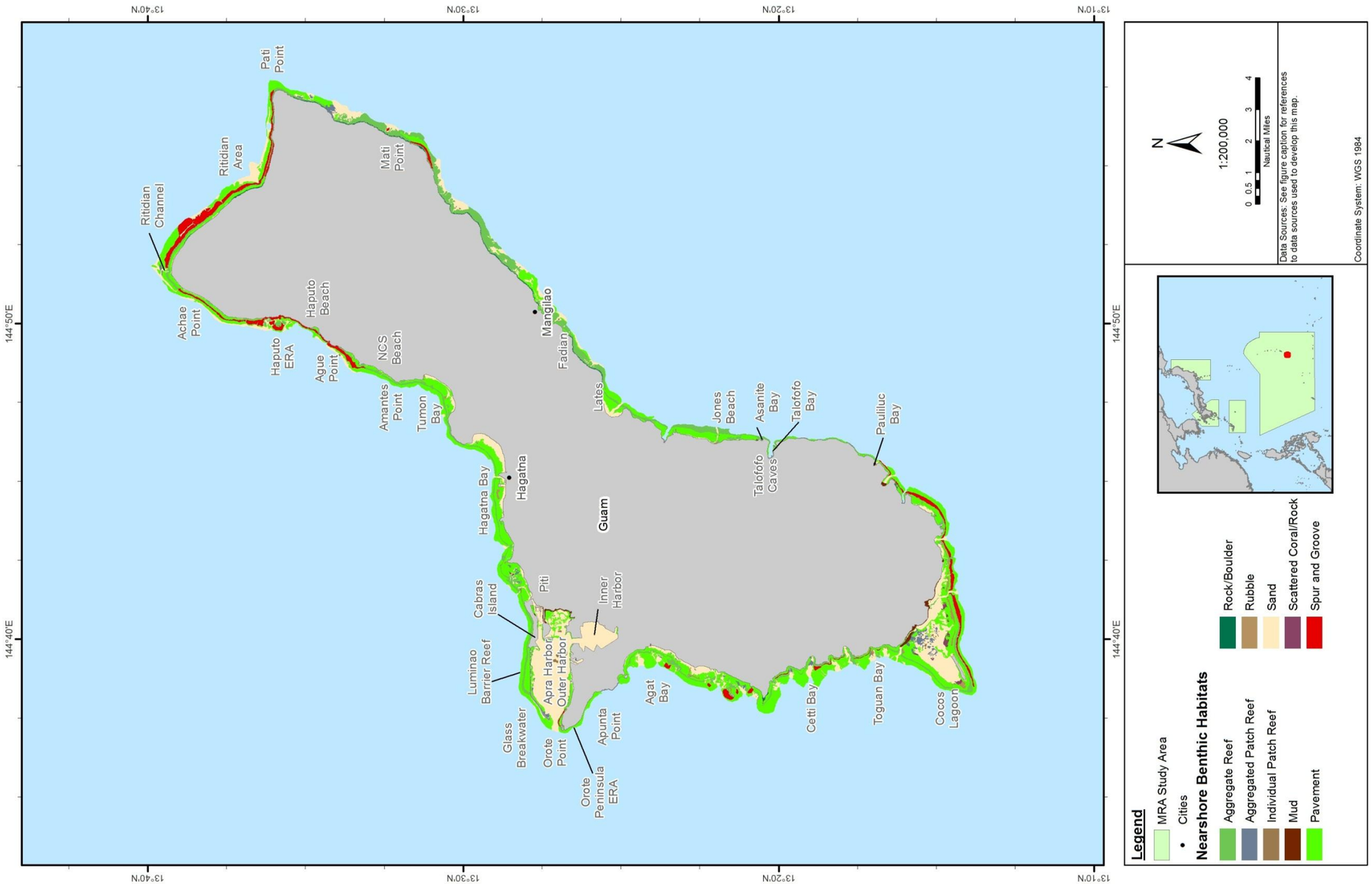

Figure 11-26: Benthic Substratum of Guam
Source: National Oceanic and Atmospheric Administration (2005b).

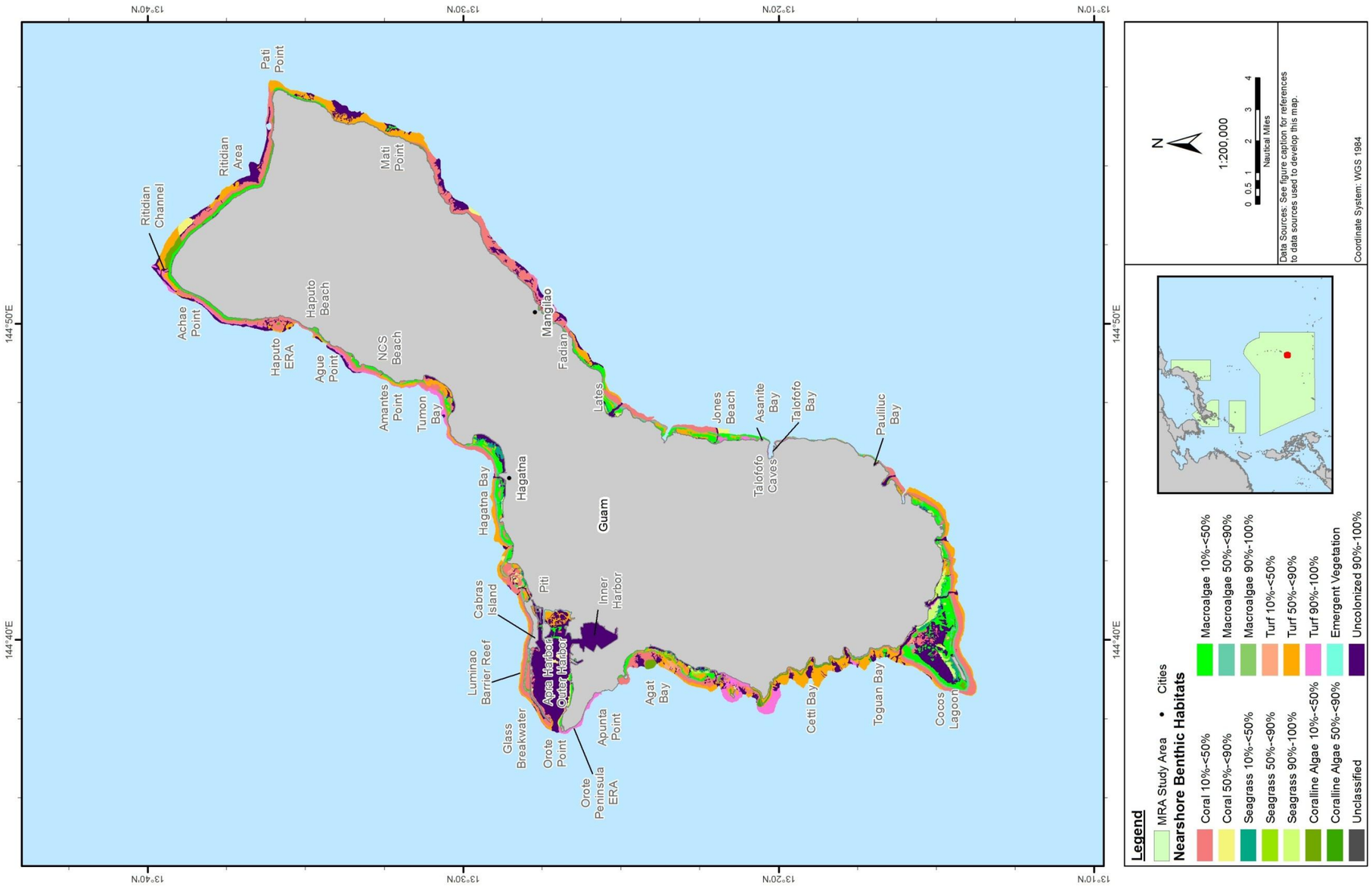

Figure 11-27: Live Cover of Coral Reef Habitats of Guam
Source: National Oceanic and Atmospheric Administration (2005b).

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11.7.3 Conditions and Stressors

Coral reefs are at risk from a variety of human activities occuring at local and global scales (Burke et al. 2011) (Figure 11-28 and Figure 11-29). Local pressures on coral reefs come from overfishing, destructive fishing, coastal development, watershed-based pollution, and marine-based pollution (Burke et al. 2011). Thermal stress and ocean acidification from climate change pose global threats to coral reefs (Eakin, Kleypas, and Hoegh-Guldberg 2008). The condition of coral reefs is also influenced storms and waves, marine debris, aquatic invasive species and species outbreaks, and disease (Clarke and Waddell 2008). Once a species is rendered vulnerable by human-caused effects, natural events such as storms may be more damaging (Friedlander, Aeby, Balwani, et al. 2008; Friedlander, Aeby, Brainard, et al. 2008; Friedlander et al. 2009).

In many areas, over-exploitation of grazing reef fish threatens coral reefs by allowing overgrowth of algae and its subsequent domination of coral (Vermeij, Dailer, et al. 2010). Human activities on land introduce pollutants into the ocean that cloud the clear water required by these corals (Field et al. 2008). Also, noise from human activities in the ocean may interfere with the ability of coral larvae to detect and respond to natural reef noises, which may disrupt larval settlement patterns (Vermeij, Marhaver, et al. 2010). Climate change contributes to coral reef decline by increasing water temperatures, which results in the loss of the algae from coral tissues (Ateweberhan and McClanahan 2010; Sheppard, Davy, and Pilling 2009). Without the algal pigments, corals appear white or bleached, and their growth, reproduction, and health are compromised. Another effect of global climate change is ocean acidification, which is caused by increased concentrations of atmospheric carbon dioxide. This change inhibits corals from creating their calcium carbonate exoskeleton that is the coral reef structure (Cohen et al. 2009). Oil is another threat to coral. In addition to the direct toxicity of the oil that spills from tankers, the dispersants used to address oil spills may also be toxic to corals, particularly at early life stages (Shafir, Van Rijn, and Rinkevich 2007). Although corals can withstand limited predation, massive outbreaks of the crown-of-thorns starfish (COTS) (*Acanthaster planci*) can kill so many corals that the reef itself is threatened (National Oceanic and Atmospheric Administration 2010b).

Coral diseases and opportunistic infections also contribute to the decline of coral reefs (Lesser et al. 2007). The incidence of coral disease may be influenced by thermal stress (Maynard et al. 2011), increased human population sizes, and host abundance (Aeby, Williams, Franklin, Haapkyla, et al. 2011; Aeby, Williams, Franklin, Kenyon, et al. 2011). Growth anomalies on corals were found to derive from surrounding healthy tissues, resulting in a negative impact on coral health (Yasuda et al. 2012).

Local pressures on coral reefs from overfishing and watershed-based pollution affected more than 55% and 25% of the world's reefs, respectively (Burke et al. 2011). With the impacts of local and global threats combined, an estimated 75% of the worlds coral reefs were rated as threated. Coral reefs in the Pacific region were rated as being under relatively less pressure from human impacts, although almost 50% of the reefs were considered threatened. Coral reefs of the FSM had the lowest threat rating of reefs in the Pacific, with under 30% threated (Burke et al. 2011). Even localized reefs within the MRA Study Area have differening threat levels, due in part to the variation of land and resourse use among the reefs (Figure 11-29).

JAPAN ARCHIPELAGO. Average coral cover has declined from 2005 to 2007 in reef and non-reef areas based on monitoring studies conducted as part of Japan's national coral reef monitoring program (Kimura et al. 2008). The decline in coral cover was attributed to outbreaks of COTS, typhoons, and coral bleaching events.

Recurring natural disturbances influencing the coral communities at these islands include low winter seawater temperature (13°C) and strong seasonal wave action during monsoons and typhoons. Miyakejima Island is a volcanic island that recently erupted in 2000, causing mudflows and a 20-cm-thick accumulation of ash in the reef environment (Shimoike, Ueno, and Igarashi 2006). The nearby Hachijojima Island is also volcanic, but it has remained inactive since 1606. Damages to corals caused by the 2000 eruption were preceded by severe impacts caused by terrestrial runoff, coastal construction, and predation by COTS and corallivorous gastropods in the 1970s and 1980s. Following the volcanic eruption of 2000, 12 coral species remained at Miyakejima Island, and coral cover was 6.7%. Tabular acroporids, once relatively abundant at Miyakejima Island, were greatly affected by the mudflows and ash deposits. The coral communities of Hachijojima Island were severely affected by coastal construction from the 1960s through the 1980s, which compounded the effects of naturally occurring disturbances.

Coastal Development and Pollution. Coastal development and red soil runoff are primary factors impacting coral reefs in the Ryukyu Islands (Kimura et al. 2008; Nakano 2006a, b; Omija 2006). Farming, land development, land clearing, and heavy rainfall erodes loose red and gray soil and country rock mudstone (collectively known as red soil). Red soil-laden terrestrial runoff causes siltation and sedimentation in the nearshore reef habitats, smothering corals. Because this red soil remains in the backreef areas, it is periodically resuspended by heavy wave action during typhoons and monsoons. The chronic exposure to red soil pollution causes coral mortality. The reefs in Okinawa, Kohama, Iriomote, and Ishigaki Islands, and the Sekisei Lagoon are all affected by red soil (Kimura et al. 2008; Omija 2006). The Okinawa Prefecture and Ichigaki City have attempted to prevent red soil pollution by developing water quality control measures, filtering out red clay from drainage channels, repairing sedimentation ponds, controlling runoff, and stabilizing loose soil with vegetative cover.

Despite multiple efforts to reduce red soil pollution, sedimentation and siltation remain the greatest threats to coral reefs of Japan—particularly those located near the mouths of rivers and nearshore fringing coral reefs (Omija 2006). West and van Woesik (2001) found that fringing reefs near the mouth of the largest river on Okinawa, the Hija River (catchment of 50.2 km^2; maximum discharge of 43.04 cubic meters (m^3)/second (s.); average discharge of 0.86 m^3/s.), have limited stony coral development (11 species; less than 0.2% cover per species) within a 300-m distance of the river, and that the degree of reef development varied inversely with concentrations of suspended particulate matter. A substantially more developed coral community was found 325 m from the river mouth (18 species; coral cover per species ranged from 0.4 to 8.1%), and a typical coral community was found approximately 390 m from the river mouth (13 species; coral cover per species ranged from 0.4 to 18.3% (West and van Woesik 2001).

Land reclamation after 1990 has impacted acroporid communities around Japan. Further, corals of the Koshikijima and Uji Islands were probably impacted by an outbreak of COTS in the 1990s. A COTS outbreak was also reported in the Sakurajima area (Nojima 2006). While reefs of the main Daito Islands have not been impacted by outbreaks of COTS, the 1998 bleaching event caused severe impacts. Coastal development and red soil pollution are also affecting the reefs in this area (Nonaka 2006). On the northwest coast of Tokashiki Island, the 1998-bleaching event and COTS predation have greatly diminished what were once the best developed *Acropora* communities of the Kerama Islands (Sakai, Iwao, and Shimoike 2006).

Delivery of nutrients to nearshore waters by submarine groundwater discharge has become increasingly recognized as a potential stressor to coral reefs in Japan and elsewhere. The nutrient fluxes can increase marcroalgal growth and alter the community structure of nearshore croral reefs (Blanco et al. 2011).

Marine Resource Use. Human-induced impacts on coral reefs include physical impacts caused by anchoring and resource depletion caused by overfishing. Anchoring by large vessels off the port of Ishigaki in the southern Ryukyu Islands has caused severe structural damage to reefs (Akimichi 2006). Further, other reefs of the southern Ryukyu Islands have incurred substantial anchoring and grounding damages caused by the increased visitation of tour boats, and increased physical impacts caused by tourist snorkellers and divers (Kimura et al. 2008). Overfishing on shallow reefs is also a recognized impact on 70% of coral reef ecosystems of Japan (Kimura et al. 2008). Coral damage by divers in tourist areas has occured at reefs of the Kerama Islands (Kimura et al. 2008). Overexploitation of fisheries resources associated with coral reefs has occurred from spearfishing using SCUBA diving or hookah fishing (Kimura et al. 2008).

Climate Change and Variability. Coral bleaching due to increased SSTs has resulted in moderate to severe loss of corals in Japan (Kimura et al. 2008). Many coral reefs recovered from the effects of the mass bleaching in 1998 (Kayanne et al. 2002; Kimura et al. 2008). The bleaching affected coral communities in 97 municipalities from the Ryukyu Islands to southern Honshū (Fujiwara et al. 2000). In 1998, mass bleaching caused an 8% loss of total coral cover and 40% mortality of acroporids in the Sekisei Lagoon (Fujiwara et al. 2000). The same bleaching event caused a 62% decline in coral cover at Ishigaki Island. From 2002 to 2003, average coral cover in the Sekisei Lagoon increased from approximately 36 to 46% (Kimura et al. 2008). During the same time, mean coral cover on reefs of Ishigaki Island increased approximately from 27 to 29%. Farther north, corals of Okinawa Island have not recovered from the 1998 bleaching, and in 2003, average coral cover was 8.5%—lower than surrounding locations (e.g., Kerama Islands, 31% coral cover; (Fujiwara et al. 2000; Kimura et al. 2008). As a result of the 1998 bleaching, the number of coral species at Sesoko Island located on the northwestern side of Okinawa Island declined from 81% in 1997 to 40% in 1999, and the live stony and soft cover dropped from 70.5% in 1997 to 10.8% in 1999 (Loya et al. 2001). Branched corals (mostly acroporids) constituted the bulk of the dead corals. Massive and encrusting corals survived the bleaching event (Loya et al. 2001). The 1998 bleaching event caused only partial bleaching of corals in Kyūshū, and all colonies recovered. Some predation on corals by COTS and corallivorous gastropods was reported for Kyūshuū Amakusa Islands. In 1991, typhoons damaged *A. solitaryensis* in the southern end of Shimojima Island (Nojima 2006).

While coral bleaching occurred in 2001 and 2003 in the Ryukyu Islands, lasting impacts were less than those of the 1998 event (Kimura et al. 2008). The recovery of reefs from bleaching and coral predation is impeded by recurrent red soil runoff and resuspension in the nearshore environment of the Ryukyu Islands and mainland Japan (Kimura et al. 2008; Omija 2006). Coral reef larvae in Japan are dispersed by the northward flowing Kuroshio Current (Kimura et al. 2008). Coral communities may be expanding in areas in the northern extent of coral distribution in Japan due to increasing SSTs (Kimura et al. 2008). The most severe coral bleaching event occurred in Sekisei Lagoon in 2006, with a 14% loss of coral cover (Kimura et al. 2008).

Storms and Waves. Storms and high waves can injure corals. Typhoons occur in Japan every year, damaging coral reefs (Kimura et al. 2008). Major damage occurred to reefs in Sekisei Lagoon, Ishigaki Island, and Ogasawara. Coral reefs of Japan are frequently impacted by typhoons, particularly in August and September (Kimura et al. 2008). On average, 11 typhoons occur each year within 300 km of Japan.

Typhoons cause recurrent physical impacts on coral communities and severe sedimentation (Kimura et al. 2008). From October to April, recurrent north monsoons generate strong winds and large swells that impact reefs (Sakai, Iwao, and Shimoike 2006).

Marine Debris. Prior to the recent tsunami in Japan, which generated unprecendented quantities of marine debris that tracked across the Pacific Ocean, concerns about marine debris had focused on locally generated beach litter such as plastic bottles, disposable lighters, and styrofoam buoys. A 2-year survey of litter washed ashore on Hassakubana beach on the Goto Islands showed that debris increased in winter (Kako et al. 2011). No systematic acquisition of data on marine debris has occured for Japan or the other islands in the MRA Study Area. One study of submerged marine debris in the East China Sea reported that the main components of large debris were discarded nets, octopus jars, fish pots, and fishing lines. In some areas, ropes, drums, rubber, plastics, metals, wood, and clothing accounted for about one quarter of the debris collected. Much of the debris originated in neighboring countries such as Korea and China, as well as Japan (Lee, Cho, and Jeong 2006). Although this study did not specifically investigate the role of marine debris in coral injury, studies from around the world have demonstrated that these kinds of discarded materials can cause coral injury and mortality.

Aquatic Invasive Species and Species Outbreaks. Coral reefs of Japan have been severely impacted by the COTS (Kimura et al. 2008). This coral predator appeared in the Amani Islands in 2000 and spread to the Okinawa Islands via the Kuroshio Current. Increases in COTS have been observed at Kerama Islands, Miyako Island, Jabiji, Ishigaki Island, Sekisei Lagoon, and Daito Islands between 2004 and 2007 (Fujiwara et al. 2000; Kayanne et al. 2002; Kimura et al. 2008; Loya et al. 2001; Yokochi 2006). The Kuroshio Current spread the COTS northward to Amakusa, Shikoku, and Kushinoto (Kimura et al. 2008).

Outbreaks of COTS have taken place from the southern Ryukyus to the Izu Islands since the late 1960s, and continue today (Kimura et al. 2008; Yokochi 2006). The starfish is probably dispersed by the northward flow of the Kuroshio Current. The western coast of Okinawa was the first area to be affected by an outbreak, which caused mass predation and mortality of corals. By the end of the 1970s, all corals of Okinawa had been affected. Chronic outbreaks of this predator at Okinawa are compromising the full recovery of corals. During the 1980s, an explosive outbreak of COTS affected the entire Seksei Lagoon and spread to the surrounding area of the Yaeyama Archipelago. By the end of the 1980s, the number of live corals had significantly decreased; this was followed by a rapid decline in the number of the starfish. This species continue to proliferate and consume corals in Japan despite extermination programs that have removed over 10 million individuals. In fact, increased numbers of COTS in Seksei Lagoon in 2003 suggested yet another outbreak (Kimura et al. 2008; Yokochi 2006).

In 2012, hundreds of starving COTS were stranded on the beach of Urasoko Bay, Ishigaki Island, in Okinawa Prefecture. Reseachers hypothesized that the starfish were starving because coral populations in the area had been decimated by starfish predation over the past three years (Suzuki, Kai, and Yamashita 2012)

Outbreaks of the coral eating gastropod, *Drupella*, have damaged coral communities in the Izu Islands, Kyūshū Island, and the west coast of Shikoku starting in the late 1970s (Kimura et al. 2008; Yokochi 2006). From 1995 to 2000, extermination programs at these high-latitude locations yielded collections of up to 200,000 *Drupella* per year. In the southern Ryukyus, outbreaks of *Drupella* have caused less impact on true coral reefs than those caused by COTS (Kimura et al. 2008). The corallivorous gastropods (particularly *Drupella fragum*) have also impacted high-latitude corals of Japan (Kimura et al. 2008; Yokochi 2006).

Disease. Coral diseases have been reported in reefs in Japan (Irikawa et al. 2011; Nishikawa 2008; Yamashiro 2006; Yasuda et al. 2012). In 2003, 30% of the sites monitored in Sekisei Lagoon, a prime location for coral reefs in Japan, contained diseased corals (Kimura et al. 2008). Coral disease has increased on Japan reefs between 2003 and 2007 (Kimura et al. 2008). Repeated physiological stresses on corals such as coral bleaching could decrease the resistance of corals to opportunistic diseases and promote mass mortality induced by disease outbreaks (Harvell et al. 1999).

Growth anamolies or tumors have been reported in Acropora, Montipora, and Porites corals in the Ryukyu archipelago, Kerama Islands, and Sekisei Lagoon in Okinawa (Irikawa et al. 2011; Nishikawa 2008; Yasuda et al. 2012). A 10-year study of growth anomalies in Acropora was conducted on the fringing reef on the east side of Amuro Island in the Kerama Islands (Irikawa et al. 2011). Growth anomalies were more prevalent on the older, central portion of large colonies. Growth anomalies were reported to affect reproduction but were not contagious and did not affect the survival of the colony. The density of growth anomalies increased immediately after thermal stress events.

MARIANA ARCHIPELAGO. Natural and human-induced disturbances affecting the reefs of Guam have caused a significant decline of coral cover and recruitment since the 1960s (Burdick et al. 2008). Human-induced disturbances on reefs in the Mariana Islands include erosion, sedimentation, polluted runoff (input of nutrients), exposure to warm water (global warming and thermal effluents) leading to bleaching, overfishing, anchor damage, tourism-related impacts, ship groundings, and certain military activities (Houk 2001; Quinn and Kojis 2003; Richmond and Davis 2002; Starmer, Trianni, and Houk 2002). Coral communities and reefs are dynamic and changing ecosystems subject to natural and human-induced disturbances. Natural disturbances that have significantly impacted coral communities and reefs in the Mariana Islands include storm-related damage caused by frequent typhoons, El Niño/La Niña-Southern Oscillation (ENSO) events, outbreaks of COTS, coral disease, freshwater runoff, recurrent earthquakes, and volcanic activity (Burdick et al. 2008)

Coastal Development and Pollution. Increased land-clearing and construction of coastal roads, housing, and tourism-related facilities have increased erosion, sedimentation, and runoff (particularly during heavy rainfall), which has reduced coral cover and recruitment in the Mariana Archipelago (Burdick et al. 2008; Houk 2001; Richmond and Davis 2002; Starmer et al. 2008; Starmer, Trianni, and Houk 2002). Impaired water bodies have been listed for enterococcus and ortho-phosphate in coastal waters of CNMI, including Talofolo Bay (Houk et al. 2010). Decreased coral species richness and recruitment has been documented at sites affected by coastal pollution (Starmer et al. 2008). Primary pollutants to waters around Guam are microbial organisms, petroleum hydrocarbons, and sediment (Burdick et al. 2008). On Guam, some reefs in Apra Harbor (excluding the Inner Apra Harbor) have been severely impacted by freshwater runoff, sedimentation, and polluted discharges (Department of Defense 1999; Richmond and Davis 2002). Infrastructure improvement projects have resulted in increased dredging, road construction, and land clearning in FSM (George et al. 2008). Sources of coastal pollution in Palau include fishing companies, hotels, and a deteriorating sewer system (Marino et al. 2008). In Palau's Ngaremeduu Bay, high turbidity and sedimentation adversely affect the distribution of corals in the bay, preventing larval settlement near the mouths of rivers (Golbuu et al. 2011).

Marine Resource Use. Coastal tourism, fishing, and recreational diving are primary uses of marine resources in the Mariana Archipelago (Burdick et al. 2008; Houk 2001; Richmond and Davis 2002; Starmer et al. 2008; Starmer, Trianni, and Houk 2002). Commercial use of coral reefs for motorized marine sports, SCUBA diving, and other activities in association with hotels is prevalent in Saipan and Guam (George et al. 2008; Starmer, Trianni, and Houk 2002). Palau has managed tourism-related SCUBA

diving impacts on coral reefs by managing mooring buoys to minize anchor damage (Marino et al. 2008). The Department of Defense carries out training activities on Guam (Burdick et al. 2008). Since 1971, FDM has been a target site for live-fire military exercises (ship-to-shore gunfire, aerial gunnery, and bombing) (U.S. Department of the Navy 2005d). Most of the ordnance found underwater at FDM during reef assessments conducted since 1999 occurs at the northwestern end of the island (U.S. Department of the Navy 2005d).

Hagåtña and Tumon Bays are centers for tourism; thus, a high level of tourism-related impacts on water quality and marine resources has occurred. Polluted runoff has affected the inner areas of Hagåtña, Tumon, and Piti Bays. Marine recreational sports (including SCUBA diving, snorkeling, fishing, underwater walking tours, and jet skis) can physically damage reefs (Burdick et al. 2008; Richmond and Davis 2002; Starmer, Trianni, and Houk 2002). Anchor damage on reefs occurs at popular dive and fishing sites. SCUBA diving is a major recreational activity on Guam, concentrated in five main dive sites (Burdick et al. 2008): Tokai Maru (Apra Harbor), the Cormoran (Apra Harbor), the Crevice (Orote peninsula), Blue Hole (Orote peninsula), and Hap's Reef (Agat Bay). Vessel groundings (recreational and commercial vessels) are also a source of physical impacts on reefs in the Mariana Islands (Richmond and Davis 2002; Starmer, Trianni, and Houk 2002). The Government of Guam maintains 34 shallow water mooring buoys to minimize injury to coral reefs from recreational fishing boats (Government of Guam 2011).

Climate Change and Variability. ENSO events have produced unusually high seawater temperature which may have caused coral bleaching (Richmond and Davis 2002). Bleaching of corals has been recorded in the Mariana Islands since 1994, and some bleaching events have caused coral mortality (Paulay and Benayahu 1999; Richmond and Davis 2002; Starmer, Trianni, and Houk 2002). In 1994, corals bleached on all reefs of Guam (Paulay and Benayahu 1999). While pocilloporids and acroporids incurred severe bleaching on Guam in 1994, Paulay and Benayahu (1999) observed no stony coral mortality during that bleaching event. Major coral bleaching events occurred in Palu and other parts of Micronesia in 1998 and 2010 (Burke et al. 2011).

Storms, Waves, and Other Natural Phenomenon. Increased severity of storms across the globe is projected as a result of climate change, although predictions vary from region to region (Deo, Ganer, and Nair 2011; Hoyos et al. 2006; Walsh, McInnes, and McBride 2012; Webster et al. 2005).The Mariana Archipelago is located in a region of the Pacific with high tropical storm activity—on average three tropical storms per year (Landers 2004). Coral reefs may be adapted to these conditions (Becerro, Bonito, and Paul 2006). The passage of a typhoon in December 1997 severely altered the reef flat coral community diversity and cover on Tinian. Coral cover on the reef flat was reduced from an original 50 to 70% cover to 2% cover. No branching corals remained on the reef flat following the typhoon (Marine Research Consultants 1999). The recent benthic habitat mapping of the CNMI by (National Oceanic and Atmospheric Administration 2005a) reflects the change in reef flat composition. The impacts of corallivorous predators on corals have most likely altered the coral composition and cover on the fore reef (Quinn and Kojis 2003).

Other sources of coral mortality include seismic and volcanic activity. Ash from a volcanic eruption in 1981 negatively affected coral reefs around Pagan (Eldredge and Kropp 1985). Reefs in the islands north of FDM are likely to have been impacted by frequent and recent seismic and volcanic activity (U. S. Geological Survey 2005). In 2003, the first known eruption occurred on Anatahan, about 120 km north of Saipan. Pyroclastic deposits were deposited through the water column onto coral reefs, obliterating the substrate along the northeastern shore of the island. Water quality was affected by suspended ash,

further stressing the remaining live corals. On the far side of the island, coral reefs received some ash, but not to the extent of complete burial (Vroom and Zgliczynski 2011).

The southern islands (Guam to FDM) have not been impacted by recent volcanic activity, but have been affected by recurrent seismic activity, as witnessed in 1993 in Guam (Earthquake Engineering Research Institute 1993).

Ship Groundings and Oil Spills. Ship groundings are inevitable in the Mariana Archipelago because of frequent and intense stropical storms. Damage to coral reefs is both physical and chemical when oil, leaching iron, and other chemicals are released into the ocean. Ship grounding can impact herbivorous fish abundance and substratum cover (Schroeder et al. 2008). At Rose Atoll in the Pacific, significantly greater substratum cover by opportunistic algae (both turf and cyanobacteria were associated with corroding steel debris (Schroeder et al. 2008). Many derelict vessels are grounded in CNMI (Starmer et al. 2008). Nine derelict vessels have been recorded in coral reef habitat in Guam (Burdick et al. 2008).

Marine Debris. Marine debris is not commonly encountered in the Mariana Archipelago (Starmer et al. 2008). Metal debris was reported along the coasts of Saipan and Tinian, including unexploded ordnance at Agingan and Naftan Points, Saipan, and at Faibus Point, Tinian (Starmer et al. 2008).

Aquatic Invasive Species and Species Outbreaks. A number of alien species have been intentially introduced to parts of the Mariana Archipelago for the purpose of aquaculture, although few have become established (Bearden et al. 2005). The chronic outbreaks and predation of COTS on corals (including *Acropora*, *Montipora*, *and Pocillopora*) have caused substantial coral mortality on reefs of the CNMI. In the fore reef zone in sheltered areas, massive corals (*Porites* and *Favia*) that are more resistant but not immune to *A. planci* have replaced the corals decimated by *A. planci* (Bonito and Richmond Submitted; Quinn and Kojis 2003). Weather and wave action-exposed reefs (e.g., Unai Dankolo, Tinian) appear to be more resilient to COTS outbreaks than are reefs in sheltered bays (e.g., Lau Lau Bay, Saipan; Sasanhaya Bay, Rota). Episodic outbreaks of this predator in the Pacific have been linked to the migrating position of North Pacific transition zone chlorophyll front, which can provide phytoplankton starfish larvae (Houk, Bograd, and van Woesik 2007).

Disease. Coral diseases and syndromes generally occur in response to biotic stresses such as bacteria, fungi, and viruses, and/or abiotic stresses such as increased sea water temperatures, ultraviolet radiation, sedimentation, and pollutants. The prevalence of coral disease has been monitored in coral reefs throughout the Mariana Archipelago (Burdick et al. 2008; George et al. 2008; Marino et al. 2008; Pacific Islands Fisheries Science Center 2008; Starmer et al. 2008). An analysis between 2002 and 2008 of 937 quantitative coral disease surveys from 13 regions across the Indo-Pacific found that prevalence of tumors in *Acropora* was strongly associated with host abundance, while prevalence of tumors in *Porites* was associated with both increased human population sizes and host abundance (Aeby, Williams, Franklin, Haapkyla, et al. 2011). White Syndrome and Black Band Disease are considered the most prevalent forms of coral disease on reefs around Guam (Burdick et al. 2008). Prevalence of coral disease on the reefs surrounding the CNMI increased from 2002 to 2005 (Starmer et al. 2008). Areas with the highest prevalence of coral disease were also areas within which much human diving occurred. Coral disease affected eight families of reef-building corals on Guam, and the prevalence of coral disease ranged from 0.2 to 12.6% based on surveys of 15 reefs (Myers and Raymundo 2009).

Areas with coral disease prevalence exceeding 10% were Luminao, Cocos Lagoon, and Shark Pit Rock (Burdick et al. 2008). Limited surveys conducted in the FSM, Kosrae, and Pohnpei indicate that coral disease is rare (George et al. 2008).

Five major disease categories of crustose coralline algae—coralline lethal orange disease, coralline fungal disease, coralline white band syndrome, coralline target phenomena, and coralline cyanophyte disease—were identified in the first quantitative study of crustose coralline algal disease on U.S. Pacific coral reefs (Vargas-Angel 2010). Occurrence of coralline algal diseases was strongly associated with percent cover of crustose coralline algae and SSTs. At islands with coralline algal diseases, the occurrence was associated with population density. Hot spots in coralline algal disease were detected around Guam, the southern CNMI, American Samoa, and the Pacific Remote Island Areas, although overall, the occurrence of disease was low.

CAROLINE ISLANDS.

Yap. Structural damage to reefs Chuuk and Yap in the FSM resulted from Typhoon Sudal in 2004 (George et al. 2008).

The corals of Yap have been affected by oil spills and ship groundings repeatedly over the years. In 2002, the *Kyowa Violet* ran aground and spilled fuel oil nearTamil Harbor (Downs et al. 2006), closing the coastal fisheries and contaminating the nearshore habitat for almost 2 years (Tafileichig 2002).

A large area of a coral patch reef was damaged by a ship grounding in Yap (George et al. 2008).

Palau. Disease states and syndromes recorded on Palau reefs include Black Band disease, Brown Band disease, Skeletal Eroding Band, and White Syndrome. Bleached patches, spots, stripes, yellow spots, and tumors have been recorded as well (Marino et al. 2008). Prevelance of coral disease is considered low, affecting 1 to 5% of coral colonies (Marino et al. 2008).

Derelict fishing gear has been recorded on reefs surrounding Guam and Palau (Burdick et al. 2008; Marino et al. 2008). Ship groundings have damaged reefs in Palau (Marino et al. 2008).

The primary direct cause of injury to coral reefs in Palau is diver behavior, especially holding and fin contact. At the most popular dive sites (in the Southern Lagoon Area of Rock Islands), guides reported that divers with cameras or gloves were the worst offenders. In addition to grabbing and kicking coral, divers knelt and dragged equipment across live corals (Poonian, Davis, and McNaughton 2010).

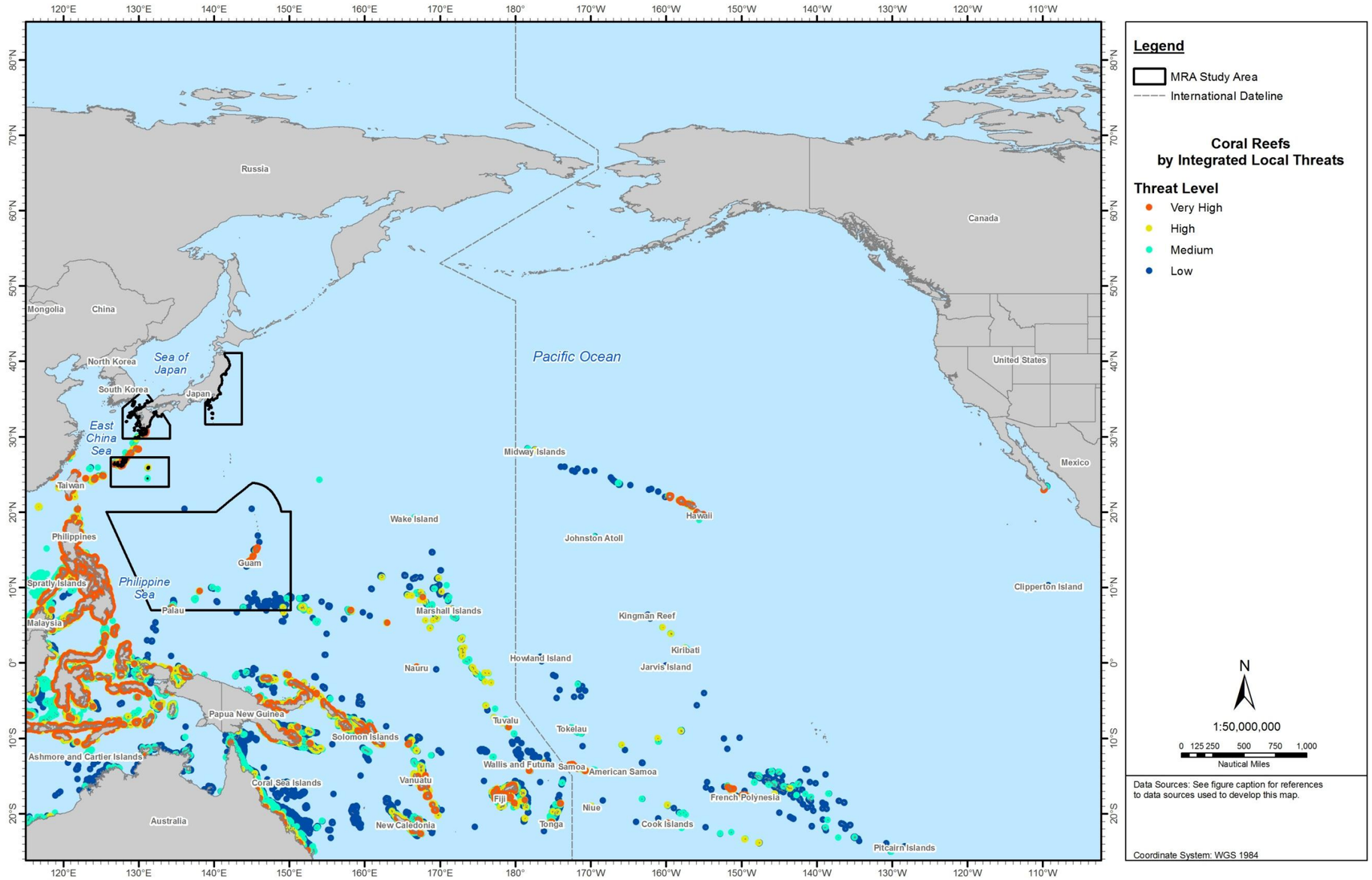

Figure 11-28: Integrated Local Threats to Coral Reefs in the Northern Pacific Ocean
Source: Burke et al. (2011).

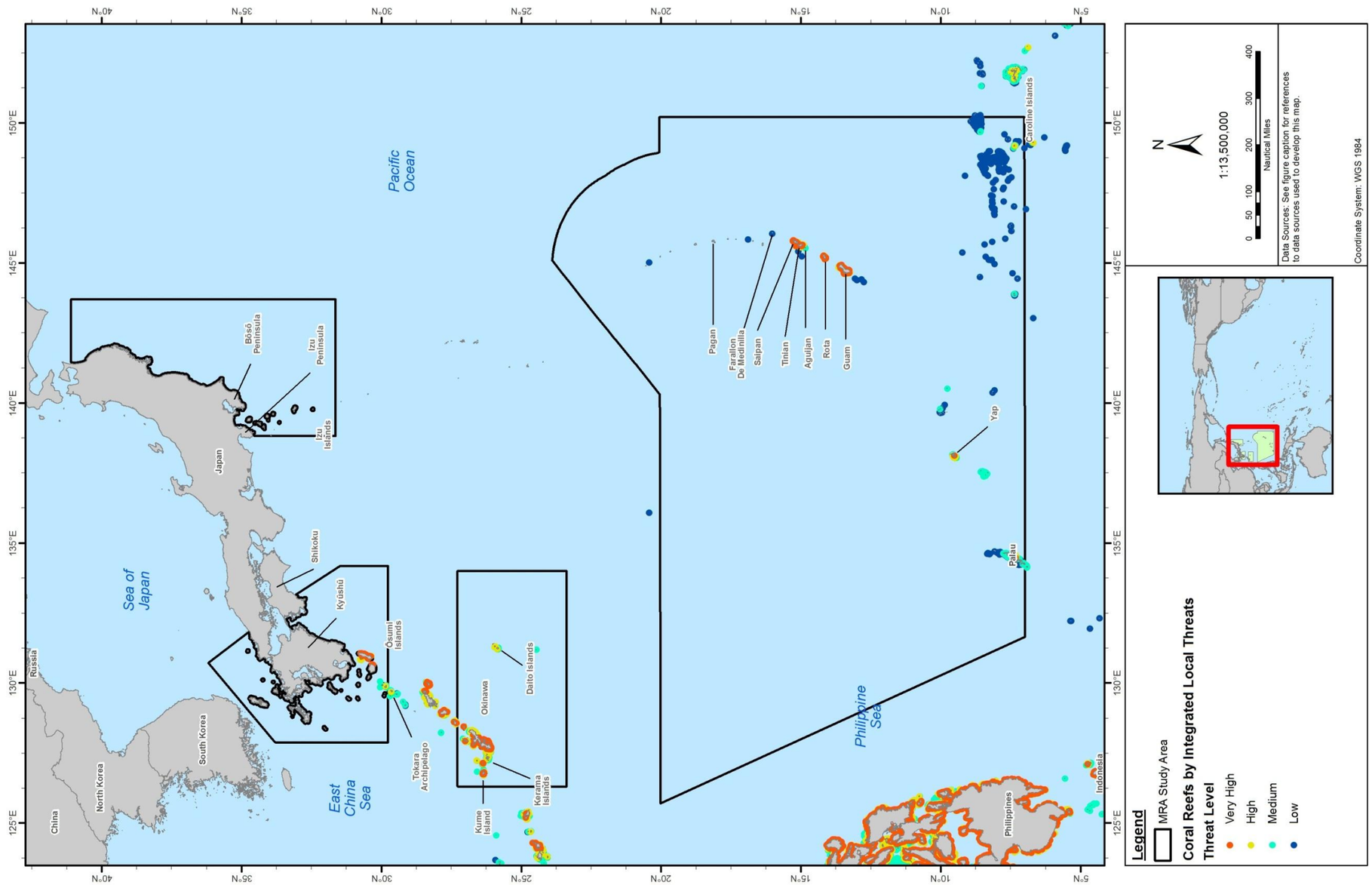

Figure 11-29: Integrated Local Threats to Coral Reefs in the MRA Study Area
Source: Burke et al. (2011).

11.8 ARTIFICIAL HABITATS (ARTIFICIAL REEF, SHIPWRECKS, OIL AND GAS PLATFORMS, FISH AGGREGATING DEVICES)

11.8.1 Description

Artificial habitats include shipwrecks, artificial reefs, oil and gas platforms, and fish aggregating devices (FADs). The first "artificial" habitat in the marine environment was likely a shipwreck. From the time that the first humans took to the sea, vessels have been lost to storms and groundings. As vessels sink to the sea floor, they are colonized by the ubiquitous encrusting and sessile marine organisms that opportunistically attach to hard substrates. Over time, the wrecks become functioning reefs, providing attachment sites, shelter, forage, and spawning sites to organisms.

People have designed and deployed artificial habitats in an attempt to supplement the ecological services provided by coral or rocky reefs. Artificial reefs range from simple concrete blocks to highly engineered structures. Artificial habitats function as natural hardbottom by providing structural attachment points for algae and invertebrates, which in turn support a community of animals that feed, seek shelter, and reproduce there (National Oceanic and Atmospheric Administration 2007). The species on artificial habitats vary by location and season and may change over time as natural succession occurs. In most instances, the distinct communities that develop on artificial reefs are thought to be attributed to the complexity and placement of the reef rather than to the material itself (Davis 2009). The feasibility of deploying artificial reefs as a mitigation strategy was assessed by the Navy for the proposed extension of Kilo Wharf in Apra Harbor, Guam (Helber Hastert & Fee 2007a).

Working oil and gas platforms also provide artificial habitat in ocean waters and are sometimes deployed as artificial reefs after they are decommissioned. Mussels, barnacles, and other invertebrates attach to the underwater structure of the platform. When these organisms are detached by storms, maintenance, or other forces, their shells drop to the seafloor, where they accumulate in shell mounds around the base of the platform, providing a large hardbottom area in the surrounding softbottom habitat (Goddard and Love 2008; Love et al. 2006). The structure provided by piers and pilings also functions in a similar manner. Fishes are known to use platforms as mid-water cover and to associate with the shell mounds beneath the platforms. Rockfishes dominate the fish community in all microhabitats around the platforms; young-of-the-year rockfish are particularly abundant (Love et al. 2006).

Fish aggregation devices are floating objects moored at specific locations in the ocean to attract mobile and migratory fishes and to reduce the effort required to locate and catch large migratory fish, such as tuna (Food and Agriculture Organization of the United Nations 2010). Ideally, FADs function as floating reefs in the sense that they provide attachment locations for algae and invertebrates, which provide food, shelter, and structure for mobile organisms. One primary goal of offshore FADs is to reduce the effort required to locate and catch large pelagic fish, such as tuna, thereby reducing the harvest of overfished inshore fish species (Food and Agriculture Organization of the United Nations 2010). Concerns about the unintended consequences of FADs include interference with the natural distribution of fishes, increasing the vulnerability of highly migratory species to capture, unacceptable bycatch, and contributing to marine debris.

11.8.2 Distribution

JAPAN ARCHIPELAGO. In Japan, a structure was constructed in 1987 to encourage upwelling for the enhancement of the fisheries ecosystem in this area. It is a man-made structure of 10 m height and 20 m width that was set at 50 m water depth to induce upwelling at the eastern part of the Bungo Channel,

the Seto Inland Sea, Japan. After the placement of this upwelling structure, the nutrients, concentration of chl *a*, and biomass of zooplankton increased (Yanagi and Nakajima 1991).

Shipwrecks from World War II (WWII) litter the islands and serve as artificial reefs and dive sites (Figure 11-30). These shipwrecks provide substrate for attachment for many benthic macrofauna and macroflora; this, in turn, provides important habitat. On the other hand, the groundings of ships can also create numerous hazards for navigation or the environment including the formation of large scars through seagrass beds or coral reefs, blockage of entry into ports or harbors, and the release of engine oil and fuel into the surrounding waters (National Oceanic and Atmospheric Administration 2004a).

FADs are located along virtually every coastline in the Japan archipelago; however, georeferenced data were only available for sites around Okinawa (Figure 11-30). FADs are also commonly placed in more offshore sites to create aggregation areas for more pelagic open ocean fishes. However, there is limited information regarding the location of FADs throughout the Japanese Islands. In 1995, the Okinawa Marine Zone Fisheries Regulation Committee deployed 177 FADs around Okinawa (Kakuma 1996). These FADs were placed less than a mile from each other and have supplied fisherman areas of high fish abundance and aggregation. One of the most important species in the Okinawan FAD catch is yellowfin tuna (Kakuma 1996).

MARIANA ARCHIPELAGO. Dedicated artificial reefs are currently found in two locations of the MRA Study Area: Agat Bay, Guam and Apra Harbor, Guam (Figure 11-31). In 1969, 357 tires were tied together and scattered over a 465 m^2 area in Cocos Lagoon (Eldredge 1979). In the early 1970s, a second reef consisting of 2,500 tires was also placed in Cocos lagoon (Eldredge 1979). These tire reefs disintegrated and no longer serve as artificial reefs (Davis personal communication). In 1977, a 16 m barge was modified to enhance fish habitat and was sunk in 18 m of water in Agat Bay. Fish abundance has increased with time, and herbivorous and carnivorous communities have thrived (Eldredge 1979). In Apra Harbor, the “American Tanker,” a 90+ m-long concrete barge, was sunk in 1944 at the entrance of the Apra Harbor to act as a breakwater (Micronesian Divers Association 2005). In 1944, the 76th Naval Construction Battalion (SEABEES) built the Glass Breakwater which forms the north and northwest sides of Apra Harbor (Thompson 2002). The enormous seawall is made of 1.5 million m^3 of soil and coral extracted from Cabras Island (Thompson 2002). The Glass Breakwater is the largest artificial substrate in the Mariana Islands.

Many shipwrecks are found within the MRA Study Area including grounded vessels and military wreckage (Figure 11-31). Vessels have probably wrecked upon the shores of the Mariana Islands since Spanish galleons sailed to these islands during the seventeenth century. There is abundant WWII-era wreckage (including sunken ships, airplanes, and tanks) along the shores of the Mariana Islands that resulted from the battles of Guam, Tinian, and Saipan (Commonwealth of the Northern Mariana Islands Coastal Resources Management 2001). Many of the shipwrecks along the shorelines of the MRA Study Area have become popular dive sites (see Section 5.4 for more information on dive site locations). The groundings of ships can also create numerous hazards for navigation or the environment including the formation of large scars through seagrass beds or coral reefs, blockage of entry into ports or harbors, and the release of engine oil and fuel into the surrounding waters (National Oceanic and Atmospheric Administration 2004b). Although many of these vesels have become superficially integrated into the substrate over the years, the vessels are considered long-term hazards because they can be remobilized during storms and cause additional physical damage to corals and other living substrates (Lord-Boring, Zelo, and Nixon 2004).

Lord et al. (2003) documented 117 abandoned vessels along the coast of Guam. Most of the vessels (80) were found in water depths greater than 12 m; the other vessels were abandoned in water depths shallower than 12 m. There are seven general locations where vessels were documented in shallow water (12 m or less) along the coast of Guam (Pacific Wrecks 2011): Piti Channel (two longliners, six sailing vessels, three landing crafts, one tug, and one barge), Outer Piti Channel (three barges, one freighter, one landing craft), Outer Apra Harbor (four barges), Inner Harbor of Piti Channel (one sailboat), Sasa Bay (one sailboat), Hagåtña Boat Basin (six sailing vessels), and Cocos Lagoon (1 sailboat) (Lord et al. 2003).

A total of 55 abandoned vessels are known along the coasts of Saipan, Rota, and Tinian (Lord et al. 2003). Ten of the vessels are found in water depths greater than 12 m. At Saipan, Lord et al. (2003) documented nearshore abandoned vessels in the general area off Tanapag (two longliners, 27 barges, one cabin cruiser, one cargo vessel, one trawler, one freighter). Lord et al. (2003) found four abandoned vessels in the Tinian Harbor: two freighters, one fishing boat, and one yacht. At Rota Island, there were five abandoned vessels along the western coast (one fishing vessel, three U.S. military M-boats, and one tugboat) (Lord et al. 2003). The *#62 Nam Sung* formed alarge debris field in Sasanlago, Rota, in an area of intense wave energy that preventsed the vessel from becoming stabilized. The large debris field to adversely affected the reef for more than 25 years before being removed in 2009 (Commonwealth of Northern Mariana Islands 2009; Helton 2007; Lord-Boring, Zelo, and Nixon 2004).

Forty-five percent of the abandoned vessels encountered in shallow water (less than 12 m water depth) were potential navigation threats (Lord et al. 2003). Fourteen of the abandoned vessels documented in the Piti Channel and the Hagåtña Boat Basin were potential navigation hazards, particularly those located in the center of the Piti Channel. Potential threats to navigation in the CNMI are for the most part WWII era barges located in sheltered and nearshore areas (Lord et al. 2003). A Japanese military freighter (possibly the *Shoan Maru*) is partially awash southeast of Mañagha Island, Saipan (15.24N; 145.72E) and is a threat to navigation. The steel freighter, *Sin Long No. 8*, in Tinian is partially exposed and is a threat to navigation.

The majority of current small boat groundings are the result of operator error. However, most major groundings of larger ships (greater than 15 m in length) are typhoon related (Commonwealth of the Northern Mariana Islands Coastal Resources Management 2001).

Currently, Guam maintains 14 FADs to support recreational fishing, according to the 2011-2014 Marine Conservation Plan (Government of Guam 2011). To the extent that federal funds from the Dingell Johnson Sports Fish Restoration Fund are available, the government conducts aerial surveys of the FADs and replaces those that are lost or damaged. The Northern Mariana Islands has turned over deployment of FADs to a private contractor and currently maintains 10 FADs deployed (three remaining) between the islands of Rota and Saipan (Chapman 2004; Commonwealth of the Northern Mariana Islands Division of Fish and Wildlife 2005).

CAROLINE ISLANDS. Shipwrecks are found throughout the Caroline Islands and serve as recreational diving sites especially in Palau (Collings 2012).

11.8.3 Conditions and Stressors

Artificial habitats are generally not considered to be stressed by natural or human-made forces; however, the use of modern steel vessels as artificial habitats may pose environmental hazards. For

example, concerns about leaving modern shipwrecks in place include the threat that iron will leach from the vessel into otherwise iron-poor waters spurring bacterial blooms that could degrade the coral reefs. Shipwrecks can also pose physical threats to the reefs as they are tossed about by storms, breaking and crushing delicate organisms in a wide area (Friedlander et al. 2009). FADs that become unmoored during storms can become marine debris that subsequently causes injury to coral reefs (Committee on the Effectiveness of International and National Measures to Prevent and Reduce Marine Debris and Its Impacts 2008).

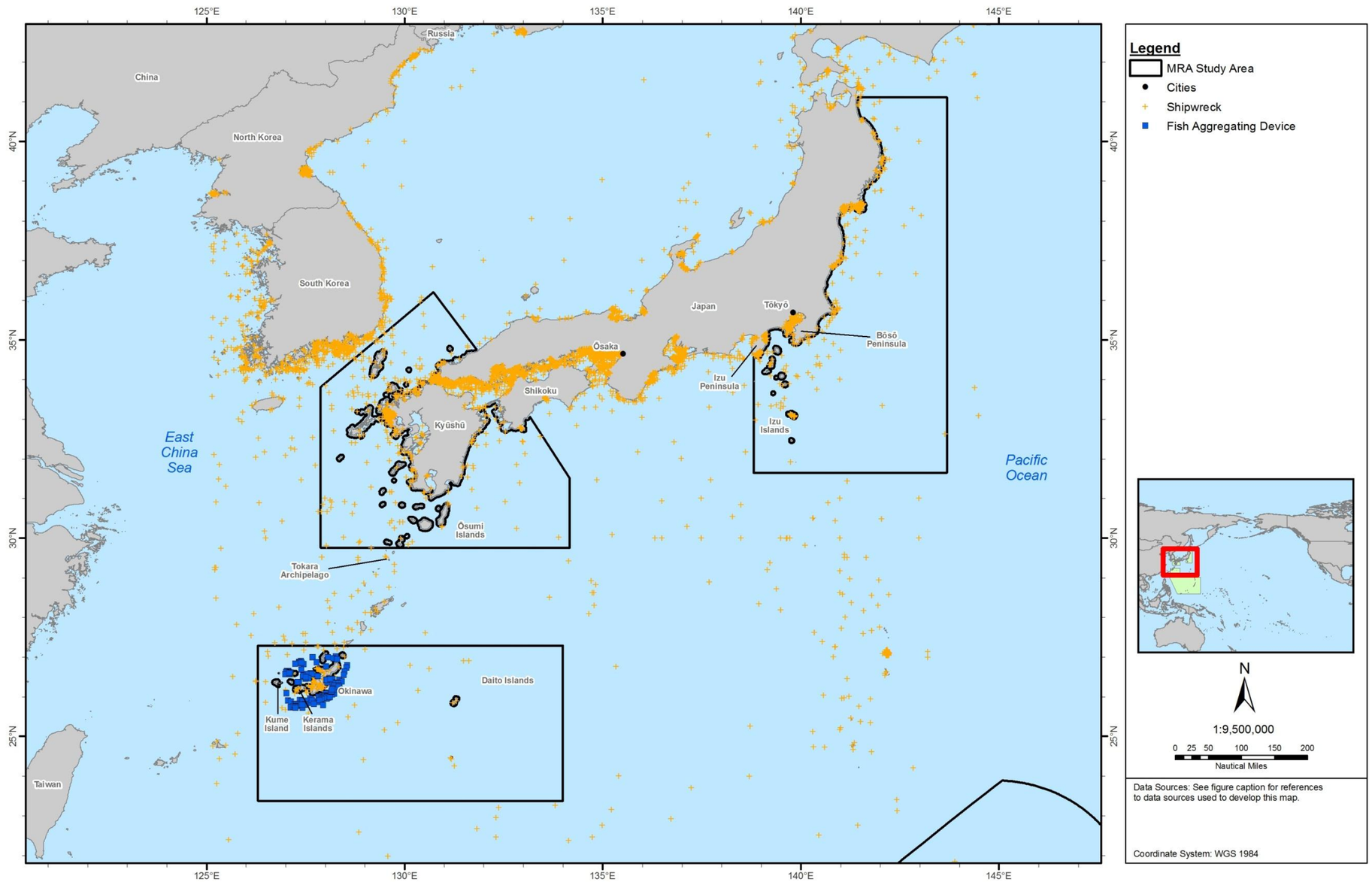

Figure 11-30: Distribution of Artificial Habitats of the Japan Archipelago (Including Shipwrecks for the Entire Area and Fish Aggregating Devices for Okinawa Island Only)
Source: U.S. Department of the Navy (2005a, c).

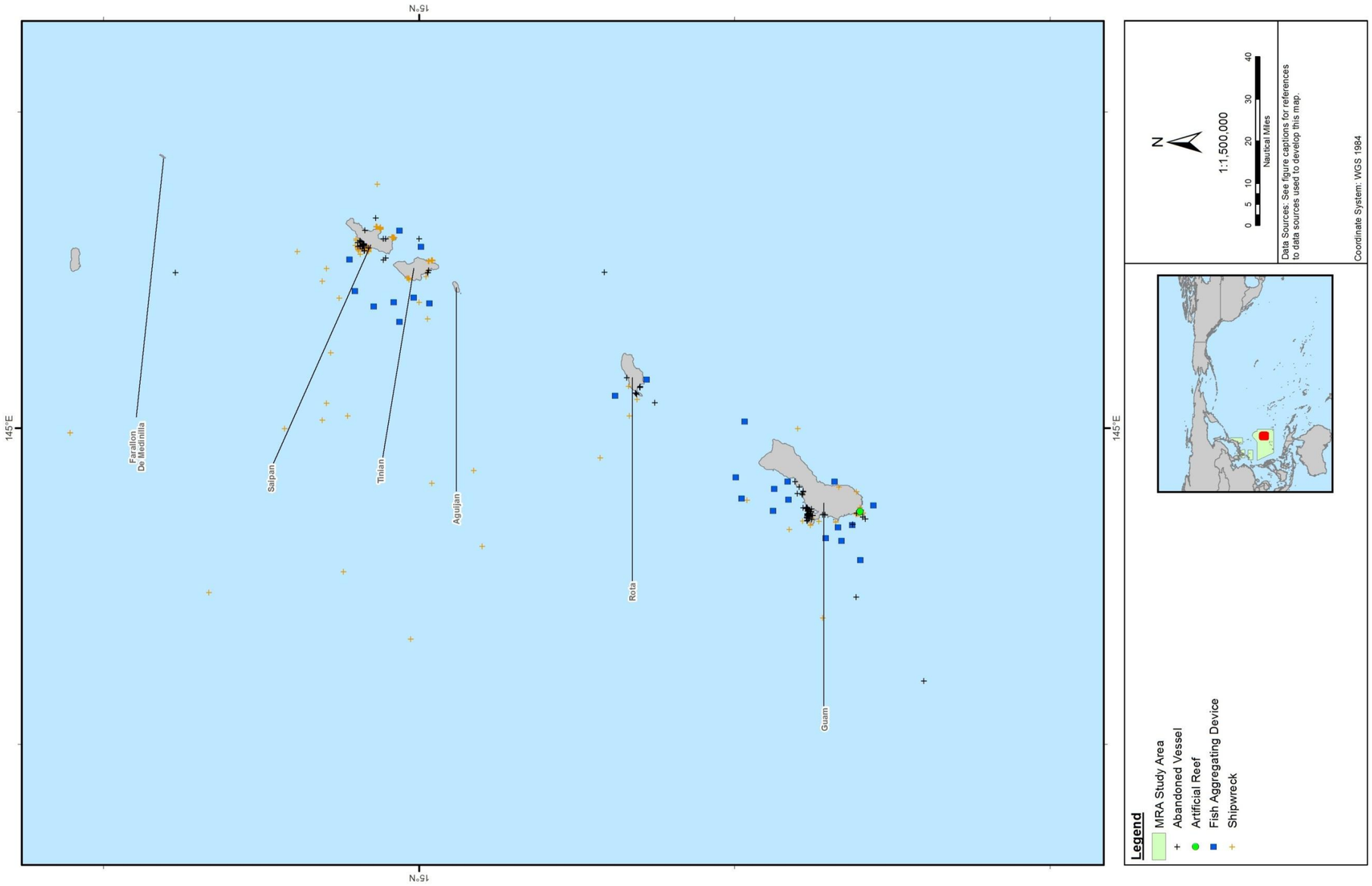

Figure 11-31: Distribution of Artificial Reefs, Shipwrecks, and Fish Aggregating Devices in the Mariana Archipleago
Source: U.S. Department of the Navy (2005b, c).

11.9 SUBMARINE CANYONS

11.9.1 Description

The most distinctive topographic features of the continental slope are steep-walled submarine canyons typically thousands of m deep (National Marine Sanctuaries 2010). Submarine canyons serve as major pathways for sediment transport from land and the continental shelf to the deep sea, with turbidity currents as an important mechanism for transport (National Marine Sanctuaries 2010). Submarine canyons provide horizontal and vertical hardbottom in the deep sea. Canyons provide a range of habitats, such as rock outcrops, boulder fields, and gravel, as well as sand and muddy deposits. A large number of species use these diverse habitats (Etter et al. 2005; Vetter, Smith, and De Leo 2010).

11.9.2 Distribution

JAPAN ARCHIPELAGO. Numerous submarine canyons occur in the Japan portion of the MRA Study Area, including Ryuyo Submarine Canyon, Tenryu Submarine Canyon, and Daisan Tenryu Submarine Canyon (Japan MRA Chapter 2).

MARIANA ARCHIPELAGO.

Guam. A bathymetric survey of a proposed dredge disposal area approximately 5 nautical miles (nm) (9.2 km) to 15 nm (28 km) northwest of Guam reported several underwater canyons (U.S. Environmental Protection Agency 2010). To the north of the dredge disposal area, a ridge of seamounts (including Spoon Bank) is incised by at least one canyon trending to the northwest down to 11,150 ft. (3,400 m) U.S. Environmental Protection Agency (2010).

CAROLINE ISLANDS. No information on submarine canyons around Yap or Palau was located. However, the morphology of the surrounding regions of the Philippine Sea Plate is consistent with presence of submarine canyons (Fang et al. 2011).

11.9.3 Conditions and Stressors

Because of their remote depth, the condition of submarine canyons is difficult to determine and the state of knowledge is poor. Ongoing and potential stressors to submarine canyons include disposal of wastes, deep-sea fishing, oil and gas extraction, and climate change (Glover and Smith 2003). Because the flow of sediments and pollutants tends to be concentrated in canyons, concentrations of persistent organic pollutants have been found higher in the deep-sea fishes of canyons than in fishes occurring in associated bays (National Marine Sanctuaries 2010). The impacts of climate change on these deep and relatively stable habitats are unknown. However, climate change could adversely affect primary production, which would indirectly reduce the supply of organic matter that drifts down from above and supports organisms living in submarine canyons (Glover and Smith 2003).

11.10 CHEMOSYNTHETIC COMMUNITIES

11.10.1 Description

Chemosynthetic organisms can live off chemicals such as methane that are released from cracks in the earth's crust in the deep sea. Larger animals acquire energy from the bacteria that live within their

bodies and which produce energy through chemosynthesis. Although all habitats in the deep sea are known to support chemosynthetic communities, large groups of invertebrates dominate the biomass only at vents and seeps (Dubilier, Bergin, and Lott 2008). The chemosynthetic communities that form on dead whales which fall to the bottom of the ocean are locally important where they occur, but are sporadic and not long lasting.

Hydrothermal Vents. The best-known and longest-lived chemosynthetic communities exist at hydrothermal vents along the mid-ocean ridges and associated rift zones. Hydrothermal vents are heated by the magma that fuels submarine volcanoes (National Oceanic Atmospheric Administration and Pacific Marine Environmental Laboratory 2010). The water that the vents eject is enriched with sulfide, hydrogen, manganese, and metals, which are expelled as tiny mineral particles. When the vents are under high pressure, clouds as tall as 150 ft. (45 m), called “black smokers,” are emitted (National Oceanic Atmospheric Administration and Pacific Marine Environmental Laboratory 2010).

Deep-sea hydrothermal vents occur in areas where new crust is being formed, near mid-ocean ridge systems both in fore-arc and back-arc regions (Humphris 1995). Seawater permeating through the crust and upper mantle is superheated by hot basalt and is chemically altered to form hydrothermal fluids. These less dense hydrothermal fluids rise through the network of fissures in the newly-formed seafloor (Humphris 1995; McMullin, Bergquist, and Fisher 2000). Water temperature in vent systems can vary significantly, and vent macrofauna are distributed according to water temperature (Nybakken 2001). Water that rises directly to the surface can exit at 350°C, forming “black smoker” chimneys. No animals are associated with these extreme temperatures (Nybakken 2001). The temperature of the hydrothermal fluid is 200° to 400°C in areas of focused flows and less than 200°C in areas of diffuse flow. Most vent communities survive in water at temperatures below 30°C (Nybakken 2001).

Hydrothermal vent fluids are rich in chemicals as the heated seawater reacts with the molten rock, causing metals and other minerals to dissolve into solution. The fluids are typically poor in oxygen content and contain toxic reduced chemicals including hydrogen sulfide and heavy metals (McMullin, Bergquist, and Fisher 2000). As the hot hydrothermal fluids come in contact with the much cooler seawater overlying the vent, heavy metals precipitate out and accumulate, forming chimneys and mounds. In complete darkness, high ambient pressure, and extreme thermal and chemical conditions of the deep sea, metazoans (multicellular animals) are able to adapt and colonize these sites to form luxuriant chemosynthetic communities. Chemosynthetic bacteria use the reduced chemicals of the hydrothermal fluid (primarily hydrogen sulfide) as an energy source for carbon fixation and generate chemosynthetic-based primary production. Because vent water is anoxic, bacteria must be capable of utilizing oxygen from the surrounding ambient water to produce organic material. The sulfide released from the vent waters is rapidly oxidized and sulfide does not persist in the water column far from the vent site. Organisms that require both oxygen and sulfide have to live in the small area where vent water and ambient water begin to interact (Nybakken 2001).

Metazoan communities associated with these chemosynthetic environments are typically characterized by high biomass and low diversity. Metazoans can either consume chemosynthetic bacteria or form symbiotic relationships. For example, the vestimentiferan, *Riftia pachyptila*, and the giant clam, *Calyptogena magnifica*, both house symbiotic chemosynthetic bacteria in their tissues (Nybakken 2001). In both cases, metazoans use numerous morphological, physiological, and behavioral adaptations to flourish in this extreme deep-sea environment. Hydrothermal vents have lifespans measured in decades. Some inactive vent systems have been observed with the remains of vent macrofauna communities; this suggests that vent organisms have life spans that are also in tens of years (Nybakken 2001).

Cold Seeps. Chemosynthetic communities also occur at cold seeps, where dissolved reducing substances are emanating from the seafloor sustain communities of benthic residnets and mobile visitors. Subduction zone cold seeps are associated with the active tectonic areas of continental margins. Numerous cold seeps have been identified in the subduction zones of the MRA Study Area (Juniper and Sibuet 1987). Cold seep communities have been found in oceans around the world. In the MRA Study Area, seep habitats are are dominated by several species of a vesicomyid clam (*Calyptogena*) and an abundance of abyssal benthic organisms (Juniper and Sibuet 1987).

11.10.2 Distribution

Since 1979, more than 200 seafloor vent sites have been located (Wheat et al. 2000). These plumes are of fundamental importance to the composition of the oceans. Hot springs support a unique ecosystem of microorganisms and animals that do not need sunlight to survive: some 500 new species have been found associated with vent systems (Wheat et al. 2000).

Chemosynthetic communities are found from shallow intertidal areas to the deep ocean, including the deep ocean trenches more than 19,685 ft. (6,000 m) deep (Jamieson et al. 2010). Cold seeps occur on the continental slopes and margins of most oceans, where fluids that contain sulfide and methane seep out of the sediment into the overlying water (Cordes et al. 2010). Cold seeps form where gases and fluids are forced upward through the seafloor, generally at depths between 1,970 and 9,840 ft. (600 and 3,000 m) (Cordes et al. 2010; Levin et al. 2010). The low temperatures, high pressure, and limited dissolved oxygen of seep areas create an extremely challenging environment for marine organisms. However, the rich supply of energy supports a diversity of invertebrates (Fisher et al. 2007). Shallow subtidal and intertidal chemosynthetic communities have been identified in areas rich in sulfide, including eel-grass sediments, mangrove mud, sediments surrounding coral reefs, and sediments in upwelling regions (Dubilier, Bergin, and Lott 2008).

JAPAN ARCHIPELAGO

Okinawa Trough. In the Okinawa Trough, hydrothermal vent communities can be found at Minami Ensei knoll, Iheya ridge, and at Izena caldron. At Minami Ensei knoll are approximately 10 chimneys with maximum temperatures exceeding 270°C. *Bathymodiolus japonicus* is dominant. White, thread-type bacteria mats cover the seafloor surrounding the chimneys (JAMSTEC 1998). In a study by Hashimoto et al. (1995), at least 48 species of vent metazoans were collected, and six additional species were observed at the Minami-Ensei Knoll. Of these 54 species, 18 are new species. This study noted that organisms segregate according to the hydrothermal habitat. For example, at the Minami Ensei Knoll, the hydrothermal habitat can be categorized into two types: (1) rocky or exposed field with active, superheated vents and/or low-temperature vents; and (2) sedimentary or covered field with slow, low-temperature (approximately 5 to 10°C higher than the ambient seawater) hydrothermal fluid flow from the sandy bottom (Hashimoto et al. 1995). At Hatoma Knoll, water temperatures were near freezing (3.8°C) at a depth of 1480 to 1530 m, where adult snailfish (*Careproctus rhodomelas*) were captured (Takemura et al. 2010).

Kagoshima Bay. In Kagoshima Bay, gases are emitted from the seafloor with high concentrations of carbon dioxide, methane, and hydrogen sulfide. The dominant metazoan at this site is *Lamellibrachia satsuma* with biomasses that exceed 9 kilogram (kg)/m^3. *Lamellibrachia* are relatively insensitive to pressure and temperature, and these are the shallowest chemosynthetic communities on earth (JAMSTEC 1998).

Izu-Ogasawara Shoto region. In this region, many submarine volcanoes and hydrothermal communities occur at the Suiyo seamount, Mokuyo seamount, Kaikei seamount, and the Nikko seamount. The Suiyo seamount is characterized by a field of chimneys that emit 300°C fluids surrounded by dense communities of *Bathymodiolus septemdierum* (JAMSTEC 1998).

Hydrothermal vent communities and cold seeps in the Japan Archipelago are listed in Table 11-2 and Table 11-3, respectively. Both types of chemosynthetic habitats are illustrated in Figure 11-32.

Table 11-2: Hydrothermal Vent Communities in the Japan Archipelago

Region	Depth	Biota
Okinawa Trough		
Izena Hole	1,310-1,580 meters (m)	Galatheid crabs, lithodid crabs, shrimps, vestimentiferans, *Bathymodiolus platiformis*, and *Calyptogena* sp. (bivalves)
Minami_Ensei Knoll	640-710 m	*C. solidissima* (vesicomyid bivalve), *B. japonicus* and *B. aduloides* (mussels), and vestimentiferans (unidentified)
Iheya Ridge	1,400-1,430 m	*C. okutanii*, *Lamellibrachia* sp. L1, *Escarpia* sp. E2, and *Alaysia* sp. A2
North Iheya Knoll	1,050 m	*C. okutanii*, *C. nankaiensis*, *L.* sp. L1, *A.* sp. A2, *B. japonicus*, and *B. platifrons*
Hatoma Knoll	1,470-1,520 m	*B. platiformis*, *Shinkaia crosnieri* (galatheid crab), and *Alvinocaris longirostrus* (bresiliid shrimp)
Kagoshima Bay		
Kagoshima Bay	82 m	*L. satsuma* and a single species of *nautiliniellid* polychaete
Izu-Ogasawara-arc		
Myojin Knoll	1,290 m	*B. septemdierum*, *Austinograea yunohana* (bythograeid crab), and garatheid crabs
Sumisu Caldera	690 m	*B.* sp. tube worms (possibly vestimentiferans), and gastropods
Suiyo Seamount	1,370 m	*B. septemdierum*, *A. yunohana*, *Alvinocaris* sp., and scale worms
Mokuyo Seamount	1,260 m	*Alvinocaris* sp., *Lebbeus, B. septemdierum*, and vestimentiferans
Kaikata Seamount	430 m	*A. yunohana*, *B.* sp., and *Symphurus* sp. (tonguefish)
Nikko Seamount	430 m	Vestimentiferans (dense colonies including *L. satsuma*), a tonguefish, a bythograeid crab, *Neolepas* sp. (a primitive barnacle), *B.* sp., and *A. yunohana*
Mariana Trough		
Daini Kasuga Seamount	386 m	Three vent endemic animals: a bythograeid crab, a primitive barnacle, and a tonguefish. Also, a microscopic structure of bacteria mats.

Source: Kojima (2002).
Note: m = meters

Table 11-3: Cold Seep Communities in the Japan Archipelago

Region	Depth	Biota
Hokkaidō Island (Pacific)		
Hiroo Submarine Canyon	1,200 meters (m)	*C.* spp. (undescribed)
Japan and Kuril Trenches		
Daiichi Kashima Seamount	5,640-5,700 m	*C. phaseoliformis*
Sanriku Escarpment (upper)	5,650-6,000 m	*C. phaseoliformis*
Kurile Trench	5,100-5,800 m	*C. phaseoliformis*
Sanriku Escarpment (lower)	6,180-6,470 m	*C. phaseoliformis*, *C. fossajaponica*, *Parathyasira kairei*, and *Acharax johnsoni*
Sanriku Escarpment (on the foot)	6,600-6,800 m	*C. fossajaponica*
Japan Trench (axis)	7,330-7,430 m	*C. phaseoliformis* and *Maorithyas hadalis* (thyasirid clam)
Japan Sea		Low biodiversity
Okushiri Ridge	3,110 m	White bacterial mats, small snails, shrimps, sea cucumbers, and anemones
Sagami Bay		*Calyptogena soyoae* and *C. okutanii* (vesicomyid clams), *Bathymodiolius* sp. (mussels), and *Lamellibranchia* sp. (vestimentiferans)
Sagami Bay (off Hatsushima)	830-1,230 m	
Okinoyama Bank	1,180-1,450 m	
Sagami Knoll	1,390-1,460 m	
Suruga Bay		
Suruga Bay (off Toi)	1,490-1,500 m	*C. fausta*
Nankai Trough		
Kanesu-no-Se Bank	290-330 m	*Mesolinga soliditesta* (lucinid bivalve) and three vestimentiferan species (*Lamellibranchia satsuma*, *L.* sp. L1, and *Escarpia* sp. E1
Muroto Knoll	600 m	*C. solidissima*
Ashizuri Knoll	600 m	*C. solidissima*
Daini Tenryu Knoll	590-610 m	*C. solidissima* and *L.* sp. L1
Ryuyo Submarine Canyon	1,090-1,100 m	*C. okutanii*, *C. nankaiensis*, *L.* sp. L1, and *E.* sp. E1
Omaezaki Spur	1,140-1,200 m	*B. aduloides*, *L.* sp. L1, and *E.* sp. E1
Yukie Ridge	1,940-2,180 m	*C. fausta, C. similaris, and L.* sp. L2
Tokai Thrust	2,080 m	*C. similaris*
Tenryu Submarine Canyon	3,760-3,840 m	*C. nautilei*, *C. laubieri*, and *C. kaikoi*
Daisan Tenryu Submarine Canyon	3,760 m	*C. tsubasa*
Daiichi Minami Muroto Knoll	3,620 m	*C. nautilei*
Muroto Point	3,210-3,270 m	*L.* sp. L2, *C. nautilei*, and *C. tsubasa*, and *C.* sp. (unidentified)
Zenisu Ridge	3,300 m	*C. tsubasa*, *C.* sp. (unidentified)
Ryukyu Islands		
Kuroshima Knoll	680-810 m	*C. solidissima*, *Vesicomyia kuroshimaena* (bivalves), *B.* sp., *L.* sp. L1, and *L.* sp. L5
Kikaijima Island	1,440-1,650 m	*C. similaris* and *E.* sp. E2

Source: Kojima (2002).
Note:
m = meters

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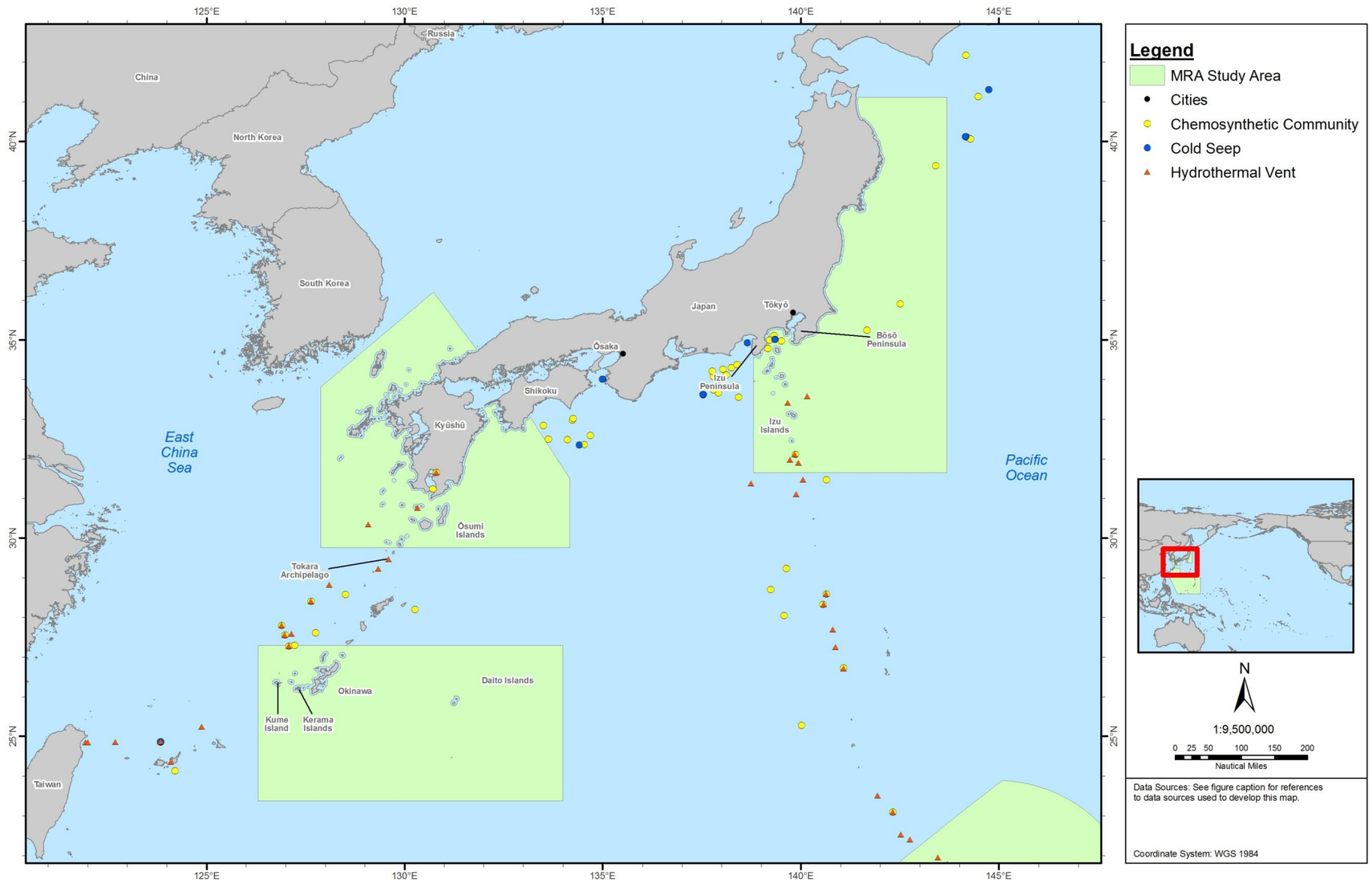

Figure 11-32: Distribution of Chemosynthetic Communities in the Japan Archipelago (Including Cold Seeps and Hydrothermal Vent Habitats)
Sources: Baker, Ramirez-Llodra, and Perry (2010); Beaulieu (2010); and U.S. Department of the Navy (2005a).

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Sagami Bay. Cold seep communities are found at five locations in Sagami Bay: off shore Hatsushima, Okinoyama banks, Sagami knoll, Misaki knoll, and Miura knoll (JAMSTEC 1998). Geologically and seismologically, the western part of Sagami Bay is one of the most active areas around Japan (Hashimoto et al. 1989). The first chemosynthetic community from Japanese waters was discovered in 1984 in the cold seep area off Hatsushima, Sagami Bay (Kojima 2002). The giant clam (*Calyptogena soyoae*) dominates this site with a biomass of approximately 20 kg/m^2, a biomass about three orders of magnitude greater than that of usual nearshore benthic communities at similar depths (Hashimoto et al. 1989; JAMSTEC 1998).

Nankai Trough. In the Nankai trough, many cold seep areas are distributed within a relatively narrow area, and presence of many undiscovered seep sites is likely (Kojima 2002). In all communities, *Calyptogena* is the dominant genera, with at least seven confirmed species (JAMSTEC 1998).

Japan and Kuril Trenches. The deepest chemosynthetic communities in the world are associated with the subduction of the Pacific Plate beneath the Northern American Plate (Fujikura et al. 2002; JAMSTEC 1998; Kojima 2002). This seep area is distributed at depths from 5,225 to 7,430 m on the landward slope of the Japan Trench, and the communities are dominated by *Calyptogena phaseoliformis* (Fujikura et al. 2002).

Japan Sea. These chemosynthetic communities are characterized by low biodiversity; this has been attributed to severe anoxic conditions during the middle period of the last glacial period (Kojima 2002). The cold seep community at the Okushiri Ridge consists primarily of bacterial mats and gastropods. This cold seep was probably formed in 1940 by the Shakotan earthquake (magnitude = 7.5) (JAMSTEC 1998).

MARIANA ARCHIPELAGO. The MRA Study Area includes the southern portion of the Izu-Bonin-Mariana arc system, a 2600-km-long, arc-trench system where the Pacific plate is subducted beneath the Philippine Sea plate. Numerous hydrothermal vent sites are associated with the seamount and island chain that rises from the seafloor about 200 km west of the subduction area (Hein et al. 2008). Evidence of active hydrothermal venting has been identified near more than 12 submarine volcanoes and at two sites along the back-arc spreading center off of the volcanic arc (Embley et al. 2004; Kojima 2002), with more systems possibly yet to be discovered. Hydrothermal vents at Esmeralda Bank, one of the active submarine volcanoes in the Mariana Islands portion of the MRA Study Area, span an area greater than 0.2 km^2 on the seafloor and expel water at temperatures exceeding 78°C (Stüben et al. 1992). West of Guam and on the Mariana Ridge are three known hydrothermal vent fields: Forecast Vent site (13°24'N, 143°55'E; depth: 1,450 m), TOTO Caldera (12°43'N, 143°32'E), and the 13°N Ridge (13°05'N, 143°41'E) (Kojima 2002). The gastropod *Alviniconcha hessleri* is the most abundant chemosynthetic organism found in hydrothermal vent fields of the Mariana Trough. Vestimentiferan tube worms also occur at these sites west of Guam (Kojima 2002).

CAROLINE ISLANDS.
No volcanic activitiy has been detected in the Palau and Yap arcs in recent times, and no hydrothermal vents or cold seeps are known to occur in this region (Kobayashi 2004).

11.10.3 Conditions and Stressors

The vent systems are under enormous stress from natural subduction processes. Humans can do little to interfere with the hydrothermal venting itself, but can exploit the mineral resources produced by hydrothermal processes and the biological resources that subsist near vents. Hydrothermal activity at vents can lead to accumulation of metal-rich deposits that will likely be mined in the future. At present,

such mining is in the exploratory stage, but its ultimate occurrence is considered inevitable (Hein et al. 2010).

11.11 DEEP CORAL COMMUNITIES

11.11.1 Description

Deep coral communities inhabit continental shelves, slopes, canyons, and seamounts in waters ranging in depth from 50 m to over 3,000 m (Hourigan et al. 2007). Deepwater corals (also called coldwater corals) that inhabit these areas do not form reefs like those in shallow tropical waters (Roberts et al. 2009). Instead, they often create dense structure- and habitat-forming colonies. Most deepwater corals are gorgonians and antipatharians (Cairns 2007; Etnoyer 2010; Hourigan et al. 2007; Parrish and Baco 2007; Whitmire and Clarke 2007). Biologically rich and diverse communities of crustaceans, molluscs, echinoderms, polychaete, and sipunculan worms, sponges, and other macrofauna can be associated with the structure-forming corals (Freiwald et al. 2004).

True deep coral communities live in complete darkness, in temperatures as low as 4°C and in waters as deep as 6,000 m (CoRIS 2003); therefore, they are also known as “cold-water coral reefs” (Freiwald et al. 2004). Deep corals lack the symbiotic zooxanthellae found in tropical reef-building corals. Thus, deep corals do not benefit from a carbon supply provided by symbiotic algae but rather survive solely on suspension feeding. The biological diversity of deep-sea corals is high; from an economic perspective, this diversity creates valuable habitat for several commercially fished species (Gass 2003). However, the full ecological importance/value of deep-sea coral habitat is still unknown (Freiwald et al. 2004). Deep-sea corals are home to thousands of species including sponges, polychaetes (or bristle worms), crustaceans (crabs and lobsters), mollusks (clams, snails, octopuses), echinoderms (starfish, sea urchins, brittle stars, feather stars), bryozoans (sea moss), and fish (Freiwald et al. 2004). Cold-water coral reefs occur worldwide, including Japan (Freiwald et al. 2004).

Much like shallow-water corals, deep-sea corals are fragile and slow growing; thus, they are vulnerable to human-induced physical impacts (Freiwald et al. 2004; Roberts and Hirshfield 2003). Deep-sea coral communities have existed for millions of years. Living communities can be 8,000 years old. Sizes of these communities can range from patches of small solitary colonies to massive reef structures (mounds, banks, and forests), from several meters to tens of km across and from 1 to tens of meters high (Cairns 1994). The growth rate of some deep-water coral reefs (*Lophelia pertusa*) ranges from 4 to 25 mm/year (Roberts and Hirshfield 2003).

11.11.2 Distribution

JAPAN ARCHIPELAGO. Deep coral reef communities possibly inhabit banks surrounding Japanese islands and numerous seamounts located off Japan . The majority of the Japanese seamounts are clustered, which probably positively influences abundance, diversity, and density of deep-water corals that may be on the seamounts.

Based on surveys conducted in the northwest Pacific, deep-water scleractinians possibly occurring off Japan include *Lophelia pertusa*, *Madrepora oculata,* and *Goniocorella dumosa* (Freiwald et al. 2004). *L. pertusa* is a common deep-sea reef habitat builder (Freiwald et al. 2004). Individual branched colonies of *L. pertusa* can be several meters across, and contiguous colonies of *L. pertusa* can form long swaths of deep-sea reef habitat. *L. pertusa* has been found at water depths ranging from 39 to 3,383 m. *M. oculata* also forms large branching colonies, but they tend to be more fragile than those of *L. pertusa*.

The documented depth range of *M. oculata* is 55 to 1,950 m. *G. dumosa* has been found within the 88- to 1,488-m depth range, with concentrated populations from 300 to 400 m. These stony corals may occur on both the continental slope and seamounts (Freiwald et al. 2004).

Cold-water soft corals usually occur with the deep-water stony corals (Freiwald et al. 2004). On high-latitude, deep-water reefs, abundance of cold-water soft corals is often greater than that of stony corals, producing what are known as "octocoral gardens." These have been observed on Japanese seamounts (Freiwald et al. 2004). Octocoral gardens are typically dominated by gorgonians, including precious corals, sea fans, and bamboo corals. Abundant, fan-shaped gorgonians and antipatharians on rocky slopes were recorded during surveys at water depths ranging from 120 to 300 m on the continental slope of Okinawa and Kume Islands, and at Miyako, Ishigaki, and Iriomote Islands (southern Ryukyu Islands, Yaeyama Archipelago). (Yamazato 1972). Other sessile organisms also found on hard substrates of the continental slope of the islands were sponges, lace corals, true soft corals (including *Siphonogorgia* sp.), anemones, non-reef building corals, bryozoans, bivalves, polychaetes, crustaceans, crinoids, and ophiuroids (Yamazato 1972).

Cold-water black and lace corals, which include precious corals, also form branched reef structures. Deep-water precious corals that occur in Japanese waters may include species that occur in the Hawaiian Islands: black corals (*Antipathes grandis*, *A. dichotoma*), pink corals (*Corallium secundum*, *C. regale*), gold coral (*Gerardia* spp.), and bamboo corals (*Keratoisis nuda*, *Acanella* spp., *Lepidisis olapa* (Grigg 1974; Grigg 2002).

A study on Shiribeshi Seamount in the Sea of Japan indicated that cold-water corals may be an important contributor to carbonate production in the deep sea environments (Matsumoto 2010). On Shiribeshi Seamount (43° 34–36'N, 139° 31–35' E) at depths of 120 to 200 m in the Japan Sea the calcium carbonate standing stock and carbonate production of gorgonian corals was estimated at 70.64 grams per square meter (g m^2)and 3 grams per square meter per year (g m^2yr^1), respectively.

Around Okinawa Island at water depths from 50 to 135 m, deep coral communities, rhodoliths, and nodules or unattached algal growth forms of coralline red algae were found covering 45% of the deep fore reef to shelf areas (Matsuda and Iryu 2011).

MARIANA ARCHIPELAGO. Distribution and abundance of deep coral communities in the Mariana Archipelago are not well documented in the published literature. A global distribution map of deepwater corals prepared in 2004 did not indicate any major deepwater coral habitat in the Mariana Islands, but the authors suggested that the absence was due to lack of research in the area (Freiwald et al. 2004). Since then, eight species of deep corals have been reported from Guam (Parrish and Baco 2007). Predictive modeling of coral distribution estimated the worldwide habitat suitability for deepwater corals at various depths. The entire Mariana Archipelago was estimated to have a 40 to 100% probability of providing suitable habitat for octocorals at depths ranging from 500 to 2000 m, particularly in association with seamounts. The estimated depth of greatest likelihood of deepwater corals habitat was 1000 m (Clark, Tittensor, and Rogers 2007).

CAROLINE ISLANDS. Distribution and abundance of deep coral communities around the Caroline Islands have not been reported in the published literature. Results of the habitat suitability modeling, described above for the Mariana Archipelgo, were the same for the Caroline Islands—deepwater corals, especially octocorals, were considered extremely likely to occur between 500 and 2000 m off the islands of Yap and Palau (Clark, Tittensor, and Rogers 2007).

11.11.3 Conditions and Stressors

The greatest threat to deepwater corals and hardbottom habitat is direct physical destruction caused by heavy bottom trawls (Lumsden et al. 2007). Additional threats are posed by expansion of oil and gas exploration and production on the outer continental shelf, and by ocean acidification, all of which are expected to increase in the coming years (National Oceanic and Atmospheric Administration 2010c).

Trawls and heavy fishing gear used by commercial fishing have severely injured deep-sea coral communities in many areas of the world. Deep-sea coral communities are also susceptible to physical impacts from fishing (e.g., bottom trawling), oil- and gas-related activities, cable laying, seabed aggregate extraction, shipping activities, disposal of waste in deep waters, coral exploitation, other mineral exploration, and increased atmospheric carbon dioxide (Freiwald et al. 2004; Gass 2003; Roberts and Hirshfield 2003). For damaged cold-water coral reefs to recover may require time spans of decades or centuries (Freiwald et al. 2004; Roberts and Hirshfield 2003).

11.12 SEAMOUNTS

11.12.1 Description

Seamounts are underwater mountains that rise more than 330 ft. (100 m) from the seafloor (Staudigel et al. 2010). Other underwater features considered seamount habitat are banks and ridges. Most seamounts are created by volcanic activity and emerge as bare rock. Once a seamount breaks the sea surface, it becomes an oceanic island. Seamounts provide unique habitat features in the open ocean, with benefits to all types of marine organisms (Pitcher et al. 2007b). Most organisms on seamounts depend on nutrients delivered by currents (Clark et al. 2010; Lundsten, Barry, et al. 2009; Rogers et al. 2007) or hydrothermal vents (Santos et al. 2010).

Once a seamount is colonized by organisms, the habitat produced by living organisms may take on the characteristics of other typical hardbottom habitat. Hydrothermal venting at some seamounts creates physical and chemical conditions that support distinct chemosynthetic communities (Clark et al. 2010). Chemosynthetic organisms can live off chemicals such as methane that are released from cracks in the earth’s crust in the deep sea. Water depth is generally the best indicator of which species occur within seamount habitats (O'Hara 2007; Rogers et al. 2007). Due to different environmental variables, however, the functional groups are represented by different species at different locations (Clark et al. 2010; Morato and Clark 2007). Corals, sponges, and crinoids, for example, are most successful on topographic features that enable them to filter plankton from swift currents (Rogers et al. 2007). Where sediments are scarce, these groups dominate the invertebrate seamount community (Samadi, Schlacher, and de Forger 2007). Nematodes, polychaetes, and other burrowing animals settle where soft sediments provide shelter and foraging opportunities (Surugiu et al. 2008). These organisms, in turn, provide structure and trophic linkages that support other species, leading to an integrated seamount community (Pitcher et al. 2007a).

It has been well-documented that seamounts serve as feeding habitat for many migratory species (De Forest and Drazen 2009; Morato and Clark 2007; Morato et al. 2008; Pitcher and Bulman 2007). Seamounts can influence the local distribution of migratory organisms in the area that may visit to take advantage of the dense aggregations of prey at seamounts (Pitcher et al. 2007b). Cross Seamount, south of Oahu, peaks just 985 ft. (300 m) beneath the surface, and attracts substantial numbers of bigeye tuna (*Thunnus obesus*), possibly there to prey on smaller fishes and squid at the top of the seamount (De Forest and Drazen 2009). Habitat value has been described for only a limited number of seamounts.

Form, size, depth, and location of a seamount determine the function and value of its habitat (Clark et al. 2010). Biological sampling has occurred on fewer than 200 seamounts worldwide; no coherent functional value has yet emerged from this limited data set (Etnoyer, Wood, and Shirley 2010). Seamounts with relatively shallow summits seem to attract top predators, such as fish (Holland and Grubbs 2007), seabirds (Thompson 2007), and marine mammals (Kaschner 2007); these and other migratory predators, such as sea turtles, are frequent visitors at many seamounts (Holland and Grubbs 2007; Kaschner 2007; Litvinov 2007; Lundsten, McClain, et al. 2009; Pitcher et al. 2007b; Santos et al. 2007; Thompson 2007).

11.12.2 Distribution

JAPAN ARCHIPELAGO. Seamounts are found along the eastern side of the Japan Archipelago. Approximately 70 seamounts occur in the Shikoku Basin, including the Kinan Seamounts, seamounts located on the Kyūshū-Palau Ridge at 26.8 N (Ishizuka et al. 2011), those on the Amami Plateau, and those located close to the Ryukyu Trench (Figure 11-32). A cluster of at least 16 seamount occurs between southern Japan and the Kyūshū -Palau Ridge (roughly between 20° and 29°N and 128° and 137°E), including seamounts associated with the Amami Plateau, Daito Ridge, Oki-Daito Ridge, Urdaneta Plateau, Kyūshū -Palau Ridge and Ogasawara Plateau (Takayanagi et al. 2007).

MARIANA ARCHIPELAGO. The first map of the West Mariana Ridge using a multibeam echosounder revealed 82 submarine peaks of various depths and morphologies comprising the ridge. The overall bathymetry of the ridge suggests recent or even current tectonic activity, probably uplift (Gardner 2010).

Guam. A bathymetric survey of a proposed dredge disposal area approximately 5 nm (9.2 km) to 15 nm (28 km) northwest of Guam reported a large conical seamount, known as Perez Bank or Tracey Seamount. This deep seamount, about 15 nm (28 km) northwest of Apra Harbor, extends from the ocean floor at almost 10,000 ft. (3000 m) up to within 2,625 ft. (800 m) of the ocean surface. A ridge of seamounts at the extreme western edge of the dredge disposal study area reaches up to within approximately 5,575 ft. (1,700 m) of the sea surface (U.S. Environmental Protection Agency 2010).

Seamount X is about 70 km west-southwest of Guam (13.25°N; 144.02°E), peaking at 1230 m below the sea surface. Sulfur flows originating from the hydrothermal vent have formed thick deposits on the seamount, where dense aggregations of thousands of squat lobsters coexisted with shrimp, crabs, and scaleworms. A caldera at the summit indicates past eruptions, but no modern record of volcanic activity is available (Global Volcanism Program 2012d).

About 70 km west of Guam (13.40°N; 143.92°E), Forecast Seamount is known for its extreme hydrothermal fluid temperatures. In 2006, vent fluids of up to 200 degrees C were measured, indicating Forcast Seamount is one of the hottest of the Mariana vent systems. Shrimp, snails, limpets, crabs, sulfide worms, and scale worms are known from this seamount (Global Volcanism Program 2012b).

Rota. During a bathymetric survey of the Mariana Island arc in 2003, NOAA charted an active submarine volcano 517 m beneath the sea surface at 14.601°N; 144.775°E (Global Volcanism Program 2012c). The seamount, named NW Rota-1, is about 64 km northwest of Rota Island (100 km north of Guam). During a return survey the following year, researchers observed NW Rota-1 undergoing a minor submarine eruption; the plume of ash, rock particles, and molten sulfur droplets was ejected from a vent named Brimstone Pit about 40 m below the peak (Global Volcanism Program 2012c).

Tinian. Two other seamounts in the Mariana Islands portion of the MRA Study Area are classified as "major volcanoes of the Mariana Islands" (U.S. Geological Survey 2003). Esmeralda Bank is a large seamount southwest of Tinian (15.00 °N, 145.25°E) with three peaks that lie only 43 to 140 m beneath the sea surface. The tallest peak reveals signs of eruption, including a west-facing caldera about 3 km wide. Esmeralda Bank is known for frequent sulfur boils that discolor the water (Global Volcanism Program 2012f). This mount is thought to have erupted about six times since 1944, although records are uncertain (Global Volcanism Program 2012f; Smithsonian National Museum of Natural History 1995).

Saipan. Ruby Seamount, about 60 km northwest of Saipan (15.62N, 145.57E), last erupted in 1995. Its surface was historically reported to lie 230 m beneath the sea surface. However, after the eruption, its peak was reported to have risen to within 185 m of the surface (Smithsonian National Museum of Natural History 1995).

Farther north (15.93°N; 145.67°E), the East Diamante seamount rises to within about 127 m of the sea surface. This seamount is characterized by sulfide emitting chimneys known as "black smokers" (Global Volcanism Program 2012a). About 12 km south of Sarigan Island, an active submarine volcano reaches to within 184 m of the sea surface at 16.58°N; 145.78°E. Known as South Sarigan, this seamount erupted in 2010, spewing ash and steam 12 km into the atmosphere. The morphology and surficial characterization of its multiple peaks suggest that this seamount has frequent volcanic activity (Global Volcanism Program 2012e).

An extremely shallow seamount, Supply Reef, peaks at only 8 m below the surface about 10 km northwest of the Maug Islands (20.13°N; 145.10°E). Although submarine eruptions have been detected in the general vicinity of Supply Reef, presence of a living coral community on its summit suggests that it has not erupted in modern times (Smithsonian National Museum of Natural History 2012b).

The Ahyi Seamount is the northernmost known seamount in the Mariana Archipelgo, about 18 km southeast of Farallon de Pajaros (Uracas) (20.42°N; 145.03°E). This shallow submarine volcano lies just 137 m below the sea surface. Fishing crews have reported seismic activity and discolored sulfuric waters in the area. As recently as 2001, seismic detections at monitoring stations have pointed to activity at or near the Ahyi Seamount (Smithsonian National Museum of Natural History 2012a).

CAROLINE ISLANDS. In general, the marine geology of the Caroline Islands is characterized by ridges and plateaus that run west-northwest to east-southeast or west-southwest to east-northeast (Kojima 1999). Surveys of seamounts in the Caroline Islands have focused on locating mineral-rich areas suitable for marine mining. A group of 17 potentially valuable seamounts was mapped in the eastern portion of the FSM (east of 140 degrees E longitude) between 5 and 10 degrees north latitude between 1000 and 2000 m deep (Kojima 1999). No seamounts near Yap or Palau were identified during the survey. Other large-scale regional reviews of seamounts have concluded that the history and development of seamounts in the Caroline Islands is obscured by the proximity of the subduction zone (Clouard and Bonneville 2001; Neall and Trewick 2008), as described in Section 11.13 below. One well-known seamount about 17 miles (mi.) north of Yap is known as Hunter Bank Seamount, or "Sippin," which means "sunken island" in the language of Yap (Manta Ray Bay Resort 2012). This popular dive spot reaches to within 547 ft. of the sea surface, according to elevations shown on Google Earth at approximately 9° 57' 21.64"N, 138° 15' 47.13"E.

11.12.3 Conditions and Stressors

A global assessment of the habitat quality of seamounts recorded substantial cumulative impacts on essentially all seamounts in the world (Halpern et al. 2008). These impacts are mainly due to deepwater trawl fisheries closely tied to seamount habitats (Rogers et al. 2008). Bottom trawls and dredges pose the most significant threat to seamount communities worldwide. Direct evidence for the destruction of seamount habitat includes bycatch of abundant live coral pieces in trawls and changes in species abundance, especially declines in top-level predators, following repeated trawls on a seamount (Clark and Koslow 2007; Clark et al. 2010; Hourigan et al. 2007; Shank 2010).

Mining of mineral resources on seamounts is an increasing threat to these habitats (Clark et al. 2010; Morato et al. 2010). Currently, mining on seamounts is minimal, but extraction of various ores is becoming more likely (Davies, Roberts, and Hall-Spencer 2007; Hourigan et al. 2007) as submersible technology and remote sensing methods improve. Currently, scientists are compiling data on the ecology, geology, oceanography, and historical exploitation of individual seamounts so that conservation and management plans can be developed (Pitcher et al. 2010; Probert et al. 2007).

11.13 DEEP OCEAN TRENCHES

11.13.1 Description

Oceanic trenches, which are linear depressions in the seafloor exceeding 6000 m deep, are most often associated with subduction zones of island-arc systems. The deep, isolated gashes in the Earth's crust form as oceanic plates move below lighter continental plate. Trenches are generally less than about 3 mi. (5 km) wide, with flat soft bottoms, but they can be as deep as 36,090 ft. (11,000 m). Troughs are similar to trenches, although not as deep (Itoh et al. 2011).

Deep ocean trenches are prone to earthquakes, volcanism, and consequent landslides (Jamieson et al. 2010), yet they still harbor living organisms. Pacific trenches host a variety of known invertebrates, including worms, copepods, gastropods, clams, cnidarians, and crabs (Danovaro, Gambi, and Croce 2002; Jamieson et al. 2009). Scavenging amphipods exhibit vertical zonation in a manner similar to the examples of zonation of attached invertebrates in rocky intertidal habitats (Blankenship et al. 2006). Fish also live in deep ocean trenches—the deepest fish ever photographed was the snailfish *Pseudoliparis amblystomopsisin* in the Japan Trench at 7700 m (Blankenship-Williams and Levin 2009). Deep sea trenches in the MRA Study Area are also discussed in Chapter 4, Oceanography.

11.13.2 Distribution

Deep ocean trenches are associated with subduction zones along continental margins. Most of the 37 known trenches are in the Pacific Ocean, including the nine deepest trenches (Jamieson et al. 2010). Deep ocean trenches run the length of the Japan Archipelago (Figure 11-32). Ocean trenches were once thought to be stagnant, lifeless places, but current evidence shows that deep currents carry oxygen and organic material through the trenches. Deep currents in the trenches of the MRA Study Area originate in the Southern Ocean (Jamieson et al. 2010). Recent work by Japanese researches suggests that the deep trench currents of Japan move in complex ways as they deliver water and nutrients to the north (Fujio and Yanagimoto 2005).

Surveys of marine life in the Kuril and Ryukyu Trenches suggest that both these trenches are enriched by organic matter originating on continental land masses or in the upper ocean. Neither of these trenches

appeared to support the high abundances of meiofaunal or bacterial biomass predicted by trophic models, however (Itoh et al. 2011).

The Mariana Trench, the deepest point on Earth, is composed of an arc of undersea mud volcanoes and thermal vents that release boiling acidic water (U.S. Fish and Wildlife Service 2009). The Champagne vent is one of only two sites in the world that produces liquid carbon dioxide. The submerged Maug caldera is one of only a few known places in the world that supports both photosynthetic and chemosynthetic communities. Hydrothermal vents occur at about 475 ft. in depth along the northeast side of the caldera. The only place on earth where pure molten sulfur occurs is at the Daikoku submarine volcano in the Islands Unit of the Mariana Trench National Monument (Tosatto 2009).

11.13.3 Conditions and Stressors

Because of the remoteness of this habitat, direct human stressors are rare although not entirely absent; a dairy cow was once discovered in a deep ocean trench (Blankenship-Williams and Levin 2009). Although some trenches may remain stable for thousands of years, tectonically active trenches undergo intense mudslides that can bury benthic communities and reduce biodiversity (Blankenship-Williams and Levin 2009).

11.14 Abyssal Plains and Other Deep Softbottom Habitat

11.14.1 Description

Beyond the continental shelf and slope, the most common seabed habitat is the sediment-dominated abyssal plain (Smith et al. 2008). Abyssal plains are flat or gently sloping areas of the deep ocean basin floor between the continental rise and the mid-ocean ridge. The abyssal plain represents the depth where the abundance of organisms levels off after it experiences rapid declines in the zone above (Rex et al. 2005). This largely unexplored habitat covers about 53% of the ocean floor, at depths below about 11,485 ft. (3,500 m). In most oceans, the abyssal zone begins about 185 mi. (300 km) offshore, where depth and distance from coastal nutrient sources limit overall productivity (Etter et al. 2005; Rex et al. 2005). Currents in most areas of the abyssal zone are sluggish (0.25 knot per hour [0.46 km per hour]), and sediment accumulation is slow (less than 4 inches [10 cm] per thousand years) (Glover and Smith 2003). Most deep sea softbottom communities depend on nutrients delivered from outside the abyssal plain (Smith et al. 2008). These organisms receive nutrients that sustain them in the form of “rain” of particulate organic matter supplemented by large “downpours” of material (Sweetman and Witte 2008).

The few fishes that inhabit the lower depths tend to be widely distributed throughout the world (Priede et al. 2010); these include the rattails and the grenadiers at depths up to 16,995 ft. (5,180 m) (Fishbase 2010).

11.14.2 Distribution

Abyssal plains and soft sediments are nearly continuous across the deep seafloors of the world, wherever other elevated features are absent (Glover and Smith 2003). Unlike the typical flat abyssal plain, the abyss beyond the continental slope has substantial topographic relief. The floor of the eastern Philippine Sea is predominantly covered with sediment. West of the Mariana Trough and the West Mariana Ridge, the Parece Vela Basin abyssal plain extends toward Japan (Hein et al. 2008).

11.14.3 Conditions and Stressors

Ongoing and potential stressors to the abyssal plain include mineral mining, wastes disposal, oil and gas extraction, and climate change (Glover and Smith 2003). Manganese nodule mining poses a significant challenge to conservation in the deep sea, and if carried out, could disturb tens to hundreds of thousands of square km of seafloor (Glover and Smith 2003). Deep-water oil and gas exploration is becoming more common, and the 2010 Deepwater Horizon disaster in the Gulf of Mexico illustrates the challenges and environmental threats associated with extracting natural resources at great depths.

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12.0 MARINE PROTECTED AREAS

12.1 INTRODUCTION

Marine Protected Areas (MPAs) have been established internationally and in U.S. federal and state waters as an important tool for marine conservation and management. MPAs are designated and managed at all levels of government by a variety of agencies. MPAs vary widely in purpose, managing agencies, management approaches, level of protection, and restrictions on human uses. They have been designated to achieve objectives ranging from conservation of biodiversity, to preservation of sunken historic vessels, to protection of spawning habitats important to commercial and recreational fisheries. The level of protection provided by these MPAs ranges from fully protected or no-take reserves, to sites allowing multiple uses, including fishing, recreation, and industrial uses (National Marine Protected Areas Center 2008).

In the United States, an MPA is defined in Executive Order (EO) 13158, *Marine Protected Areas,* as "any area of the marine environment that has been reserved by federal, state, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein" (The White House 2000). EO 13158 defined specific criteria that must be met for an MPA to qualify for inclusion in the United States' official National System of Marine Protected Areas. Section 5 of EO 13158 specifies that each federal agency whose actions affect the natural or cultural resources protected by National System MPAs must identify these actions. "To the extent permitted by law and to the maximum extent practicable, each federal agency, in taking such actions, shall avoid harm to the natural and cultural resources that are protected by a Marine Protected Area" (National Marine Protected Areas Center 2008). The National Oceanic and Atmospheric Administration (NOAA) National Marine Protected Areas Center maintains a comprehensive inventory of the federal, state, tribal, and local sites that have been nominated and met the criteria to be included in the National System of MPAs (National Marine Protected Areas Center 2012b); as of March 2012, 355 MPAs have been nominated and accepted into this national system (National Marine Protected Areas Center 2012a). The National Marine Protected Areas Center also keeps an inventory of elligable and inelligable MPAs. For more information on the National System of MPAs, refer to Chapter 2.0, Applicable Legislation and Chapter 3.0, Methodology.

Eighteen percent of National System MPA sites are multiple-use areas allowing such human activities as fishing and other extractive uses. Eighty-three percent of the sites designated no take (79 percent [%]), no-access (2%), no-impact (<1%), or zoned with no-take areas (1%), prohibiting extraction or significant destruction of resources (mostly due to the highly protected and very large Papahanaumokuakea Marine National Monument). Less than 1% of U.S. waters are designated as no-take waters and 3% of all U.S. waters are covered by the National System of MPAs (National Marine Protected Areas Center 2010, 2012a). The Pacific Islands region has the largest area (83%) of sites within the National System of MPAs.

While the National System of MPAs includes 355 MPA sites, more than 1,700 MPAs are documented as established by federal, state, territorial, tribal, and local governments in the United States are not included in the National System of MPAs (National Oceanic and Atmospheric Administration 2011). One hundred and seven national system sites (30%) are managed by the U.S. Fish and Wildlife Service (USFWS), and the National Park Service manages 32 sites (9%). Federal agencies manages 44% of the national system sites, 48% are managed by state agencies, with the remaining 8% under federal/state partnership and territory management (National Marine Protected Areas Center 2012a). All MPAs cumulatively cover more than 40% of U.S. marine waters.

This chapter describes the institutional and management framework for MPAs in the MRA Study Area for the Japan and Mariana Archipelagos (the MRA Study Area) and provides lists of MPAs in the Japan Archipelago, Mariana Archipelago, and Caroline Islands. Profiles for MPAs managed by the federal government are included for the Mariana Archipelago.

12.2 MARINE PROTECTED AREAS OF THE JAPAN ARCHIPELAGO

Several organizations participate in the decision making process related to the sustainable use and conservation of marine living resources in Japan. Likewise, various programs and levels of resource and environmental protection are in place to support Japan in issues of relevance to conservation and sustainability of the oceans and seas (Integrated Coastal Management 1998; Yagi et al. 2010). Japan has six types of MPAs with different management authorities, legal instruments, purpose, and prohibitions (Table 12-1). A list of MPAs in Japan is provided in Table 12-2.

Table 12-1: Institutional and Management Framework for Marine Protected Areas in Japan

MPA Type	Management Authorities	Governing Legal Instruments	Purpose	Prohibited Activities
Marine Park Areas (type I)	Ministry of the Environment; Prefectural Governments	Natural Parks Law	Protection of scenic beauty and conservation of biodiversity.	Capturing aquatic plants and animals designated by governments and water pollution or sewage disposal.
Marine Special Areas (type II)	Ministry of the Environment; Prefectural Governments	Nature Conservation Law	Conservation of biodiversity and the natural environment.	Capturing aquatic plants and animals designated by governments and mining minerals or removing gravels.
Special Protected Zones in Wildlife Protection Areas (type III)	Ministry of the Environment; Prefectural Governments	Wildlife Protection and Appropriate Hunting Law	Protection of wildlife, control on Hunting, biodiversity conservation, sound development of agriculture, forestry, and fisheries.	Hunting and taking of seabirds and certain marine mammals, reclamation, and tree logging.
Protected Waters (type IV)	Ministry of Agriculture, Forestry, and Fisheries; Prefectural Governments	Act on the Protection of Fisheries Resources	Protection and enhancement of fishery resources and development of fisheries.	Restriction or prohibition on the take of aquatic species, land reclamations, dredging, and construction works.
Legally Binding No-take Zones(type V)	Ministry of Agriculture, Forestry, and Fisheries; Prefectural Governments	Prefectural Fishery Coordinating Regulations	Protection and enhancement of fishery resources, monitoring and control of local fisheries.	Fishery harvest of certain species and or all fishing activities.

Table 12-1: Institutional and Management Framework for Marine Protected Areas in Japan

MPA Type	Management Authorities	Governing Legal Instruments	Purpose	Prohibited Activities
Community-based Self-imposed No-take zones (type VI)	Local Fisheries Cooperative Association (FCA) with Peer-monitoring Mechanism	Formal (published) or informal (unpublished) agreements of FCA members	Protection and enhancement of fishery resources and control of local fisheries.	Fishery harvest of certain species or all fishing activities.

Source: Yagi et al. (2010).
Notes:
FCA = Fisheries Cooperative Association
MPA = Marine Protected Area

Table 12-2: Marine Protected Areas of the Japan Archipelago

Site Name	Date	Designation	Total Area (km^2)	Marine Area (km^2)	Latitude	Longitude
Ogasawara Islands						
Ogasawara	1972	Marine Park	4.63	4.63	27° 00' 00" N	142° 10' 00" E
Ogasawara	1972	National Park	60.99	NL	27° 05' 31" N	142° 11' 40" E
Pacific Ocean Coast						
Abashiri	1958	Quasi National Park	372.60	NL	43° 53' 26" N	144° 34' 47" E
Ashizuri Uwakai[1]	1972	National Park	113.50	NL	32° 44' 16" N	132° 31' 27" E
Awa-oshima[1]	1971	Marine Park	0.16	0.16	33° 40' 00" N	134° 40' 00" E
Awa-takegashima[1]	1972	Marine Park	0.10	0.10	33° 30' 00" N	134° 15' 00" E
Fuji Hakone Izu[1]	1936	National Park	NL	NL	34° 21' 45" N	139° 13' 20" E
Furenko	1993	National Wildlife Special Protected Area	78.06	NL	43° 19' 00" N	145° 18' 00" E
Hamatonbetsu Kutcharoko	1983	National Wildlife Special Protected Area	28.03	NL	45° 09'0 0" N	142° 19' 60" E
Hidaka - Sanmyaku - Erimo	1983	Quasi National Park	1,034.00	NL	42° 04' 18" N	143° 01' 14" E
Hotokegaura[1]	1975	Marine Park	0.06	0.06	41° 19' 60" N	143° 01' 14" E
Ise - Shima	1946	National Park	746.40	191.00	34° 22' 52" N	136° 45' 39" E
Kamae1	1974	Marine Park	0.34	0.34	32° 49' 60" N	132° 00' 00" E
Katsuura	1974	Marine Park	0.15	0.15	35° 10' 00" N	140° 19' 60" E
Kashinishi[1]	1972	Marine Park	0.17	0.17	33° 00' 00" N	133° 30' 00" E
Kesennuma[1]	1971	Marine Park	0.23	0.23	38° 51' 35" N	142° 12' 0" E
Kirishima –Yaku[1]	1934	National Park	570.80	NL	34° 12' 28" N	139° 09' 07" E
Kiritappu Marsh	NL	Reserve	NL	NL	43° 00' 00" N	145° 00' 00" E
Kujukuri	1979	Prefectural Wildlife Protection Area	1.840	NL	35° 19' 48" N	140° 22' 48" E
Kumano Nada Nigijima	1975	Marine Park	0.140	0.140	33° 55' 00" N	136° 10' 00" E
Kuroshima Kyanguch[1]	1977	Marine Park	0.460	0.460	30° 13' 00" N	130° 30'0 0" E
Kushimoto	1970	Marine Park	0.390	0.390	33° 30' 00" N	135° 49' 60" E
Mikawa Wan	1958	Quasi National Park	94.57	NL	34° 36' 59" N	137° 08' 49" E
Minami – Bōsō[1]	1958	Quasi National Park	56.90	NL	35° 07' 45" N	140° 07' 46" E
Minami - Sanriku Kinkazan[1]	1979	Quasi National Park	370.6	231.6	38° 32' 03" N	141° 30' 58" E
Miyakejima[1]	1994	Marine Park	0.520	0.520	34° 00' 00" N	139° 30' 00" E
Muroto - Anan Kaigan	1964	Quasi National Park	62.25	NL	33° 52' 10" N	134° 27' 17" E
Nanbokuura[1]	1974	Marine Park	0.490	0.490	32° 30' 00" N	131° 45' 00" E
Nichinan[1]	1970	Marine Park	0.560	0.560	31° 30' 00" N	131° 30'00" E
Nichinan Kaigan[1]	1955	Quasi National Park	45.42	NL	31° 59' 33" N	131° 17' 21" E
Nippo Kaigan[1]	1974	Quasi National Park	284.7	241.8	32° 41' 43" N	131° 49' 28" E
Okinoshima[1]	1972	Marine Park	0.360	0.360	32° 49' 60" N	132° 30' 00" E
Rikuchu – Kaigan[1]	1955	National Park	122.1	NL	39° 29' 56" N	141° 54' 13" E
Sarufutsu Marsh	1978	Prefectural Wildlife Protection Area	1.900	1.900	45° 16' 12" N	142° 12' 00" E
Sata Misaki[1]	1970	Marine Park	0.120	0.120	31° 00' 00" N	130° 40' 00" E
Seto - Naikai	1934	National Park	627.9	NL	34° 12' 15" N	133° 07' 52" E

Table 12-2: Marine Protected Areas of the Japan Archipelago

Site Name	Date	Designation	Total Area (km^2)	Marine Area (km^2)	Latitude	Longitude
Shimokita Hanto	1968	Quasi National Park	187.3	NL	41° 31' 33" N	140° 55' 25" E
Shiokawa Tidal	NL	Hunting Reserve	2.800	NL	34° 40' 60" N	137° 16' 60" E
Shiretoko	1964	National Park	460.3	74.00	44° 08' 46" N	145° 09' 41" E
Shirigai[1]	1995	Marine Park	0.100	0.100	32° 49' 60" N	132° 45'0 0" E
Shiro[1]	1975	Marine Park	0.150	0.148	30° 30' 00" N	133° 00' 00" E
Suigo – Tsukuba[1]	1959	Quasi National Park	343.1	NL	36° 01' 57" N	140° 25' 60" E
Taijima	1975	Marine Park	0.040	0.040	41° 04' 54" N	141° 00' 08" E
Takeno	1971	Marine Park	0.100	0.100	30° 30' 00" N	134° 45' 00" E
Tatsukushi[1]	1972	Marine Park	NL	NL	32° 43' 59" N	132° 46' 33" E
Tohfutsuko	1982	Prefectural Wildlife Protection Area	20.51	NL	43° 55' 48" N	144° 25' 12" E
Torinoumi[1]	1986	Prefectural Wildlife Protection Area	1.800	NL	34° 27' 17" N	144° 55' 00" E
Toyooka[1]	1971	Marine Park	0.080	0.080	30° 30' 00" N	134° 49' 60" E
Tsutomezaki[1]	1995	Marine Park	0.080	0.080	32° 49' 60" N	132° 45' 00" E
Ukishima	NL	Prefectural Wildlife Protection Area	3.000	NL	35° 57' 00" N	140° 28' 12" E
Uwakai[1]	1972	Marine Park	0.320	0.320	33° 00' 00" N	132° 30' 00" E
Yokkaichi (Oita)[1]	1966	Fisheries Resources Protected Area	0.170	NL	33° 30' 00" N	131° 30' 00" E
Yoshino	1985	Prefectural Wildlife Protection Area	5.000	NL	34° 04' 48" N	134° 36' 00" E
Yoshino - Kumano	1936	National Park	598.0	NL	33° 47' 56" N	135° 56' 24" E
Yudoh	1972	Prefectural Wildlife Protection Area	38.55	NL	42° 37' 48" N	143° 34' 12" E
Ryukyu and Daitoshoto Islands						
Amami – Gunto[1]	1974	Quasi National Park	78.61	NL	27° 25' 31" N	128° 41' 30" E
Aragusuku-jima Maibishi	1977	Marine Park	0.480	0.480	24° 30' 00" N	124° 00' 00" E
Iriomote	1972	National Park	135.5	NL	24° 18' 19" N	123° 46' 05" E
Kametoku[1]	1974	Marine Park	0.700	0.700	28° 00' 00" N	129° 30' 00" E
Kasari Hanto Higashi Kaigan[1]	1974	Marine Park	0.930	0.930	28° 30' 00" N	129° 30' 00" E
Kiyanguchi	1977	Marine Park	0.460	NL	24° 18' 20" N	123° 43' 00" E
Kurio	2002	Marine Park	1.140	1.140	24° 30' 00" N	124° 00' 00" E
Maibishi	1977	Marine Park	0.480	NL	24° 18' 20" N	123° 52' 60" E
Manko[1]	1977	National Wildlife Special Protected Area	2.500	NL	26° 10' 60" N	127° 39' 00" E
Okinawa Kaigan[1]	1972	Marine Park	1.400	1.400	26° 40' 00" N	128° 00' 00" E
Okinawa Kaigan[1]	1972	Quasi National Park	103.2	NL	26° 28' 19" N	127° 49' 46" E
Okinawa Senseki[1]	1972	Quasi National Park	31.27	NL	26° 05' 34" N	127° 41' 36" E
Sakiyamawan	1983	Marine Park	1.280	1.280	24° 21' 18" N	123° 39' 35" E
Setouchi	1974	Marine Park	0.580	0.580	28° 00' 00" N	129° 00' 00" E
Shimobishi	1977	Marine Park	0.830	NL	24° 18' 20" N	123° 52' 60" E

Table 12-2: Marine Protected Areas of the Japan Archipelago

Site Name	Date	Designation	Total Area (km^2)	Marine Area (km^2)	Latitude	Longitude
Taketomi-jima Shimobishi	1977	Marine Park	0.830	0.830	30° 30' 00" N	124° 00' 00" E
Taketomi-jima Takedonguchi	1977	Marine Park	0.370	0.370	30° 30' 00" N	124° 00' 00" E
Takidunguchi	1977	Marine Park	0.370	NL	24° 18' 20" N	123° 43' 00" E
Tokashiki[1]	1978	Marine Park	1.200	1.200	26° 08' 18" N	127° 26' 23" E
Yoronto[1]	1974	Marine Park	1.550	1.550	27° 00' 00" N	128° 30' 00" E
Zamami[1]	1978	Marine Park	2.330	2.330	26° 10' 00" N	127° 15' 00" E
Sea of Japan Coast						
Aikawa	1971	Marine Park	0.060	0.060	38° 00'0 0" N	138° 30' 00" E
Ama	1977	Marine Park	0.076	0.076	36° 06' 17" N	133° 10' 11" E
Amakusa[1]	1970	Marine Park	0.050	0.050	32° 30' 00" N	130° 00' 00" E
Chokai	1963	Quasi National Park	NL	NL	NL	NL
Daisen - Oki	1936	National Park	350.5	NL	36° 04' 14" N	133° 03' 10" E
Echizen - Kaga Kaigan	1968	Quasi National Park	205.2	112.7	36° 14' 38" N	136° 12' 24" E
Fukue[1]	1972	Marine Park	0.110	0.110	32° 30' 00" N	129° 00' 00" E
Genkai[1]	1970	Marine Park	0.460	0.460	33° 30' 00" N	130° 00' 00" E
Genkai[1]	1956	Quasi National Park	101.6	NL	33° 28' 34" N	129° 58' 52" E
Goshikigahama	1990	Marine Park	0.210	0.210	35° 40' 00" N	135° 00' 00" E
Hamasaka	1971	Marine Park	0.190	0.190	35° 30' 00" N	134° 30' 00" E
Iki Tanagashima[1]	1978	Marine Park	0.100	0.100	33° 30' 00" N	129° 30' 00" E
Iki Tatsunoshima[1]	1978	Marine Park	0.090	0.090	33° 30' 00" N	129° 30' 00" E
Iki Tsumagashima[1]	1978	Marine Park	0.090	0.090	33° 30' 00" N	129° 30' 00" E
Iki –Tsushima[1]	1968	Quasi National Park	119.5	NL	33° 48' 34" N	129° 40' 17" E
Izumi –Takaono[1]	1987	National Wildlife Special Protected Area	8.420	NL	32° 06' 00" N	130° 16' 00" E
Jodogaura	1975	Marine Park	0.210	0.208	36° 10' 00" N	133° 15' 00" E
Kinoura	1971	Marine Park	0.060	0.060	37° 30' 00" N	137° 00' 00" E
Kirishima-Yaku[1]	1934	National Park	548.3	NL	31° 04' 25" N	130° 42' 23" E
Kita - Nagato Kaigan	1955	Quasi National Park	123.8	NL	34° 27' 60" N	131° 23' 22" E
Kuniga	1975	Marine Park	0.070	0.073	36° 00' 00" N	133° 00' 00" E
Matsumae (Hokkaidō)	1974	Fisheries Resources Protected Area	0.140	NL	41° 25' 48" N	140° 00' 00" E
Mikata	1971	Marine Park	0.300	0.302	35° 30' 00" N	136° 00' 00" E
Niseko - Shakotan - Otaru Kaigan	1963	Quasi National Park	190.1	NL	42° 53' 28" N	140° 33' 06" E
Noto Hanto	1968	Quasi National Park	412.6	315.9	36° 52' 34" N	136° 43' 19" E
Oga	1973	Quasi National Park	81.56	NL	39° 54' 50" N	139° 43' 18" E
Ogi	1971	Marine Park	0.050	0.050	37° 49' 60" N	138° 19' 60" E
Okushiri (Hokkaidō)	1954	Fisheries Resources Protected Area	1.800	NL	42° 09' 00" N	139° 00' 00" E
Otaru Kaigan	1972	Marine Park	0.150	0.150	43° 15' 00" N	141° 00' 00" E
Otaru Kaigan (Hokkaidō)	1972	Marine Park	0.150	NL	43° 15' 00" N	141° 00' 00" E

Table 12-2: Marine Protected Areas of the Japan Archipelago

Site Name	Date	Designation	Total Area (km^2)	Marine Area (km^2)	Latitude	Longitude
Rishiri - Rebun - Sarobetsu	1950	National Park	241.7	NL	45° 09' 14" N	141° 38' 01" E
Sado - Yahiko - Yoneyama	1950	Quasi National Park	294.6	NL	37° 45' 20" N	138° 50' 23" E
Saikai[1]	1955	National Park	246.5	NL	32° 40' 12" N	128° 37' 38" E
Sakurajima[1]	1970	Marine Park	0.150	0.150	31° 30' 00" N	130° 30' 00" E
Sanin - Kaigan	1963	National Park	87.84	NL	35° 38' 33" N	134° 40' 50" E
Shakotan Hanto	1972	Marine Park	0.290	0.290	43° 20' 24" N	140° 19' 60" E
Shimane Hanto	1972	Marine Park	0.070	0.070	35° 30' 00" N	132° 45' 00" E
Shinji	1982	Prefectural Wildlife Protection Area	88.00	NL	35° 25' 48" N	132° 52' 12" E
Shokanbetu -Teuri Yagishiri	1990	Quasi National Park	435.6	NL	43° 14' 31" N	141° 22' 42" E
Sotokaifu	1971	Marine Park	0.100	0.100	38° 18' 57" N	138° 29' 27" E
Surikozaki[1]	1974	Marine Park	0.700	0.700	30° 30' 00" N	129° 19' 60" E
Susawan[1]	1997	Marine Park	0.330	0.330	34° 37' 12" N	131° 34' 42" E
Tomioka[1]	1970	Marine Park	0.160	0.160	30° 30' 00" N	130° 00' 00" E
Tsugaru	1975	Quasi National Park	259.7	NL	41° 10' 01" N	140° 35' 25" E
Tsushima Asowan[1]	1978	Marine Park	0.100	0.100	34° 00' 00" N	129° 00' 00" E
Tsushima Kanzaki[1]	1978	Marine Park	0.100	0.100	34° 30' 00" N	129° 30' 00" E
Uchiura	1971	Marine Park	0.320	0.320	37° 00' 00" N	137° 00' 00" E
Unzen – Amakusa[1]	1934	National Park	282.9	NL	32° 19' 08" N	130° 10' 15" E
Uradome Kaigan	1971	Marine Park	0.100	0.100	35° 30' 00" N	134° 10' 00" E
Ushibuka[1]	1970	Marine Park	0.300	0.300	32° 15' 00" N	130° 00' 00" E
Wakamatsu[1]	1972	Marine Park	0.190	0.190	33° 00' 00" N	129° 00' 00" E
Wakasa Wan	1955	Quasi National Park	211.8	NL	35° 29' 47" N	136° 01' 08" E
Zuibaiji Estuary[1]	1986	Prefectural Wildlife Protection Area	267.1	NL	33° 36' 00" N	130° 15' 00" E

Source: MPA Global (2012).
Notes:
[1]MPAs within or adjacent to the MRA Study Area
Total Area - the total area of the site including terrestrial land
Marine area - only the marine compondent of the MPA
km^2 = square kilometers
NL = not listed

12.3 MARINE PROTECTED AREAS OF THE MARIANA ARCHIPELAGO

Several organizations participate in the decision making process related to the sustainable use and conservation of marine living resources in the Mariana Archipelago. Likewise, various programs and levels of resource and environmental protection are in place to support the area in issues of relevance to conservation and sustainability of the oceans and seas. The Mariana Archipelago has eight types of MPAs with different management authorities, legal instruments, purpose, and prohibitions (Table 12-3).

Table 12-3: Institutional and Management Framework from Marine Protected Areas in the Mariana Archipelago

MPA Type	Management Authorities	Governing Legal Instruments	Purpose	Prohibited Activities
Marine Preserve	Department of Agriculture's Division of Aquatic and Wildlife Resources	Public Law No. 24-21	To protect coral reef habitat and aquatic animals and restore fish stocks.	Fishing (unless authorized), shell collecting, removal of sand/rocks, and/or development.
National Wildlife Refuge	U.S. Fish and Wildlife Service	National Wildlife Refuge System Administration Act	Management habitat for conservation, management and restoration.	Restrict certain hunting and fishing.
Territorial Seashore Park	Department of Parks & Recreation	Territorial Protection Act	Promote public safety, health, and welfare and to protect public and private property, wildlife, marine life, and other oceanic resources, and the natural environment.	NL
Ecological Reserve Area	Guam U.S. Naval Station	NL	NL	NL
National Historic Park	Federal Government	National Historic Preservation Act	To protect places of historic significance in the United States.	It is unlawful to excavate, remove, disturb, deface, or destroy any historic or prehistoric building structure, ruin, site, or in-place exhibit, artifact or object, or to collect, appropriate, excavate, damage, disturb, or destroy artifacts, pictographs, petroglyphs, objects of antiquity, fossils, or scientific specimens.
Marine Conservation Area	CNMI Division of Fish and Wildlife	Public Law 12-46	Management habitat for conservation, management and restoration.	All extractive activities for the entire site.

Table 12-3: Institutional and Management Framework from Marine Protected Areas in the Mariana Archipelago

MPA Type	Management Authorities	Governing Legal Instruments	Purpose	Prohibited Activities
Focal Species Sanctuary	CNMI Division of Fish and Wildlife	Division of Fish and Wildlife Regulations, promulgated under authority of Public Law 2-51	Management of habitat and population for conservation of the species in focus.	All extractive activities due to fishing and other living resources (all types) for the entire marine area.
Marine National Monument	U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration, Department of Defense, Government of the Commonwealth of the Northern Mariana Islands	The Antiquities Act of 1906	To protect places of historic or scientific significance.	Commercial fishing.

Source: MPA Global (2012).
Notes:
MPA = Marine Protected Area
NL = not listed

Twenty-four local MPAs are located in the Marianas MRA Study Area and vicinity. Thirteen are located at U.S. Territory of Guam (Guam), and 11 are located in the CNMI (Table 12-4).

Table 12-4: Marine Protected Areas of the Mariana Archipelago

Site Name	Date	Designation	Total Area (km^2)	Marine Area (km^2)	Latitude	Longitude
COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS						
Bird Island Sanctuary	2001	Marine Conservation Area	2.105	1.415	15° 15' 04" N	145° 48' 56" E
Bird Island Sea Cucumber Reserve[1]	2000	Marine Conservation Area	0.000062	NL	15° 18' 80" N	145° 81' 37" E
Forbidden Island Sanctuary	2001	Marine Conservation Area	2.650	2.622	15° 09' 14" N	145° 47' 25" E
Lau Lau Bay Sea Cucumber Sanctuary	2000	Focal Species Sanctuary	1.966	1.966	15° 08' 59" N	145° 44' 53" E
Lighthouse Reef Trochus Sanctuary	1982	Focal Species Sanctuary	1.503	1.503	15° 11' 21" N	145° 42' 15" E
Mañagaha	2000	Marine Conservation Area	5.044	4.990	15° 14' 23" N	145° 42' 53" E
Mariana Arc of Fire	2009	National Wildlife Refuge	0.018263	NL	11° 22' 40" N	142° 35' 50" E
Mariana Trench	2009	National Wildlife Refuge	17.765	NL	11° 22' 40" N	142° 35' 50" E
Northern Mariana Islands Marine National Monument	2009	Marine National Monument	21.195	NL	11° 22' 40" N	142° 35' 50" E
Sasanhaya Bay Fish Reserve	1994	Marine Conservation Area	0.844	0.844	14° 07' 16" N	145° 09' 59" E
Tank Beach Trochus Reserve[1]	1981	Marine Conservation Area	0.000007	NL	15° 10' 30" N	145° 47' 09" E
GUAM						
Achang Reef Flat	1997	Marine Preserve	4.85	4.85	13° 14' 43" N	144° 42' 49" E
Aratama Maru[1]	1988	National Register of Historic Places	0.000017	NL	13° 20' 05" N	13° 45' 58" E
Cormoran[1]	1974	National Register of Historic Places	0.000019	NL	13° 27' 33" N	144° 39' 15" N
Guam	1993	National Wildlife Refuge	94.00	1.50	13° 39' 00" N	144° 52' 00" E
Haputo	1984	Ecological Reserve Area	1.02	0.29	13° 34' 01" N	144° 49' 01" E
Orote Peninsula	1984	Ecological Reserve Area	0.66	0.54	13° 26' 35" N	144° 37' 01" E
Pati Point	1997	Marine Preserve	1.12	1.12	13° 34' 48" N	144° 55' 48" E
Piti Bomb Holes	1997	Marine Preserve	3.36	3.36	13° 28' 34" N	144° 42' 16" E
Sasa Bay	1997	Marine Preserve	1.02	1.02	13° 27' 00" N	144° 40' 60" E
Tokai Bay[1]	1988	National Register of Historic Places	0.000018	NL	13° 21' 53" N	144° 46' 02" E
Tumon Bay[1]	1997	Marine Preserve	0.000374	NL	13° 30' 60" N	144° 48' 62" E
War in the Pacific	1978	National Historic Park	7.79	4.05	13° 18' 00" N	144° 40' 01" E

Sources: MPA Global (2012), [1]National Marine Protected Areas Center (2011).
Notes:
km^2 = square kilometers
NL = not listed

Territory/Commonwealth Managed MPAs

Marine Preserves, Territorial Seashore Parks, Marine Conservation Areas, Marine Sanctuaries, and Marine Species Reserves. The Commonwealth of the Northern Mariana Islands (CNMI) Division of Fish and Wildlife is the Commonwealth-level agency in charge of designating and overseeing MPAs in the CNMI. The purpose of the CNMI Division of Fish and Wildlife is to establish and enforce regulations governing hunting, fishing, and conservation of fish and wildlife in the CNMI. These sites include the Managaha Marine Conservation Area, Bird Island Marine Sanctuary, Forbidden Island Marine Sanctuary, Lighthouse Reef Trochus Reserve, Lau Lau Bay Sea Cucumber Reserve, and Sasanhaya Bay Fish Reserve. Each of these MPAs occurs around the island of Saipan except for the Sasanhaya Bay Fish Reserve, which is at Rota. Although most MPAs in Guam are designated and managed by the Department of Agriculture's Division of Aquatic and Wildlife Resources (DAWR), management of MPAs located on Guam vary depending on the type on management area and location. Refer to MPA descriptions for information on management entities.

U.S Navy Managed MPAs

Haputo and Orote Peninsula Ecological Reserve Areas. An Ecological Reserve Area (ERA) is a physical or biological unit within which current natural conditions are maintained insofar as possible. These conditions are usually achieved by allowing natural, physical, and biological processes to prevail without any human intervention (Pacific Division Naval Facilities Engineering Command 1986). To compensate for the loss of 5.7 hectare (ha) of reef and limestone habitats during construction of an ammunition wharf in Apra Harbor on Guam in 1984 the Navy set aside 168 ha of coastal habitat at two sites. These protected areas are known as the Orote Peninsula and Haputo ERAs (Pacific Division Naval Facilities Engineering Command 1984).

The Haputo ERA totals 102 ha in two distinct areas. The terrestrial unit (TU) totals 73 ha and was set aside to preserve limestone forests, an important habitat for native birds (Pacific Division Naval Facilities Engineering Command 1986), but also includes two sand beach coves (United Nations Environment Programme and International Union for the Conservation of Nature and Natural Resources 1988). The TU encompasses the area from the shoreline cliff boundary line to the mean low water (MLW) line. The marine unit, with a total of 29 ha of submerged land, includes Double Reef. The marine unit extends from the MLW line to the edge of the reef. Double Reef is one of Guam's few remaining healthy leeward fringing reefs, and provides a nursery for marine species of subsistence and commercial fishery value (Pacific Division Naval Facilities Engineering Command 1986).

The Orote Peninsula ERA totals 66 ha and consists of two distinct regions. The first region spans from the shoreline cliffs to the MLW line and encompasses 12 ha. The cliff area also encompasses a large limestone forest (Pacific Division Naval Facilities Engineering Command 1984). The second region is composed of submerged coastal lands spanning from the MLW line to the 36.6 meter (m) isobath. It is populated primarily by undisturbed coral reefs and encompasses an area totaling 54 ha (Pacific Division Naval Facilities Engineering Command 1984). Blue Hole, one of Guam's premier dive locations, is located off of the Orote Peninsula ERA (United Nations Environment Programme and International Union for the Conservation of Nature and Natural Resources 1988).

The proposed extension of the ammunition Wharf in Apra Harbor, Guam will result in a loss of coral reef habitat. The Navy is considering alternative strategies to mitigate the potentail loss, including adjustments to the Navy's existing Haputo and Orote ERAs (Helber Hastert & Fee 2007).

Federally Managed MPAs

Marianas Trench Marine National Monument. The Marianas Trench Marine National Monument was established on January 6, 2009, under authority of the Antiquities Act of 1906. Presidential Proclamation 8335 (Bush 2009) established the monument, which includes about 61,10,000 acres (U.S. Fish and Wildlife Service 2011b), or 95,216 square miles of land and ocean (Figure 12-1). The national monument is composed of three units: the Islands Unit, the Volcanic Unit, and the Trench Unit (National Oceanic and Atmospheric Administration 2012). The Islands Unit includes water and submerged lands of the northernmost Mariana Islands of Farallon de Pajaros, Muang, and Asuncion Island (from approximately 21°23'42"N to 19°22'0"N and 144°1'22"E to 146°18'36.75"E). The Volcanic Unit, also designated the Mariana Arc of Fire National Wildlife Refuge, includes a 1 nm by 1 nm submerged lands surrounding 21 undersea volcanoes and vents. No waters are included in the Volcanic unit. The Trench unit, also designated the Mariana Trench National Wildlife Area, includes virtually unexplored seafloor terrain. The CNMI maintains authority for managing the three islands within the Island Unit above the MLW line (U.S. Fish and Wildlife Service 2012b).

The Marianas Trench Marine National Monument harbors the largest active mud volcano, the Champagne vent (produces almost pure liquid carbon dioxide observed at only one other place on Earth, in the Okinawa Trough), the Sulfur Cauldron (liquid sulfur pool at the Daikoku submarine volcano, observed also on a moon of Jupiter), basalt-requiring reef communities, Maug Crater (simultaneous photosynthesis and chemosynthesis), and countless undiscovered ecosystems and biota (Bush 2009; U.S. Fish and Wildlife Service 2012b). The waters around the seamounts, islands and trenches support some of the most diverse reefs in the world, including many apex predators larger and more abundant than elsewhere in the Mariana Archipelago and the Pacific Ocean (National Oceanic and Atmospheric Administration 2012). In the monument's depths, the Mariana Trench, created by subduction of the Pacific Plate below the Philippine Sea Plate, is 940 nm long and 38 nm wide. Within the trench is the deepest known point in the oceans, worldwide (36,000 feet at the Challenger Deep) (Bush 2009). The depths of the Mariana Trench encompasses approximately 50,532,102 acres of virtually unidentified terrain and biology (U.S. Fish and Wildlife Service 2012b).

Management of the monument is assigned by the Secretary of the Interior (USFWS) through Secretary Order 3284 to the Secretary of Commerce (NOAA), with consultation of the Department of Defense (DoD) and the government of the CNMI (National Oceanic and Atmospheric Administration 2012; U.S. Fish and Wildlife Service 2012d). Duties differ among organizations and government bodies. The Trench and Volcanic Units fall within the National Wildlife Refuge System. Thus, these units are to be managed by USFWS. NOAA is responsible for fishery-related management within the waters of the Island Unit. In addition, the Mariana Monument Advisory Council provides recommendations and advice on management plan development for the monument. This council includes at least three officials from the CNMI government, one representative form the DoD, and another representative from the U.S. Coast Guard (USCG) (U.S. Fish and Wildlife Service 2012b). The designation as a marine national monument increases international, national, and local awareness of the Mariana Archipelago as a crucial area for seabirds, sea turtles, coral reefs, and other life within the seamounts and hydrothermal vents present within the monument's borders (Bush 2009; National Oceanic and Atmospheric Administration 2012).

USFWS and NOAA are working with the CNMI government, DoD, Department of State, USCG, and others to develop a management plan for the monument. Key issues have been identified following the planning notice (U.S. Fish and Wildlife Service 2011a), the preliminary screening for the management plan (U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration 2011), and

public meetings (U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration 2012b). These key issues take in to account specific roles and responsibilities; include plans for public education programs and outreach, and for conservation efforts; and consider traditional access for indigenous persons while protecting culturally significant places and practices. In addition, the management plan recognizes the need for programs promoting scientific exploration, tourism, and economic activities. Monitoring programs to ensure continued conservation of this Marine National Monument have also been proposed (U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration 2011). Public recommendations include a proposed visitor center, improvements to vessel groundings (moorings and ramps), concerns about fishing regulations, and inclusion of climate change in management plans (U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration 2012a). All practices must receive a Compatibility Determination in order to ensure that activities within the managed area are consistent with the refuge's original designation and goals (U.S. Fish and Wildlife Service 2012c).

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Figure 12-1: Map of the Mariana Arc of Fire National Wildlife Refuge and the Mariana Trench Marine National Monument
Source: National Oceanic and Atmospheric Association (2013).

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Guam's Marine Preserve System. Guam's Marine Preserve System (Figure 12-4) comprises five marine preserves (Pati Point, Tumon Bay, Piti Bomb Holes, Sasa Bay, and Achang Reef Flat) that encompass almost 12% of the shoreline (Abraham et al. 2004). Although the Sasa Bay Marine Preserve includes Navy-owned submerged lands, the DoD does not recognize the Navy-owned lands as part of a designated marine preserve. All types of fishing, as well as shell collecting, use of gaffs, and removal of sand and rocks are prohibited in these preserves. The seaward boundaries of each preserve (excluding Sasa Bay) extend to the 183 m isobath. The shoreward boundaries are located 10 m inland from the mean high tide mark or along the nearest public right-of-way, whichever comes first (University of Guam Marine Laboratory 2004). A cooperative agreement between Guam's Marine Preserve System (Public Law 24-21) and Andersen Air Force Base (AAFB) has established a conservation area at Pati Point (Pacific Air Forces 2000; Twenty-Fourth Guam Legislature 1997; University of Guam Marine Laboratory 2005), under which the provisions of the Guam Marine Preserve System mirror the regulations of the Pati Point Preserve created by AAFB.

Guam National Wildlife Refuge. Guam National Wildlife Refuge was established in 1993 because of the listing of six local endangered species (including the Mariana fruit bat, Mariana crow, and the *Serianthes nelsonii* tree) in 1984 under the Endangered Species Act (ESA). Heavy historical use of pesticides and introduction of invasive species further indicated clear need for the refuge (U.S. Fish and Wildlife Service 2009). The Guam National Wildlife Refuge covers 871 acres (~150 ha) of coral reef habitat, with an additional 832 acres (~336 ha) of terrestrial habitat (totaling 1,203 acres or 487 ha) owned by the USFWS (Figure 12-4). The MPA within the Guam National Wildlife Refuge is in an area known as the Ritidian Unit (Puntan Litekyan). The Ritidian Unit was established in 1993 on excess land that had been acquired from the Navy. It is located at the northern tip of the island in Yigo, Guam (Figure 12-4). About 22,500 adjacent acres (9,088 ha) are an "overlay refuge" owned by the DoD in Air Force and Navy installations (U.S. Fish and Wildlife Service 2012a). Although military missions come first on these lands, the USFWS assists in protecting native species and habitats. The Guam National Wildlife Refuge aims to protect and recover endangered and threatened species. The Guam National Wildlife Refuge, as a whole, provides habitat for the last remaining populations of the endangered Mariana fruit bat, Mariana crow, and the hayun lågu tree ("northern tree" or "foreign tree"), *Serianthes nelsonii*. Conservation of habitat, control of invasive species, and preservation of cultural resources for the Chamorro people are also important issues for this refuge (U.S. Fish and Wildlife Service 2012a). Purposes of the Ritidian Unit (U.S. Fish and Wildlife Service 2009) are:

> "...to conserve (A) fish or wildlife which are listed as endangered species or threatened species...or (B) plants..." 16 U.S.C. 1534 (ESA of 1973).
>
> "...for the development, advancement, management, conservation, and protection of fish and wildlife resources..." 16 U.S.C. 742f(a)(4), (Fish and Wildlife Act of 1956).
>
> "...for use as an inviolate sanctuary, or for any other management purpose, for migratory birds" 16 U.S.C. 715d (Migratory Bird Conservation Act).
>
> "...suitable for (1) incidental fish and wildlife-oriented recreational development, (2) the protection of natural resources, (3) the conservation of endangered species or threatened species..." 16 U.S.C. 460k-1 (Refuge Recreation Act) 16 U.S.C. § 460k-460k-4, as amended.

In the Guam National Wildlife Refuge's Comprehensive Conservation Plan (U.S. Fish and Wildlife Service 2009), goals and objectives are set for management and restoration of the refuge over a 15-year period. The plan describes current and future concerns relating to the listed species and their coastal and/or terrestrial environments. This document also addresses potential issues resulting from climate change, cultural resources, interagency coordination (military uses), land and water uses, pest management, and promotion of awareness through scientific discovery and community outreach.

Pets are prohibited on the beach in the Ritidian Unit, but permits can be issued allowing visitors to collect plants and other materials from within the reserve's boundary (U.S. Fish and Wildlife Service 2010).

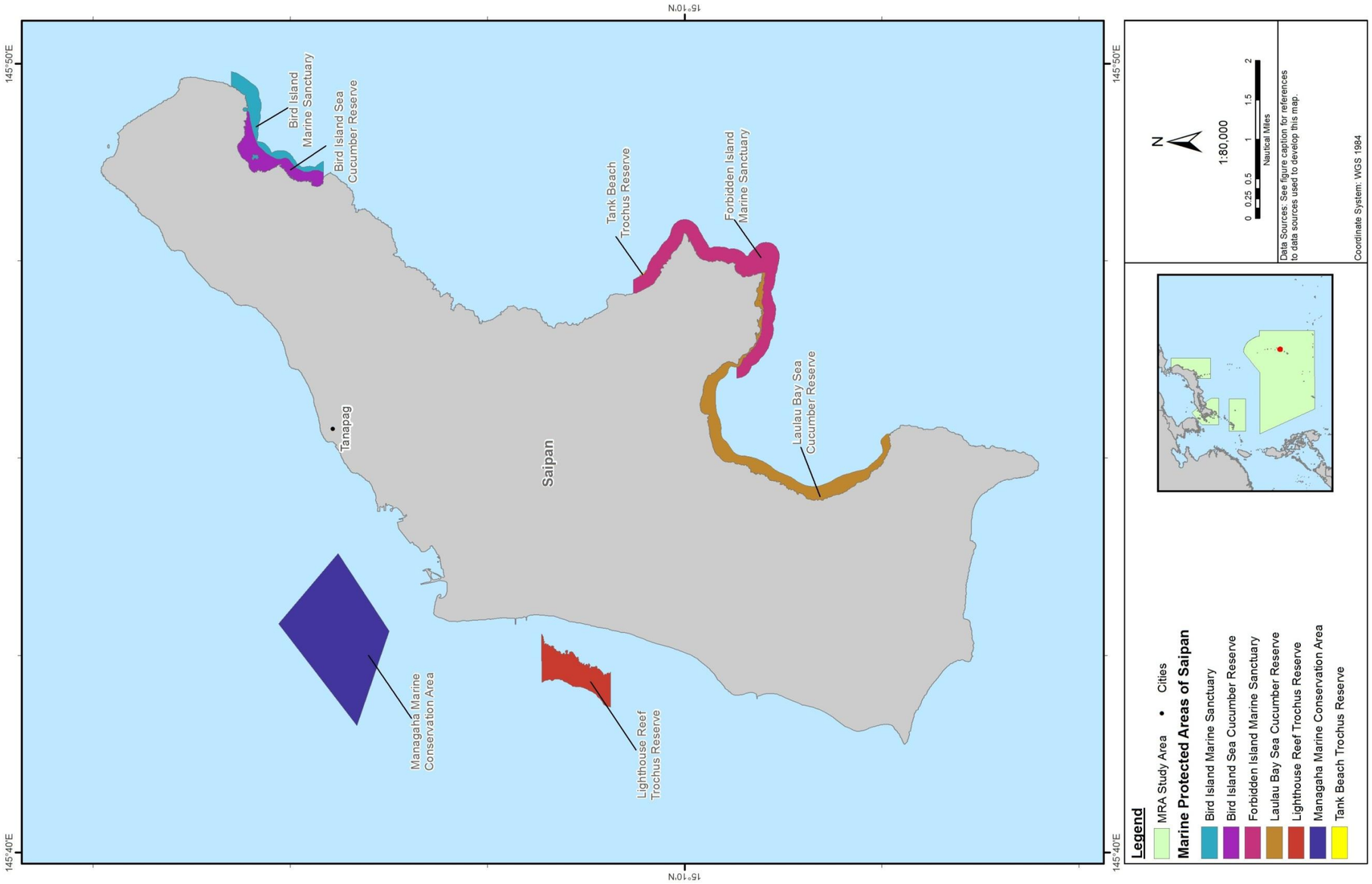

Figure 12-2: Map of the Protected Areas in Saipan
Source: National Oceanic and Atmospheric Association (2013).

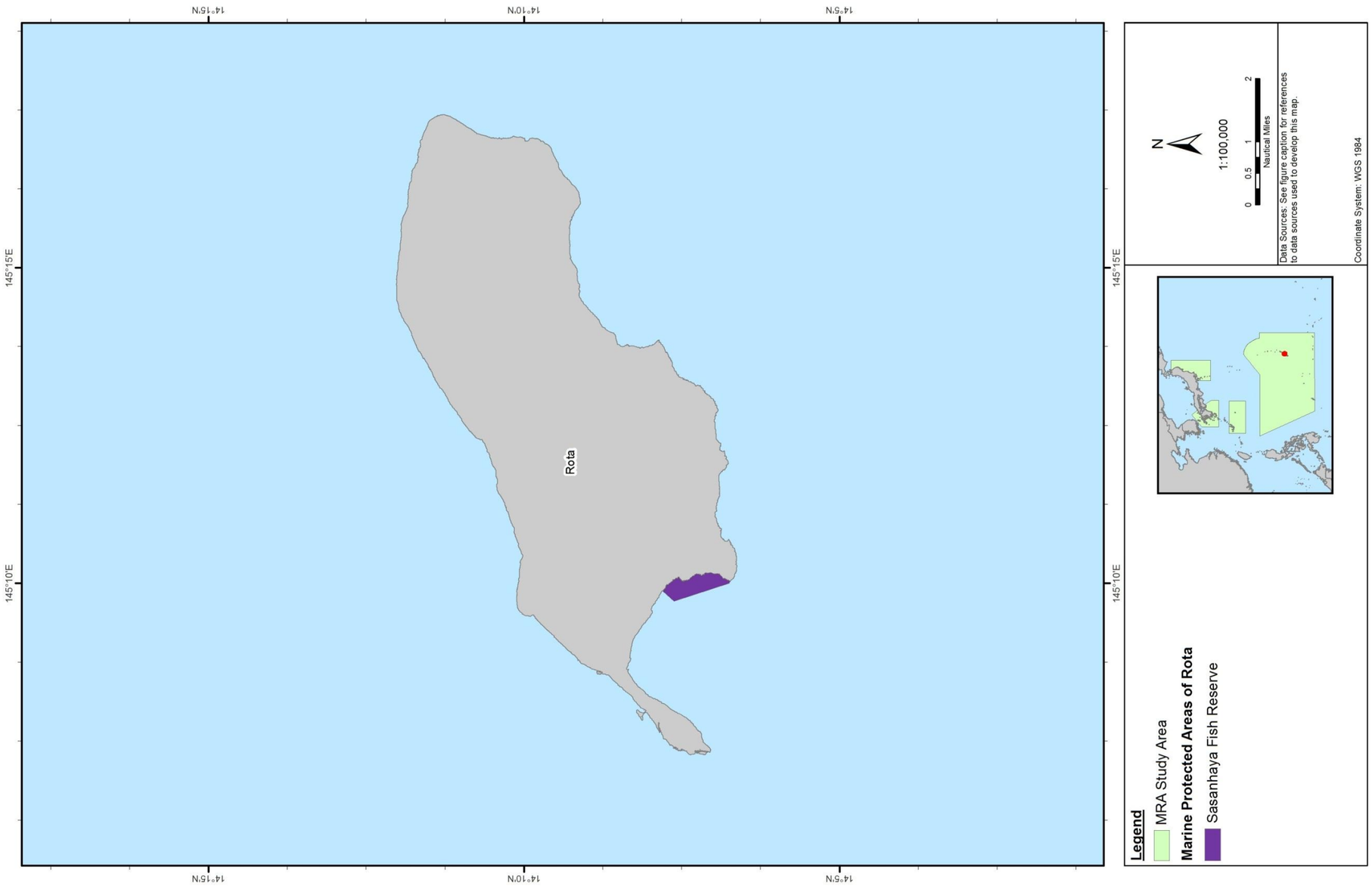

Figure 12-3: Map of the Protected Areas in Rota
Source: National Oceanic and Atmospheric Association (2013).

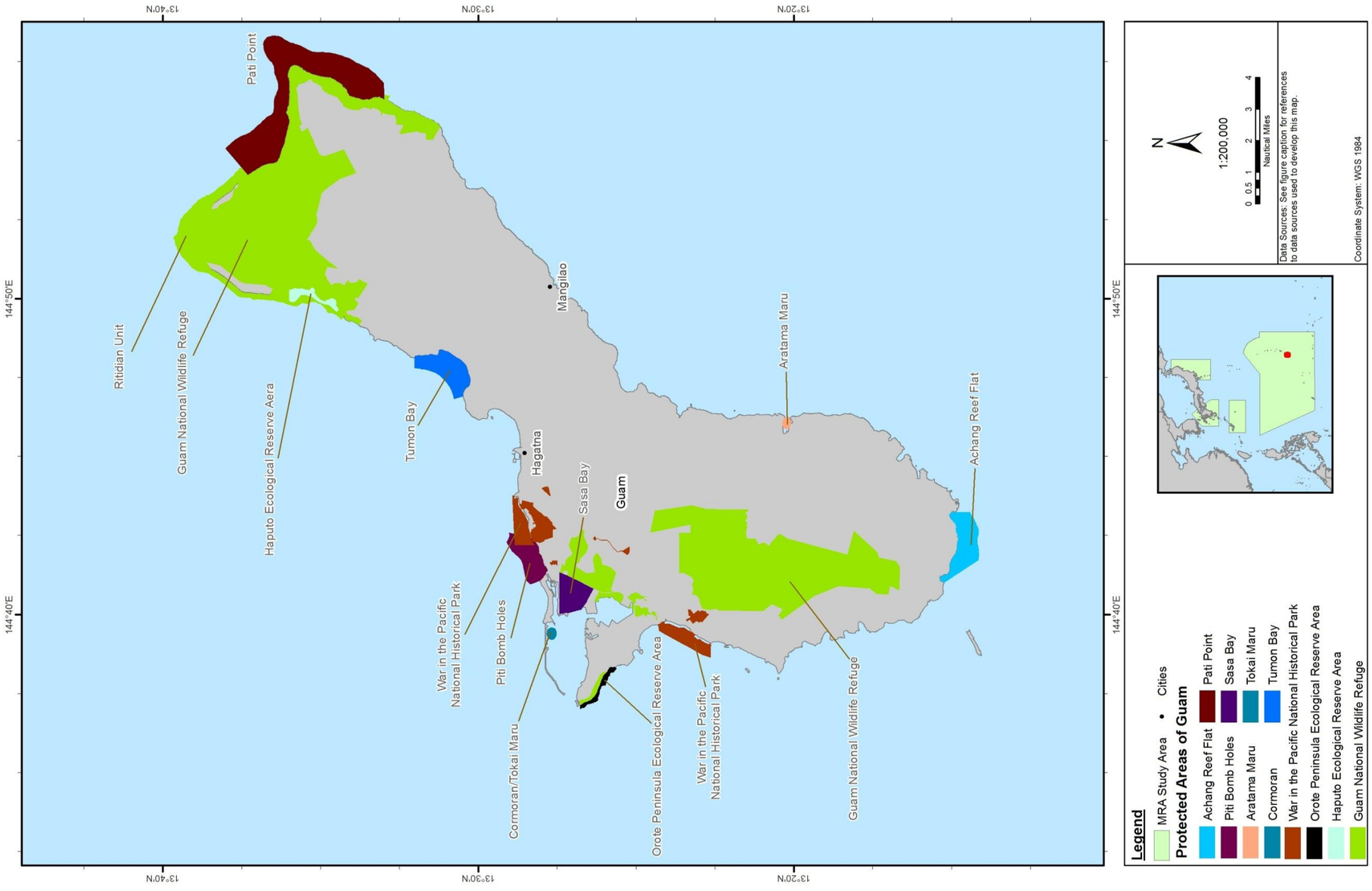

Figure 12-4: Map of the Protected Areas in Guam
Source: National Oceanic and Atmospheric Association (2013).

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12.4 MARINE PROTECTED AREAS OF THE CAROLINE ISLANDS

In the past, land and water in Republic of Palau (Palau) and Yap have been managed through traditional resource management; yet because of increased resource degradation, these local management practices were becoming insufficient.

The local government works with the U.S. federal government to safeguard natural resources of the Federated States of Micronesia (FSM). Several organizations participate in the decision-making process related to the sustainable use and conservation of marine living resources in Yap (Government of the Federated States of Micronesia 2012). Likewise, various laws, regulations, and policies are in place to support Yap in addressing the conservation and protection of the natural resources of the oceans and seas (Table 12-5). In addition, Table 12-5 briefly describes programs set forth by the federal government, the government in Yap, and non-governmental agencies for the management of Yap's natural resources and environment.

Table 12-5: Summary of Applicable Information from the Constitutional Division of Environmental Responsibilities and other Programs in the Federated States of Micronesia

Regulatory Field	Primary Responsibility	Description
Constitutional Division of Environmental Responsibilities[1]		
Water quality	National	In any area of public health the national government has power to set minimum standards. Only if a state is unable to meet the minimum standard would the national government have authority to ensure the state meets the minimum standards. States may always set stricter standards.
Ecosystem protection	State	The national government has no power except where a threat is posed to public health or to traditions of the people.
Protection of animal life (within 12-mile limit)	State	NL
Protection of animal life (beyond 12-mile limit)	National	NL
Protection of migratory species	State/National	Where (1) a lack of management in one state may affect harvest in another state (such as turtle eggs), then the national government can exercise power to protect traditions of the people; (2) the national government has power to act where a species comes under international treaty.
Endangered species, (including wildlife reserves)	State/National	Under normal circumstances protection of endangered species and establishment of wildlife reserves is a state responsibility. But, as the traditional way of life includes native species, the national government may act to protect endangered Micronesian species.
Other Programs		
Palau Conservation Society	Local Government	Conserve the unique natural resources and beauty of Palau through community interaction and education for social and economic benefit (Palau Conservation Society 2012).
Yap State Resource Management Division	Local Government	Manage, conserve, and develop marine resources in a way that delivers the greatest economic and social advantage currently and in the future (Yap State Department of Resources and Development 2012).

Table 12-5: Summary of Applicable Information from the Constitutional Division of Environmental Responsibilities and other Programs in the Federated States of Micronesia

Regulatory Field	Primary Responsibility	Description
Yap Environmental Protection Agency	Local Government	Control pollution, pesticides, and hazardous waste, protect water quality; further public education and awareness (Yap Environmental Protection Agency 2012).
Yap Community Action Program	Community	Non-profit organization whose primary goal is to aid underprivileged families in finding suitable homes (Government of the Federated States of Micronesia 2010).
Micronesia Conservation Trust	Interagency/ Intergovernmental	Increases financial and technical resources to the Federated States of Micronesia for resource management; utilizes best management practices for small isolated island communities; brings together government agencies, community advocates and donors in order to best protect the local environment (Rose 2012).
Federated States of Micronesia Protected Area Network	Local Government	Implement Marine Protected Area (MPA) standards; analyzes and identifies gaps in management and monitoring; develops planning; conducts financial planning for MPAs in the area; engages community in management; balances protection and pressures to ensure balance of economic interests and conservation (FSMPAN2012).
Micronesia Challenge	Interagency/ Intergovernmental	Increases grant potential and manages funds; increases and measures community contribution; implements and manages monitoring programs and assessments, region-wide (Micronesian Conservation Trust 2009).
Locally-Managed Marine Areas	Interagency/ Intergovernmental	Conducts organized community-based monitoring with training and education for design, data management, fundraising, and communications. Program aims to improve local fishing practices and reef biodiversity, and to share information through training, workshops, and meetings (Locally-Managed Marine Area Network 2012).

Source: [1]Government of the Federated States of Micronesia (2012).
Notes:
MPA = Marine Protected Area
NL = not Listed

Palau. MPAs are designated in Palau by the federal and local governments are shown in Table 12-6 and Figure 12-5. Only Helen Reef (listed in Table 12-6) is outside the MRA Study Area and therefore, not depicted in Figure 12-5. These MPAs aim to protect much of the sensitive, low-lying land and coral reef which surrounds most of the 12 inhabitable islands. Biota within these reefs include over 700 species of coral, 7 out of the 9 species of giant clams,and the most isolated population of the endangered Dugong. In Palau, the Protected Areas Network Act (United Nations Environment Programme 2012):

- Establishes a formal system for Palau's protected areas
- Recognizes/supports local ownership and management
- Feeds to national, and global biodiversity conservation objectives
- Takes into account all elements of resilience
- Adopted International Union for Conservation of Nature (IUCN) categories
- Welcomes international partners and facilitates cooperation

The Locally-Managed Marine Area (LMMA) program was launched in 2000 and connects local marine management with community-based practitioners. In Palau, one of the LMMAs is Helen reef, where radio tagging of turtles (which are still harvested for community functions), construction limited to that of native huts, and reef surveillance help protect this area rich in biology and culture. LMMAs may later become designated MPAs (Locally-Managed Marine Area Network 2008).

Yap. Traditional management has been the established practice in managing and protecting Yap's natural resources. On Ulthi Atoll, the reef and lagoon areas belong to the dominant standing clan. This clan's chief is also the chief of the atoll. The marine areas within the atoll are divided into sections managed by the chiefs of each clan associated with the particular areas. A clan has fishing rights in any waters over which it presides. In contrast, on Woleai Atoll, the reef and lagoon are sectioned off and controlled by the highest ranking group in each island or settlement. No single chief has authority over the whole atoll. The head of every clan and its elders control the clan's own areas. They can independently determine when and if waters should be closed for fishing and other activities. Each person is able to fish in that person's clan regions at any period. Uniquely on Satawal Atoll, the three regions divide overall atoll responsibilities among the three chiefs. The "chief of the sea" controls use of marine resources and fishing. Fringing reef areas are open to fishing, but uses of mounts and uninhabited atolls require consent from this "chief of the sea" (Tafileichig and Inoue 2001).

Although traditional management has been successful in the past, and some degree of internal, unorganized regulation persists, with increased urbanization and influence from abroad, it is becoming increasingly evident that traditional practices alone cannot make up for the increased degradation of natural resources. As of 2008, one formal MPA, the Manta Ray Sanctuary, had been established on Wa'ab (Table 12-6). The boundaries of this Sanctuary were not available for mapping. Implementation of two more MPAs—the Nimpal Channel LMMA and the Peelaek Channel LMMA—is under discussion among local stakeholders (George et al. 2008). The proposed MPAs are currently in the LMMA program, so acquisition of baseline data is occurring through community involvement (Locally-Managed Marine Area Network 2008). Other community-based monitoring and management programs have been implemented in Yap and supplement the MPA system on a local level. The Yap State Coral Reef Monitoring Program established a monitoring program in 2006. This type of program is one of the main management techniques in the FSM. In Yap, NOAA and the Yap State fund the program and partner with Yap Community Action Plan, Yap Environmental Protection Agency, and Yap State Resources Management Division in implementing this program. The Yap State Coral Reef Monitoring Program periodically obtains data to monitor and promote conservation actions within the community. This information can be shared among agencies to fill data gaps, and to increase local knowledge and stewardship (George et al. 2008).

Continuing work aims to formally designate MPAs on Yap in order to safeguard the abundance of natural resources here. Through federal government initiative and local support, where MPAs have yet to be implemented, monitoring programs can provide baseline data or knowledge that can help maintain the long-term health of these resources.

Table 12-6: Marine Protected Areas of the Caroline Islands

Site Name	Date	Designation	Total Area (km^2)	Marine Area (km^2)	Latitude	Longitude
Palau						
Airai #1	1994	Conservation Area	1.0	1.0	7° 23' 18" N	134° 36' 44" E
Airai #2	1997	Conservation Area	1.0	1.0	7° 19' 30" N	134° 38' 16" E
Anguar	2004	Conservation Area	0.4	0.4	6° 54' 8.999" N	134° 7' 40.08" E
Bkulengrill	2006	Conservation Area	0.7	0.7	7° 31' 48" N	134° 30' 0"E
Ebiil	2000	Conservation Area	15.0	15.0	7° 46' 58" N	134° 34' 59" E
Helen Reef	2001	Reserve	163.0	163.0	2° 53' 47" N	131° 46' 60" E
Imul Mangrove	2003	Conservation Area	0.4	0.4	7° 25' 11.99" N	134° 30' 0" E
Lake Ngardok	2000	Reserve	4.39	NL	7° 30' 46.79" N	134° 36' 11" E
Ngaraard Beach	NL	Conservation Area	12.0	NL	7° 37' 28.91" N	134° 35' 36" E
Ngaraard Mangrove	1994	Conservation Area	1.4	1.4	7° 36' 55.79" N	134° 36' 24" E
Ngatpang	NL	Conservation Area	0.5	NL	7° 28' 5.52" N	134° 27' 56" E
Ngchesechang Mangrove	1994	Conservation Area	1.0	1.0	7° 23' 18.23" N	134° 36' 43" E
Ngederrak Reef	2001	Conservation Area	6.0	6.0	7° 17' 39" N	134° 28' 8" E
Ngemai	1997	Conservation Area	1.0	1.0	7° 31' 54" N	134° 37' 29" E
Ngemelis Conservation Area	1995	Sanctuary	30.0	30.0	7° 7' 28" N	134° 14' 35" E
Ngelukes	2002	Conservation Area	1.0	1.0	7° 25' 43.32" N	134° 36' 2" E
Ngerameduu	2000	Conservation Area	4.8	NL	7° 32' 1" N	134° 28' 40" E
Ngeran Clam Area	NL	Clam Area	1.0	NL	7° 24' 7.2" N	134° 30' 15" E
Ngeream	NL	Conservation Area	1.6	NL	7° 20' 59.99" N	134° 31' 48" E
Ngerheba Island Wildlife	NL	Conservation Area	1.0	NL	7° 24' 36" N	134° 26' 59" E
Ngerkebesang	2002	Conservation Area	0,1	0,1	7° 21' 29.52" N	134° 26' 10" E
Ngermasech	1998	Conservation Area	7.0	7.0	7° 34' 47" N	134° 32' 5" E
Ngeruangel	1996	Reserve	17.0	17.0	8° 10' 19" N	134° 37' 38" E
Ngerukuid (Ngerukewid) Islands Preserve	1956	National Preserve	12.0	11.1	7° 10' 23" N	134° 16' 3" E
Ngerumekoal Spawning Area	1976	Conservation Area	3.5	3.5	7° 17' 8" N	134° 15' 3" E
Ngkisaol Sardines	1999	Sanctuary	0.008	0.008	7° 14' 45" N	134° 21' 13" E
Reef of Ileyakl Beluu (Ileakelbeluu)	2004	Conservation Area	0.5	0.5	7° 35' 23.99" N	134° 30' 35" E
Rock Islands Southern Lagoon	1999	Conservation Area	840.6	840.6	7° 12' 53.28" N	134° 16' 55" E
Tululeu Seagrass	2001	Conservation Area	0.40	0.40	7° 2' 52" N	134° 15' 42" E
Yap						
Manta Ray Sanctuary[1]	2008	Marine Sanctuary	21,349	NL	9° 32' N	138° 07' E

Sources: Burke et al. (2011); MPA Global (2012) and Protected Planet.net (2010).
Notes:
[1]Office of Insular Affairs (2008, August 31)
km^2 = square kilometers
NL = not Listed

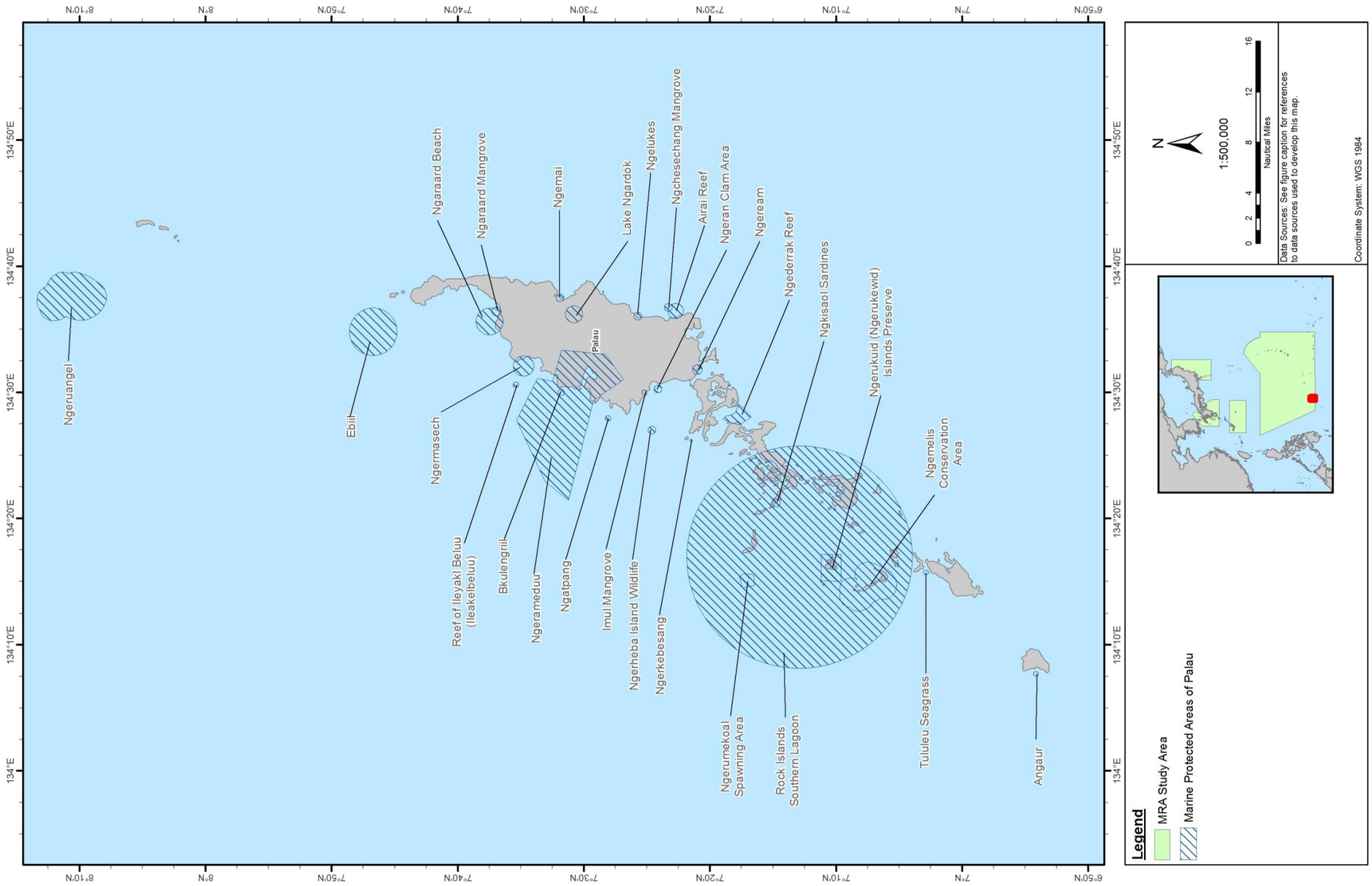

Figure 12-5: Marine Protected Areas and Marine Managed Areas in Palau
Source: Burke et al. (2011).

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13.0 HUMAN USES AND STRESSORS

The resources of the MRA Study Area for the Japan and Mariana Archipelagos (the MRA Study Area) are utilized by humans in a variety of ways, including commercial, recreational, and subsistence fishing; recreation and tourism; commercial shipping; and oil and gas. Regulation of these activities varies in authority and extent, depending on location within a nation's territorial waters, contiguous zone, or Exclusive Economic Zone (EEZ). The EEZs in the Pacific Ocean and within the MRA Study Area can be seen in Figure 13-1 and Figure 13-2, respectively. Stressors that may result from these uses are as diverse as the uses themselves. The sections that follow discuss the human-use activities and stressors that occur in the MRA Study Area, within the context of the geographic zones of the Japan Archipelago, the Mariana Archipelago, and the Caroline Islands.

13.1 FISHERIES (COMMERCIAL, RECREATIONAL, SUBSISTENCE)

Fisheries are described in terms of gear type and habitat, as fisheries agencies have organized their management regimes by both gear types as well as by area these fisheries operate. In general, nearshore fisheries employ a wide variety of gears and techniques to target a wide variety of species, while offshore fisheries employ only a few types of gears and generally target a single species. The fisheries status in terms of level of effort and total catch, types of management, and locations of fisheries are described for the MRA Study Area.

13.1.1 Description

Fisheries in the MRA Study Area occur are located in the Indo-West Pacific region, an area of immense pelagic fishery resources that provide more than 40 percent (%) of the world tuna catch, totaling more than 1 million metric tons and $1.5 billion annually (Western Pacific Regional Fishery Management Council 1999). Defining fisheries in the region is difficult because of the large number of harvested species, and diverse geographies, cultural practices, and economies among the different islands (Carpenter 1998; Zeller et al. 2007). The Western Pacific Ocean is a major setting for commercial, recreational, and subsistence fishing due to an abundance of species and high populations of people living in coastal areas throughout the region. While many traditional fishing techniques are still employed on the islands, new technologies in finding and capturing fish are much more efficient. Major pelagic fish species harvested in the offshore waters of the MRA Study Area include skipjack and yellowfin tuna, marlin, dolphinfish, and wahoo (National Marine Fisheries Service 2004), while sardine, mackerel and pollock are the major commercial coastal fisheries of Japan (Ishida et al. 2009).

Fisheries are often defined by the habitat type of the target species, gear employed, or a combination of these attributes. Gear types include trawl nets, boat seines, purse seines, gillnets, fixed nets, hook-and-line gear, longlines, traps and pots, and fish aggregation devices (FADs). Some of the fishing methods, such as purse seining and trawling, may involve either a single vessel or two vessels working together. A variety of gillnet designs allow this class of gear to be effectively used to catch species that live at the surface, in mid-water, and on the seafloor (Japanese Coast Guard 2005). FADs, although not considered fishing gear, are employed to congregate fish in the pelagic habitat, improving the catch rates for a variety of fishing techniques.

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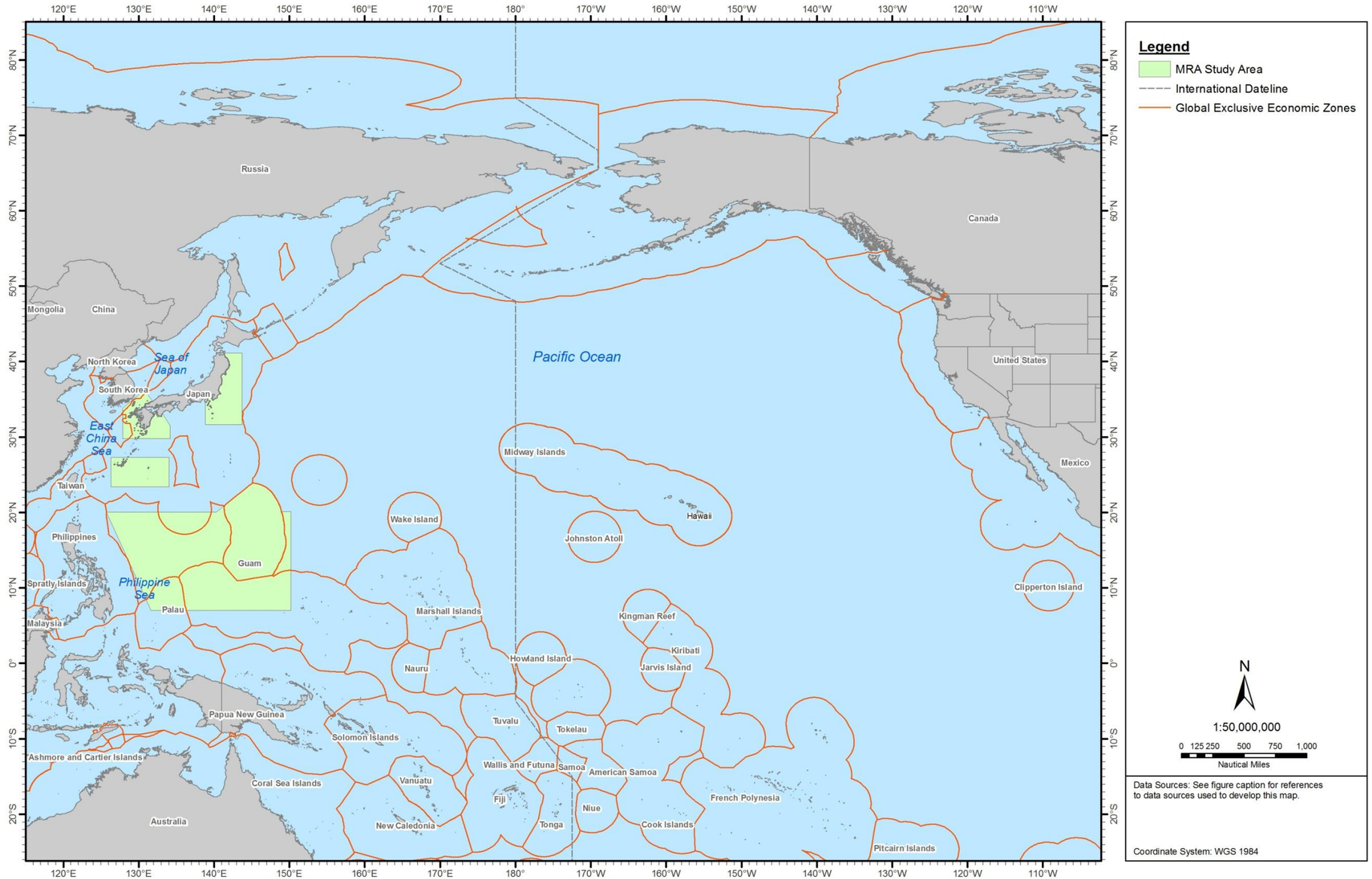

Figure 13-1: Exclusive Economic Zones in the North Pacific Ocean
Source: Claus et al. (2013).

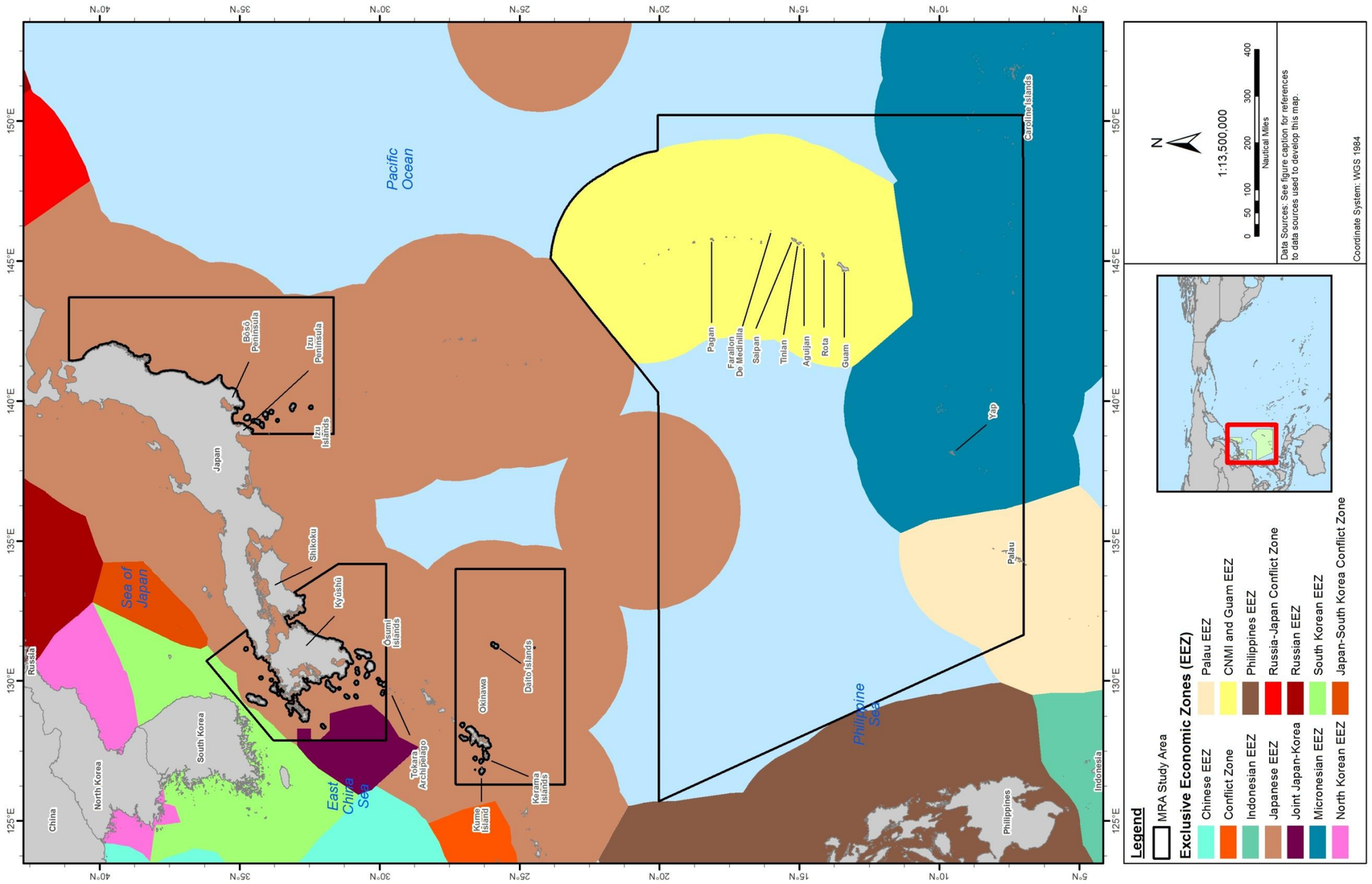

Figure 13-2: Exclusive Economic Zones of MRA Study Area
Source: Claus et al. (2013).

Coral reef fisheries. The majority of the coral reef fisheries in the U.S. Pacific Islands occur in nearshore waters (80 to 100%), with only a small component (< 20%) occurring in the U.S. EEZ. In the MRA Study Area, coral reef species may be harvested by commercial, recreational, or subsistence fishers. The methods used to collect these species range in sophistication from hand-collection to the use of complex traditional techniques, as well as with modern vessels and equipment. Hook-and-line is currently the most common gear type used to catch finfish in the MRA Study Area, and includes simple handlines and high-tech rods and reels with lures and baited hooks (Hensley and Sherwood 1993). Spearfishing, the use of a spear or spear gun to impale a fish, is most effective at night using underwater flashlights to target parrotfish, surgeonfish, and squirrelfish.

Longline fisheries. Longline fisheries generally occur on larger vessels, due to the size of the equipment needed to power modern longline fishing operations. Large vessels have hydraulically powered reels to set and haul as much as 40 miles (mi.) of polypropylene mainline (Western Pacific Regional Fishery Management Council 2009a). Smaller vessels less than 40 feet (ft.) long deploy and retrieve much less gear manually, using hand reels and often a natural (e.g., coconut) fiber mainline (Chapman n.d.). Pelagic longlining attaches floats to the mainline, with gangions and baited hooks set evenly along the length of the line. While smaller vessels average 350 hooks per set, a vessel over 50 ft. can set 2,000 hooks, can stay out at sea much longer and can store twenty times more fish than a small vessel (Western Pacific Regional Fishery Management Council 2009a). Demersal, or bottom-set longlining, conversely, uses weights to hold the mainline on the seafloor with buoyant gangions to catch bottomfish species. The primary species landed by pelagic longlines are tunas (yellowfin, albacore, and bigeye) and billfishes (swordfish, striped marlin, blue marlin, black marlin, sailfish, and shortbill spearfish (Western Pacific Regional Fishery Management Council 2009a). Demersal longline fisheries generally target halibut, cod, sablefish, and a variety of deepwater snappers.

Hook-and-line fisheries. Hook-and-line fisheries operate in nearshore waters, and can target pelagic species, including skipjack, albacore, big eye scad and yellowfin tuna as the vessel is trolling, or can target bottom fish species if the vessel is anchored or drifting. Specific gear types are used depending on the type of fishing.

Trawl fisheries. Mid-water trawling, or pelagic trawling, consists of towing a large cone-shaped net through the water column to catch pelagic species that occur in nearshore waters. Pelagic trawls primarily catch jacks, porgies, and croakers, and a variety of other fishes such as anchovies, grunts, chubs, common squids, salmons, and puffers. A bottom trawl consists of a wide-mouthed net that narrows to a closed “cod end,” with wheels mounted underneath the mouth to allow the trawl to be pulled along the seafloor without significant damage to the equipment. The trawl is towed behind one or two vessels, catching anchovy, cod, flounder, halibut, herring smelts, shrimps, and a variety of other benthic species. The largest bottom trawl fishery in the world is for the Japanese anchovy, with a mean annual catch of 544,134, tons (Watson et al. 2004). Dredges operate in a similar manner as bottom trawls, but dig into the seafloor to harvest a variety of bivalve mollusks (e.g., scallops, oysters, clams, and mussels), gastropods (snails), and crustaceans (Watson et al. 2004).

Inshore net fisheries. A variety of net fishing occurs in the MRA Study Area. Gillnets are generally placed in the path of moving schools of fish, and left unattended for a period of time prior to retrieval (Western Pacific Regional Fishery Management Council 2009c). They can be set to float at the surface, hang in mid-water, or can be positioned on the seafloor. Surface and mid-water gillnets can be either anchored or allowed to drift. All gill net gear are marked with floats and are rarely set in high-traffic waters. Mackerel are often targeted by drift gillnets, while gillnets set on the seafloor catch cod, yellowtail

amberjack, and mackerel (Japanese Coast Guard 2005). Drag nets are used in sandy areas of the reefs where the net can be set and then pulled onto the beach without being snagged on rocks or corals. These require several people and harvest a variety of species. Cast nets are thrown such that they open in the air and fall over the fish school, trapping as many fish as possible. They are used to harvest rabbitfish, bigeye scad, mullet, goatfish, and surgeonfish. Surround nets require several people to deploy and are used to surround large groups of fish on the reef. They target the same species as cast nets, but in greater numbers. Large numbers of bigeye scad are taken in cast nets during seasonal runs.

Purse seine fisheries. Purse seine gear consist of a long wall of netting with floats above and weighted rings below. A line runs through the rings which can close the bottom of the netting to prevent fish from escaping during hauling. The netting is attached to the main vessel while a second smaller boat takes the other end and encircles a school of fish. The main vessel draws the line in, which closes the bottom of the net and hauls the catch aboard. Small-scale coastal purse seine vessels are 2 to 3 tons, while the largest are 500 to 1000 tons gross vessel weight (Japanese Coast Guard 2005). The primary species targeted by purse seines are tunas. FADs are often employed to draw the schools to these locations, improving overall catch rates (Japanese Coast Guard 2005).

Trap fisheries. Traps and pots are used to capture various fishes and invertebrates. Crabs, lobsters, octopuses and eels are the primary species targeted. These gear are usually set in coastal areas and are marked with floats at the surface. The fishing process involves setting traps or pots on location, and then returning to retrieve these after a length of time, often overnight. A large number of traps or pots are usually strung together along a single line (Japanese Coast Guard 2005).

JAPAN ARCHIPELAGO. There are 6,245 fishing communities centered around 2,931 fishing ports in Japan (Schmidt 2003). Japanese marine fisheries are divided into three categories: coastal, offshore, and distant water (Ruddle 1987; Swartz 2004). Fishery activity can be high year-round (Japanese Coast Guard 2005).

Coastal Fisheries. Coastal fisheries operate in nearshore waters and generally use boats of less than 10 metric tons. These boats are usually motorized, but older, traditional, sail-powered vessels still are utilized (Japanese Coast Guard 2005). Coastal fisheries have lower annual landings (around 2 million tons) than offshore or distant water fisheries, but are economically important because these vessels harvest high-value species such as porgies and amberjack (Ruddle 1987; Schmidt 2003; Swartz 2004). High-value coastal species play a major part in the economics of the fish market (Schmidt 2003). In the year 2000, 140,000 of 150,000 Japanese fishery enterprises operated in coastal waters, with 240,000 individuals participating (Schmidt 2003). Coastal resources were depleted in the 1950s and impacted by pollution in the 1960s, but some areas have recovered due to management and awareness efforts. Within the coastal fishing area off Japan, resources are parceled into jurisdictions that are “owned” and managed by individual fishery cooperative associations with exclusive rights to harvest. Management of these areas includes species prohibitions, size and gear limitations, closed seasons, and establishment of conservation, recovery, and closed zone regulations (Matsuda et al. 2010; Ruddle 1987; Schmidt 2003). Albacore and bigeye tunas, swordfish, and billfishes are caught with longlines around coastal areas of Japan (Bayliff and Olson 2004).

Offshore Fisheries. Offshore fisheries operate in waters beyond the coasts but within Japan’s EEZ, as well as in the EEZs of China, South Korea, and Russia. These fisheries utilize vessels averaging 100 metric tons and generally target small pelagic and demersal species in the Northwest Pacific, Sea of Japan, and East China Sea (west of Okinawa and the Ryukyu Islands). Tunas, swordfish, and billfishes are also

important target species caught in offshore waters. Japan's offshore fishery sector lands the most fish by weight of the three sectors (3.3 million tons in 2001) (Ruddle 1987; Swartz 2004). Fishes caught in offshore waters of the Oyashio and Kuroshio Currents off the eastern coast of Japan include the Japanese sardine (pilchard), Pacific saury, anchovy, jack mackerel, frigate mackerel, yellowtail amberjack, filefish, herring, sea robin, and parrot bass (National Marine Fisheries Service 2003; Sugiyama, Staples, and Funge-Smith 2004). The Japanese sardine accounted for more than 40% of marine fisheries landings until the fishery collapsed by the end of the 1980s. Currently, the most important fishes in offshore waters of Japan are Alaska pollock (walleye pollock), jack mackerel, saury, squid, and snow crab (Schmidt 2003).

In the Sea of Japan, major fisheries use purse seines and trawls (Bayliff and Olson 2004). Common squid, Japanese sardine, chub mackerel, horse mackerel, anchovy, filefish, and Alaska pollack are the major species caught in the Sea of Japan (Chiba et al. 2004). Japanese sardine and common squid are the most important of these fisheries. Bluefin tuna are caught using traps, gillnets, and trawls (Bayliff and Olson 2004). Fishing in the southern portion of the Sea of Japan is common year-round (Chiba et al. 2004).

In the East China Sea, fisheries use large trawls (including pair trawls) and purse seines, targeting hairtail, filefish, and common squid (Bayliff and Olson 2004; Yoo and Kim 2004). Small yellow croaker, largehead hairtail, chub mackerel, and anchovy are caught in the southern Yellow Sea and northern East China Sea during the winter (Yoo and Kim 2004).

Foreign vessels also fish in waters of Japan. For example, vessels from China and South Korea often fish in the Sea of Japan (Chiba et al. 2004). After the establishment of national EEZs, Japan was involved in negotiations that effectively allowed Soviet (Russian), Chinese, and Korean fisheries to operate in various parts of its EEZ, including the Sea of Japan and the East China Sea (Swartz 2004).

Distant Water Fisheries. Distant water fisheries operate on the high seas (international waters beyond national EEZs). Distant water fishing vessels are 200 metric tons or more. In 1973, distant water fisheries production peaked at 4 million tons, representing 41% of Japan's total marine fisheries landings. By 2001, however, the landings had decreased to 820,000 tons, 21% of the peak production (Swartz 2004). Because distant water fisheries lie outside the scope of the MRA Study Area, these will not be described further. Some elements of the offshore fisheries overlap with distant water fisheries, such as target species and vessel activity (i.e., some offshore vessels operate in high seas areas). Pelagic longline fishing in offshore waters, the largest longline fishery in the MRA Study Area, has been decreasing since a peak in the 1980s (Polacheck 1991).

MARIANA ARCHIPELAGO. The Western Pacific Regional Fishery Management Council (WPRFMC) designates both the Commonwealth of the Northern Mariana Islands (CNMI) and U.S. Territory of Guam (Guam) as "fishing communities." This designation is based on considerations such as the portion of the population depending on subsistence fishing; economic importance of fishery resources to the islands; and geographic, demographic, and cultural attributes of the communities (Western Pacific Regional Fishery Management Council 2006).

In the Mariana Archipelago, federal fisheries are managed as bottomfishing, coral reef fishing, and pelagic fishing. Until 1930, when the more modern Japanese fishing fleet began fishing in the Mariana Archipelago, the region was subsistence-based, and fishing occurred mainly in the coastal zone (Miller 2001; Simonds 2003). Traditional fishing methods are still practiced today, however more efficient fishing methods are now common. In the Mariana Archipelago, fisheries are described according to the

type of fish caught. For territorially managed fisheries, the two main divisions are inshore fisheries, which include bottomfish, troll, and reef fisheries; and offshore, also known as pelagic fisheries.

Approximately 74% of the registered boats in the CNMI participate in some form of fishing activity (Pacific Islands Fisheries Science Center 2004). Charter vessels generally retain their catch, selling more than half to local fish markets. Within the CNMI, about 70% are used in the commercial fisheries. In 2003, about 55 vessels were identified as involved in full-time commercial fishing, and 41 vessels were classified as part-time (Western Pacific Regional Fishery Management Council 2004b).

Inshore Bottomfish Fisheries. Bottomfish species are harvested by both boat-based and inshore methods that include spearing, trolling, and use of nets such as gillnets, castnets, and surround nets (Western Pacific Regional Fishery Management Council 2009c). Federal regulations prohibit the use of destructive fishing techniques, including explosives, poisons, trawl nets, and bottom-set gillnets (Western Pacific Regional Fishery Management Council 2009c). In the Mariana Islands, bottomfishing is highly seasonal and is a combination of recreational, subsistence, and small-scale commercial fishing. The majority of vessels used for bottomfishing are less than 25 ft. (7.6 meters [m]) long and operate in shallow waters (depths less than 500 ft.) (<152.4 m). Smaller, operator-owned boats tend to target shallow water, while the commercial fishermen tend to target the deeper water. A few larger commercial bottomfish vessels fish around the islands north of Saipan, landing between 20,000 and 30,000 pounds (lbs.) annually (Division of Fish and Wildlife and Western Pacific Fisheries Information Network 2011). Less than 20% of shallow water harvests are taken outside the 3-mi.territorial waters, largely due to deeper water and stronger currents in the EEZ (Western Pacific Regional Fishery Management Council 2009b). Bottomfishing charters have accounted for 15 to 20% of bottomfishing trips since 1995, and these have increasingly become catch-and-release activities (Western Pacific Regional Fishery Management Council 2009b).

Deep-water species (depths 150 to 250 m), such as snappers and groupers, are targeted largely by commercial fishermen, whereas shallow-water species (depths <150 m)—including reef-dwelling snappers, groupers, emperors, and jacks—are caught by both subsistence and commercial fisheries (Pacific Islands Fisheries Science Center 2004). Snappers targeted in the deep-water fishery include members of *Etelis* (notably the longtail snapper) and *Pristipomoides*, whereas the eight-banded grouper (*Epinephalus octofasciatus*) is the only targeted grouper. Of the bottomfish species, deepwater snappers can be sold for the highest commercial prices. The shallow-water fishery targeting the redgill emperor (*Lethrinus rubrioperculatus*) is mostly commercial but also includes subsistence fishermen (Western Pacific Regional Fishery Management Council 2009c). Hand lines, home-fabricated hand reels, and electric reels are the commonly used gear for small-scale fishing operations, whereas electric reels and hydraulics are the commonly used gear for the larger operations in this fishery. Demand for fishes in the deep and shallow-water complexes continues to exceed the locally caught supply (Hensley and Sherwood 1993), and may be contributing to the overall decline in nearshore and reef-associated bottomfish populations.

Inshore Coral Reef Fisheries. The coral reef fisheries in the Mariana Islands are mostly limited to nearshore areas, especially off the islands of Saipan, Rota, Tinian, and Guam. Less than 20% of the total coral reef resources harvested in Guam are taken from the EEZ, primarily because these are associated with less accessible offshore banks (Western Pacific Regional Fishery Management Council 2001). Most offshore banks are deep, remote, and subject to strong currents, limiting access to calmer weather that occurs generally from May to September. Finfish and invertebrates are the primary targets of the coral reef fishery; however, small quantities of seaweed are also taken (Western Pacific Regional Fishery

Management Council 2001). Invertebrates, including crustaceans, mollusks, and echinoderms, are primarily harvested in the nearshore habitats (Hensley and Sherwood 1993; Western Pacific Regional Fishery Management Council 2009c). The lobster harvest in the Marianas Archipelago occurs exclusively within 3 nautical miles (nm) of shore, primarily for personal consumption, and volume is not reported. While local subsistence or recreational fishermen do not harvest coral with any frequency, poaching by foreign boats is believed to occur (Western Pacific Regional Fishery Management Council 2006).

More than 100 species of fish are harvested from the coral reefs around Guam (Hensley and Sherwood 1993), and seven families (Acanthuridae, Mullidae, Siganidae, Carangidae, Mugilidae, Lethrinidae, and Scaridae) are consistently among the top 10 species, accounting for 45% of the annual fish harvest (Western Pacific Regional Fishery Management Council 2009c). Spearfishing is generally a highly selective fishery and targets fish of larger species such as parrotfish. Scuba-assisted spearfishing and gill netting are still allowed on Guam, contrary to the prevailing conservation ethic. Certain species such as the bumphead parrotfish, humphead wrasse, stingrays, parrotfish, jacks, emperors, and groupers are rare on shallow reefs because of intense fishing efforts (Green 1997). Improved technology (high-capacity tanks, high-tech lights, and bang sticks) has allowed scuba-assisted spearfishing to occur in deeper water (30 to 42 m). For this reason, these larger species are now reappearing in the fishery catch statistics (Green 1997). The Chamorro people (indigenous people of Guam) have a long history of net fishing, but gillnets are a more recent introduction to the island (Hensley and Sherwood 1993). Gillnets are popular due to their availability, comparatively low cost, and effectiveness of the material (Hensley and Sherwood 1993).

Recreational and subsistence fishing activities within CNMI primarily occur in shallow waters (less than 500 ft. [152.4 m]) and are limited to daylight hours within a 30-mi. (48.2-kilometers [km]) radius of Saipan due to the distances to port and the limited size of the vessels (usually less than 24 ft. (7.3 m) in length) (Western Pacific Regional Fishery Management Council 2006). This type of fishing is conducted without fathometers or nautical charts as the fishermen rely on land features for guidance to a fishing area (Western Pacific Regional Fishery Management Council 2009c). Little information is available regarding inshore subsistence and recreational catches of coral reef resources, but the harvest is assumed substantial, especially in the more accessible areas like Saipan Lagoon (Western Pacific Regional Fishery Management Council 2009c). A survey program is being established to generate catch and effort data for these fisheries. In 2005, the Division of Fish and Wildlife reported 150 vessels used for subsistence fishing (Western Pacific Regional Fishery Management Council 2006). Recreational fishing ("catch and release") is not practiced in the Mariana Archipelago—fish caught are kept for personal use, distributed within the community, or sold in markets (National Marine Fisheries Service 1996).

Pelagic Fisheries. Pelagic fisheries include (1) distant-water purse seiners and foreign longliners that fish primarily outside the EEZ and transship through Guam, and (2) small recreational boats that troll for fish in local waters of the Mariana Islands (Pacific Islands Fisheries Science Center 2004, 2011). The primary fishery is the small-boat troll fishery, conducted by 12 to 24 foot long outboard powered boats (Division of Fish and Wildlife and Western Pacific Fisheries Information Network 2011), with a limited travel radius (approximately 32-km) from the islands. These vessels generally conduct one-day trips close to the islands, and primarily catch mahi-mahi, wahoo, skipjack tuna, yellowfin tuna, and Pacific blue marlin. Skipjack tuna dominate the commercial landings, contributing over 40% of the total landings by weight. Yellowfin tuna and dolphinfish are also important species for local fishermen as they can be found close to shore during their seasonal runs. All production from the domestic commercial fishery is consumed locally. No large-scale longline or purse seine activity occurs around the Mariana Islands (Simonds 2003).

From year to year, there have been large fluctuations in the number of these species caught. Pelagic fish tend to be highly migratory and at the top trophic level of oceanic predators.

The pelagic fishery in the CNMI occurs from Farallon de Medinilla (FDM) south to the island of Rota. The number of commercial trolling vessels in the CNMI has decreased by 60% since 2001, with only 44 vessels making commercial landings in 2009 (Western Pacific Regional Fishery Management Council 2011). Guam has a much larger trolling fleet, with 368 vessels making documented landings in 2009, totaling 719,892 pounds (Western Pacific Regional Fishery Management Council 2011). A small but significant portion of the pelagic fishing vessels are charter boats, contributing approximately 7.5% of the total pelagic landings (Western Pacific Regional Fishery Management Council 2011).

In 2006, charter boats comprised about seven percent of the pelagic fleet. The remainder of the pelagic fleet included residents using owner-operated boats, mostly towed to launch sites, as opposed to semi-permanent marina docking (Allen and Bartram 2008). The charter industry caters primarily to tourists and U.S. military personnel. Pelagic charter trips totaled roughly 2,000 in 2006, with an estimated 67,000 lbs. (3039.1 kilograms [kg]) of catch; the top three species were mahi-mahi, skipjack, and wahoo (Allen and Bartram 2008). Charter boats account for the majority of trolling hours, trips, and pelagic catch on Guam (Pacific Islands Fisheries Science Center 2004; Simonds 2003). Currently, Guam and CNMI employ large vessel exclusion zones to maintain opportunities for small-scale commercial, recreational, and subsistence fishermen. The zone extends from shore to 50 nm of Guam and the southern Islands of the CNMI and to 10 nm around the Northern Island of Alamagan (Western Pacific Regional Fishery Management Council 2009c). Figure 13-3 shows harbors and boat ramps that are used by fishermen in Guam and monitored for creel surveys to estimate total landings. A creel, or angler survey, is a tool to gain information on fisheries by interviewing fisherman, measuring fish, documenting the hours fished, counting boats entering/exiting the water, etc.

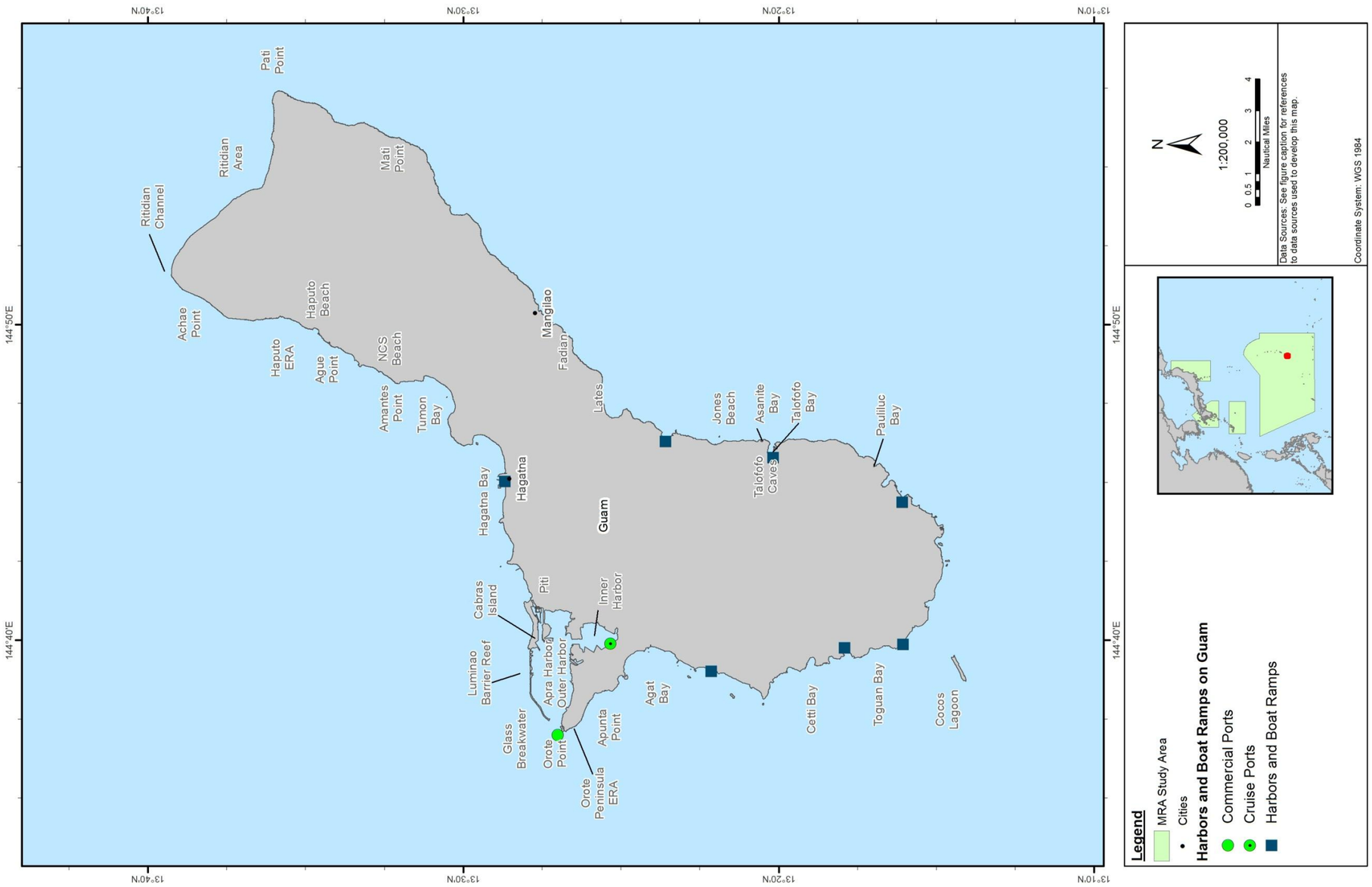

Figure 13-3: Harbors and Boat Ramps on Guam
Sources: Burke et al. (2011); Tetra Tech (2013).

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CAROLINE ISLANDS.

Palau. Republic of Palau (Palau) has 629,000 square kilometers (km²) of EEZ, mostly pelagic habitat, with 1,531 km² of mangrove and coral reef habitats adjacent to the 343 low-lying volcanic islands (Food and Agriculture Organization of the United Nations 2009b). Coastal fishing is primarily carried out for subsistence and commercially to supply local markets, while offshore fishing for tuna is an export product (Food and Agriculture Organization of the United Nations 2009b). A few coastal products, trochus and aquarium fish, are exported as well. Coastal fisheries are carried out using a variety of gears, including hand collection, hook-and-line, spear, net and trolling (Food and Agriculture Organization of the United Nations 2009b). At least 25% of households in Palau own fishing boats. Offshore tuna fishing is conducted by approximately 100 locally-based foreign longliners, ranging in size from 53 to 89 ft. (16 to 27 m).

Yap. Marine resources of Yap include tuna and other pelagic species, and a wide variety of fish and invertebrates in the coastal environment. Because of their relative accessibility, coastal resources form the basis of most of the small-scale fisheries in Federated States of Micronesia (FSM), which are primarily subsistence-based (Food and Agriculture Organization of the United Nations 2010). Yap state has also invested in a purse seiner to fish for tuna in the waters of the FSM EEZ as well as in international waters (Food and Agriculture Organization of the United Nations 2010). Nevertheless, the foreign-owned vessels contribute approximately 80% of the total value of the fisheries of FSM (Food and Agriculture Organization of the United Nations 2010).

13.1.2 Status and Management

Wise management has become crucial to protecting fishery industries and maintaining fishery resources. At the federal level, laws, executive orders, proclamations, and regulations have been created to aid in the conservation of fishery resources. In Japan, the Fisheries Law (1949) is the main form of regulation for Japan fisheries (Food and Agriculture Organization of the United Nations 2009a). Japan has a decentralized fisheries co-management system, where coastal fisheries are managed by local fishery cooperatives (Matsuda et al. 2010), while the national government manages the more industrialized and commercially oriented offshore fisheries (Food and Agriculture Organization of the United Nations 2009a). In addition, international border disputes continue among Japan, China, and South Korea in the Sea of Japan and the East China Sea, and currently, each country is allocated their own fishing quotas (Kataoka 2011; Nagasawa 2011). Nearshore fisheries management (0–3 nm) in Guam and CNMI are under the purview of the territorial government, and include data collection, research activities to inform management decisions, enforcement of territorial regulations, as well as the promotion of local fishing activities and maintenance and improvement of fishery infrastructure, including harbors, boat ramps and shore-based facilities. Management in the FSM is both centralized for the offshore sector, and under local control for the nearshore resources of each island.

Although natural patterns of variation are expected in marine fishery stocks, human activities are known to significantly affect fish distributions and abundances. Over the past two centuries, and especially within the past 50 years, the overall intensity of fishery effort (commercial and recreational) has increased. High demand for fishery products has led to increased fishing activity and has resulted in depletion of certain species stocks (Parker and Dixon 1998; Waite et al. 1994). While improvements in fishing gear and methods continue, overall catch rates in relation to effort expended are decreasing. Fishery declines are directly and indirectly attributed to several factors that include habitat loss, physical habitat damage, natural events and cycles, fishing pressure, stream flow alteration, and degradation of

water quality. Overfishing is considered one of the main causes of declining catch rates (Waite et al. 1994). As fishery landings have diminished, commercial fishers have broadened the number of target species to include species once discarded, but are currently available in harvestable quantities. Smaller fish are now also targeted for commercial sales (Pauly et al. 1998).

JAPAN ARCHIPELAGO. The Japanese have traditionally relied on fish, and Japan has one of highest per capita fish consumption rates in the world, providing almost 50% of its population's protein intake (Schmidt 2003; Sugiyama, Staples, and Funge-Smith 2004; Swartz 2004). In 2005, fishing and fish products accounted for 61.2 kg per capita of annual intake (Food and Agriculture Organization of the United Nations 2009a). Marine, freshwater, and aquaculture fisheries provide fishery products to help support this high demand. The largest fisheries sector is marine fisheries, accounting for 90% of Japanese fishery production (Fisheries Global Information System 2001; Swartz 2004). Of domestic fishery production, 86% was used for human consumption in 2006, while the rest was incorporated into industrial uses (Food and Agriculture Organization of the United Nations 2009a). While still relying heavily on domestic fisheries, Japan has recently become one of the world's biggest importers of fishery products.

In 2007, Japan was ranked fifth in the world in capture fishery production, with a total production of 5 million tons (Food and Agriculture Organization of the United Nations 2009a). Landings from marine fisheries increased from 2.3 million tons in 1945 to 11.3 million tons in 1984, followed by a decline to 5.7 million tons in 2000 (Swartz 2004). The decline was related to a variety of factors, including establishment of 200-nm national EEZs, which effectively reduced the amount of productive coastal fishing grounds available to the Japanese fishing fleets.

Nevertheless, the Japanese had developed extensive fisheries and a formidable fishing fleet in the latter half of the twentieth century, and many of these are still active (Swartz 2004). About 98% of Japan's fishers are considered artisanal, although this term is not defined by Japanese Law (Matsuda et al. 2010). In general, artisanal fisheries are designated based on the size of the vessels used and their capacity to fish beyond nearshore waters (Matsuda et al. 2010). These coastal fisheries employ the majority of people (89%) in the fishing industry, totaling 212,470 workers in 2006 and 204,330 workers in 2007. This 4% decline highlights an aging population in the industry. There were 232,534 power fishing vessels registered in Japan 2005 (Food and Agriculture Organization of the United Nations 2009a). While only consisting of two percent of the fleet, industrial fisheries have contributed a large percentage, a much as 50%, of the total annual catch (Matsuda et al. 2010). Aquaculture of fishes and seaweed has increased in Japan while coastal fisheries (including traditional, which are barely active) have decreased (Sakai 2006).

Since the early 1990s, walleye pollock (Sea of Japan stock), chub mackerel, and Japanese sardine fisheries have fallen to historically low levels (Ishida et al. 2009). While distant-water and offshore fisheries have been declining, coastal fisheries have stayed relatively stable (Food and Agriculture Organization of the United Nations 2009a; Matsuda et al. 2010). The marine trophic index, developed by the *Sea Around Us* project at the University of British Columbia Fisheries Centre, was established to investigate the impacts of fisheries on the world's marine ecosystems. The marine trophic index is higher in Japan than the global average and is not showing a long-term decline (Matsuda et al. 2010). While local management agencies can control the type, location and amount of fishing effort, fisheries are susceptible to a variety of outside stressors as well. Rising sea surface temperatures over the past 100 years may have caused changes in marine biota found in the Sea of Japan, affecting the species caught in the fisheries (Kishida and Kidokoro 2008). In March 2011, the Great East Japan Earthquake and

tsunami devastated Japanese fisheries. In Iwate Prefecture, 90% of fishing boats were lost (Kemuyama 2011). In the Ibaraki Prefecture, 18% of fishing boats were lost and 36% were damaged, at a total cost of 65.9 billion yen in damages to fisheries (Ebisawa 2011). The earthquake caused 31.84 billion yen in damage in Hokkaidō Prefecture (Sato 2011), and 4.08 billion yen in fishing damages in Mie Prefecture, of which 90% was to aquaculture facilities (Matsuda 2011). In Iwate Prefecture, the Fisheries Technology Center is providing support for local fishery recovery (Kemuyama 2011).

The Fisheries Law (1949) is the main form of regulation for Japan fisheries (Food and Agriculture Organization of the United Nations 2009a). Coastal fisheries are co-managed between resource users and prefecture governments. Local fisheries are organized into fisheries cooperative associations to manage the local fishing grounds, a system governed by the Fisheries Cooperation Association Law of 1948 (Matsuda et al. 2010). Both the Fisheries Resources Conservation Law of 1951 and the Basic Law of Fisheries of 2001 address conservation and sustainability in fisheries. Japan is a signatory to the United Nations Convention on the Law of the Sea (UNCLOS) and the United Nations Fisheries Stock Agreement (UNFSA) (Food and Agriculture Organization of the United Nations 2009a).

Japan has few centralized fisheries management programs. Individual fishing quotas have rarely been implemented (Matsuda et al. 2010), and offshore and distant water fisheries are regulated by a licensing system (Food and Agriculture Organization of the United Nations 2009a; Matsuda et al. 2010). In 1997, Japan implemented a total allowable catch system for seven species: Alaska pollack, sardine, jack mackerel, common and spotted mackerel, common squid, and snow crab (Food and Agriculture Organization of the United Nations 2009a). In offshore waters, Regional Fisheries Coordination Committees, composed of representatives of the various fisheries, implement conservation measures and autonomously enforce regulations (Matsuda et al. 2010). Management measures include the establishment of Total Allowable Catch and Total Allowable Effort (Food and Agriculture Organization of the United Nations 2009a).

Commercial coastal fishing is subject to more regulation than coastal recreational fishing (Ruddle and Segi 2006). Despite lack of a comprehensive management framework for recreational fishing, the activity falls under several different types of laws. Recreational fishing is locally managed and subject to ethical agreements instead of legally binding agreements. Only regulations that directly impacts the interests of commercial fishermen rights are monitored and enforced (Ruddle and Segi 2006).

MARIANA ARCHIPELAGO. The primary act regulating fisheries in federal waters of the United States is the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) (see Section 2.2.9 for details). One of the mandates of the Act was creation of a number of interstate management agencies, the Fishery Management Councils (FMCs), to oversee the condition of fishery stocks in federal waters of the U.S. EEZ (3 to 200 nm from shore). In the U.S. portion of the MRA Study Area, the Western Pacific Fishery Management Council has developed the *Fishery Ecosystem Plan for the Mariana Archipelago* and the *Fishery Ecosystem Plan for Pacific Pelagic Fisheries of the Western Pacific Region* (Western Pacific Regional Fishery Management Council 2009a, c) that set forth management objectives for fishery resources within the U.S. portion of the MRA Study Area as well as for U.S.-flagged vessels operating in international waters of the Western Pacific. National Oceanic and Atmospheric Administration (NOAA) Fisheries participates in fishery management efforts by providing fisheries data and analysis, creating regulations based on the Fishery Council's recommendations and enforcing these regulations (National Marine Fisheries Service 2003). NOAA Fisheries has the authority to restrict or prohibit the use of specific fishing gears in some areas to protect habitats, fishery stocks, or species assemblages, and to promote recovery of threatened or endangered species. Area closures can be seasonal or short-term, or

year-round and in place for many years. Within the territorial waters of the CNMI and Guam, the Division of Fish and Wildlife and the Division of Aquatic and Wildlife Resources (DAWR), respectively, manage the waters from 0–3 nm in a similar manner.

Commonwealth of the Northern Mariana Islands. The primary domestic commercial fishery in the CNMI is the small boat, one day troll fishery. These vessels are usually 12–24 ft. in length. In order to commercially fish in the CNMI's EEZ in a 25- to 50-foot (7.6 to 15.2 m) boat (over 5 net tons), a commercial fishing license is required and issued annually. NOAA's Pacific Island Fisheries Science Center (PIFSC) issues approximately four commercial fishing licenses on an annual basis (National Oceanic and Atmospheric Administration 2006).

A total of 1,693,798 lbs. of fish, valued at $3,526,200 (see Table 13-1), has been landed in CNMI over the past 5 years (Division of Fish and Wildlife and Western Pacific Fisheries Information Network 2011). A recent estimation of commercial and recreational non-pelagic fisheries catches throughout the Pacific Islands indicates a decline of 54% in CNMI from 1950–2002. The estimation of reef fish catch per capita dropped from 160 to 6.3 lbs. (72.6 to 2.9 kg). An under reporting of landings has likely contributed to an underestimation of official fisheries value (Zeller et al. 2007).

Table 13-1: Commonwealth of the Northern Mariana Islands Commercial Fishery Landings

Year	Pounds (Kilograms)	Value
2007	471,397 (213,822)	$879,603
2008	388,425 (176,187)	$823,821
2009	331,506 (150,369)	$709,985
2010	285,378 (129,445)	$608,970
2011	217,092 (98,471)	$503,821
TOTAL	**1,693,798 (768,294)**	**$3,526,200**

Source: Pacific Islands Fisheries Science Center (2012a).

Commercial pelagic landings in CNMI totaled approximately 88,485 lbs. in 2011—a decrease of 53% from 2010 and the lowest commercial pelagic landing recorded for CNMI since the time series began in 1981 (Figure 13-4) (Pacific Islands Fisheries Science Center 2012c). In comparison, the highest total commercial pelagic landings during that 30-year period totaled 372,110 lbs. Commercial bottomfish landings in 2011 totaled 11,959 lbs., a 47% decrease from 2010. Throughout the 30-year time series (1981–2011), the commercial bottomfish landings have ranged from 7,092 to 71,659 lbs. Commercial reef fish landings for CNMI in 2011 totaled approximately 37,241 lbs., a decrease of 38% from 2010. Throughout the 30-year time series (1981–2011), total commercial reef fish landings have ranged from 25,218 to 300,538 lbs. (Figure 13-4) (Pacific Islands Fisheries Science Center 2012c).

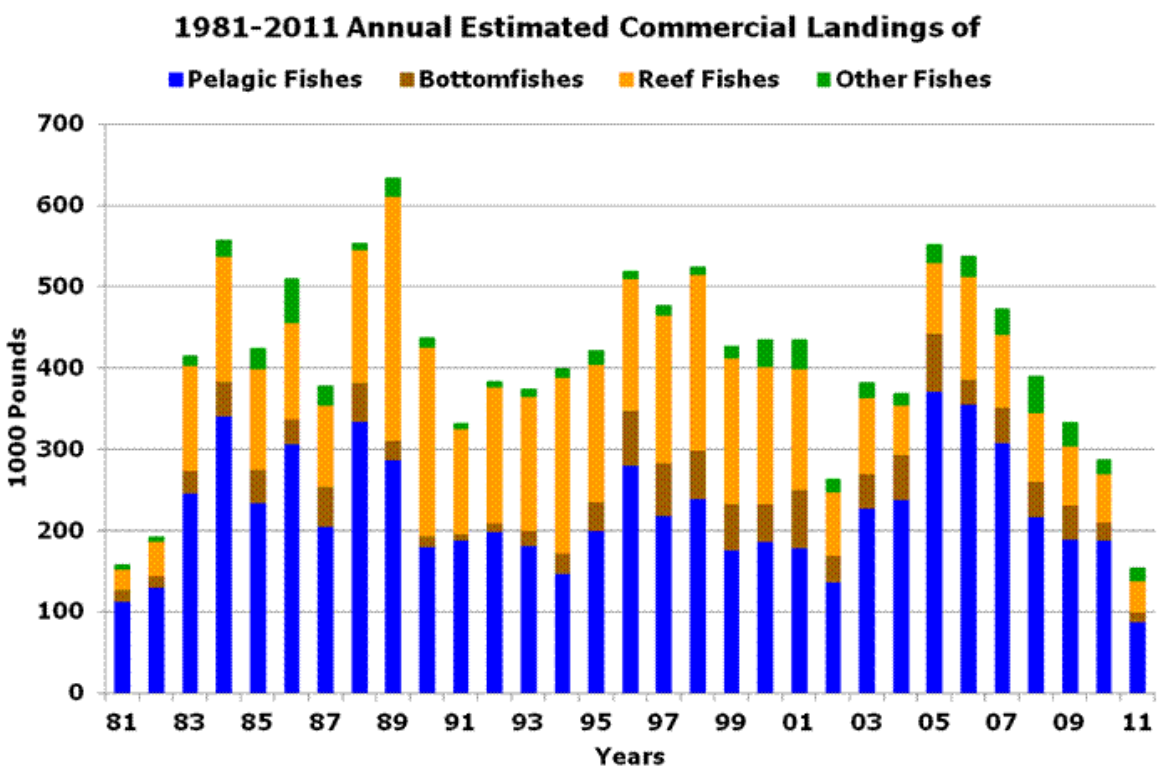

Figure 13-4: Annual Estimated Commercial Fish Landings for Commonwealth of the Northern Mariana Islands
Source: Pacific Islands Fisheries Science Center (2012c).

Commercial landings of coral reef fisheries average 130,000 to 175,000 lbs. per year of reef fish and 2,000 to 3,000 lbs. per year of spiny lobster (Western Pacific Regional Fishery Management Council 2001). In 1994, annual coastal fishery production on CNMI was 5.9 million lbs., of which, 5.65 million lbs. was from the subsistence fishery and 282,000 lbs. was from the commercial fishery (Preston 1997). Shallow-water bottomfish species such as snappers, emperors, and groupers might also make up an unknown proportion of the coral reef fishery within CNMI (Green 1997).

CNMI maintains a large vessel (greater than 50 ft.) exclusion zones to provide opportunities for small-scale commercial, recreational, and subsistence fishermen. The zone extends from shore to 50 nm around the southern Islands and to 10 nm around the Northern Island of Alamagan (Western Pacific Regional Fishery Management Council 2009c). Mandatory reporting only applies to large bottomfish vessels (50 ft. or greater) because large vessels have a greater capacity to deplete local populations of bottomfish (Western Pacific Regional Fishery Management Council 2009c).

The Division of Fish and Wildlife collect landings data from commercial fisheries through a voluntary dealer invoicing system (Division of Fish and Wildlife and Western Pacific Fisheries Information Network 2011). These data are provided to the Pacific Islands Fishery Science Center for data processing and generation of annual summary reports. Estimates since 1982 indicate that more than 90% of the commercial bottomfish landings of CNMI have been recorded in Saipan (Division of Fish and Wildlife and Western Pacific Fisheries Information Network 2011).

Guam. The domestic commercial pelagic fishing fleet on Guam is small, but by providing tuna processing facilities, transshipment (i.e., transferring fish to a receiving vessel), and home-port industries, Guam developed fishery-associated industries to benefit from the large-scale commercial fishing of the western Pacific. Guam is one of the largest tuna transshipment centers in the Pacific. Apra Harbor is the homeport of several hundred longline and purse seine vessels (Western Pacific Regional Fishery Management Council 1999). Since the late 1970s, the most important commercial fisheries activity in Guam has been as a major regional fish transshipment center and resupply base for domestic and foreign tuna fishing fleets. Fleet expenditures for fuel, provisions, and repairs enhance the island economy by boosting the job market and investment opportunities (Western Pacific Regional Fishery Management Council 1999).

Transshipment of tuna species and non-tuna species has varied since 1990. Transshipment of tuna species has decreased overall—from approximately 11,760,086 lbs. in 1990 to approximately 1,897,447 lbs. in 2011, with a peak of 11,764,990 lbs. in 2001 (Pacific Islands Fisheries Science Center 2012e). Transshipment of non-tuna species peaked at 1,058,192 lbs. in 1999, but has steadily declined to 119,755 lbs. in 2011 (Pacific Islands Fisheries Science Center 2012e).

According to the Western Pacific Fisheries Information Network (WPacFIN), between 1980 and 2009, the ex-vessel value of domestic commercial landings ranged from about $179,000 in 1980 to $1.33 million in year 2000 (Western Pacific Fisheries Information Network 2011). Commercial landings in Guam over the past 5 years total 1,643,693 lbs. valued at $3,891,207 (see Table 13-2). A recent re-estimation of commercial and recreational non-pelagic fisheries catches (1950–2002) throughout the Pacific Islands indicates a decline of 86% in Guam, where per capita reef fish landings dropped from 16.0 to 0.8 kg. As in the CNMI, underreporting has likely contributed to an underestimation of official fisheries value (Zeller et al. 2007).

Table 13-2: Guam Commercial Fishery Landings

Year	Pounds (Kilograms)	Value
2007	422,152 (191,485)	$889,221
2008	287,212 (130,277)	$692,809
2009	293,499 (133,129)	$770,752
2010	369,906 (167,787)	$919,949
2011	265,483 (120,421)	$677,765
TOTAL	**1,638,252 (743,099)**	**$3,950,496**

Source: Pacific Islands Fisheries Science Center (2012b).

Boat-based pelagic landings were 586,962 lbs. in Guam for 2011, a 25% decrease from 2010. Over a 29-year period, boat-based pelagic landings have ranged from 297,390 to 922,394 lbs. (Figure 13-5) (Pacific Islands Fisheries Science Center 2012d). Total commercial pelagic landings were approximately 143,052 lbs. in 2011, a 36% decrease from 2010. From 1980 to 2011, total commercial pelagic landings ranged from 118,251 to 400,200 lbs. (Pacific Islands Fisheries Science Center 2012d).

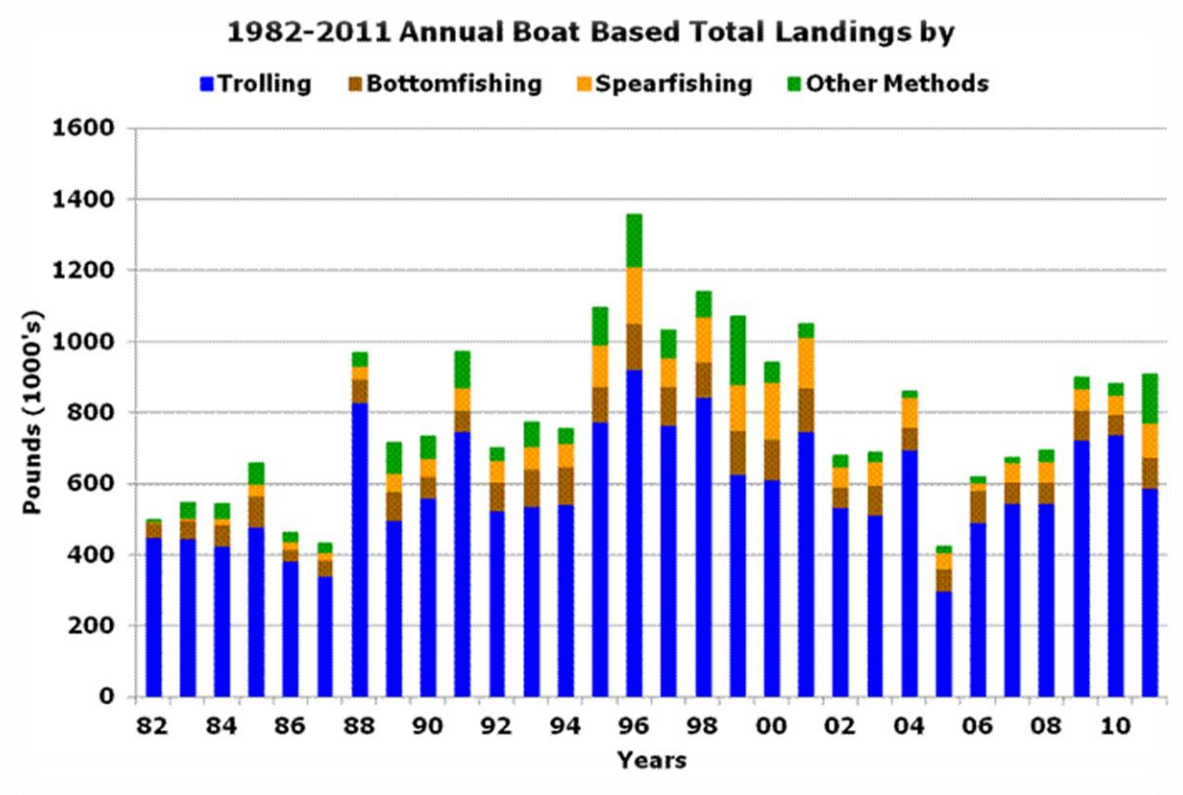

Figure 13-5: Annual Boat-Based Total Landings for Guam (1982-2011)
Source: Pacific Islands Fisheries Science Center (2012d).

Bottomfish harvest in Guam is varies more because of variation in fishing effort than changes in fish stocks (Western Pacific Regional Fishery Management Council 2009c). Total boat-based bottomfish landings in 2011 were 88,910 lbs., an increase of 56% from 2010 (Figure 13-5). The total commercial bottomfish landings in 2011 were 16,049 lbs., a 16% increase from 2010 (Figure 13-6). Throughout the 31-year time series, the commercial bottomfish landings have ranged from 6,617 to 30,488 lbs.

The total commercial reef fish landings in 2011 were approximately 98,170, a decrease of 20% from 2010. Throughout the 29-year time series (1980–2011), total commercial reef fish landings ranged from 2,598 to 205,030 (Figure 13-6) (Pacific Islands Fisheries Science Center 2012d). In Guam, lobster is harvested in nearshore waters and is primarily for personal consumption. The commercial trade is low, with only 1,168.0 lbs. (529.8 kg) caught and sold for $4,329 in 2008 (Guam Division of Aquatic and Wildlife Resources and the Western Pacific Fishery Information Network 2010). Commercial harvest of shrimp and crab has been attempted, but has been unsuccessful because of strong currents, rough bottom topography, and fishing depths that result in high rates of gear loss. Four permits have been issued for crustacean harvest in the EEZ around Guam, but results are unknown.

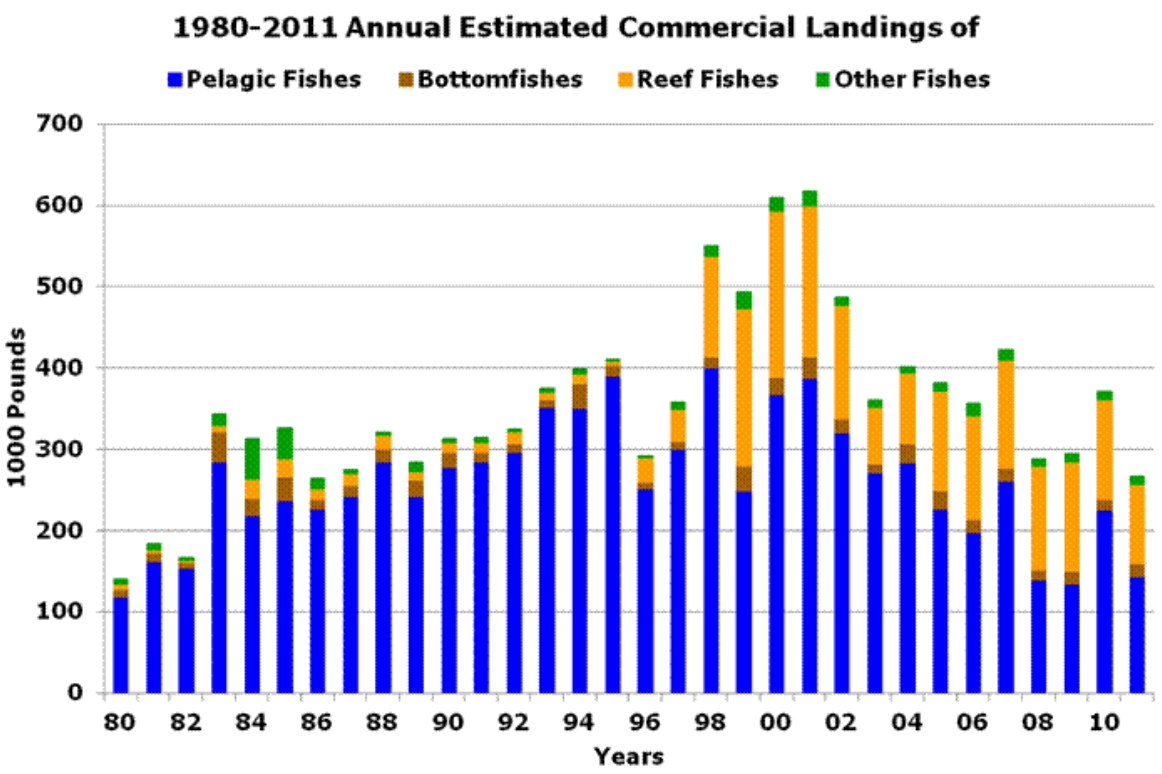

Figure 13-6: Annual Estimated Commercial Landings for Guam
Source: Pacific Islands Fisheries Science Center (2012d).

There is both inshore and offshore zoning in Guam. There are five nearshore marine preserve areas (Pati Point, Tumon Bay, Piti Bomb Holes, Sasa Bay, and Achang Reef Flat). Hook-and-line fishing from shore is allowed within the Pati Point and Tumon Bay Preserves. Cast nets are also allowed within the Tumon Bay Preserve for certain species. (Public Law 24-21). Bottom fishing is allowed only in the Tumon Bay Preserve seaward of the 100 foot depth contour. Trolling is allowed in all preserves from the reef margin seaward only for pelagic fish. The large vessel exclusion zone encompasses 43.7 million km^2 of ocean area, and extends from shore to 50 nm around all of Guam. This closure was implemented to prevent gear conflicts and provide opportunities for small scale fisheries (Western Pacific Regional Fishery Management Council 2009a).

In 2008, the PIFSC released an administrative report titled *Guam as a Fishing Community,* which noted that, although income from commercial fishing contributes substantially to a few households, nearly all of Guam's domestic fishermen hold jobs outside the fishery (Myers 1993), and the contribution of commercial fisheries to Guam's economy has been relative minor. Chamorro fishing practices are for subsistence purposes. Sales of fish may occur to cover expenses, but the primary purposes are for subsistence and cultural activities that include donations to assist each other and celebrations of life events. A high value is placed on sharing one's fish catch with relatives and friends. The social obligation to share one's fish catch extends to part-time and full-time commercial fishermen (Amesbury and Hunter-Anderson 1989). Of the fish consumed by Guam households in 2005, 51% was purchased at a store or restaurant, approximately 24% was caught by a family member, 14% was caught by a family friend or extended family member, and 9% was purchased at a flea market or from a roadside stand (Haider et al. 2007). Domestic fishing on Guam supplements family subsistence, which is maintained via

a combination of small-scale gardening, ranching, and wage work (Amesbury and Hunter-Anderson 1989).

Several factors have negatively impacted Guam fisheries, including the Asian market decline, a decrease in tourism, and a decrease in outside capital investments. These factors, along with rising fuel and boat maintenance costs, declining government finances, and environmental variation (e.g., El Niño events), have induced locals to turn to alternative sources of income. For those who continue to fish, improved fish catch through the introduction of FADs and focusing on tuna has provided additional income. Overfishing is considered one of the main causes of declining catch rates (Waite et al. 1994), and concerns for overfishing nearshore reefs has been a concern since the 1970s (Zeller et al. 2007).

CAROLINE ISLANDS. As islands communities, the Caroline Islands rely heavily on commercial and subsistence fishing for livelihoods and food.

Palau. Palau's commercial fisheries fall into six categories: (1) coastal commercial, (2) coastal subsistence, (3) offshore – locally based, (4) offshore – foreign-based, (5) freshwater, and (6) aquaculture. These fisheries are valued, respectively, at $2,843,000; $2,511,000; $13,779,656; $4,947,496; $8,000; and $50,000 (Food and Agriculture Organization of the United Nations 2009b). The coastal fishery is utilized primarily for subsistence purposes and for domestic urban markets, although some of the coastal fisheries catch is exported. The offshore fisheries are operating on an industrial scale by locally-based foreign longline vessels and by one domestic hook-and-line-vessel. The offshore fishery mainly targets three species of tuna for export: big-eye, yellowfin, and albacore.

The Bureau of Marine Resources (a branch of the Ministry of Natural Resources, Environment and Tourism), in conjunction with 16 state governments, controls fishing in marine waters up to 12 mi. offshore (Food and Agriculture Organization of the United Nations 2009b). Coastal fisheries are managed by the Palau constitution; the Ministry of Natural Resources, Environmental & Tourism; non-governmental organizations (NGO); and the community. The offshore fishery in Palau is managed through the "Palau National Tuna Fisheries Management Plan 2001." The management plan requires licensing (including payment of fees) and pollution controls, and is supplemented with regional measures, including specific terms for foreign vessels and purse seine vessel limits (Food and Agriculture Organization of the United Nations 2009b).

The balance between sustainment of local nutritional needs, tourism, and export benefits is a prominent issue in Palau fisheries, and a ban on exporting coastal food resources has been suggested. In 2007, Palau produced 1,003 tons of fish for direct consumption, imported 461 tons of fish, and exported 332 tons. The per capita supply for fish in 2007 was 67.7 kg (Food and Agriculture Organization of the United Nations 2009b). Gear restrictions, catch bans, and closed seasons all are utilized to manage the fisheries. Palau is considered a pioneer in the implementation of MPAs. Nearly all households in Palau are fishing communities.

Residents and tourists of Palau participate in recreational fisheries. One game fishing association is active, annual derbies occur, and about 10 vessels occasionally (and a few regularly) participate in sports fishing (Food and Agriculture Organization of the United Nations 2009b). Most sports fishing involves pelagic trolling outside of the reef. No active management of the recreational subsector occurs.

Yap. The national government's management strategy is to manage the tuna resources of the EEZ, and leave any management or development of the fisheries within 12 mi. of land to Yap, where traditional ownership and management authority of the communities and their leaders is still recognized by the

state constitution. As such, inshore fishery management is community-based (Food and Agriculture Organization of the United Nations 2002a). Overexploitation does not appear to be a problem in Yap due to the small population and large resource base. Approximately 1,680 tons of fish are landed in Colnia, Yap, with 1,460 tons from coastal fisheries, and 220 tons in offshore pelagic species (Food and Agriculture Organization of the United Nations 2002a).

13.1.3 Distribution of Operations

JAPAN ARCHIPELAGO.

Bōsō Peninsula, Izu Peninsula, and Izu Islands. In the southern Bōsō Peninsula region, fisheries are active at Katasuura, Choshi, and Chikura, with the highest landings from the port at Chikura, mainly from the fishing boat and rocky shore fisheries. The fishing boat fishery is conducted by small boats targeting horse mackerel, chub mackerel, squid, and flying fish. The rocky shore fishery catches primarily ear shell and seaweed (Shimoike, Ueno, and Igarishi 2006). On Izu Peninsula, octopus fishing occurs on a small scale in Uchiura Bay (Shimoike, Ueno, and Igarishi 2006). In the Izu Islands, red algae and shellfish are important species. Fishing is not conducted within coral communities of this area. Flying fish, caught by gillnets in this region, are an important fish stock in the Izu Islands (Shimoike, Ueno, and Igarishi 2006). Many of the nearshore fishing grounds in Miyakejima were damaged by the volcanic eruption in 2000 (Shimoike, Ueno, and Igarishi 2006).

Fishing occurs year-round between Kyūshū and South Korea, starting primarily in the East China Sea in January and then diminishing within the area in December. The season around the Izu Islands south of Tōkyō starts in late April. Fishing extends coastally and offshore of southern Honshū and offshore of northeastern Honshū, then diminishes off the Izu Islands starting in July, and stops by the end of December. Coastal longline fisheries operate primarily near Honshū throughout the year, with some activity extending to the west near Shikoku and the Ryūkyū Islands in the later part of the year (October-December). Albacore is actively targeted near the Izu Islands from November through March (Miyabe et al. 2004). Swordfish and bigeye tuna are targeted by longliners year-round, with fishing for swordfish occurring at night (Miyabe et al. 2004). From May through September, bluefin tuna are caught off Honshū with purse seines (Bayliff and Olson 2004). Trawls and dredges are heavily used north of Tōkyō in offshore, coastal, and nearshore waters. Hook-and-line fishing varies seasonally, extending to coastal and offshore waters of northern Honshū from April through June, and then concentrating farther to the northeast in coastal and offshore waters through the end of the year (Miyabe et al. 2004).

Okinawa Island, Kerma Island, Kume Island, Daito Islands. Okinawa has 23 fisheries cooperative associations. About 30 fishermen are on Minamidaito Island, four of whom are reported as full-time fishermen. Offshore tuna and mackerel are targeted using rods, harpoons, and trolling. One fisherman is reported as catching reef fish (including parrotfish and grouper) using scuba. Blue sprat is sometimes caught using a net and snorkel (Nonaka 2006). Near Okinawa, fishing for diamond squid occurs from November through April (Bower and Miyahara 2005). This is primarily a daytime fishery, with gear set at approximately 500 meter depth.

Some purse seining occurs in the East China Sea west of Okinawa and the Ryukyu Islands from April through August. Bluefin tuna are caught with a variety of gear types off Japan. South of Shikoku Island, from July through October, bluefin tuna are caught with trolling gear (Bayliff and Olson 2004). Hook-and-line fishing varies seasonally and is concentrated off Okinawa and the Ryukyu Islands from January through June (Miyabe et al. 2004). Hook-and-line fisheries around the Okinawa and the Ryukyu Islands

often use anchored FADs (Miyabe et al. 2004). Use of FADs is common around Okinawa and the Ryukyu Islands, with 177 documented in 1996. Yellowfin tuna is the primary species caught near FADs, but also caught are albacore, skipjack, and bigeye tunas, as well as other pelagic species like black marlin, dolphin-fish, and wahoo (Kakuma 1996).

Kyūshū Island, Ōsumi Island, and Tokara Archipelago. Trawls are used in the nearshore waters around Kyūshū and offshore waters in the northern Tsushima Strait between Kyūshū and South Korea. Trawls also operate in the East China Sea (Watson et al. 2004; Japan Coast Guard 2005). Pacific saury, anchovy, jack mackerel, frigate mackerel, yellowtail, filefish, herring, sea robin, and parrot bass migrate seasonally, moving southward in the winter to breed off Kyūshū and moving northward in the summer to feed (North Pacific Marine Science Organization 2004). From November through April, bluefin tuna are caught west of Kyūshū (Bayliff and Olson 2004). Fishing for diamond squid and Bluefin tuna using traps and hooks occurs in the Tsushima Straits and southern Sea of Japan from July through February (Bayliff and Olson 2004); Bower and Miyahara 2005). Fishing in Shikoku is limited primarily to fixed shore net, gill net, longline, and single-rod fishing because of the topography (Iwase 2006). In Tanegashima (Ōsumi Islands), skin diving for Japanese abalone is a common fishing practice. In Yakushima, fishing for blue mackerel with hook-and-line is common. Yakushima also claims the top catch of flying fish. The Tokara Archipelago has excellent fishing grounds because of its location within the Kuroshio Current. Fishermen from more remote islands are known to travel to these waters (Nakai and Nojima 2006).

MARIANA ARCHIPELAGO. Fishermen in the Mariana Islands typically fish in waters less than 500 ft. (152.4 m) deep, and target the red-gilled emperor bottomfish. Fishing peaks in summer, but occurs year-round in some locations where conditions are usually calmer (e.g., leeward side of the islands). Some small-scale commercial fishing takes place in waters deeper than 500 ft. (152.4 m) and focuses on snapper and grouper species (Western Pacific Regional Fishery Management Council 2009c).

Sportfishing also peaks in summer (June through August) when popular sport fish, including blue marlin and yellowfin tuna, are most abundant. Skipjack tuna are present year-round, but are most abundant in summer. Mahi mahi arrive in January and reach peak abundance in February or March, and wahoo typically have two peak abundances during the year, in spring and fall. Jacks, snapper, and grouper are targeted off of reef flats surrounding the island (GoFishn.com 2011).

Saipan. The CNMI bottomfish fishery occurs primarily around the islands of Saipan, Tinian, and Rota. Saipan has by far the largest market of the three islands (Western Pacific Regional Fishery Management Council 2004a). CNMI's bottomfish fishery is composed of small fishing boats engaged in subsistence and commercial bottomfishing within a 17.3- nm radius of Saipan (Pacific Islands Fisheries Science Center 2004). The bottomfish fishery is broken down into two sectors: deep-water (>150 m) and shallow-water (20 to 150 m) fisheries. Fishing trips are usually short in duration (1 day) and restricted to daylight hours. Common gear types include handlines, handmade hand reels, and electric reels. Fishermen do not employ fathometers or nautical charts, relying on land features for guidance to fishing areas. This results in inefficient catch rates compared to pelagic trolling fisheries. Large commercial vessels (>5 tons), able to make extended fishing trips, focus their efforts from Esmeralda Bank to Zealandia Bank (Pacific Islands Fisheries Science Center 2004; Western Pacific Regional Fishery Management Council 2004a). These vessels utilize Global Positioning System (GPS) instrumentation, fathometers, and electric or hydraulic reels—and are believed to have landed the majority of deep-water bottomfish harvested around CNMI (Pacific Islands Fisheries Science Center 2004).

Rota. Bottomfishing on banks around Rota (White Tuna, Santa Rose, and Rota) occurs only during calm weather because the distance from port for these small vessels can create a safety at sea issue during high seas (Green 1997). Local fishermen report that up to 10 commercial boats (with two to three people per boat) and some recreational boats use the banks, weather-permitting (Green 1997). Currently, bottomfishing by hook-and-line and jigging at night for bigeye scad are the most popular techniques employed at the banks (Western Pacific Regional Fishery Management Council 2001, 2008). At the Galvez and Santa Rosa Banks, bottomfish are caught by a combination of recreational vessels (<25 foot [<7.6 m] long) and larger commercial vessels (>25 foot [>7.6 m] long) (Moffitt, Brodziak, and Flores 2007).

Guam. Overall, more fishing occurs on the western (leeward) side of the island. However, productivity is greatest on the eastern (windward) side, which can be fished only during calm weather. These climate variations result in sporadically or seasonally high levels of fishing effort on the eastern side during calm conditions (Western Pacific Regional Fishery Management Council 2004a). Galvez Bank is the most popular bank because of its proximity and accessibility (Western Pacific Regional Fishery Management Council 2001).

Both commercial and recreational fishing activities generally originate from one of the three principal harbors located on the west coast and southern tip of Guam. However, the following public boat launch sites are also used:

- Agana Boat Basin is centrally located on the western coast, and is used for fishing off the central and northern leeward coasts and the northern banks.
- Merizo Boat Ramp provides access to the southern coasts, Apra Harbor, Cocos Lagoon, and the southern banks.
- Seaplane Ramp in Apra Harbor provides access to the southern coasts, Cocos Lagoon, and the southern banks.
- Agat Marina provides access to the southern coasts, Apra Harbor, Cocos Lagoon, and the southern banks.
- Ylig Bay provides access to the east side of the island.

CAROLINE ISLANDS. Palau and Yap fisheries are primarily either inshore subsistence based or offshore tuna fisheries prosecuted by foreign longline and purse seine vessels (Food and Agriculture Organization of the United Nations 2002a, b, 2009b, 2010). There is little available information on specific locations fished within the coral reef and mangrove habitats. It is likely that location depends highly on target species, although as with most subsistence fisheries, a wide variety of species are utilized (Food and Agriculture Organization of the United Nations 2010). While foreign longline vessels home port in FSM, the area around Palau and Yap are not productive tuna grounds and these vessels likely fish across a wide range of the South Pacific (Western and Central Pacific Fisheries Commission 2011).

13.2 RECREATION AND TOURISM

Recreation and tourism are important aspects of coastal life in the MRA Study Area. SCUBA diving is a major recreational and tourism activity that supports the local economy.

13.2.1 Description

Coastal tourism and recreation can be defined as the full range of tourism, leisure, and recreationally oriented activities that take place in the coastal zone and the offshore coastal waters. These activities include coastal tourism development (e.g., hotels, resorts, restaurants, food industry, vacation homes) supported by a diverse infrastructure (e.g., retail businesses, marinas, fishing tackle stores, dive shops, fishing piers, recreational boating harbors, beaches, recreational fishing facilities). Ocean recreation service businesses, such as ecotourism, ocean cruises, recreational boat rentals, charter fishing, and snorkeling and diving rely on and are intertwined with this infrastructure (National Oceanic and Atmospheric Administration 2012)—as are non-business recreational activities, including swimming, surfing, and recreational fishing. Whale watching encompasses all commercial tours that aim to see, swim with, and/or listen to cetaceans (whales, dolphins, and porpoises) in the wild (Hoyt 2001). Cultural and historic sites, including historic shipwrecks and World Heritage Sites, are also an important aspect of tourism. Some of these resources are also governed under the National Historic Preservation Act, Abandoned Shipwreck Act, and Sunken Military Craft Act. World Heritage Sites within the Japan section of the MRA Study Area (e.g., Ogosawara Islands, Yakushima Island) are specifically protected under the National Historic Preservation Act Section 402.

JAPAN ARCHIPELAGO. In Japan, whale watching offers a viable alternative to whaling and dolphin hunting. In some regions of Japan, whale watching and whaling businesses economically benefit from each other; they share information about the whales seen so that whale watch operators know where to locate the animals and whalers are more efficient hunters (Segi 2003). Japan's first formal whale watch trip departed from Tōkyō in 1988 and targeted humpback whales in the Ogasawara Islands (Hoyt 2001). Since then, the value of whale watching in Japan has almost doubled every year, and the industry has expanded to include over 45 operations and 30 communities (Hoyt 2001). Whale watching peak season is in the spring and summer (Hoyt 2001). These businesses provide extra income in fishing communities during off or low fishing seasons but are the primary business in some areas (Hoyt 2001). Whale watching has also replaced whaling in many communities since the International Whaling Commission's moratorium on whaling (Dudzinski 1998). Over 95% of whale watch tourists are Japanese; whale watching contributes to the domestic tourism economy and could attract more international travelers through marketing and advertising (Hoyt 2001). In Japan, whale watching operators mostly offer boat-based tours. In 2001, over 185 boats were involved in part-time or full-time whale watching. These boats are generally small and carry 10 to 12 passengers (Hoyt 2001). Most whale watch tours in Japan involve locating and watching large whales in the wild; however, dolphin and porpoise tours are becoming increasingly popular, particularly since the development of swim-with programs in the early 1990s (Dudzinski 1998; Mori 1999). Swim-with-dolphin businesses have also been providing services to tourists since 1990, primarily in the Ogasawara Islands (Mori 1999), operating seasonally in the southern areas of Japan, where warmer water temperatures are more conducive to swimming with wild cetaceans (Dudzinski 1998).

The Japanese Islands are one of the world's great diving destinations because of an abundant and diverse array of marine life, a multitude of professional dive charter boats, clear visibility, unique shipwreck dive sites, coral reef ecosystems, and a unique convergence of warm and cold currents. The diverse environments of Japan's islands attract scuba divers from around the world (Outdoor Japan 2004). The warm Kuroshio Current from the south mixes with the cold Oyashio current from the Arctic Ocean in the north. This unusual combination brings both tropical and temperate species to the main Island of Honshū; this provides the unique opportunity to enjoy an array of dives from ice diving in

northern Japan, kelp forests in mid-Japan, and tropical coral reefs among the scattered islands of the archipelago in southern Japan (Outdoor Japan 2004).

The Japanese Islands offer both natural and artificial marine habitat. Natural environments include vertical wall drop-offs, coral reefs, boulders and talus, sea arches, volcanic tunnels, pinnacles, and caves (Outdoor Japan 2004). The most prominent underwater features are coral reef ecosystems and vertical walls or drop-offs. Vertical walls (submerged cliffs) are well-defined ledges that run parallel to the shore, creating steep walls cut by ravines, caves, and grottos; they may be located anywhere from the shore out to approximately 300 m (Wallin 1991). In addition, numerous artificial habitats include FADs, artificial reefs, and sunken wrecks—ships, boats, and planes (Wallin 1991). These natural and artificial marine habitats attract an abundant and unique array of marine life, terrain, and underwater visibility across the archipelago.

MARIANA ARCHIPELAGO. The Mariana Archipelago consists of 10 volcanic, uninhabited islands in the northern part of the chain and the five limestone-populated islands of Guam, Rota, Aguijan, Tinian, and Saipan. With an average temperature of 84 degrees Fahrenheit [°F] and average humidity of 79%, these islands offer an attractive climate for a variety of land-based recreational activities. Ocean temperature averages 82°F, and ocean tourism includes scuba diving (including historic ship and aircraft wrecks), snorkeling, parasailing, water skiing, submarine tours, and sea walker tours (a 3-m [9.8 ft.] dive for the non-scuba-certified tourist), banana boat rides (a non-motorized boat pulled by a motor boat), bird watching, deep sea fishing, flora and fauna tours, glass bottom boats, and cultural festivals featuring native food, arts, and crafts.

Guam and the CNMI are located in one of the richest sectors of the world's ocean in terms of species and habitat diversity. As a result, scuba diving and snorkeling are popular activities throughout the region, although scuba diving in the CNMI is not as widespread as on Guam. In fact, some of the most popular scuba destinations in the North Pacific are in the Mariana Archipelago, with more than 78 identified dive sites that are particularly popular with divers (Figure 13-7) (Coastal Resource Management Office for the Commonwealth of the Northern Mariana Islands 2012; Hanauer 2001; Pacific Division Naval Facilities Engineering Command 1999; Rock 1999). The majority of accessible dive sites in the CNMI are on Rota and Saipan. Divers are attracted to year-round warm air and water temperatures, clear underwater visibility, unique shipwreck dive sites, and coral reef diversity (Hanauer 2001). In the 1990s, three dive operations expanded their businesses to include whale watching, focusing on spinner dolphins and occasionally pilot whales. In 1998, 4,000 visitors to Guam participated in a marine mammal watching cruise, with an estimated $100,000 in direct expenditures (Hoyt 2001).

CAROLINE ISLANDS. Tourism in the FSM has a large inherent degree of opportunity for growth. The laid-back lifestyle and beauty of the land and sea is relatively unspoiled. In addition, each island has its own languages/dialects and traditions making for a varied and rich experience (Lee, Ghandi, and Eliptico 2007). Diving, underwater photography, surfers, and fishing are all ideal activities for the islands' many lagoons and atolls (Lee, Ghandi, and Eliptico 2007). There are also ruins, crafts, ancient currency (money stones), traditions, and legends from native peoples for those interested in history and culture (Yap Visitors Center 2012).

13.2.2 Status and Management

Tourism is important to many of the coastal areas within the MRA Study Area. Many outside forces influence the number of tourists visiting Japan, the Marianas, and Caroline Islands. These include cyclical

global financial issues, threats of pandemic diseases including the Asian-originated bird flu virus, and many other concerns. Nevertheless, tourism is a major part of each of these economies. Within the U.S., marine tourism employs 1.9 million people and is a major part of a $223 billion ocean economy in the U.S. (National Oceanic and Atmospheric Administration 2011).

JAPAN ARCHIPELAGO. In 2002, Japan's tourism economy was estimated at $180 billion and employed 1.97 million people (Organisation for Economic Co-operation and Development 2002), making tourism one of the leading industries along with auto manufacturing and telecommunications. In 2001, 4.77 million people visited Japan, with Korea, Taiwan and the U.S. constituting the largest percentages of visitors (Organisation for Economic Co-operation and Development 2002). This number increased to 8.6 million in 2010. The March 2011 tsunami and earthquake that devastated parts of Japan caused a 30% drop in total tourists, although a year later, tourism appears to be on the rise. (Harpaz 2012, March 9).

MARIANA ARCHIPELAGO. Tourists to the Marianas are primarily from Asian countries, particularly Japan, who benefit from direct flights to Guam and year-round warm weather. The majority of tourists remain on Guam, with only 3-5% travelling on to the CNMI.

Commonwealth of the Northern Mariana Islands. While small compared to Guam, tourism is the largest industry in the CNMI. Most of the visitors come from Asian countries, including Japan. Despite serious declines in recent years due to the Asian financial crisis, Severe Acute Respiratory Syndrome, and the 9/11 attacks on the United States (Cohen 2006, March 1), between 1988 and 1996, the tourism industry had risen 15% annually. After a sharp decline in 1997 and 1998, a modest recovery had begun before the September 11, 2001, incidents, after which a 1.4% decline occurred (Pacific Business Center Program - University of Hawaii 2008).

Tourism continues to face economic difficulties, including increased labor costs associated with an increase in the CNMI minimum wage standards (from $3.05 an hour in 2007 to $5.05 an hour in 2010), and with proposed subsequent wage increases of $0.50 a year until the CNMI reaches the federal minimum wage standards of $7.25 an hour (Eugenio 2010). Lagging tourist numbers and increased operating costs have resulted in a short-term imbalance in the economy. Withdrawal by Japan Air Lines of scheduled flights between Japan and Saipan reduced the CNMI Japanese tourist population from 40 to 29% of the total visitor numbers in 2005 (Cohen 2006, March 1). The Marianas Visitors Authority reported a 23% drop in arrivals between July 2010 and July 2011, with only 27,203 visitors to the CNMI (Tenorio 2011). While arrivals from Japan fell an additional 17% in 2011, and no growth in Korean tourism occurred due to cuts in direct flights by airlines in Japan and Korea, tourism from secondary markets has increased within CNMI. Tourism from China and Hong Kong increased by 9% in 2011, and Russian tourism increased 19% in 2011 (Tenorio 2011).

Guam. Marine recreation is enjoyed by residents and visitors alike. Most residents partake in beach barbeques approximately once a month, while swimming is enjoyed by 87% of the resident population (Haider et al. 2007). Other activities popular with the local population include recreational fishing (45% participate), snorkeling (44%), kayaking (21%), and diving (19%) (Haider et al. 2007).

Tourism is big business in Guam. In 2010, Guam welcomed approximately 1.2 million visitors. Visitors from Japan accounted for approximately 76% of Guam's visitors, Korea contributed 10%, the United States contributed 5%, and the smaller markets of Hong Kong, China, Australia, the Philippines, Micronesia, and Russia made up approximately 5% of visitors according to the Guam Visitors Bureau

(Guam Visitors Bureau 2010). The economic value of Guam's coral reefs to tourism has been estimated at $94.63 million (Haider et al. 2007).

The estimated 1.2 million visitors to Guam each year are offered a variety of ocean recreation activities, from diving and snorkeling to jet skiing, wind surfing, sea kayaking, water tours, dolphin watching, and submarine and semisubmersible tours (Haider et al. 2007). Guam has grown into a popular dive destination for Japanese tourists, and is gaining in popularity with divers from other Asian countries and the United States. Scuba diving and marine based activities account for 5% and 15%, respectively, of the reason tourists choose to visit Guam (Haider et al. 2007). Visitors to Guam enjoy water clarity that seasonally has visibility up to 150 ft. (45.7 m), and dive for photography and spear fishing on wrecks and reefs. Guam's warm waters allow dives by people at all skill levels, with numerous opportunities for the uncertified diver, as well as the most skilled. The island boasts over 50 dive sites (Franko Maps Ltd. 2005), including World War II (WWII) shipwrecks and coral reefs.

CAROLINE ISLANDS. Management of marine resources are left up to each state government through the establishment of a marine resources committee of representatives which, by law, can "promote, develop, and support commercial utilization of living marine resources within its jurisdiction" (Government of the Federated States of Micronesia 1975b). Growth of the tourism industry throughout the FSM is expected, due in part to the transference of military personnel from Japan to Guam in the coming years (Lee, Ghandi, and Eliptico 2007). One aspect of tourism, the local governments are beginning to promote is eco-tourism. This provides economic benefit with protection to the delicate ecosystem characterizing theses small oceanic islands. Promotion and growth of tourism is also expected to aid in the expansion on local infrastructure (Lee, Ghandi, and Eliptico 2007).

13.2.3 Distribution of Operations

JAPAN ARCHIPELAGO. Whale watch operations are located throughout Japan from northern Hokkaidō south to the Okinawa and Ogasawara Islands. In Hokkaidō, tours operate from Nemuro, Shibetsu, Rausu, and Shari along the east coast, and from Muroran along the southern part of the island (Hoyt 2001). These tours operate between March and October and target Pacific white-sided dolphins, Dall's porpoises, harbor porpoises, killer whales, short-finned pilot whales, minke whales, and Baird's beaked whales. The waters around Mikura, Miyake, and Toshima Islands, part of the Izu Islands chain, are among the most popular dolphin watching locations in the archipelago. Dolphin tours and swim-with-dolphin programs target bottlenose dolphins, which are routinely found within 200 m of the islands (Dudzinski 1998; Uchida 1997). In southeastern Honshū, popular whale watch tours operate from Kushimoto, Koza, and Nachi-katsuura near Taiji, and target sperm whales and Risso's dolphins. Finless porpoises attract tourists offshore of Mihama (Hoyt 2001).

The seven Islands of Izu, east of the Izu Peninsula, is also a popular dive region, offering warmer waters and better visibility than the dive sites on mainland Honshū. Togahama and Igaya are popular dive sites on Miyake Island in the Izu chain. Along the southern coast of Miyake, a 200-m^3 tide pool (2.5 m deep) is used for recreational and educational purposes. Tourism has been limited since volcanic eruptions in June 2000. Additional dive sites in the Izu Islands include Sokodo, Kaminato, Yaene, and Nazumado on Hachijo Island (Shimoike, Ueno, and Igarishi 2006).

The Izu Peninsula on Honshū is the most popular dive area of the region (Table 13-3), with the largest number of dive sites on mainland Japan. Izu Oceanic Park, on the east coast, is the first dive site

explored on the peninsula, and Osezaki, on the west coast, is the most popular dive site in Honshū (Outdoor Japan 2004).

Table 13-3: Dive Sites on Izu Peninsula

NAME: DIVE SITES	DIVE ACCESS	HABITAT	BIOTA	COMMENTS
Ito Bay	Steep rocky beach access.	Large boulders with a wall drop-off 35 m from shore.	NL	Isolated; subject to harsh wind, wave, and water conditions in the winter.
Osezaki	NL	Shallow (20 m), sandy dive at the base of a drop-off.	Lionfish, seahorses, frogfish, and soft corals covering the substrate.	NL
Futo: Sankaku, Kurodaine	Summer = Beach; Winter = Boat	Lava block shelf atop a sandy bottom[1]; sharp drop-off leading to a sandy bottom at 15 m.	Sponges, anemones, macroflora, soft coral, seahorses, many unique fishes, rays, and eels.	Can undergo heavy swells where visibility is reduced in the winter[1].
Atami: Chinsen, Sodaine, Bitagane, Kosogadokutsu, Harbor	Seawall; calm and accessible waters; night dives as well.	Talus covered by coral; large shipwrecks; rocks; sea arch with a 40-m tunnel.	Soft corals, sponges cover rocks; diverse group of fish, including fish that live in crevices, and pelagic fish.	Kosogadokutsu is accessible only during the winter months.
Izu Ocean Park	Beach access dive.	Old lava flow.	Abundance of marine life.	Besides Futo, Izu Ocean Park is the best known dive spot.
Kumomi: Ushitsuki, iwa Kurozaki	Naturally sheltered harbor.	Rock outcrop; small caves; holes; deep tunnels.	Reef fish, eels, sting rays, squid, and crab are common in the caves.	NL
Mikomoto: Aone, Kamene, Budaine	Drift dive	Trenches; boulders; drop-offs; jagged pinnacles	Soft corals, reef fish, and many large pelagic fish; blue corals; yellowtails and hammerheads.	Sheltered from strong currents by Mikomoto Islet.
Hokkawa: Kajikaki	NL	Shallow rocks that are exposed at low tide.	Soft corals, shrimp, nudibranchs, gorgonians, lobster, and fish.	Marine life changes dramatically with the seasons.

Sources: Outdoor Japan (2004) and Whipple (1998a, b, c, d).
Notes:
m = meter
NL = not listed

Kyūshū Island, Ōsumi Island, and Tokara Archipelago. Several whale watch tours operate along the coast of Shikoku, specifically around the Kochi Prefecture. The main whale watch area extends from Saga to Tosa-Shimizu (Hoyt 2001). Popular whale watch tours in Kyūshū are located in Itsuwa and Reihoku along the west central coast, and Kasasa on the southern tip of the island. These tours target Bryde's whales and bottlenose dolphins (Hoyt 2001). Dolphin watching also takes place around the Amakusa Islands off the southwest coast of Kyūshū (Uchida 1997). In Shikoku, surfing and scuba diving are the most popular water sports (Iwase 2006).

Glass-bottomed boats operate in marine park zones in Ushibuka, Kyūshū Island. Scuba diving has increased in popularity in this region, and many of the dive shops (mainly located in Kumamoto) utilize

the "Famous 15" dive spots of Amakusa and Ushibuka. Locations off of Myokengaura and Amakusa are used for diver training (Nojima 2006). Seven designated marine parks zones are on the western coast of Amakusa Islands—two in Reihoku (Tomika Marine Park), one in Amakusa (Amakusa Marine Park), and four in Ushibuka (Ushibuka Marine Park). Surfing, offshore recreational fishing, and recreational boat charters all occur on the western coasts of the Amakusa Islands (Nojima 2006).

Okinawa Island, Kerama Islands, Kume Island, and Daito Island. Whale watch destinations around the Ryukyu Archipelago include the Amami, Kerama, and Okinawa Islands (Uchida 1997). During the winter and spring, tours mainly target humpback whales, which use the islands as breeding grounds between January and April (Hays 2010). The Ogasawara Islands are a main breeding area for humpback whales. Whale watch tours target humpbacks, spinner and bottlenose dolphins in coastal waters, and spotted dolphins and sperm whales farther offshore (Mori 1999). Swim-with-dolphin programs are also common around the Ogasawara Islands (Mori 1999). Glass-bottomed boats are available in Naha harbors, Chinen Village, and Onna Village, and an underwater observatory is in Nago City (Sakai 2006).

Some Japanese shores are subjected to harsh wind, wave, and water conditions; therefore, these are not suitable dive sites throughout the entire year. Suitability of a site for diving depends on its accessibility and water conditions—determined by marine weather conditions and coastal geography (Wallin 1991). The following paragraphs provide general information about the Izu Peninsula (Honshū), Okinawa, and Ogasawaras dive regions located within the Japan/Okinawa Complexes Operating Area (OPAREA) and vicinity; included is information regarding the more popular dive sites and the associated marine life within these dive regions.

The warm waters of the Okinawa Islands support a fringing reef, with beautiful corals and great visibility. Many shipwrecks around Okinawa from WWII have become popular dive sites. Ishigaki, Iriomote, and Yonaguni Islands have numerous dive sites (Outdoor Japan 2004). Okinawa and its surrounding islands host more than 70 species of corals (both hard and soft) and more than 250 marine animals (e.g., crabs, snails, mantas, turtles, stingrays, whales, and hammerhead sharks in the winter months); and night dives provide access to abundant octopuses and cuttlefish; (Outdoor Japan 2004). Among the more popular spots are the Sunabe seawall, Maeda Point, and Onna Point (Outdoor Japan 2004). Tengan Bay on the Pacific coast hosts the highest concentrations of marine life in the entire Okinawa region (Schalk 1997b). The Tengan pier acts as an artificial reef and has been known to support abundant cowries (Schalk 1997b). While diving is popular, with more than 130 dive shops on Okinawa, and more than 25 easily accessible beach dive sites, the reefs have become degraded, causing some tourists to shift to the Keramas Islands.

The Keramas Islands, approximately 5 mi. west of Okinawa in the South China Sea, includes 28 islands, some inhabited and some not (Outdoor Japan 2004; Schalk 1997a). The Keramas have some of the top diving in the world, with more than 100 dive sites, some of the best corals in the Pacific, and nearly perfect visibility (Outdoor Japan 2004). Most diving concentrates around the main island of Tokashiki, home of renowned dive sites including Ariga Cable, Nozaki point, and Gishippu (Outdoor Japan 2004). Some of the smaller islands host popular dive sites, including the Sand Island chain, Zamami Island, Ie Island, the Chijbishi Island chain, and Ariga-kita. These Islands boast unlimited visibility with pristine corals, white tip reef sharks, turtles, tuna, mantas, and tropical fish (Schalk 1997a). Zamami Island features a pinnacle that originates from solid rock at 50 m depth and rises 70 m above sea level. This dive site supports abundant pelagic and cryptic marine life including the blue ribbon eel and many pelagic sharks (Whipple 1998a). To the north, Ie Island offers diverse topography including several deep drop-offs and some large caves that support well-developed gorgonian corals and large schools of tuna

(Outdoor Japan 2004). The Chijbishi Island chain consists of a group of four small islands, and marine life associated with these islands is spectacular—including coral gardens, giant clams, and many tropical fish (Whipple 1998d). Ariga-kita is a shallow dive over white sand substrate and coral heads that harbor tropical fish such as pyramid angelfish, lionfish, barracudas, and frogfish (Whipple 1998a).

Within the Daito Islands of the Ryuku Islands chain are three main islands—Kitadaito Island, Minamidaito Island, and Okidaito Island. Tourism in the Diato islands is sparse, and the majority of the visitors are fishers (about 100 people annually) and scuba divers (about 200 people annually). A cruise boat to the islands brings about 100 visitors annually (Nonaka 2006).

MARIANA ARCHIPELAGO. There are numerous dive sites across the southern Mariana Islands (see Figure 13-7).

Saipan. Saipan offers excellent dive locations (Figure 13-7), although access to prime locations can be difficult (Hanauer 2001). Popular dive sites include the Grotto, the Bomber Wreck (B-29), and Banzai Cliff. Tanapag Harbor contains an estimated 18 sunken Japanese ships, a sunken Japanese seaplane, a multi-engine bomber, a submarine chaser, a zero fighter, and landing craft.

Tinian. The island of Tinian has a total land area of approximately 39 square miles (mi^2.) but only about 13 mi^2. of the island is outside Department of Defense (DoD)-leased lands. Local government is the island's largest employer, and Tinian is the only populated island in the Mariana Islands that has not undergone dramatic economic development over the last 15 years. Most retail establishments are located in San Jose, and include a large hotel/casino, nightclubs, convenience stores, gas stations, small restaurants, bakeries, and banks (United States Department of the Interior 2001). Although gambling is the most profitable tourist attraction, the WWII historic sites and wildlife viewing also attract tourists to the island and encourage longer stays. Most of the historic sites are located within the exclusive military use area. Tinian shows promise of becoming an excellent diving location with its clear water, low population pressure, and rocky coastline; however, the island lacks the necessary infrastructure to gain widespread popularity with the diving community (Hanauer 2001).

Rota. Many divers overlook Rota, even though the island contains what are arguably the clearest waters in all of Micronesia (Hanauer 2001). The majority of dive sites on Rota lie along the southern shore (Hanauer 2001). Popular dive sites include the wreck of the Shoun Maru, the underwater grotto at Senhanom Cave, and the Coral Garden (Figure 13-7). The island of Rota is the smallest of the three islands, with a land area of approximately 33 mi^2. The island primarily offers outdoor recreation and sightseeing, including a famous swimming hole on the western side of the island, a limestone quarry used by ancient Chamorros, and a seabird sanctuary providing habitat for thousands of seabirds (Marianas Visitors Authority n.d.).

Guam. Tumon Bay, halfway between Apra Harbor and the northern part of the island, is the premier resort destination on Guam. Luxury hotels line the beachfront with access to white sand and crystal-clear, warm waters ideal for swimming and snorkeling. A few hotels are also located in the southern and central parts of the island. Talofofo Falls is a waterfall located in the southern section of Guam at Talofofo Falls Park. Tourists arrive via a gondola ride and spend their time at the falls swimming.

Guam may have the only dive site in the world with shipwrecks of different countries from World War I and WWII, which can be visited at the same time: the Tokai Maru and the SMS Cormoran (Guam Visitors Bureau 2006). Although the majority of dive sites are in nearshore shallow waters, diving is primarily boat-based to increase the likelihood of observing marine life, and to prevent injury from strong

undercurrents and rips that occur along the surf zone (Rock 1999). Figure 13-7 shows popular dive sites in Guam.

Apra Harbor – Apra Harbor is also a popular location for divers because of its wide range of wrecks and military debris. Popular dive sites in Apra Harbor include the *Tokai Maru*, the *Cormoran*, the *Kitsugawa*, and the Seabee Junkyard (Franko Maps Ltd. 2005; Hanauer 2001; Rock 1999).

Agat Bay - Popular reef dive sites include Shark Pit along Agat Bay on the western coast and Tumon Bay and Gun Beach along the northwestern shoreline.

CAROLINE ISLANDS. The Caroline Islands are culturally rich islands where visitors can see ancient stone money discs and banks, native art (often using turtle shells and black coral), dance, ruins, monoliths and carved stone faces. Kayaking, biking, underwater photography and diving are also popular activities for tourist visiting these islands (Rock 1999; Yap Visitors Center 2012).

Yap. Dancing is also a popular form of art in Yap. Described and "raucous and colorful" these dances are taught to men and women at an early age. Tomil Harbor is a popular surf site in Yap (Government of the Federated States of Micronesia 2011). An upscale dive resort is also located on the island. Diving and ocean fishing are popular activities for travelers seeking a more adventurous experience. Manta rays are commonly seen in Yap's clear waters, more consistently seen here than anywhere else (Yap Visitors Center 2012).Manta rays are attracted to a cleaning station in the Miil Channel. All dives on Yap are boat dives that must be chartered through local guides. Popular sites are found on the southern point, southern and south-central coastlines of Yap (Rock 1999). Ocean kayaks are the preferred way to view Yap's immense mangrove forests (Yap Visitors Center 2012).

Palau. Palau is another popular site for underwater photography and scuba diving. Some of the best wall diving can be experiences in Palau, where schools of sharks and other abundant marine life can be seen. Many dives around Palau are drift dives. Most of the popular dive sites are located on the southern drop-offs around Ngemelis Island and German Channel (Rock 2000).

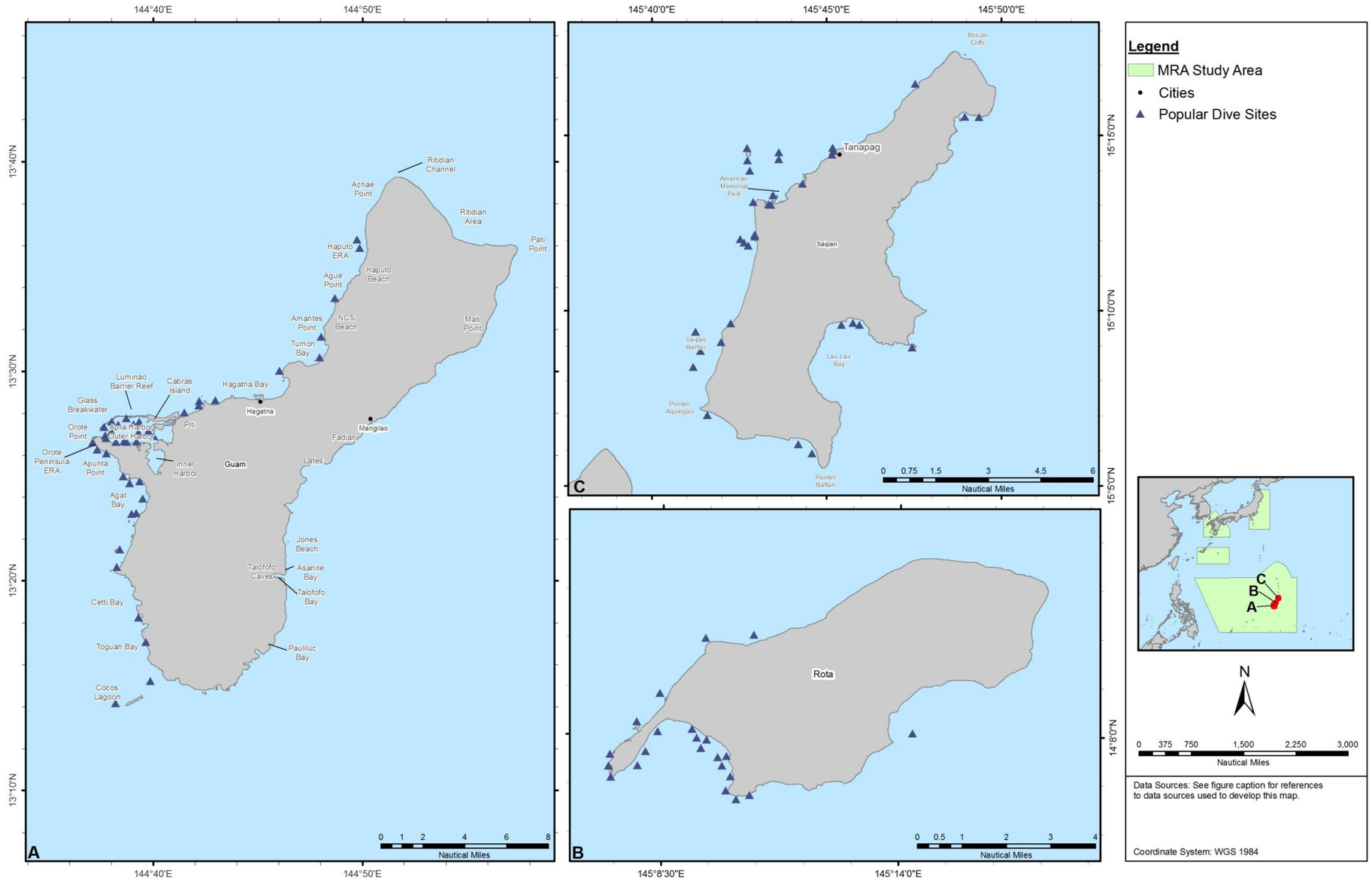

Figure 13-7: Popular Dive Sites Within (A) Guam, (B) Rota, and (C) Saipan
Source: U.S. Department of the Navy (2005).

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13.3 NAVIGABLE WATERWAYS AND COMMERCIAL SHIPPING

13.3.1 Description

Ocean traffic is the transit of commercial, private, or military vessels at sea, including submarines. Ocean traffic flow in congested waters, especially near coastlines, is controlled by use of directional shipping lanes for large vessels, including cargo ships, container ships, and tankers. Traffic flow controls are also implemented to ensure that harbors and ports-of-entry remain as uncongested as possible. Less control is imposed on open-ocean traffic involving recreational boating, sport fishing, commercial fishing, and activity by naval vessels. Generally, the factors that govern shipping or boating traffic are adequate depth of water, weather conditions (primarily affecting recreational vessels), availability of fish, and water temperature. Higher water temperatures increase recreational boat traffic, jet skis, and diving activities.

Navigable waterways of the United States are those waters currently used to transport interstate or foreign commerce. Once a determination of navigability is made, the classification remains regardless of later actions or events that impede or destroy navigable capacity (33 CFR 329.4). The U.S. transportation system includes approximately 25,000 mi. (40,000 km) of commercially navigable waterways.

JAPAN ARCHIPELAGO. The geography of Japan dictates that most international trade and domestic trade move by sea (Ministry of Land Infrastructure Transportation and Tourism 2006b). Shipping is a blend of dense traffic through straits and along coasts accompanied by long-distance, open-ocean transit (Asia-Pacific Economic Cooperation 2005).

MARIANA ARCHIPELAGO. Most shipping lanes are located close to the coast, but those that are trans-oceanic start and end to the northwest of Guam.

CAROLINE ISLANDS. Although the majority of shipping occurs on a small, coastal scale, all of the island states have deep-water port facilities (with storage, warehousing and handling capabilities). These ports can harbor vessels up to 10,000 tons. Services are available from Japan (Kyowa), the US (Matson Line) and Guam (Horizon) (Lee, Ghandi, and Eliptico 2007).

13.3.2 Status and Management

Vessel traffic in the vicinity of major U.S. ports and harbors is often governed by systems of traffic separation schemes and/or safety fairways. Traffic separation schemes are internationally recognized routing designations created by the USCG that separate opposing flows of vessel traffic into lanes, including a zone between lanes that traffic is to avoid (33 CFR 166). These schemes, which are delineated by a series of geographic (latitude/longitude) coordinates, allow for safe navigation into and out of major ports. Safety fairways are lanes or corridors in which no artificial island or fixed structure is permitted, whether temporary or permanent (33 CFR 167). These fairways, also delineated by a series of geographic coordinates, provide unobstructed approaches for vessels using U.S. ports. Vessels are not required to use these schemes or fairways, but failure to use one, if available, would be a major factor in determining liability if a collision with another ship or an underwater structure would occur (California Environmental Resources Evaluation System 2003).

A notice to mariners advises mariners of important matters affecting navigational safety, including new hydrographic discoveries, changes in channels, and navigational aids. The notice to mariners provides information to update all U.S. Government navigation charts, and is published weekly by the National

Geospatial Intelligence Agency. Local USCG districts also publish weekly local notices to mariners. Local notices to mariners are the primary means of disseminating information concerning aids to navigation, hazards to navigation, and other items of interest to mariners on the waters of the United States, including information on channel conditions, restricted areas, and scheduled regattas.

JAPAN ARCHIPELAGO. According to Japan's Port and Harbor Law, ports are managed by the Ministry of Land, Infrastructure and Transport, a wide variety of government agencies (the Ministry of Finance, the Ministry of Agriculture, Forestry, and Fisheries), in addition to internal port management authorities (Ministry of Land Infrastructure Transportation and Tourism 2006a).

Major Japanese ports and cargo volume for 2002 are represented in Figure 13-8. In 2007, the east-bound route (Asia to North America), saw an increase in the movement of cargo but slowed by the middle of 2007 to 13, 730 thousand ton-miles. (1% increase from 2006), where 70% of shipments originated in China. The west-bound route (North America to Asia), saw an increase to 5,370 thousand ton-miles. (16% increase from 2006), where 40% of cargo was shipped to China. The Japanese merchant fleet included 1,597 vessels from flag identification. Japan plans on increasing flagship capacity in order to ensure growth and sustainability for tans-Pacific shipping (Maritime Bureau and Ministry of Land Infrastructure Transportation and Tourism 2008).

MARIANA ARCHIPELAGO. On Guam, a safety fairway has been established in order to regulate approaches into and out of Apra Harbor.

CAROLINE ISLANDS. The Micronesian Shipping Commission (MSC) is and inter-governmental entity (Republic Marshall Islands [RMI], FSM, and Palau) for cooperation, coordination and regulation of international shipping to and from these small islands (Republic of the Marshall Islands 2012). The three Freely Associated States have internal laws charging regulation of commercial shipping to the MSC (Jaynes 2010).This commission has multiple responsibilities including the regulation and enforcement of shipping policies in the area (Republic of the Marshall Islands 2012). The MSC intervenes when state and federal maritime laws are in opposition. The MSC has been in existence for over 20 years (Jaynes 2010).

13.3.3 Distribution of Operations

In the western Pacific Ocean, commercially navigable waterways link Guam and the CNMI with major ports to both the east and west. The two waterways running east serve ship traffic going to and from Hawaiʻi and the mainland United States, while the waterway running west connects Guam and the CNMI with ports in Asia such as Okinawa. Commercial ships traveling from the mainland United States or Hawaiʻi to Micronesia often make their first stop in Guam, with later stops at the neighboring islands of Saipan, Tinian, Rota, Yap, Chuuk, Pohnpei, Kosrae, and Palau (Matson Navigation Company 2004).

Major commercial shipping vessels use the transit corridors for shipping goods between Hawaiʻi, the continental United States, and Asia. However, there are no direct routes between Guam and the United States—rather stops are made in Asia, and usually Japan or Korea, before continuation to either Hawaiʻi or the continental United States. Vessels using this corridor are outside of military training areas and typically follow all USCG maritime regulations.

JAPAN ARCHIPELAGO. Japan is home to approximately 4,000 seaports, including fishing ports (Nagai 1994). Major ports include Nagoya, Chiba, Yokohama, Tomakomai, Mizusima, Kawasaki, Ōsaka, Kitakyuushu, Tōkyō, Sakaisenboku, Kobe, Kisarazu, Yokkaichi, and Oita (Chiba Prefecture 2005); Tōkyō Bay (six harbors, including Yokohama and Tōkyō), Ōsaka Bay (five harbors including Kobe and Ōsaka),

and Ise Bay (five harbors including Nagoya) are considered the three major bays—handling approximately 35% of all port cargo. The coastal ferry system is among the most extensive and best developed in the world; however, international ferry services linking Japan and Asia are less prevalent (Baird 2000). Domestic coastal shipping services accounted for 43% of all freight moved in 1995 (Baird 2000).

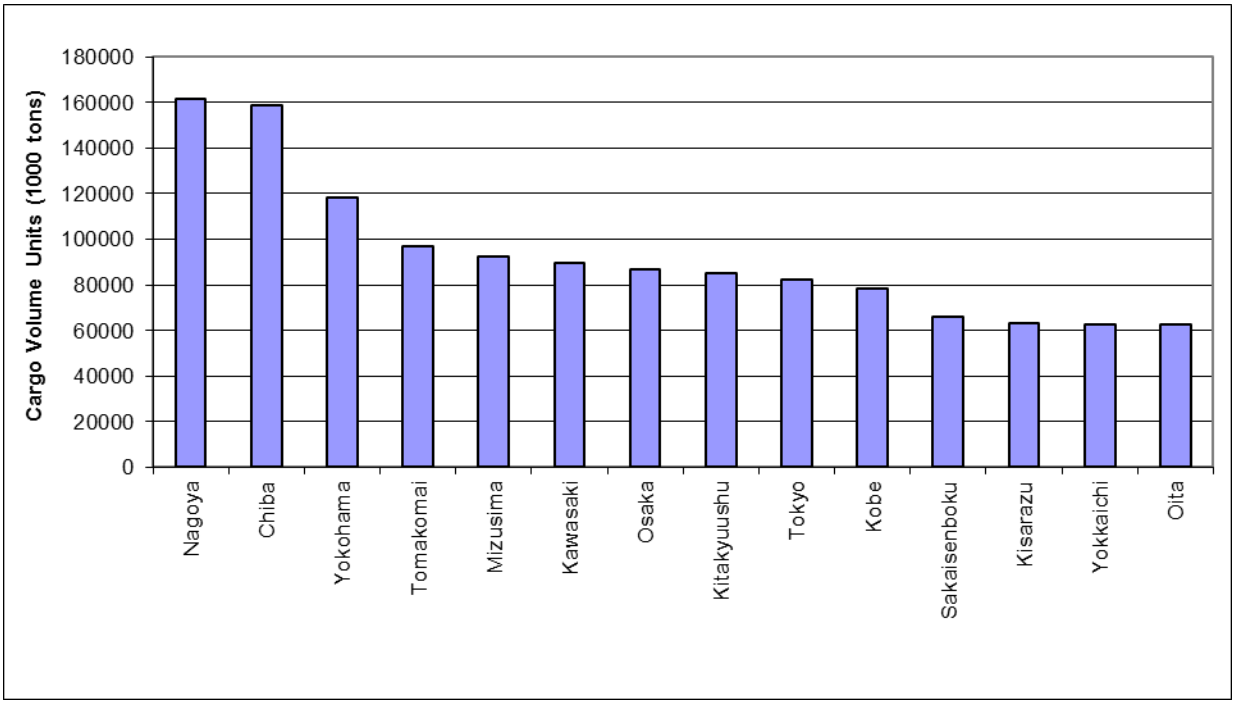

Figure 13-8: Major Japanese Ports and Cargo Volumes for 2002
Source: Chiba Prefecture (2005).

MARIANA ARCHIPELAGO. Four commercially used waterways link Guam and CNMI with major ports to both the east and west. These navigable waterways are utilized by commercial vessels.

Farallon De Medinilla. FDM and the nearshore waters have been leased to the United States for military purposes since January 6, 1983 (U.S. Department of the Navy 2008), specifically for use as a live-fire naval gunfire and air warfare air strike training range. As such, FDM and its nearshore area have been off limits to all personnel both civilian and military because of concerns regarding unexploded ordnance. The lease agreement between the CNMI and the United States specifies in the pertinent part at Article 12 of the lease (Commonwealth of the Northern Mariana Islands 1983) that "Public access to FDM Island and the waters of the Commonwealth immediately adjacent thereto shall be permanently restricted for safety reasons." The restriction around FDM and nearshore areas prohibits entry of all personnel, civilian and military, from the island without specific permission from the Commander, Joint Region Marianas.

Saipan. The Port of Saipan is the largest and most advanced of the three ports of the CNMI, but is nevertheless described as a small seaport with poor shelter by the World Port Source. A number of facilities and services are available at the port, including a cargo terminal with pierside water depth ranging from 16 to 20 ft. (4.9 to 9.1 m) and an oil terminal with a 21- to 25-foot (6.4- to 7.6-m) depth range (World Port Source 2012a). In addition, 2,600 linear ft. (792.5 m) of berthing space, cranes and

lifts capable of handling loads over 100 tons, and a 22-acre (8.9-hectare) container yard enabled the port to transfer over 338,000 tons of cargo in 2009 (Commonwealth Ports Authority 2005, 2010). The Port of Saipan has two sections: (1) Garapen Anchorage, located in the outer harbor, and (2) Puetton Tanapeg harbor, sheltered by a barrier reef to the north and considered the inner harbor. The Port of Saipan is on the southwest shore and houses U.S. Navy ships, commercial ships, and small local boats or ferries.

Tinian. The Port of Tinian is described by the World Port Source as a small port offering excellent shelter, which is provided by a coastal breakwater. Three finder piers and a small boat ramp are available at the port. Pierside water depth ranges from 26 to 30 ft. (7.1 to 9.1 m), allowing relatively large vessels to dock. Mobile Oil operates a fuel plant at the port, and a ferry service transports tourists from Saipan to the hotel and casino, which is one of the main attractions on Tinian (Commonwealth Ports Authority 2005; World Port Source 2012b).

Rota. The Port of Rota, or Rota West Harbor, is located on the southwestern tip of the island. It is classified as a very small port by the World Port Source, which also describes the harbor as poorly sheltered (World Port Source 2012c). The port includes a jetty or wharf with a pierside water depth of 6 to 10 ft. (1.8 to 3 m), which limits the size of vessels that can access the pier. The Port of Rota is mainly used by ferry boats transporting tourists and residents to and from Tinian. The Commonwealth Ports Authority is seeking funding to dredge the harbor and upgrade the port facilities in preparation for possible future development on the island (Commonwealth Ports Authority 2005).

Guam. The total number of vessels transiting through the Port of Guam steadily decreased from 2,924 in 1995 to 1,022 in 2008 (U.S. Department of the Navy 2010). However, the number of container ships increased from a low of 103 in 2003 to a high of 165 in 2008. The Port of Guam handled over 99,000 containers in 2008. Most other types of cargo passing through the Port of Guam—including break-bulk cargo (i.e., cargo packed in cases, drums, and bales, etc.), bulk cargo, and roll-on-roll-off cargo (e.g., automobiles)—has decreased substantially since 1995 (U.S. Department of the Navy 2010).

The United States provides 60% of Guam's imported goods, with the balance from the Asian and Pacific markets of Japan, Taiwan, the Philippines, Hong Kong, and—to a lesser extent—Australia, New Zealand, and the islands of Micronesia (Port Authority of Guam 2011).

***Apra Harbor* -** Located in Piti, at the northeast end of Apra Harbor, the Port Authority of Guam operates the largest U.S. deepwater port in the western Pacific Ocean. The Port of Guam handles approximately 2 million tons of cargo a year (Port Authority of Guam 2011). The Port Authority's Harbor Rules and Regulations (also known as Public Law 26-172) specify that all commercial vessels wanting to enter Apra Harbor must first stop at an unmarked approach designated Alpha Hotel (13°26'8"N, 144°34'09"E), located 3.2 km west of Udal Point (Figure 13-9). Apra Harbor also provides economical transshipment services from the United States, Hawai'i, and East Asia to the entire western Pacific. At this station, a pilot boards the vessel and ensures that it is properly aligned on the entrance range.

CAROLINE ISLANDS. In the Caroline Islands, shipping is concentrated near the coast, yet there is limited trans-oceanic movement. Commercial passenger ships are also a part of the commercial maritime environment around the Caroline Island (Jaynes 2010).

Yap. The MSC also helps to alleviate maritime disputes among islands. When a barge headed for Yap ran aground in Palau and was fined severely, many other islands were worried about future shipments and potential fines, the MSC made sure shipments of good to Yap continued (Jaynes 2010).

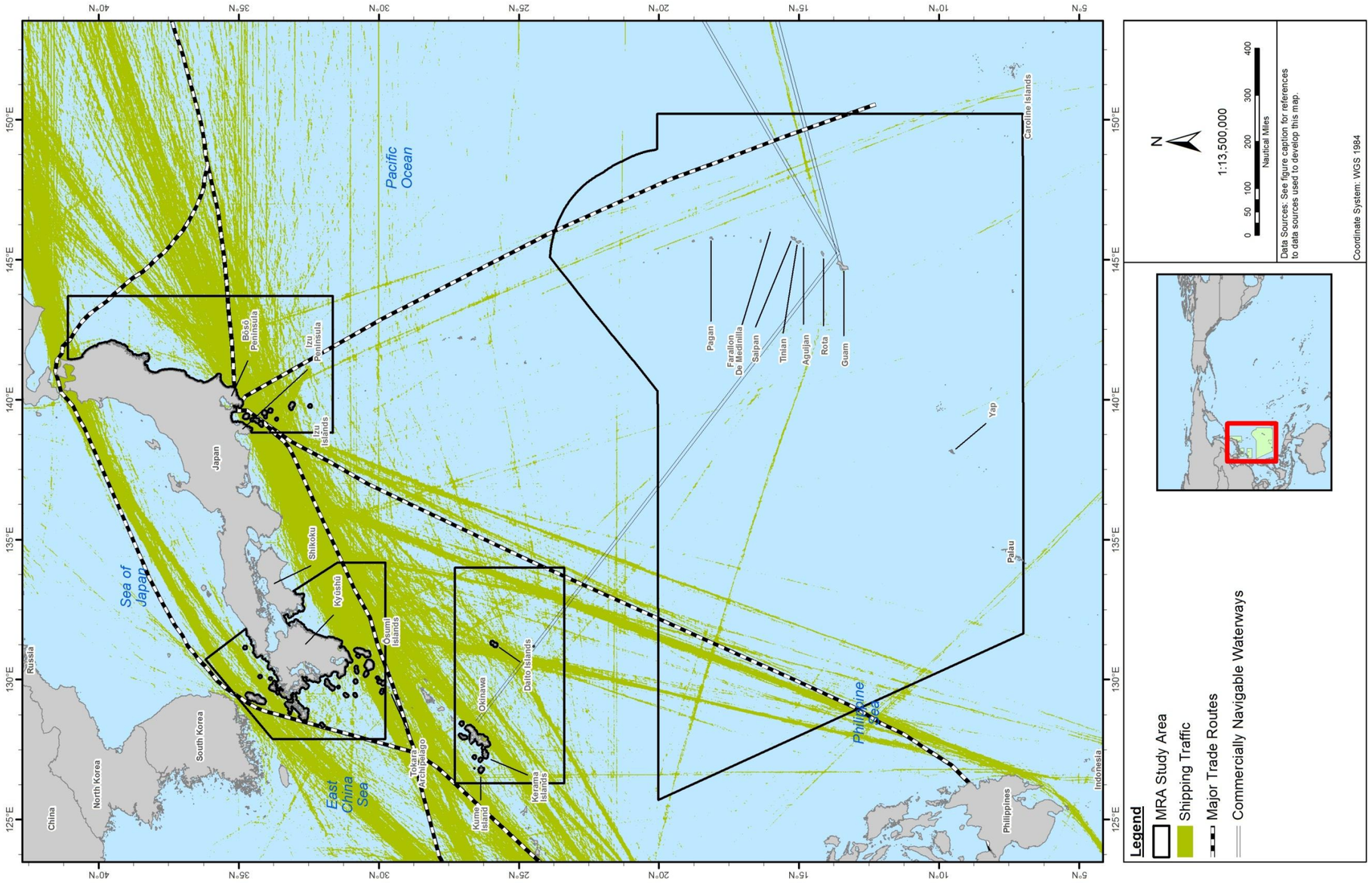

Figure 13-9: Shipping Lanes in the MRA Study Area
Sources: Burke et al. (2011); Research and Innovative Technology Administration's Bureau of Transportation Statistics (2011); and U.S. Department of the Navy (2005).

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13.4 MARITIME BOUNDARIES: TERRITORIAL WATERS, CONTIGUOUS ZONE, AND EXCLUSIVE ECONOMIC ZONE

13.4.1 Description

Maritime boundaries are critical elements that affect planning of activities in the marine environment (General Dynamics Advanced Information Systems 2003). They delimit the extent of a nation's sovereignty, exclusive rights, jurisdiction, and control over the ocean areas off its coast. Maritime boundaries may include a 12-nm territorial sea, an 18- to 24-nm contiguous zone, a 200-nm EEZ, and a nation's continental shelf (Figure 13-10). Because maritime boundaries are delimited, rather than demarcated, physical evidence of the boundary generally is absent. As a result, confusion, disagreement, and conflicting versions of marine boundaries may transpire between distinct nations and/or territories (National Oceanic and Atmospheric Administration 2005).

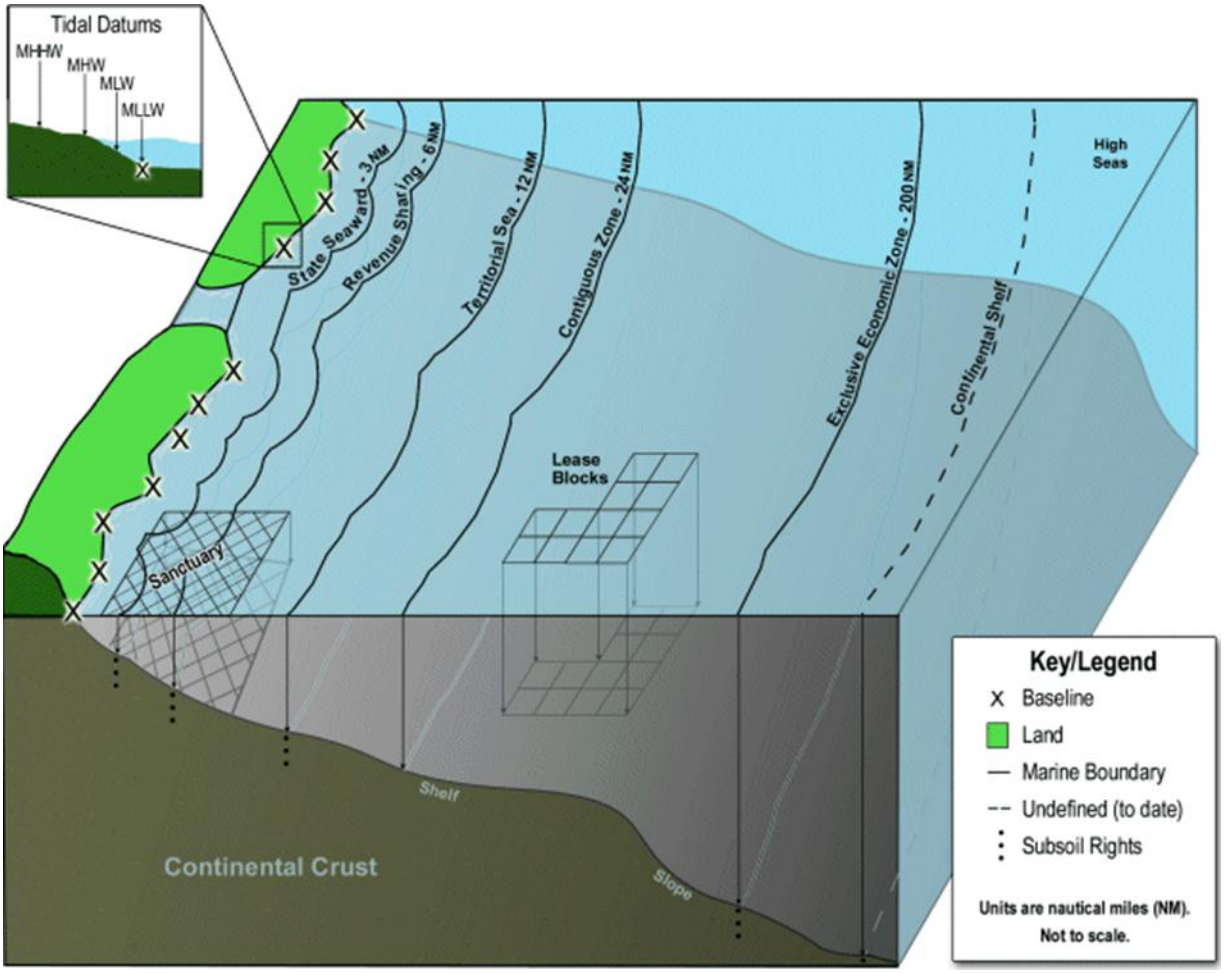

Figure 13-10: A 3-Dimentional Depiction of the U.S. Maritime Boundaries
Tidal datums – Mean Higher High Water, Mean High Water, Mean Low Water, and Mean Lower Low Water.
Image taken from: National Oceanic and Atmospheric Administration (2005), used with the permission of Mr. David Stein.

Although the U.S. and other nations historically used 3 nm as their seaward territorial limit, some American states (e.g., Texas and the Gulf Coast of Florida) and territories (e.g., Puerto Rico) have historical seaward boundaries of 3 marine leagues or 9 nm. These territorial limits were measured from the baseline of each nation or state. The United States has traditionally used the "rule of the tidemark"

as the baseline from which to measure the width of its territorial waters. This baseline coincides with the mean lower low water/tide line found along the shore, and is often termed the "normal" baseline (Figure 13-10) (Kapoor and Kerr 1986; Prescott 1987). At the mouths of bays, rivers, or other areas where the coastline is not continuous, a straight baseline is drawn over the coastal feature. Rather than use the normal baseline, an increasing number of countries use either the straight baseline or archipelagic baseline system from which to measure their territorial waters (Kapoor and Kerr 1986; Prescott 1987).

The U.S. EEZ covers approximately 7.8 million km^2 of ocean space, half of which is in the western Pacific Ocean around U.S. possessions such as Hawai'i, American Samoa, Guam, and the CNMI (Figure 13-2). Overlapping boundaries with other nations exist in 25 situations. International maritime boundaries are those agreed upon by one or more countries to resolve these overlapping claim issues. In cases where a nation's 200 nm EEZ overlaps with that of another country, both countries' EEZs are deemed to end at what is called the "median line," an imaginary line equidistant from the baseline of each country. Two instances of overlapping national EEZs occur around Guam and CNMI: south of Guam, the U.S. EEZ runs along the median line between Guam and the FSM, while north of Farallon de Pajaros, the U.S. EEZ runs along the median line between the CNMI and Japan's Ogasawara Islands.

The United Nations (UN) Law of the Sea Treaty, created in 1982 and entered into force in 1994, delimits the international maritime sovereignties of coastal nations as 12 nm for territorial seas, 18 to 24 nm for a contiguous zone, and 200 nm for an EEZ (U.S. Office of the President 1988), 54 FR 777. While the U.S. has not yet signed the Law of the Sea Treaty, it does recognize and abide by many of its rules. For instance, in 1988, U.S. Presidential Proclamation No. 5928 extended the seaward territorial limit of the United States to 12 nm from the baseline (Table 13-5). This expansion of federal territorial waters from 3 nm (or in some cases 9 nm) to 12 nm provided the United States' jurisdiction and supreme power over this area (Table 13-4). The seabed and its resources, the biota of the water column, the airspace above, and use of surface waters are under the jurisdiction of the United States. Although the territorial waters of the United States extend 12 nm seaward from its baseline, the part of the territorial sea closest to shore (3 to 9 nm) remains under the primary jurisdiction of each coastal state. In most areas of the Marianas, the territorial government controls waters out to 3 nm (Environment Hawaii 1998). In February 1983, Japan signed the Law of the Sea Treaty and later ratified it in June 1996, enforcing the UN guidelines for maritime boundaries, territorial seas, contiguous zones, and EEZs (Asia-Pacific Economic Cooperation 2005).

U.S. control over the waters adjacent to its shores was further solidified in 1999 when President Clinton's Presidential Proclamation No. 7219 extended U.S. federal jurisdiction by the additional 12 nm maximum allowed by international law. This 24-nm contiguous zone is measured from the U.S. baseline and, as its name implies, is an area contiguous or next to a nation's territorial waters that provides an added area of limited jurisdiction. The U.S. makes no territorial claims within its contiguous zone, but it does, however, claim the right to exercise the control necessary to prevent infringement of its fiscal, customs, immigration, or sanitary laws/regulations, and to obtain redress for infringement of these laws/regulations committed within the zone (Division for Ocean Affairs and the Law of the Sea 2004). Establishment of the U.S. contiguous zone additionally advances both the law enforcement and public health interests of the United States (Table 13-4).

Table 13-4: The Maritime Boundaries and their Seaward and Jurisdictional Extents

Maritime Boundary	Seaward Extent	Jurisdictional Extent
State waters	3 to 9 nm from U.S. baseline (depending on state's historical maritime boundary)	State or territory jurisdiction over the air, sea, and seabed
Territorial Waters	12 nm from baseline	Federal jurisdiction over the air, sea, and seabed
Contiguous Zone	24 nm from baseline	Power to prevent and obtain redress for infringement of fiscal, customs, immigration, and sanitary laws
Exclusive Economic Zone (EEZ)	200 nm from baseline	Sovereign rights over all natural (EEZ) resources, and jurisdiction to protect the marine environment

Source: Division for Ocean Affairs and the Law of the Sea (2004).
Notes:
EEZ = Exclusive Economic Zone
nm = nautical miles

JAPAN ARCHIPELAGO. Japan's territorial sea extends 12 nm offshore, measured from the baselines determined in accordance with the Japanese "Law on the Territorial Sea" enacted in 1977. The territorial sea extends 3 nm offshore in the following designated areas: the straits of Soya, Tsugaru, Ōsumi, and the eastern and western channels of the Tsushima Strait (Asia-Pacific Economic Cooperation 2005). This baseline coincides with the mean lower low tide line along the shore, and is often termed the "normal" baseline (Figure 13-10) (Kapoor and Kerr 1986; Prescott 1987). At the mouths of bays, rivers, or other areas where the coastline is not continuous, a straight baseline is drawn over the coastal feature. Rather than use the normal baseline, an increasing number of countries use either the straight baseline or archipelagic baseline system from which to measure their territorial waters (Kapoor and Kerr 1986; Prescott 1987).

The Japanese EEZ covers approximately 3.6 million km^2 of ocean space, and its boundaries are adjacent to the EEZ of six other nations: China, the Republic of Korea, the Democratic People's Republic of Korea, the Philippines, Russia, and the United States (Asia-Pacific Economic Cooperation 2005). International maritime boundaries are those agreed upon by one or more countries to resolve these overlapping claim issues. In cases where a nation's 200-nm EEZ overlaps with that of another country, both countries' EEZs are deemed to end at what is called the "median line," an imaginary line equidistant from the baseline of each country. The Japan MRA Study Area is predominantly located within the Japanese EEZ. The northwest portion of the West Japan Study Area stretches beyond the Japanese EEZ and into the territorial sea of South Korea.

Oil exploration in the East China Sea has triggered boundary disputes between Japan, China, and South Korea (Gao and Wu 2005). These disputes led to an agreement between Japan and South Korea, which formed a "Joint Development Zone" (Gao and Wu 2005). The zone is approximately 85,000 km^2, and includes all areas of disputed continental shelf, except the Chinese claims of sovereignty over the shelf extending to the Okinawa Trough (Gao and Wu 2005). The East China Sea has also been the subject of 30 years of seabed controversy between Japan and China (Gao and Wu 2005). Recent progress between the nations has led to the development of "conflict avoidance" regimes, including joint fishing agreements and a prior notification scheme for scientific research (Gao and Wu 2005).

MARIANA ARCHIPELAGO. Disputes over ocean sovereignty between the U.S. Federal Government and the territorial governments of Guam and the CNMI have been frequent.

CAROLINE ISLANDS. Territorial seas extend 12 nm from the established baseline (which includes a fringing reef), where the FSM hold sovereign right over living and nonliving resources there within (Government of the Federated States of Micronesia 1975a). The FSM also asserts ownership over any waters connecting the archipelago (except those spoken for within an international obligation).

The FSM's EEZ is 2.98 million km^2 (Government of the Federated States of Micronesia 1975b). This EEZ contains the most productive tuna fishing grounds in the world (Government of the Federated States of Micronesia 2012). In the constitution of the FSM (Article I, title 8), the EEZ extends up to 200 nm outward from the baselines (Seventeenth Congress of the Federated States of Micronesia 2012) whose conservation, management, and exploitation is managed by the Micronesian Maritime Authority (Government of the Federated States of Micronesia 2012). Within the EEZ, the FSM has (Government of the Federated States of Micronesia 1975a):

1. Sovereign rights for the purpose of exploring and exploiting, conserving and managing the natural resources, whether living or nonliving, of the waters superjacent to the seabed and of the seabed and its subsoil, and with regard to other activities for the economic exploitation and exploration of the zone;

2. Jurisdiction with regard to the establishment and use of artificial islands, installations, and structures; marine scientific research; and the protection and preservation of the marine environment; and

3. Other rights and duties provided for in international law.

The constitution does allow some jurisdiction in waters under treaty obligations, yet within each agreed EEZ that state has ultimate authority (Seventeenth Congress of the Federated States of Micronesia 2012).

13.4.2 Status and Management

According to presidential proclamations and treaties that established or extended the maritime boundaries of the U.S. (territorial waters, contiguous zone, and EEZ), existing federal or state laws or any associated jurisdiction, rights, legal interests, or obligations were not extended or altered in any way. The following federal legislation and Executive Orders (EOs) have associated maritime zone or boundary limitations. The maritime boundary associations detailed in the legislation or orders relevant to the Mariana Islands MRA Study Area are listed below (see Section 1.3 for a full description of this subject). The term "high seas" generally refers to international waters outside the jurisdiction of any single nation.

- The Marine Mammal Protection Act (MMPA) protects, conserves, and manages marine mammals in waters under the jurisdiction of the United States, which are defined by the MMPA as the U.S. territorial seas, EEZ, and the eastern special areas between the United States and Russia. The act further regulates "takes" of marine mammals on the global commons (i.e., the high seas or Antarctica) by vessels or persons under U.S. jurisdiction.

- The Endangered Species Act (ESA) regulates protection, conservation, or management of endangered species in the U.S. territorial land and seas, as well as on the high seas.
- The MSFCMA, also known as the Sustainable Fisheries Act (SFA), claims sovereign rights over fish and fishery management in the U.S. EEZ, except for highly migratory species. The U.S. cooperates with nations or international organizations involved in fisheries for the highly migratory species in order to conserve and promote optimum yields of the species in their entire range in and beyond the U.S. EEZ.
- The National Environmental Policy Act (NEPA) established the Council on Environmental Quality and a national policy that encourages productive harmony between humans and their environment. It also promotes efforts that will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man. Jurisdiction of this act includes the territorial lands and waters of the United States to the limit of the territorial seas.
- The Marine Protection, Research, and Sanctuaries Act (MPRSA) regulates dumping of materials in the ocean. It is applicable to material transported by any U.S. person, vessel, aircraft, or agency from any location in the world and by any person outside the United States intending to dump materials in U.S. territorial seas and the contiguous zone.
- EO 12114 extends environmental impact evaluation requirements for U.S. federal agencies beyond the territorial seas and contiguous zone to include the environments of other nations and the global commons outside the jurisdiction of any nation.
- The Marine Plastic Pollution Research and Control Act (MPPRCA) prohibits pollution of the marine environment by any vessel with U.S. registry or under U.S. authority and all vessels in the U.S. territorial waters or EEZ.

Table 13-5 provides a chronological summary of U.S. jurisdiction and maritime boundaries in the Mariana Islands MRA Study Area.

Table 13-5: Timeline Detailing the Establishment of U.S. Jurisdiction and Maritime Boundaries

YEAR	ESTABLISHMENT	DESCRIPTION
Antiquity – Early 20th century	**NA**	Nations individually established seaward boundaries of 3 to 9 nm under the "cannon shot" concept.
1945	**Truman Presidential Proclamation No. 2667 on the Continental Shelf**	For the purpose of conserving and utilizing natural resources, the United States claimed jurisdiction and control of the subsoil and seabed of the continental shelf contiguous to its coast. The waters overlying the continental shelf were not affected.
1945	**Truman Presidential Proclamation No. 2668 on Coastal Fisheries**	Conservation zones were established in areas of the high seas contiguous to U.S. coasts for the purpose of protecting coastal fishery resources.
1950	**The Organic Act of Guam**	Created the government structure now understood on Guam. Gave concurrent jurisdiction of submerged lands (from the line of mean high tide and seaward to a line 3 geographical miles distant from the coastline) to the Government of Guam.
1953	**Outer Continental**	The subsoil and seabed of the outer continental shelf was declared to be

Table 13-5: Timeline Detailing the Establishment of U.S. Jurisdiction and Maritime Boundaries

YEAR	ESTABLISHMENT	DESCRIPTION
	Shelf Act	under U.S. jurisdiction, control, and power. The waters overlying the outer continental shelf were not affected by this act, so fishing and navigation were unrestricted. This act nullified Presidential Proclamation No. 2667 (67 Stat. 462, 43 U.S.C. 1331 et seq.).
1958	**UN Convention on the Law of the Sea I**	The UN convened the first international conference on maritime boundaries.
1960	**UN Convention on the Law of the Sea II**	The UN convened the second international conference on maritime boundaries.
1973	**UN Convention on the Law of the Sea III**	The UN convened the third international conference on maritime boundaries.
1976	**Fishery Conservation and Management Act**	This legislation established a fishery conservation zone extending 200 nm from the U.S. baseline, except in several areas such as the Caribbean Sea, where to the west, south, and east of Puerto Rico and the United States Virgin Islands, the limit of the fishery conservation zone was determined by geodetic or straight lines connecting points of latitude and longitude that were delineated in the act.
1977	**Fishery Conservation and Management Act**	The fishery conservation zone, established by the 1976 Fishery Conservation and Management Act, went into effect.
1982	**UN Convention on the Law of the Sea Treaty**	This international treaty has not yet been ratified by the United States. The treaty provides a comprehensive legal regime in the world's oceans and seas by establishing rules governing all uses of the oceans and their resources. Most nations, including the United States, adhere to its guidelines for maritime boundaries, including territorial seas, contiguous zones, and EEZs.
1983	**Reagan Presidential Proclamation No. 5030 on the EEZ**	An EEZ was formally established to facilitate wise development and use of the oceans consistent with international law, as well as to recognize the zone adjacent to a nation's territorial seas where a nation may assert certain sovereign rights over natural resources. Establishment of the U.S. EEZ advanced development of ocean resources and promoted protection of the marine environment but did not affect other lawful uses of the zone, including navigation and over flight. This proclamation set the EEZ at 200 nm from the baselines of the U.S. and its territories, except where nations are less than 400 nm apart. In such cases, equidistant lines delineated the EEZ boundary. The EEZ boundaries coincided with those established by the 1976 Fishery Conservation and Management Act. This proclamation did not affect existing U.S. policies concerning the continental shelf, marine mammals, or fisheries. Jurisdiction and sovereign rights will be exercised in accordance with rules of international law.
1988	**Reagan Presidential Proclamation No. 5928 on the Territorial Sea**	The seaward extent of the U.S. territorial sea was extended to 12 nm from the baseline of the nation and its territories by this proclamation. The territorial sea is the zone over which the U.S. exercises supreme sovereignty and jurisdiction from the airspace over the sea to the seabed and its soil. This extension of the territorial sea advanced national security and other interests of the U.S. This proclamation did not extend or alter existing federal or state laws (jurisdiction, rights, legal interests, or obligations).
1994	**UN Convention on the Law of the Sea**	The UN entered into force the 1982 Law of the Sea Treaty. It has yet to be ratified by the United States.

Table 13-5: Timeline Detailing the Establishment of U.S. Jurisdiction and Maritime Boundaries

YEAR	ESTABLISHMENT	DESCRIPTION
1999	**Clinton Presidential Proclamation No. 7219 on the Contiguous Zone**	The contiguous zone of the United States was established 24 nm from the nation's baseline by this proclamation. The contiguous zone is the area where the U.S. exercises the control necessary to prevent and obtain redress for infringement of its fiscal, customs, immigration, or sanitary laws and regulations within its territorial sea. Establishment of the U.S. contiguous zone advanced the law enforcement and public health interests of the nation. This proclamation did not change existing federal or state laws, and did not alter the rights of the United States in the EEZ.

Sources: Department of State (1977), U.S. Office of the President (1988), Glassner (1995), de Blij and Muller (1999), Guam Office of the Attorney General (2002), Division for Ocean Affairs and the Law of the Sea (2004), and Rosenberg (2005).
Notes:
EEZ = Exclusive Economic Zone
NA = Not applicable
nm = nautical miles
UN = United Nations

13.4.3 Distribution of Operations

JAPAN ARCHIPELAGO. All warning areas, restricted areas, and other Navy training areas lie within Japanese territorial waters and are located within or adjacent to Japan's territorial sea and contiguous zone (Table 13-4). Warning areas that occur in nearshore waters include W-174, W-176, W-178A, W-183, and W-183A.

MARIANA ARCHIPELAGO. Nearly all of the waters encompassed by the Mariana Islands Study Area are found within the limits of the U.S. EEZ. South of Guam, the EEZ does not extend to the maximum 200 nm due to the proximity of the FSM, situated less than 400 nm away from Guam. Instead, the EEZ runs along a hypothetical median (or equidistant) line between Guam and the FSM based on existing maritime boundary agreements (General Dynamics Advanced Information Systems 2003). The DoD has ownership of the submerged lands off of its federal lands on Guam.

CAROLINE ISLANDS. The maritime boundaries of the CNMI and RMI have overlapped in some areas (Seventeenth Congress of the Federated States of Micronesia 2012) but an agreement on specific EEZ boundaries has been reached (Government of the Federated States of Micronesia and Government of the Republic of the Marshall Islands 2006) yet, this can still create tension among adjacent states.

13.5 OIL AND GAS

13.5.1 Description

JAPAN ARCHIPELAGO. Indication of the possible presence of oil in the East China Sea has led to boundary disputes among Japan, China, and South Korea, including the Tokdo/Takeshima islets in the Sea of Japan and the Senkaku/Diaoya islets in the East China Sea (Shin and Savage 2011). Japan contains almost no oil reserves of its own and currently imports between 98 and 99% of its oil (Department of Energy 2004).

MARIANA ARCHIPELAGO. The CNMI and Guam do not have conventional energy resources and import petroleum products to meet their energy demand (U.S. Energy Information Adminstration 2009).

CAROLINE ISLANDS. One million acres of area surrounding Palau in about 40 m of water was approved for oil exploration by the Palau Pacific Exploration Company in the state of Kayangel, based on 1997 seismic data that were reprocessed in 2007 (ASIA Miner 2009). Two potential oil reservoir zones were identified (ASIA Miner 2009). The Governor of Kayangel approved an exploration extension for the company through December 31, 2012, although the state legislature did not pass the measure (Whipps 2011).

13.5.2 Status and Management

JAPAN ARCHIPELAGO. Japan has insufficient domestic hydrocarbon resources, and is thus the third largest net importer of crude oil and the largest importer of liquefied natural gas and coal (U.S. Energy Information Administration 2011). As of 2010, Japan used about 4.4 million barrels per day of oil, and is the third largest petroleum consumer in the world (U.S. Energy Information Administration 2011). Japan's oil reserves amounted to 44 million barrels in January 2011, a decrease from 58 million barrels in 2007 (U.S. Energy Information Administration 2011). According to the Oil and Gas Journal, Japan has 145 producing oil wells distributed among 13 fields. Domestic exploration for oil reserves slowed in 2009-2010 because of a low rate of production compared to exploration costs. Japan produced about 132,631 barrels per day of oil in 2010, of which 4,940 barrels was crude oil (U.S. Energy Information Administration 2011).

MARIANA ARCHIPELAGO. The CNMI and Guam do not have conventional energy resources.

13.5.3 Distribution of Operations

JAPAN ARCHIPELAGO. Methane hydrate, with an estimated 1.1 trillion cubic meters of gas, was discovered in Nankai Trough 50 km off Honshū (PennEnergy 2010).The East China Sea has known oil and gas deposits, although development of these has been slowed by national boundary disputes. In 2008, a preliminary accord was reached between Japan and China over two fields (Chunxiao/Shiakaba and Longjing/Asunaro), although China had yet to implement the agreement by September 2010, increasing tensions between the two governments (U.S. Energy Information Administration 2011). In addition, the Tokdo/Takeshima islets in the Sea of Japan and the Senkaku/Diaoya islets in the East China Sea remain under dispute among China, Taiwan, and Japan (Shin and Savage 2011).

MARIANA ARCHIPELAGO. The CNMI and Guam do not have conventional energy resources.

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15.0 GLOSSARY

Abiotic—nonliving

Abundant—an indication of the plentifulness of a species at a particular place and time; an abundant species is more plentiful than an occasional or rare species

Abyssal plain—flat, sediment-covered part of the ocean floor between the continental rise and the mid-ocean ridge at a depth greater than 4,000 to 5,000 m

Abyssal zone—flat, sediment-covered part of the ocean floor between the continental rise and the mid-ocean ridge at a depth between 4,000 and 7,000 m

Acanthuroids—coral reef fishes comprising the families of surgeonfishes, rabbitfishes, and Moorish idols

Acre—a measurement of land area and is equivalent to 0.004 km^2

Active margin—a continental margin that is tectonically deformed as it collides with another tectonic plate. It is the leading edge of a continent as it moves away from an oceanic spreading center

Adult—developmental stage characterized by sexual or physical (full size and strength) maturity

Advection—the horizontal movement of water, as in an ocean current

Aerobic—life or biological processes that can occur only in the presence of oxygen

Aggregation—group of animals that forms when individuals are attracted to an environmental resource to which each responds independently; the term does not imply any social organization

Agonistic behavior—see aggression

Ahermatypic coral—non-reef building types of coral that lack symbiotic zooxanthallae and are not restricted by depth, temperature, or light penetration; may be solitary or colonial

Akaumigame—Japanese for loggerhead turtle

Algae—one-celled or many-celled plants that have no roots, stems or leaf systems

Allee effect—a phenomenon seen in animal populations with extremely low numbers where a small number of individuals result in difficulties in finding a mate and possible inbreeding; this effect can drastically reduce the fitness and genetic diversity of an animal population

Allochthonous—material that has originated elsewhere, non-native

Alpha male—the dominant male

Ambient—of the surrounding area or environment

Amphipod—an order of laterally compressed (shrimp-like) crustaceans with thoracic gills, no carapace, and similar body segments. An important component of zooplankton and benthic invertebrate communities

Anaerobic—life or biological processes that occur in the absence of oxygen

Anchialine pools—land-locked, marine or brackish pools of water located along rocky coasts and connected to the sea via underground caves, tunnels, or fissures

Anemone—a cnidarian of the Class Anthozoa that possess a flexible cylindrical body and a central mouth surrounded by tentacles

Annelids—invertebrate animals of the phylum Annelida in which the body is typically made up of a series of rings or segments covered by a soft cuticle and lacking jointed appendages (e.g., marine worms)

Anomaly—something irregular or abnormal

Anthozoan—a class of the coelentrates in which the medusiod stage is absent and the polyp (hydroid) stage is better developed than in other coelentrates (e.g., sea anemones, corals, alcyonarians, sea fans, sea pens, sea pansies, sea feathers)

Anthropogenic—describing a phenomenon or condition created, directly or indirectly, as a result of human activity

Anticyclonic—clockwise circulation in the Northern Hemisphere and counterclockwise circulation in the Southern Hemisphere; in oceanography, synonymous with warm-core ring

Aoumigame—Japanese for green turtle

Apex predator—a species that kills and eats other animals, but has virtually no predators of its own

Archipelago—a group or chain of oceanic islands

ArcScene™—application software used for combining and viewing features, surfaces, and graphics in a three-dimensional perspective

Artificial habitat—a human-made, estuarine/marine habitat (sunken ships, artificial reefs: rubble, concrete igloos, FADs) created in navigable waters of the U.S. or in waters overlying the continental shelf to attract aquatic life

Artificial reef—a human-made, marine habitat (sunken ships, concrete igloos, rubble) created in the navigable waters of the U.S. or in waters overlying the continental shelf to attract aquatic life

Artisanal fishing—fisheries involving skilled but non-industrialized operators; typically a small-scale, decentralized operation

Ascidians—sea squirts; taxonomic class of globular or cylindrical animals that inhabit shallow and deep water, attach themselves to substrates (rocks, pilings, the bottom of ships, and coral reefs), and may be solitary or colonial

Assemblage—the populations of various species from a larger taxon characteristically associated with a particular environment that can be used as an indicator of the environment

Atoll—an organic reef that surrounds a lagoon and is bordered by open sea, often with low sand islands

Audiogram—a hearing sensitivity curve drawn as a function of frequency and sound pressure level; describes the hearing ability of an animal

Back-arc—referring to the region behind the island arc (the concave side of the arc)

Baiu Zensen—rainy front where a cold mass over the Okhotsk sea and a warm mass over the Pacific Ocean meet

Baleen—the interleaved, hard, fibrous plates made of keratin (protein in fingernails and hair) that hang side by side in rows from the roof of the mouth of mysticete whales; baleen takes the place of teeth and serves to filter the whale's food from the water

Bandwidth—the difference between the highest and lowest frequencies; measured in Hertz

Bank—a submerged ridge, shoal, sandbar, or other unconsolidated material that rises from the seafloor to near the water's surface, sometimes creating a navigational hazard

Barnacles—a collective name for various marine crustaceans of the subclass Cirripedia; the adults form a hard outer shell and attach to underwater surfaces such as rocks and ships, as well as to certain whales

Barrier reefs—offshore reefs composed of wave-resistant consolidated limestone (can be 300 to 1,000 m wide and located as far as 100 km offshore). Barrier reefs are separated from the nearshore intertidal area by a lagoon

Basalt—an inner layer of worldwide extent underlying ocean and granitic continents

Baseline—the line from which maritime boundaries (EEZ, contiguous zone, territorial waters) are measured; in the U.S., the baseline is the low tide line except at the mouths of inland water bodies (bays) where a closing line (straight line) is drawn

Basking—an activity performed by pinnipeds and sea turtles while on land in which they expose themselves to pleasant warmth

Batch spawning—releasing gametes into the sea for external fertilization and development

Bathymetry—the topography of the ocean floor

Bay—a body of water partially enclosed by land, but with a large outlet to the sea or ocean

Beaked whales—members of the Family Ziphiidae, includes the genus *Ziphius*, *Mesoplodon*, *Indopacetus*, and *Berardius*

Behavioral audiogram—a graphic representation of an animal's auditory threshold that is determined by tests with trained animals; measures the hearing ability of an animal

Benign—noncancerous

Benthic—organisms living on or near the ocean floor; the term is used irrespective of whether the sea is shallow or deep

Benthonic—relating to or happening on the bottom under a body of water

Benthopelagic—the ecological zone from the seabed to 100 m above the seabed

Benthos—organisms that live in, on, or are attached to the ocean bottom substrate

Bicarbonate—essential for regulating vital functions and one of the important buffers necessary to maintain normal acid-base balance in the body. Body metabolism results in mainly acid production, and neutralizing some of such acids is its constant activity, thus it plays a key role in metabolic acidosis or alkalosis. Bicarbonate may be lost through watery feces, or can decrease when lungs cannot expel carbon dioxide

Bioaccumulation—higher concentration of a chemical in cells than in the nonliving surroundings

Biodiversity—the spectrum of different life-forms

Biogenic—originating from living organisms

Biological/biochemical oxygen demand (BOD)—the amount of oxygen needed by microorganisms to decompose (by aerobic respiration) the organic material in a given volume of water

Biomass—the amount of living matter per unit of water surface or water volume

Bioprospecting—searching for commercially valuable biochemical and genetic resources in plants, animals, and microorganisms for use in food production, development of new drugs, and other biotechnology applications

Biotic—pertaining to life or living organisms

Bivalve—a group of marine or freshwater mollusk that consists of a soft body protected by two hinging shells (e.g., scallops and oysters)

Blackfish—a colloquial term adopted from American whalers and sometimes applied to pilot whales and other superficially similar species including false killer, pygmy killer, and melon-headed whales

Bloom—the usually seasonally dense growth of algae or phytoplankton that is triggered by an increase in the nutrient concentration or increased availability of light

Blow—air exhaled through the blowhole of a cetacean mixed with surrounding water that is displaced by the exhalation

Blowhole—the nostrils or nasal openings on top of the head of a cetacean

Boreal—comprising or throughout far northern regions

Bottlenose dolphin—the former common name for *Tursiops truncatus,* now called the common bottlenose dolphin

Boxfishes—any of numerous small tropical fishes of the family Ostraciidae having body and head encased in bony plates

Buoyancy—the tendency of a body to float or to rise when submerged in a fluid; the power of a fluid to exert an upward force on a body placed in it

Brackish—having a salinity between that of fresh and sea water

Brittlestar—starfishlike echinoderm belonging to Class Ophiuroidea that has 5 to 8 elongate, slender, cylindrical arms distinctly radiating from a flat central disc

Brooded planulae—incubation of planula (flat, ciliated, larva of hydrozoan coelenterates) within the polyp of corals; form of asexual reproduction

Brown algae—division of algae (Phaeophycophyta) consisting of large macroscopic forms occurring widespread in marine habitats attached either to rocks, stones or coarser algae (kelp); commonly found relatively shallow water in the intertidal and subtidal zones along the coast, in estuaries, and muddy bottoms of salt marshes

Bryozoan—phylum of small, aquatic colonial animals that are commonly called moss animals; each zooid or animal in the colony has a crown of ciliated tentacles

Bubble netting—a coordinated feeding technique of humpback whales, in which they use bubbles to corral and trap small fish or invertebrates

Budding—asexual reproduction in which small portion of an organism grows out from and eventually develops into another individual or another equivalent part of a colony

Bull—a male seal or whale, especially an adult male

Buoy—a bright-colored float attached by rope to the seabed to mark channels in a harbor or underwater hazards

Bycatch—any species caught in a fishery, but which are not sold or kept for personal use; includes economic and regulatory discards

Calanoids—most numerous in size and species of planktonic copepods

Calcareous—containing calcium carbonate

Caldera—a type of volcanic crater that is extremely large (over one mile in diameter), usually formed by the collapse of a volcanic cone or by a violent volcanic explosion

Calf—a young animal dependent on its mother

Callosity—a patch of thickened, keratinized tissue on the head of a right whale, inhabited by large numbers of whale lice

Calving—the process of giving birth by a whale, dolphin, porpoise, or manatee

Calving interval—the period of time from one birth to the next, generally applicable to cetaceans

Calyx—one of two outermost whorls of a flower

Canopy—a fairly continuous layer in forests produced by the intermingling of branches of trees

Cape—a darker region on the back of many species of dolphins and small whales, generally with a distinct margin

Carangids—a percoid fish of the family Carangidae

Carapace—the outer covering of the back of a sea turtle, which is bony for all sea turtle species with the exception of the leatherback, which has a leathery covering

Carbonate—type of rock or sediment formed of carbonate (CO_3^{-2}) and another element such as calcium or magnesium; limestone and dolomite are common carbonate rocks

Caridean shrimp—a caridoid decapod crustacean with phyllobranchiate gills, second abdominal pleura forming a caridean saddle, and usually two pairs of chelae but never three

Carbonate compensation depth—depth at which almost all carbonate dissolves, approximately 4,000 to 5,000 m

Carnivore—an animal that feeds exclusively on another animal's tissue

Carrion—dead and rotting body of an animal

Carrying capacity—the theoretical maximum number of individuals an environment can support

Catch per unit effort (CPUE)—measure of a species relative abundance

Cephalopods—any marine mollusk of the class Cephalopoda, with the mouth and head surrounded by tentacles (squid, octopus, cuttlefish)

Cetaceans—whales, dolphins, and porpoises

Chaetodontids—fishes comprising two major circumtropical reef-associated families, butterflyfishes and angelfishes

Chaetognaths—known as arrowworms that are active elongated, transparent predators in marine plankton

Charter fishing—fishing from a vessel carrying a passenger for hire (as defined in Section 2101[21a] of Title 45, U.S.C.) who is engaged in recreational fishing

Cheloniidae—the family of hard-shelled sea turtles that includes the green, hawksbill, Kemp's ridley, Olive ridley, and loggerhead turtles

Chemosynthesis—the formation of organic compounds from inorganic substances using energy derived from oxidation

Chevron—a V-shaped stripe

Chimeras—a deep-sea cartilaginous fish of the Family Chimaeridae having a smooth-skinned tapering body and a whip-like tail

Chitons—marine mollusks of the Order Polyplacophora that consist of long oval bodies covered by calcareous plates which are partially or totally covered by thick, bristly girdle; lives on rocks

Chlorophyte—green algae

Chlorophyll a (chl a)—a green pigment plants use to harness the energy in sunlight

Circumglobal—the distribution pattern displayed by organisms around the world, within a range of latitudes

Circumpolar—ranging all the way around high northern or southern latitudes

Circumtropical—organisms which occur around the tropics of the world (land or sea)

Cladocerans—order of microscopic crustaceans with trunk limbs enclosed in a carapace used for feeding and antennae used for swimming; called water fleas

Clasper—a copulatory organ along the inner edge of each pelvic fin in male sharks and other cartilaginous fish

Click—a broad-frequency sound used by toothed whales for echolocation and which may serve a communicative function; usually with peak energy between 10 kHz and 200 kHz

Clutch—a total number of eggs from one nesting

Cnidarians—the phylum of animals that includes corals, sea fans, sea anemones, hydroids, and jellyfish; known for the stinging cells on their tentacles; these animals exhibit two body types, polyps (may be attached or planktonic) or medusa, sometimes at different periods of one species development

Coast—where land and water meet

Coastal water—water that is along, near, or relating to a coast

Cochlea—a spiral bony structure in the inner ear that looks like a snail shell and contains over 10,000 tiny hair cells, which are the receptor organs essential for hearing and that bend in response to sound waves, the bending of the hair cells in stimulates nerve cells to send messages to the brain, which the brain interprets as sound

Coda—a patterned series of 3 to 20 clicks lasting about 0.5 to 2.5 sec, used by sperm whales for communication

Cold-core ring—an eddy or circular current of warm water; in the North Atlantic Ocean, the water in cold-core rings circulates cyclonically (counterclockwise)

Cold-stunning—the behavior exhibited by sea turtles in response to cold water temperatures; turtle becomes lethargic and adopts a stunned floating posture

Colonial—nesting in groups or colonies rather than in isolated pairs

Colony—highly integrated group of animals; herein refers specifically to birds and land-breeding pinnipeds

Commensal—relationship between two organisms of different species in which one benefits and the other neither benefits nor is harmed

Commercial fishing—the stock of fisheries where fish and other seafood resources are taken for the purpose of marketing them

Common—in the case of sea turtles, common means that sea turtles have been recorded in all, or nearly all, proper habitats, but some areas of the presumed habitat are occupied sparsely or not at all and/or the region regularly hosts large numbers of the species

Community—an association of different species living together at the same time in a defined habitat with some degree of mutual dependance

Concentrated occurrence—a subarea of a species' expected occurrence, where there is the highest likelihood of encountering that species; based primarily on concentrated sightings and habitat preference

Conspecific—member of the same species, and in many cases, the same age or even sex

Conservation—the careful and sensible management of natural resources

Contaminant—any naturally occurring substance whose concentrations have been increased as a result of human activity

Continental margin—the boundary or transition between the continents and the ocean basins that consists of the physiographic provinces of the continental shelf, continental slope, and continental rise

Continental rise—the province of the continental margin with a sloping seabed (1:100-1:700 gradient change) and a generally smooth surface, which lies between the abyssal plains and continental slope

Continental shelf—the province of the continental margin with a gently seaward-sloping seabed (1:1,000 gradient change) extending from the low-tide line of the shoreline to 100 to 200 m water depth where there is a rapid gradient change

Continental shelf break—the area where the slope of the seabed rapidly changes from gently sloping (1:1,000) to steeply sloping (1:40) where the continental shelf transitions into the continental slope

Continental slope—the province of the continental margin with a relatively-steeply sloping seabed (1:6 to 1:40 gradient change) that begins at the continental shelf break (usually around 100 to 200 m) and extends down to the continental rise; along many coasts of the world, the slope is furrowed by deep submarine canyons

Contour—a line of connected points of equal value on a surface

Convention on International Trade in Endangered Species [of Wild Fauna and Flora] (CITES)—is an international agreement between governments. Its aim is to ensure that international trade in specimens of wild animals and plants does not threaten their survival

Coordinate system—set of numbers used to assign a location in a given reference system (x and y in a planar coordinate system and x, y, and z in a 3-D coordinate system); a pair of coordinates represents a location on the earth's surface relative to other locations

Copepods—very small planktonic crustaceans present in a wide variety and great abundance in marine habitats, forming an important basis of ecosystems; they are a major food of many marine animals and are the main link between phytoplankton and higher trophic levels

Coral bleaching—the release of the symbiotic colored algae normally living within coral animals, which occurs when coral animals are stressed (by high temperatures, for example) and makes the coral appear whites

Coral boomies—coral outcroppings

Coral patches—rocky outcrops colonized by sessile organisms including hard coral, soft corals, hydroids, algae, and sponges

Coral polyps—are small marine animals with a tube-shaped body with a mouth which is surrounded by tentacles; polyps can be either solitary or colonial

Coral reef—a massive, wave-resistant structure built largely by colonial, stony coral via deposition of calcium carbonate

Coral reef ecosystem (CRE)—those species, interactions, processes, habitats and resources of the water column and substrate located within any waters less than or equal to 50 fathoms (100 m) in total depth

Coral reef ecosystem management unit species (CRE MUS)—an extensive list of coral reef organisms; includes some management unit species from existing fishery management plans (bottomfish, crustaceans, precious corals) for which primary management would remain under their current fishery management plans but ecosystem effects would be addressed by the CRE FMP. CRE MUS are listed into two categories: CHCRT and PHCRT

Coralline algae—family of red algae (Corallinaceae) having bushy or encrusting form and deposits of calcium carbonate either on branches or as crusts in the substrate

Cosmopolitan—having a broad, wide-ranging distribution

Countershading—a form of camouflage exhibited by many fish and cetaceans, with dark upper body surfaces and lighter undersides. When viewed from above the darker dorsal surface blends in with the water; from below the lighter ventral surface matches the light coming from the sky, making the animal hard to see

Courtship—behavior related to the attraction of the opposite sex and mating

Coverts—small feathers that cover the basis of other, usually larger, feathers and provide a smooth, aerodynamic surface

Crepuscular—appearing or active at twilight

Crinoid—class of sessile echinoderms commonly called sea lilies and feather stars; these animals have a cup-shaped body that attaches to the substratum by a stalk (sea lilies) and have feathery arms

Critical habitats—the portion (minimum) of the habitat that is essential for the survival of threatened and endangered species and may include areas essential for feeding or reproduction by those species

Critically Endangered Species (IUCN Red List)—a species that is considered to be facing an extremely high risk of extinction in the wild

Crust—the outer shell of the planet. It is composed of sedimentary, metamorphic, and igneous rock

Crustaceans—arthropods that have two pairs of antennae and a hard exoskeleton; lobster, shrimp, and crabs are the most familiar examples

Crustose—having a thin crusty thallus that adheres closely to the surface on which it is growing

Cryptic—hidden; living in holes, caves, burrows

Cryptofauna—cavity-dwelling organisms

Curios—objects valued for their rarity or unusualness

Currently harvested coral reef taxa (CHCRT)—a sub-category of MUS including species that have been reported on commercial fishery catch reports for federal EEZ waters but are not MUS under any the Council's already-implemented FMPs; membership in this group is based on two criteria: (1) more than 1,000 lbs (454.54 kg) annual harvest for all members of a taxon (families or subfamilies) based on commercial fishery catch reports and (2) within these taxa particular genera or species are identified based on their appearance on catch reports

Curved carapace length (CCL)—the length of a sea turtle's carapace measured by researchers working on nesting beaches with a flexible tape measure

Cuttlefish—marine mollusk of the Class Cephalopoda that has 10 arms including two long tentacles it can draw back into its body

Cyanobacteria—large and varied group of bacteria that possesses chlorophyll a and carries out photosynthesis in the presence of light and air, with concomitant production of oxygen; formerly regarded as blue-green algae; may produce harmful algal blooms in low-salinity systems with excessive nutrients

Cyclone—a large-scale circulation of winds around a central region of low atmospheric pressure, counterclockwise in the Northern Hemisphere, clockwise in the Southern Hemisphere

Cyclonic—counterclockwise circulation in the Northern Hemisphere or clockwise in the Southern Hemisphere; in oceanography, synonymous with cold-core ring

Data deficient species (IUCN Red List)—a species for which there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status; a species for which appropriate data on abundance and/or distribution are lacking

Datum—set of parameters and control points used to define the three-dimensional shape of the earth and which defines part of a geographic coordinate system that is the basis or backbone for a planar coordinate system

Decapod—order of freshwater, marine, and terrestrial crustaceans having five pairs of legs on the thorax and a carapace completely covering the throat (e.g., shrimps, crabs, lobsters)

Decibel (dB)—a logarithmic measure of sound strength; it is a ratio of intensity (pressure) at reference range compared with a reference level; in air, the reference pressure is 20 µPa and the reference range is 1 m, while for underwater sound, the reference is 1 µPa and the reference range is also at 1 m

Deep-scattering layer—a layer of dense aggregation of fishes, squid, and other species found at depth that migrate vertically in the water column each day; the layer of organisms moves toward the surface at night to feed and returns to depth at dawn

Deepwater—the area of the ocean that is past the continental shelf break, deeper than 100 to 200 m of water

Defoliate—to deprive of leaves especially prematurely

Delayed implantation—in mammals it is the suspended development of an embryo between shortly after conception and subsequent attachment (implantation) to the uterine wall

Delimitation—fixing a boundary

Delphinus—it is the genus of oceanic dolphins consisting of short-beaked and long-beaked common dolphins, which are similar in appearance

Demersal—applied to fish that live close to the seafloor, such as cod and hake

Demosponges—largest and most complex group of siliceous and horny sponges; includes forms with needle-shaped or four-branched siliceous spicules, which may or may not be sported by spongin

Demography—birth and death rates that determine a population's dynamics; abundance, age, and sex structure of the population and reproductive status and life cycle of individuals

Density—physical property measured by mass per unit volume; in biology, the number of organisms per unit of distance

Deposit feeders—an animal that feeds on organic matter that settles on the bottom

Dermal denticles—tiny flat V-shaped scales present on sharkes and rays that are more like teeth than fish scales

Dermochelyidae—the family of sea turtles that includes only one species, the leatherback turtle

Desiccation—removal of water, dehydration; the process of drying

Developmental habitat—an environment crucial to the growth of late-stage juvenile animals; for some sea turtles, this environment can be a shallow, sheltered habitat where forage items such as seagrasses, sponges, mollusks, and crustaceans are abundant

Diandric—possessing two different types of males, a large, brightly-colored and aggressive terminal phase and a smaller drab and relatively non-aggressive initial phase (e.g., wrasses)

Diatoms—microscopic algae (Bacillariophyceae) in which the cell wall (frustule) is composed of silica and consists of two major valves and girdle bands; unicellular, colonial, or filamentous; important components of freshwater and marine habitats as members of both planktonic and benthic communities; comprised of two major types based on symmetry: pennate – bilateral, centric – radial; forms the primary food base for marine ecosystems; may produce harmful algal blooms in marine habitats (domoic acid producing *psuedo-nitzschia*)

Diel—refers to 24-hour activity cycle based on daily periods of light and dark

Digitize—encoding geographic features into a digital geographically referenced form

Dimorphic—having two different forms

Dinoflagellates—microscopic single-celled plant of the Class Pyrrhophyceae that has two flagella, one propelling water to the rear and providing forward motion, attached just behind the center of the body and directly posteriorly, the other causing the body to rotate and move forwards, forming a transverse ring or spiral of several turns around the center of the body; some are naked, others are covered with a membrane or plates of cellulose; often abundant; dense growths may produce luminescent bays and harmful algal bloom in freshwater and marine habitats (*Alexandria*)

Dioecious—pertaining to an organism in which male and female reproductive systems are in different individuals

Dispersal—spreading of individuals throughout suitable habitat within or outside the population range. In a more restricted sense, the movement of young animals away from their point of origin to locations where they will live at maturity

Display—any behavior that conveys information, usually to members of the same species or to predators; often used during mating or territory defense

Dissolved organic matter (DOM)—is dissolved and colloidal organic material that passes through a filter with a mesh size of between ~0.1 and 1 microns; dissolved organic carbon is the carbon component of the DOM

Distinct population segment—a population segment of fish, wildlife, or plants that is “discrete” (i.e., separated from other populations of its species or subspecies) and “significant” (i.e., essential to the long-term conservation status of its species or subspecies)

Distribution—see “Range”

Diurnal—active or occurring during daylight hours; having a daily cycle

Dominant species—species most prevalent in a particular community, or at a given period

Dorsal—relating to the upper surface of an animal

Downwelling—downward movement or sinking of surface water towards the ocean bottom; may be caused by convergent currents or density differences

Dredge spoils—materials dredged out of an area

Drift net—a monofilament gillnet set at or near the surface that stretches up to 60 km or more in length, used passively (drifts) to entangle fish or invertebrates, which also catches a large number of non-target species, including marine mammals and sea turtles

Drive fishery—small cetaceans (such as pilot whales) are maneuvered into a confining situation where they are either entrapped or immediately driven ashore and killed

Dry season—the period extending from January through June in tropical climates. The dry season is characterized by steady tradewinds and low rainfall

Echinoderms—phylum of marine invertebrates with radial symmetry, a calcareous endoskeleton, and a water vascular system; sea stars and sea urchins are common examples

Echinoid—referring to echinoderms, e.g., sea urchins and sand dollars

Echiuroids—unsegmented marine worms with one or more pairs of bristles; live in sand or rock crevices intertidally or in shallow water

Echolocation—the production of high-frequency sound waves and reception of echoes to locate objects and investigate the surrounding environment

Ecology—the study of the interactions of organisms with their environment and with each other

Ecosystem—a system of ecological relationships in a local environment comprising both organisms and their nonliving environment, intimately linked by a variety of biological, chemical, and physical processes

Ecosystem services—important environmental benefits that ecosystems provide to people, including clean air to breathe, clean water to drink, and fertile soil in which to grow crops

Eddy—the circular movement of water

Elasmobranch—fishes of the class Chondrichthyes that are characterized by having a cartilaginous skeleton; includes sharks, skates, and rays

Eelgrass—vascular flowering plants of the Genus *Zostera* that are adapted to living under water while rooted in shallow sediments of bays and estuaries

El Niño—periodic movement of warmer than usual water in the southeastern Pacific Ocean towards the west coasts of the Americas; typically occurs in December or January and is the result of the Southern Oscillation

El Niño/Southern Oscillation (ENSO)—the climatic phenomenon that causes changes in wind and current patterns (reversal of the Pacific equatorial currents) that leads to changed ocean temperatures and weather patterns over vast distances; leads to the disruption of coastal upwelling and die-offs of plankton, fish, sea birds, and marine mammals

Elliptical—rounded like an egg

Embayment—an indentation in the shoreline that forms a bay

Embryo—an organism in early stages of development, before hatching from an egg

Encrusting—form a crust or a hard layer

Endangered species (ESA)—any animal or plant species in danger of extinction throughout all or a significant portion of its range; the authority to list a species is shared by the USFWS (plants and animals on land) and NMFS (most marine species) under provisions of the ESA (Endangered Species Act)

Endangered species (IUCN Red List)—a species that is considered to be facing a very high risk of extinction in the wild

Endemic—occurring in a specific area

Endemic species—species native and confined to a certain region and having restricted distribution (i.e., a species unique to a place, found naturally nowhere else

Endocrine disruptor—a chemical that interferes with the actions of the endocrine system. Including certain plastics such as polycarbonate; chlorine compounds such as PCBs and dioxin; the heavy metals lead and mercury; and some pesticides such as DDT, keptone, chlordane, and endosulfan

Endolithic—living inside rock

Energy flux density—the average rate of sound energy flow per area for one period

Entrainment—the process of picking up and carrying along

Environmental impact statement (EIS)—a detailed written statement that helps public officials make decisions that are based on understanding of environmental consequences and to take actions that protect, restore, and enhance the environment

Epibenthic—refers to organisms living on the ocean floor

Epicontinental waters—shallow waters which occupy wide portions of continental shelf

Epifauna—animals living on the surface of the ocean floor; any encrusting fauna

Epipelagic—the oceanic zone from the surface to 200 m

Epizoically—living on the surface of another organism

Equatorial—of or existing at or near the geographic equator

Equidistant line or equidistance—a median line, every point of which is the same distance from the nearest points on the baselines of two countries

Equilibrium—the state of a system in which no further net change is occurring; the free energy is at a minimum

Essential fish habitat (EFH)—those habitats necessary to fish for spawning, breeding, feeding, or growth to maturity; designated by the NMFS

Estuary—a semi-enclosed body of water where freshwater mixes with saltwater; often an area of high biological productivity and important as nursery areas for many marine species

Erosion—in hydrologic terms, wearing away of the lands by running water, glaciers, winds, and waves, can be subdivided into three process: Corrosion, Corrosion, and Transportation. Weathering, although sometimes included here, is a distant process which does not imply removal of any material

Euphausiids—known as krill, these are pelagic shrimp-like crustaceans

Euphotic zone—the uppermost area of the ocean (up to 150 m) that is sufficiently illuminated to permit photosynthesis by phytoplankton, algae, and submerged aquatic vegetation

Eurybathic—an organism that can tolerate of a wide range in depth

Euryhaline—an organism that can tolerate living in waters with a wide range of salinity

Eurythermal—an organism that can tolerate a wide range of temperatures

Eutrophication—the process by which nutrient-rich water promotes a rapid growth of algae and phytoplankton, which reduces the water's dissolved oxygen content

Exclusive Economic Zone (EEZ)—all waters from the low-tide line outwards to 200 NM (except for those that are close together, i.e., Mediterranean countries) in which the inner boundary of that zone is a line coterminous with the seaward boundary of each of the coastal states; the country has the power to manage all natural resources

Existence value—value that individuals may attach to the mere knowledge of the existence of something, as opposed to having direct use of that thing; synonymous with non-use value

Exogenous—originating or produced outside the body

Expected occurrence—an area encompassing the expected distribution of a protected species that is indicative of where one would expect to encounter that species; areal designation of this occurrence estimate is based on sightings per unit effort (SPUE) data for all years of line-transect surveys averaged by season and this category is representative of the middle half or two quartiles of the SPUE data frequency distribution

Extant—a group with all or some living members; as opposed to extinct

Extent—coordinate pairs that define the rectangular boundary (xmin, ymin and xmax, ymax) of a data source and in which all the coordinates for that data source fall

Extirpated—species that no longer exists in the wild

Extralimital—outside the normal limits of an animal's distributional range

Extrapolate—to estimate a value that falls outside a range of known values

Extreme high tide—flooding associated with extremely large tides and during storm surges or wind-driven tidal inundations

Falcate—sickle-shaped and curved (refers to the dorsal fin of some cetaceans)

False crawl—an abandoned sea turtle nesting attempt or simply a U-shaped crawl from the ocean up the beach, and then back to the water

Fathom—a marine unit of measure of water depth equaling 1.83 m

Fauna—animal life of a region

Fecundity—the potential of an organism to produce offspring (measured as a number of gametes)

Fish aggregating device (FAD)—single or multiple floating structures that are connected to the ocean floor by ballast or anchors; used to attract fish

Fishery—one or more stocks of fish that can be treated as a unit for purposes of conservation and management and that are identified on the basis of geographical, scientific, technical, recreational and economic characteristics, and any fishing for such stocks

Fishery management plan (FMP)—plan prepared by a Regional Fishery Management Council or by NMFS (if a Secretarial plan) to manage fisheries

Fission—reproduction of some unicellular organisms by division of the cell into two more or less equal parts

Fissiped—refers to animals in the Order Carnivora other than the pinnipeds (for example, otters)

Fjord—a deep, steep-walled, U-shaped valley formed by erosion by a glacier and submerged with seawater

Flank—side of the body; used mainly to refer to the side of the posterior half of the body

Flatfish—members of the fish order Heterosomata which swims or lies on one side of its body; sides are greatly flattened and compressed; mainly marine animals (e.g., flounders, soles)

Fledging—the moment of flying at the end of the nesting period when young birds are more or less completely feathered

Flipper—the flattened forelimb of a marine mammal

Flora—all the plant species of a given area

Flotsam—parts of a wrecked ship and goods lost in a shipwreck

Flukes—the horizontally spread tail of a cetacean or dugong

Foliose—leaflike

Forage—search for food

Foraminiferan—planktonic or benthic protozoan that possesses protective coverings usually composed of calcium carbonate

Fore-arc—referring to the region ahead of the island arc (the convex side of the arc)

Fore reef—area from the seaward edge of the reef crest that slopes into deeper water to the landward edge of the bank/shelf platform. Features not forming an emergent reef crest but still having a seaward-facing slope that is significantly greater than the slope of the bank/shelf are also designated as fore reef

Fragmentation—type of asexual reproduction where a thallus breaks into two or more parts, each of which forms a new thallus

Fringing reefs—reefs made of corals that grow on hard surfaces of rocky shores below the lowest tide mark. These reefs follow shorelines at a close distance

Front or **frontal**—see "ocean front"

Fundamental frequency—the lowest frequency of a harmonic series; measured in the Hz (cycles per second)

Fusiform—spindle-shaped or torpedo-shaped and tapering at one or both ends

Gadids—members of the Family Gadidae which includes Pacific cod and hake

Galatheid crabs—deep sea scavenging crabs found in abundance around hydrothermal vents, cold seeps, and whale falls

Gametes—mature egg or sperm, capable of reproduction after fertilization with sperm or egg from same species

Gangions - one of the short lengths of moderate-weight line that bear hooks and are attached at regular intervals to a longline

Gape—the mouth in cetaceans, usually referring to the junction of upper and lower lips

Gastropods—class of symmetrical, univalve mollusks that have a true head, an unsegmented body, and a broad, flat foot

Gemmules—group of overwintering amoebocytes covered by a hard outer covering; asexual reproductive method in sponges

Genera—one of taxonomic or scientific classifications of plants and animals

Geochemical processes—processes affecting the amount, distribution, or structure of chemical elements in air, water, soil, rocks, and minerals

Geographic coordinate system—reference system of latitude and longitude that defines the locations of points on the surface of a sphere or spheroid

Geographic coordinates—location on the earth's surface expressed in degrees of latitude and longitude

Geographic Information Systems (GIS)—a computer-based graphics program that allows the superposition of plan-maps of thematic elements, such as roads, rivers, land use patterns, and the like to aid in local or regional planning activities

Georges Bank—an immense oval-shaped bank (28,000 km^2 in size) that lies 120 km off the coast of southern New England

Gestation—period of development in the uterus from conception until birth (pregnancy)

Gestation period—period of development of an embryo within the uterus of a viviparous animal from conception to birth

Gillnet—a type of fishing gear made of rectangular mesh panels that are set more or less vertically in the water so that fish swimming into it are entangled by their gills; they can be set to fish at the surface, midwater, or on the bottom of the water column

Gorgonians—any of the various corals, such as sea fans, in the order Gorgonacea

Grapsoid—crabs pertaining to the genus Grapsus or of the family Grapsidae

Grazer—an organism that feeds primarily on plants

Great whales—typically refers to all the baleen whales plus the sperm whale

Green algae—division of algae (Chlorophyta) consisting of plankton and benthic forms occurring widespread in both marine and freshwater habitats; marine species are primarily macroscopic forms frequently attached to rocks, wood, pilings, or larger algae or grow on sandy bottoms on shells in quiet estuaries; consist of motile and nonmotile types; may be unicellular, colonial, filamentous, membranous (e.g., sea lettuce), and tubular

Gregarious—used to describe animals that form social groups

Groundfish—group of fishes that spend most of their lives on or near the ocean floor (e.g., cod, haddock, hakes, and flounders); also known as demersal species

Gulf of Maine—large semi-enclosed basin (90,700 km^2 in size) that is situated between northern New England (Maine, New Hampshire, and northern Massachusetts) and western Nova Scotia

Gyre—circular movement of waters, larger than an eddy; usually applied to oceanic systems

Habitat—the living place of an organism or community of organisms that is characterized by its physical or living properties

Habitat area of particular concern (HAPC)—discrete areas within essential fish habitat (EFH) that either play especially important ecological roles in the life cycles of federally managed fish species or are especially vulnerable to degradation from fishing or other human activities

Habitat preference—the choice by an organism of a particular habitat in preference to others

Hadley circulation—the process in which warm air rises from the surface, travels away from the equator, cools, and sinks back to the surface of the Earth

Haermic—pair spawning

Halophyte—a plant that grows in soils that have a high content of various salts

Handgear—term used for type of fishing gear that are mainly operated by hand including harpoons, handlines, rods and reels

Hard coral—see hermatypic coral

Hardbottom—area of the sea floor, usually on the continental shelf, associated with hard substrate such as outcroppings of limestone or sandstone that may serve as attachment locations for organisms such as corals, sponges, and other invertebrates or algae

Harem—a group of females whose breeding is controlled by a single male who seeks to prevent other males from breeding with them

Harmful algal blooms (HABs)—a bloom on algae that produces toxins potent enough to poison both aquatic and terrestrial organisms in freshwater and marine waters affected by a complex set of physical, chemical, biological, hydrological, and meteorological conditions

Haru Ischiban—first strong southerly wind that signals the onset of spring

Hatchling—a newly hatched bird, amphibian, fish, or reptile

Haul out—the process by which pinnipeds crawl or pull themselves out of the water onto land

Haulout—intertidal rock outcrops, sandbars, shoals, mudflats, or sandy beaches where marine animals, such as pinnipeds, periodically and purposefully come ashore

Haven—refuge or sanctuary

Hectare—a measurement of land area and is equivalent to 0.01 square kilometers

Herbivore—an animal that eats plants as its main source of energy

Herbivorous—feeding on plants; phytophagous; protozoans that feed on bacteria and/or algae

Hermaphroditic—having both sexes in the same individual, either at the same time or at different times

Hermatypic coral—reef-building coral containing symbiotic, unicellular zooxanthallae in their endodermal tissue; usually colonial, may be solitary, found in shallow, warm, sunlit waters

Hexacorals—coral distinguished by hexameral symmetry; scleractinian

High tide—the highest level to which the tide rises within the daily tidal cycle

Himeumigame—Japanese for olive ridley turtle

Holdfast—the algal (seaweed) equivalent of roots that attaches the organism to a surface or the seafloor

Hybrid—the offspring resulting from a cross between two species

Hydric soil—soils that are saturated or flooded long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation

Hydrocarbon—organic compounds composed entirely of carbon and hydrogen atoms

Hydrographic—used with reference to the structure and movement of bodies of water, particularly currents and water masses

Hydrography—the science of measuring and describing the surface waters of the Earth

Hydroids—class of solitary or colonial coelenterates that have a hollow cylindrical body closed at one end with a mouth surrounded by tentacles at the other end

Hydrophone—transducer for detecting underwater sound pressures; an underwater microphone

Hydrothermal vent—location on the ocean floor in which water percolates down through fractures in recently formed ocean floor, is heated by underlying magma, and surfaces through chimneys. Hydrothermal vents are usually located near the axis of spreading on ocean ridges and rises

Hydrozoans—delicate marine animals usually in clusters or colonies of the phylum Coelenterata; individual polyps are encased in gelatinous cups and often secrete coral as supporting structures; highly branched polyp or hydroid stage of many members is important component of fouling

Hypersaline—having more salt than normal sea water

Hypoxia—low dissolved oxygen concentrations that occur in many bodies of water when nutrients stimulate the growth of algae that subsequently die and are decomposed by oxygen-using bacteria. Hypoxia often causes too little oxygen for other aquatic life

Ice floe—a large mass of sea ice (pack ice) kept in motion by winds, currents, and wave action

Ichthyofauna—all fish that live in a particular area

Ichthyoplankton—fish eggs and larvae drifting in the water column

Immature—not fully grown or developed; not yet capable of reproducing

Indo-Pacific—the area of the Indian and western Pacific oceans

In situ—in the natural or original position

Incidental fisheries bycatch—the catch of additional species, such as fishes, turtles, or marine mammals, that are not targeted by a fishery but are harvested in addition to the target or sought after species

Incubation—the act of keeping an egg warm so that development is possible

Indigenous species—a species ***native*** to a place or biota

Indo-Pacific—widespread species with western limit west of the Andamans and eastern limit east of non-marginal areas of the Pacific Plate

Indo-Pan Pacific—species found throughout the Indo-Pacific

Indo-West Pacific—widespread species with northeastern limit on the Pacific Plate marginally in the Carolines, but not reaching the Marshalls

Infauna—organisms that live buried in the soft substrate (sand or mud)

Infrasonic—sound at frequencies too low to be audible to humans, generally below 20 Hz

Inshore—lying close to the shore or coast

Insular—pertaining to or situated on an island

International Union for Conservation of Nature (IUCN) Red List—system for classifying species at high risk of extinction

Inter-nesting interval—the amount of time between successive sea turtle nesting events during the nesting season

Interpolate—extrapolation to predict values for a parameter between limited data points

Interstitial—pertaining to, or occurring within, the pore spaces (interstices) between sediment particles

Intertidal—the area of shore exposed between high and low tide

Invasive species—Ability of a species to spread beyond its introduction site and become established in new locations where it may provide a deleterious effect on organisms already existing there

Irradiance—the density of radiation incident on a given surface usually expressed in watts per square centimeter or square meter

Irruptive—entering an area where not characteristically seen

Islet—a small island

Isobath—bathymetric contour of equal depth; usually shown as a line linking points of the same depth

Isopods—shrimp-like animals of the Order Isopoda that have their body flattened dorso-ventrally

Isotherm—contour of equal temperature; usually shown as a line linking points of the same temperature

Isthmus—a narrow strip of land connecting two larger land areas

Juvenile—mostly similar in form to adult but not yet sexually mature; a smaller replica of the adult

Karstic—Substrate having the properties of karst (limestone substrate characterized by sinks, ravines, and subterranean streams)

Kelp—usually large blade-shaped or vinelike brown algae of the Order Laminariales that typically grows on rock or stony bottoms (i.e., giant kelp, bull kelp, etc.)

Kelp holdfast—a branched, modified stem that attaches kelp to rocks or other hard substrata

Keystone species—a species that is crucial in determining the nature and structure of the entire ecosystem in which it lives; other species of a community depend on or are generally affected by the keystone species, whose influence is much greater than would be expected by its relative abundance

Kilopascal (kPa)—standard unit of pressure in the International System of measurements

Kogia—the genus comprised of the pygmy sperm whale (*Kogia breviceps)* and dwarf sperm whale (*Kogia sima*)

Krill—known as euphasiids, these are pelagic shrimp-like crustaceans

Kuroshio—the fast-flowing western boundary current of the North Pacific subtropical gyre

Kuroshio current—fast ocean current flowing northeastward from Taiwan to Ryukya Islands and close to coast of Japan to about 150° East

La Niña—when ocean temperatures in the eastern equatorial Pacific are unusually cold; it is essentially the opposite of the El Niño phenomenon; La Niña sometimes is referred to as the cold phase of an El Niño/Southern Oscillation (ENSO) event

Labroids—coral reef fishes comprising the families of parrotfishes, damselfishes, and wrasses

Lactation—secretion or formation of milk by the mammary glands for the purpose of nursing offspring

Lagoon—a shallow stretch of seawater partly or completely separated from the open ocean by an elongated, narrow strip of land such as a reef or barrier island

Lagoon reefs—area enclosed by the low tide line to the inner edge of the atoll reef flat; often contains numerous patch reefs

Lair—a resting place used by an animal; often for giving birth, nursing young, or hibernating; den

Lancetfish—large elongate scaleless oceanic fish with sharp teeth and a long sail-like dorsal fin of the Family Alepisauridae

Lanternfish—small, usually deep sea fish with many luminescent spots on their bodies of the Family Myctophidae

Larval—young fish between time of hatching and attainment of juvenile characteristics

Leads—long narrow channels of open water in the sea ice which form between pack ice and the shore

Least Concern species (IUCN Red List)—a species that does no qualify for Critically Endangered, Endangered, Vulnerable, or Near Threatened status since it is widespread and abundant
Lee—the side (as of a ship) that is sheltered from the wind

Leptocephalic—small, elongate, transparent, planktonic larva of eel

Limestone—rock that is formed chiefly by accumulation of organic remains (as shells or coral), consists mainly of calcium carbonate, is extensively used in building, and yields lime when burned

Lineage—trace the flow of genetic information from generation to generation

Lithified—turned to stone

Littoral—the zone or division of the ocean bottom that lies between the high and low tide lines; intertidal

Live bottom community—a concentration of benthic invertebrates and demersal fishes that is associated with a region of vertical relief and structural complexity that can be organic (e.g., coral skeletons) and inorganic (e.g., rocks) in origin; such oasis-like communities are often surrounded by expanses of bottom with little relief or structure

Live rock—any natural, hard substrate (including dead coral or rock) to which is attached, or which supports, any living life-form associated with coral reefs

Longitudinal fission—asexual division of new polyps within the same coral head

Longline—a type of fishing gear using a buoyed line onto which are attached numerous branch lines each terminating in a baited hook; longlines may extend for tens of kilometers and are usually left to drift in surface waters or near the seafloor

Lost year—the early juvenile stage (first years of life) of most sea turtle species that is spent far offshore; few turtles are observed during this time

Low/unknown occurrence—an area where the likelihood of encountering a species is rare or not known

Low tide—the lowest level to which the tide ebbs within the daily tidal cycle

Lunge feeding—a batch feeding method employed by some baleen whales, in which the animal lunges through swarms of small prey, taking a great mouthfuls of prey and water

Macroalga—classification of multicellular algae consisting of red, green, or brown species that are defined according to the size of the plant where the body of the plant is large enough to be observable to the human eye and project more than one centimeter above the substratum

Macrobenthic—organisms that live on the bottom of a water body (or in the sediment) on the surface of bedforms (e.g. rock, coral or sediment-epibenthos) or within sedimentary deposits (infauna), that are >50 cm in length

Macrofauna—animals larger than 500 µm

Macroflora—Aquatic plants large enough to be seen with the unaided eye. The most common macrophytes are rooted vascular plants that are usually arranged in zones in aquatic ecosystems and restricted by light and sediment deposition along the shoreline

Macrophyte—Aquatic plants large enough to be seen with the unaided eye. The most common macrophytes are rooted vascular plants that are usually arranged in zones in aquatic ecosystems and restricted by light and sediment deposition along the shoreline

Macroplankton—large planktonic organisms, 2 to 20 cm in size

Macroscopic algae—large algae, commonly referred to as seaweed

Magma—fluid rock material from which igneous rock is derived through solidification. It can intrude into crevices and fissures as it upwells through the crust

Malacological—branch of zoology that deals with mollusks

Mandible—the lower jaw bone

Mangrove—a variety of salt-tolerant trees and shrubs that inhabit the intertidal zones of tropical and subtropical regions; tropical equivalent of salt marshes

Mantle—the zone between the core and the crust of the Earth. It comprises the bulk of the Earth

Map projection—a mathematical formulation that transforms feature locations on the Earth's curved surface (three-dimensional) to a map's flat surface (two dimensions)

Marine debris—is any manufactured or man-made solid material that enters the coastal or marine environment

Marine managed area—any area of the marine environment set aside by federal, state, local, or tribal governments to protect geological, cultural, or recreational resources and which currently may not be protected as marine protected areas; marine managed areas encompass a broader spectrum of management purposes than marine protected areas

Marine protected area—any area of the marine environment reserved by federal, state, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources within the area

Mass stranding—the simultaneous stranding of two or more animals (excluding mother and calf/pup) of the same species in the same area

Masking—obscuring of sounds of interest by interfering sounds, generally at similar frequencies

Mean—(arithmetic) average

Mean high tide—the average of all the high tides as calculated over a long period of time

Mean higher high tide—the arithmetic average of the elevations of the higher high waters of a mixed tide over a specific 19 year period. For shorter periods of observation, corrections are applied to eliminate known variations and reduce the result to the equivalent of a mean 19 year interval

Mean higher high water (MHHW)—average height of all daily higher high waters recorder over 19 year period, or computed equivalent period

Median—(arithmetic) the middle number in a set of data when it is calculated from lowest to highest; it is an indicator of central location in a dataset

Medusa—free-swimming, sexually mature form of coelenterates; umbrella- or bell-shaped; swims by pulsations of its body; tentacles and sense organs are located at edge of bell

Melon—a fatty cushion forming a bulbous "forehead" in toothed whales; may act to focus sound for echolocation

Mesopelagic—occurring in the oceanic zone from 200 to 1,000 m

Mesoplodon—a genus of beaked whales, which includes the Blainville's beaked whale, Ginkgo-toothed beaked whale, Hubbs' beaked whale, Perrin's beaked whale, and pygmy beaked whale

Mesoscale—large scale

Metabolism—all biochemical reactions that take place in an organism

Metadata—information about geospatial data (such as GIS shapefile or coverage file) that describes the source of the data or information, the creation date, the data format, the projection, the scale, the accuracy, and the reliability of the GIS file with regard to some standard

Metamorphosis—change in form and structure undergone by animal from embryo to adult stage

Metazoan—an organism composed of many cells

Microatolls—a miniature atoll; a colony of corals with a live raised rim surrounding a lower, dead coral surface

Microhabitat—a smaller part of a habitat that has some internal interactions allowing it to function self-sufficiently within a generally larger habitat

Microphytic—microscopic plant life (e.g., cyanobacteria, phytoplankton, and picoplankton)

Microplankton—small planktonic organisms, 20 to 200 µm in diameter

Microzooplankton—single cell animals that drift with or are carried with the motion of the currents

Migration—the periodic movement between one habitat and one or more other habitats involving either the entire or significant component of an animal population; this adaptation allows an animal to monopolize areas where favorable environmental conditions exist for feeding, breeding, and/or other phases of the animals' life history

Mollusk—group of marine and terrestrial invertebrates consisting of snails, slugs, squids, octopus, clams, and others

Molt—the once a year shedding of fur (pinnipeds) or skin (beluga whales)

Monandric—protogynous hermaphrodites among which all males are sex-reversed females

Monogamy—a social system in which individuals have only one mate per breeding season

Monospecific—genus with only one species

Morbillivirus—a serious pathogen that is contagious, and affect animals by suppressing their immune system

Morids—of or belonging to the family Moridae, which includes the codlings and deepsea codfishes

Moratorium—a legally authorized period of delay in the performance of a legal obligation or the payment of a debt; a waiting period set by an authority

Morphology—the form and structure of an organism considered as a whole; appearance

Morphometric—the study of comparative morphological measurements

Mouthbrooder—fish which broods or protects the eggs or young by taking them in its mouth; oral brooder

Mudflat—relatively flat, muddy regions found in intertidal areas that are submerged by the rise of the tide

Myctophids—family (Myctophidae) of small oceanic fishes which live between 2,000 to 4,000 m; characteristically have numerous small photophores on side of the body; contribute to sound-scattering layers in the ocean

Mysids—small shrimp-like crustaceans

Mysticeti—suborder of cetaceans comprised of the baleen whales

Nanoplankton—plankton less than 50 µm in length that cannot be captured in a plankton net and must be removed from water by centrifuge or special microfilters

Nasal septum—the wall of flexible cartilage dividing the nasal cavity into halves

Nautical mile (NM)—a distance unit used in the marine environment that is equal to one minute of latitude or 1.85 km

Nautilus—small cephalopod mollusk that is common fossil; found in Pacific and Indian Oceans, pearly or chambered; has many small arms and lives in outermost chamber of beautiful spiral, chamber shell

Near Threatened species (IUCN Red List)—a species that does not qualify for Critically Endangered, Endangered, or Vulnerable status, but is close to qualifying for or is likely to qualify for one of those categories in the near future

Nearshore—an indefinite zone that extends seaward from the shoreline

Nektonic—pertaining to marine swimming animals

Neonate—a newborn

Neritic zone—the shallow portion of pelagic ocean waters; ocean waters that lie over the continental shelf, usually no deeper than 200 m

Nocturnal—applied to events that occur during nighttime hours

North Atlantic—the part of the Atlantic Ocean found north of the Equator

North Pacific—the part of the Pacific Ocean found north of the Equator

Northwest Atlantic—the part of the Atlantic Ocean found north of the Equator and west of the mid-ocean ridge (or roughly the area between Iceland and Greenland); synonymous with western North Atlantic Ocean

No expected occurrence—an area within the operating area where a species is not expected to be encountered

Nudibranch—member of the mollusk class Gastropoda that has no protective covering as an adult; carries on respiration by gills or other projections on the dorsal surface (sea slug)

Nursery habitat—an environment crucial for the development of early-stage animals; for some sea turtles, this environment is often an open-ocean area characterized by the presence of *Sargassum* rafts and/or ocean current convergence fronts

Nutrients—element or compound essential for animal and plant growth. Common nutrients in fertilizer include nitrogen, phosphorus, and potassium

Occurrence record—a marine mammal or sea turtle sighting (aerial or shipboard survey), stranding, incidental fisheries bycatch, nesting, or tagging data record for which location information is available. An occurrence record, especially sighting occurrence records, may represent the occurrence of one or multiple animals of a particular species; for instance, one occurrence record from a marine mammal sighting survey may indicate that 34 short-finned pilot whales were observed at a location but this information would be plotted on a MRA map figure as one occurrence record

Oceania—the group of islands in the south Pacific including Melanesia, Micronesia, and Polynesia

Ocean acidification—occurs when carbon dioxide in the atmosphere reacts with water to create carbonic acid, decreasing both ocean pH and the concentration of the carbonate ion, which is essential for calcification by marine organisms such as corals

Oceanic zone—the deepwater portion of pelagic ocean waters; ocean waters beyond the continental shelf or that are deeper than the depth of water overlying the continental shelf break (typically 100 to 200 m deep)

Oceanography—the scientific study of the oceans, including the chemistry, biology, geology, and physics of the ocean environment

Octave band—the frequency band whose upper limit in Hz is twice the lower limit

Octocorals—erect, non-crusting group of soft corals whose polyps are always formed into colonies; each polyp having eight pinnate (side-branching) tentacles

Odontoceti—the suborder of cetaceans comprised of toothed whales (e.g., beaked whales, dolphins, porpoises, sperm whale)

Offshore—open, ocean waters over the continental slope and beyond that are deeper than 200 m; water seaward of the continental shelf break

Olfactory—relating to the sense of smell

Oligotrophic—water that is lacking in nutrients, which results in low primary production

Olivine—a usually greenish mineral that is a complex silicate of magnesium and iron used especially in refractories

Omnivore—an animal that feeds on both plant and animal tissue

Ooze—a sediment that contains greater than 30 percent detrital biogenic hard parts by mass

Open Ocean—the part of the ocean seaward of the continental margin

Ophuiroid—referring to brittle stars and basket stars

Opportunistic—used to describe organisms that take advantage of all feeding opportunities and do not prey on a few specific items

Overfish—a rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce the maximum sustainable yield on a continuing basis

Overwinter—staying the winter in one area

Oviparous—producing eggs that hatch outside mother's body

Ovoviviparous—giving birth to live young which have developed from eggs that hatched within the mother's body

Pacific Decadal Oscillation (PDO)—long-lived El Niño-like pattern of Pacific climate variability marked by widespread variations in Pacific Basin and North American climate

Pacific Ocean—a major ocean area contained in a basin extending approximately from 70° west longitude (Cape Horn) to 147° east longitude. The separation of the Pacific Ocean from the Atlantic Ocean is a line marking the shortest distance between Cape Horn and the South Shetland Islands. The Pacific and Indian Oceans are separated by a line running through the Malay Peninsula, Sumatra, Java, Timor, Cape Londonderry (Australia), Tasmania, and the 147° east longitude to Antarctica

Pack ice—sea ice, especially that which is unattached to land and usually moving and shift to same extent

Parasite—something that lives in, with, or on another organism and obtains benefits from the host, which it usually injures

Parturition—act of giving birth

Passive margin—the margin of a continent that is not significantly deformed by tectonic processes because it is the trailing edge of a continent. It does not directly collide with other tectonic plates. The Atlantic coast of North America is an example

Patch reef—a coral boulder or a clump of corals unattached to a major reef structure

Pavement—flat, low-relief, hard carbonate (limestone) rock. Typical live cover on pavement includes macroalgae, stony corals, zoanthids, and other sessile invertebrates.

Pectoral fin—flipper; flattened fore-limb of a cetacean (supported by bone); for fishes, this fin is part of pair, which is supported by the pectoral girdle and usually located just behind the gill opening

Pedal laceration—asexual reproduction where small masses of cells are pinched off the margins of the pedal disk; grow slowly and differentiate into small anemones

Pelage—the fur or hair covering a mammal

Pelagic—open ocean; the primary division or zone in the open ocean that encompasses the entire water column and is subdivided into the neritic (shallow) and oceanic (deep) zones

Persistent organic pollutants (POPs)—a group of persistent, toxic chemicals that bioaccumulate in organisms and can travel long distances through the air and water to contaminate sited far removed from their original source; some disrupt the endocrine system, cause cancer, or adversely affect the developmental processes of organisms

pH—the negative logarithm of the hydrogen ion concentration in an aqueous solution

Phaeophyte—brown algae

Phocids—all of the "true" seals (i.e., "earless" species); from the Family Phocidae. Generally used to refer to all recent pinnipeds that are more closely related to Phoca than to otariids or the walrus

Photic zone—the uppermost zone in the water where sunlight permits photosynthesis

Photo-identification—the use of photographs to identify animals individually; for example, dorsal fin shape and markings for dolphins and the underside of flukes for humpback whales

Photosynthesis—the autotrophic process in which solar energy is converted into organic matter (cellular energy) by synthesizing water and carbon dioxide with chlorophyll; plants, algae, and phytoplankton synthesize organic compounds via this process

Phototactic—movement of a whole organism toward (positive) or away from (negative) light

Phototrophic—capable of deriving energy from light

Physiographic—pertaining to geographic features of the earth's surface

Physiography—physical geography of the ocean bottom and continental margins

Phytophages—plant-eating

Phytoplankton—microscopic, photosynthetic plants and plant-like protists (algae) of the epi-pelagic and neritic zones that are the base of offshore food webs on which ultimately most shellfish, fish, birds, and

marine mammals depend; drift with currents, but usually have some ability to control their level in the water column

Picoplankton—small plankton within the size ranging 0.2 to 2.0 µm in size; composed primarily of bacteria

Pinnacles—sharp pyramidal or cone-shaped rock partly or completely covered by water

Pinnipeds—seals, sea lions, and walruses

Piscivorous—a carnivorous animal that eats flesh

Planktivore—an animal that eats phytoplankton and/or zooplankton

Plankton—organisms that drift in the water column or on the water's surface, with no means of propelling or moving themselves

Planktonic—free-floating

Plastron—bony shield composing the ventral side of a turtle's shell

Pleopods—one of paired abdominal appendages among crustaceans; may be used in swimming, fanning water, respiration or reproduction

Plume—a column of water

Poaching—stealing

Point—single x, y coordinate pair that represents a single geographic feature (e.g., sea turtle sighting)

Polar—in latitudes near one of the poles (North or South), typified by cold and ice-infested waters

Pollution—any undesirable alteration of air, water, or soil that harms the health, survival, or activities of humans or other organisms

Polychaete—class of soft-bodied, metamerically segmented coelomate worms; marine; may be free-swimming, errant, burrowing or tube dwelling

Polygon—area represented by a two-dimensional feature

Polyp bail-out—dissociation and dispersal of coral polyps from adult colonies; asexual reproduction

Polyp balls—daytime corals release small balls of coral tissue which fall on the reef surface near the parent and grow into new colonies

Population—a group of individuals of the same species occupying the same area

Porifera—phylum of simple multicellular animals, called sponges; enclosed in a single central cavity or penetrated by numerous interconnected cavities; filter feeder, sessile; may be marine or freshwater

Posterior—situated near or toward the back of an animal's body

Potentially harvested coral reef taxa (PHCRT)—subcategory of MUS including coral reef organisms that are not known to be currently caught or for which very little fishery information is available; several CHCRT are also PHCRT; all genera or species in these taxa that are not listed as CHCRT are by default PHCRT

Practical salinity unit (psu)—the currently used dimensionless unit for salinity, replacing parts per thousand (ppt)

Precision—number of significant digits used to store coordinate values; imperative for accurate feature representation, analysis, and mapping

Precipitation—the process where water vapor condenses in the atmosphere to form water droplets that fall to the Earth as rain, sleet, snow, hail, etc

Predation—an interspecific interaction where one animal species (predator feeds on another animal or plant species (prey) while the prey is alive or after killing it. The relationship tends to be positive (increasing) for the predator population and negative (decreasing) for the prey population

Primary producer—an autotroph or organism able to utilize inorganic sources of carbon and nitrogen as starting materials for biosynthesis; uses either solar or chemical energy

Primary production—organic matter synthesized by organisms from inorganic substances

Prochlorophytes—are believed to be cyanobacteria, also synthesize chlorophyll b, and live in soil crusts

Proboscis—a flexible, elongated snout of certain animals

Projection—mathematical formula that transforms the three-dimensional real world features and their locations on the Earth's curved surface into a mapped, two-dimensional surface; projections cause distortions in one or more of the following spatial properties: distance, area, shape, and direction

Propagate—to cause to continue or increase by sexual or asexual reproduction

Protist—a eukaryotic microorganism that are neither animal, fungi, plant, nor achaean. Unicellular forms include the amoeboid protozoans and algae, such as the formaniferans and radiolarians, and dinoflagellates and diatoms, respectively. Some algae are either multicellular or colonial, such as the red algae and freshwater *Volvox*, respectively

Pumiceous—a volcanic glass full of cavities and very low in density that is used especially in powder form for smoothing and polishing

Pup—a young animal of various species, especially young pinnipeds

Pupping—the process of giving birth by pinnipeds

Purse seine—a large commercial fishing net pulled by two boats, with ends that are pulled together around a shoal of fish so that the net forms a pouch or "purse"

Pyrosome—blue-green bioluminescent, pelagic, tunicates that form thimbled-shaped colonies of the Genus *Pyrosoma*

Radiolarian—planktonic or benthic protozoan that possesses protective coverings usually made of silica

Radula—the ribbon-like band of teeth of molluscs

Rainy season—the period extending from July through December in tropical climates. The rainy season is characterized by heavy winds, squalls, gales, and heavy rainfall

Range—the maximum extent of geographic area used by a species

Rare—a plant or animal restricted in distribution or number; in the case of sea turtles, rare means that a species occurs, or probably occurs, regularly within the region but in very small numbers

Re-cementation—asexual development in corals where pieces of branching and plate corals break off and reattach themselves to the surface of the reef where they continue to grow

Recreational fishing—fishing for sport or pleasure

Recruitment—the settling of a coral larva on a reef substrate and the establishment of new coral colony

Red algae—division of algae (Rhodophyta) consisting of large multicellular, structurally complex photosynthetic organisms that grow attached to rocks or other substrates; largely marine; some forms instrumental in formation of coral reefs by precipitating calcium carbonate; form large rocky masses

Reef crest—shallow portion of a bank/barrier reef that is seaward of the lagoon

Reef drop-off—outer reef slopes that are nearly vertical to slightly undercut

Reef flat—shallow (semi-exposed) area between the shoreline intertidal zone and the reef crest of a fringing reef. This zone is protected from the high-energy waves commonly experienced on the shelf and reef crest

Reef front—the fore reef area including the buttress reef, the reef terrace, reef escarpment, and reef slope

Reef passes—channels that connect the lagoon to the outer reef slope

Reef slope—zone of the fore reef occurring below the reef escarpment which is the steeply-sloped transition between the fore reef terrace and the fore reef slope. The fore reef slope is steeply sloped and occurs in water depths of 55 m to 60 m

Reef top—area comprising the reef flat and reef crest

Regular—in the case of marine mammals and sea turtles, a species that occurs as a regular or normal part of the fauna of the area, regardless of how abundant or common it is

Relief—the inequalities (elevations and depressions) of the sea bottom

Rehabilitation—to restore to a former capacity

Remigration interval—the amount of time between successive sea turtle nesting seasons

Resources—(1) any part of the natural environment that are used to promote the welfare of people or other species; examples include clean air , fresh water, soil, forests, minerals, and organisms. Also called *natural resources*. (2) anything form the environment that meets a particular species' needs

Rhodophyte—red algae

Robust—powerfully built

Rookery—an animal's breeding ground; for sea turtles, it is the specific beach on which they nest

Rorqual—any of six species of baleen whales (the minke, blue, humpback, fin, Bryde's, or sei whale) belonging to the family Balaenopteridae; characterized by a variable number of pleats that run longitudinally from the chin to near the umbilicus; the pleats expand during feeding to increase the capacity of the mouth

Rostrum—the snout or beak of a cetacean; in fish, a forward projection of the snout

Rugosity—an important coral reef parameter that describes the amount of "wrinkling" or roughness of the reef profile. It is an index of substrate complexity. Areas of high complexity are likely to provide more cover for reef fishes and more places of attachment for algae, corals and various sessile invertebrates

Saddle—a light-colored patch behind the dorsal fin of some cetaceans

Sagittal crest—prominence on top of he cranium, causing a noticeably raised forehead on males of some otariid pinniped species

Salinity—the concentration of salt in water, measured in practical salinity units (psu)

Salp—barrel-shaped tunicate without an exoskeleton that forms asexual polymorphic colonies that are found in the upper levels of most oceans

Salt marsh—coastal ecosystem that is inundated by seawater for some period of time. Plants in this ecosystem have special adaptations to survive in the presence of high salinities. Generally, found in temperate or subpolar climates

Sand flat—A flat expanse of sand on the coast or in an estuary

Sargassum—a genus of brown algae commonly found in temperate and tropical waters

Scavenger—an animal that feeds on dead organic matter

School—a social group of fish, drawn together by social attraction, whose members are usually of the same species, size, and age; the members of a school move in unison along parallel paths in the same direction

Scleractinian—hard or stony corals known as true corals that dominate reef ecosystems; they have a compact calcareous skeleton and polyps with no siphonoglyphs (grooves)

Sclerosponge—slow growing calcareous organisms who secrete their skeletons in carbon and oxygen isotopic equilibrium with their environment and can provide proxy records of salinity and water temperature over a 100 to 1000 year time range

Scombrids—family of mackerels, tunas, and bonitos that are generally predators of the open ocean who are capable of considerable speed

Scorpaenids—of or belonging to the suborder Scorpaenoidei, which includes the scorpion fishes and rockfishes

Scutes—long, thickened scales that cover underlying bony plates of carapace and plastron of sea turtles that are used for protection

Scyphozoans—any of various marine coelenterates of the Class Scyphozoa, which includes large jellyfishes, characterized by the absence of a velum and by a polyp stage that is very small or lacking entirely

Sea anemones—large, heavy, complex polyps that belong to the cnidarian class Anthozoa

Sea cucumbers—echinoderm having a flexible sausage-shaped body with tentacles surrounding the mouth and tube feet; free-living feeder

Sea surface temperatures (SST)—the temperature of the layer of seawater (approximately 0.5 m deep) nearest the atmosphere

Sea whips—erect colony of marine animals of the phylum Cnidaria with whip-like branches; skeleton consists of a horny axis, overlaid with small calcareous bodies called spicules

Seagrass—submerged aquatic vegetation that form extensive underwater meadows (or beds) found in shallow-water depths and various temperatures and salinity ranges

Seamount—an undersea mountain that rises steeply from the ocean floor to an altitude greater than 1,000 meters above the ocean basin

Secondary production—organic material produced by processing organic material other than that from primary production; consumers

Sediment—solid fragmented material, either mineral or organic, that is deposited by ice, water, or air

Sedimentation—the sinking of a molecule under the opposing forces of gravitation and buoyancy

Semelparous—producing all offspring at one time; usually these fish die after reproduction

Serial spawner—a fish that spawns in bursts or pulses more than once in a spawning season in response to an environment stimulus

Sessile—used to describe an animal that is attached to something rather than free moving

Sestonophages—organisms that utilize suspended particulate matter in the water column for food (e.g., mollusks); sessile sestonophages: attached to a substratum; not free to move about (e.g., oyster); mobile sestonophages: moving or capable of moving readily (e.g., amphipods).

Set gillnets—gillnets that are anchored to the seafloor and may be fished on the ocean bottom or floating above the anchors; used to catch California halibut, sharks, white seabass, barracuda, white croaker, flying fish, and rockfish

Sexual maturity—the state in which an animal is physiologically capable of reproducing

Sexually dimorphic—differences in the appearance of the sexes of a species; size differences are a primary difference where males are generally larger than females; other differences may be in body shape and color

Shallow water—water that is between the shore and the continental shelf break or shallower than 200 m

Shapefile—vector data storage format used to store the location, shape, and attributes of geographic features; a shapefile must be one and only one of three possible feature classes: lines, points, and polygons

Shelf break—region where the slope of the seabed rapidly changes from gently sloping to steeply sloping and the continental shelf gives way to the continental slope; the world-wide average water depth at which the shelf break is found is 155 m, but on average, the shelf break usually occurs between 100 to 200 m water depth

Shelf break region—the geographic area surrounding the continental shelf break and including both the outer continental shelf and upper continental slope

Shield volcano—A broad, fairly flat mountain, formed chiefly by very fluid lava, having the shape of a shield when viewed from side

Shoals—a submerged ridge, bank, or bar consisting of, or covered by, unconsolidated sediments (mud, sand, gravel) which is at or near enough to the water surface to constitute a danger to navigation

Silica—Silicon oxide (SiO_2(s)), which can occur in crystalline form, e.g.,quartz, or noncrystaline form, e.g., opal

Silicate compensation depth—depth at which almost all silica dissolves, approximately 8,000 m

Siliceous—composed of silica

Siphonophore—hydrozoan that exist as drifting colonies

Sirenia—the order of marine mammals that consists of manatees and the dugong

Site fidelity—the tendency to return to the same site repeatedly

Softbottom—as substrate comprised of soft sedimentary material such as sand, silt, or mud

Soft corals—class of corals (Anthozoa) characterized by having retractable polyps with eight, branching tentacles (i.e., sea anemones); usually attached to rocks

Source level—the acoustic pressure that would be measured at a standard distance (usually 1 m) from a point source radiating the same amount of sound as the actual source

South Pacific—the part of the Pacific Ocean found south of the Equator

Spatial analysis—study of and relationship between the locations and shapes of geographic features and the process of analyzing, modeling, and interpreting those results; there are four main types or categories of spatial analysis: topological overlay and contiguity analysis; surface analysis; linear analysis; and raster analysis

Spawn—the release of eggs and sperm during mating

Species—a population or series of populations of organisms that can interbreed freely with each other but not with members of the other species

Species diversity—the number of different species in a given area

Species of concern—species about which NMFS has some concerns regarding status and threats, but for which insufficient information is available to indicate a need to list the species under the Endangered Species Act

Spheroid—earth shaped

Spicule—a small needlelike calcareous or siliceous form found in sponges, radiolarians, chitons, and echinoderms that acts to support the tissue or provide a protective covering

Sponges—any of numerous primitive, chiefly marine animals of the phylum Porifera, characteristically having a porous skeleton composed of fibrous material or siliceous or calcareous spicules and often forming irregularly shaped colonies attached to an underwater surface

Spreading half-rate—the motion of one plate away from the spreading axis over a period of time

Squall—a strong wind characterized by a sudden onset in which the wind speed increases at least 16 knots and is sustained at 22 knots or more for at least one minute. In nautical use, a severe local storm considered as a whole, that is, winds and cloud mass and (if any) precipitation, thunder and lightning

Standard deviation (S.D.)—a statistical measure of the amount by which a set of values differs from the arithmetical means; simply, how widely values are dispersed from the mean

Stenella—in the Pacific, it is the genus of oceanic dolphins consisting of striped, pantropical spotted, and spinner dolphins, which are similar in appearance

Stenellid—refers to dolphins of the Genus *Stenella*

Stock—a genetically separate population of a species (biological stock) or a discrete population subject to management (management stock)

Stock structure—the genetic diversity of a stock

Stomatopods—group of predatory marine crustaceans that comprises the mantis shrimp, elongate, flattened and shrimp-like or lobster-like organisms with enlarged anterior pincers whose outer joints fold back against the basal joints in the praying mantis

Stranding—the act where marine mammals or sea turtles accidentally come ashore, either alive or dead

Strategic stock—any marine mammal stock: (1) from which the level of direct human-caused mortality exceeds the potential biological removal level; (2) which is declining and likely to be listed as threatened under the Endangered Species Act; or (3) which is listed as threatened or endangered under the Endangered Species Act or as depleted under the Marine Mammal Protection Act

Stratify—to layer

Subadult—maturing individuals that are not yet sexually mature pertaining

Subduction—a process by which one tectonic plate descends beneath another. The surface expression of such a process may by an island-arc system or a folded mountain range

Sublittoral—benthic region extending from mean low waters to a depth of about 200 meters

Submarine canyon—deep, steep-sided valley cut into the continental shelf or slope

Submarine ridge—a ridge of submarine mountains where two massive tectonic plates are moving apart

Subnertitic zone—the benthic environment extending from the shoreline across the continental shelf to the shelf break

Subnivean lair—a lair dug into the ice

Subpopulations—an identifiable fraction or subdivision of a population

Subsistence fishing—fishing primarily to obtain for personal use rather than for sale or recreation

Substrate—the material to which an organism is attached or in which it grows and lives; also, the underlying layer or substance

Subtidal—marine or estuarine environment that lies below mean low-water; always submerged in a tidally-influenced area

Subtropical—the regions lying between the tropical and temperate latitudes

Suction feeding—capture of prey using suction, generally with the tongue employed as a piston to create a vacuum pressure

Surf line—point offshore where waves and swells are affected by the underwater surface and become breakers

Surf zone—area between outermost breaker and limit of wave uprush

Surge—long wave, which is longer than wind wave, but shorted than tidal wave

Suspension feeder—an animal that eats by filtering out tiny particles or organic material suspended in the water

Sustainability—the wise use of natural resources without compromising the ability of future generations to meet their needs

Symbiont—the smaller participant in a symbiotic relationship; living in or on the host

Sympatric—species or subspecies occurring together; having overlapping areas of distribution

Syngnathids—family of fish containing seahorses and pipefishes

Taimai—Japanese for hawksbill turtle

Talus—weathered rock which has fallen from and accumulated at the bottom of a cliff

Target species—species of fish or invertebrate specifically sought by a fishery

Taxa (taxon)—a defined unit (e.g., species, genus, or family) in the classification of living organisms

Taxonomy—the study of the rules, principles, and practice of classification, especially of living organisms

Tectonic plate—an area of the earth's crust which moves during geological time resulting in continental drift and other major changes in the topography of the surface of the globe

Temperate—the region of the Earth at the mid-latitudes that is characterized by a mild, seasonally changing climate

Temporary threshold shift (TTS)—a temporary impairment in hearing ability caused by exposure to strong sounds

Terrace—zone of the fore reef occurring below the mixed zone of buttress zone from 10 to 25 m water depth. The terrace can be relatively wide (30 to 100 m)

Terrigenous—derived from land or a continent

Territory—an area occupied exclusively by one animal and defended by aggressive behavior or displays

Thermocline—the depth in the ocean (water column) in which there is an abrupt temperature change

Thermohaline circulation—density-driven water circulation caused by differences in temperature and/or salinity

Thermoregulatory—an organism's ability to maintain a specific body temperature regardless of the environmental temperature

Threatened species (ESA)—any plant or animal species likely to become endangered within the foreseeable future throughout all or a part of its range; the authority to designate a species as threatened is shared by the U.S. Fish and Wildlife Service (terrestrial species, sea turtles on land, manatees) and National Marine Fisheries Service (most marine species) under provisions of the Endangered Species Act

Tidepools—pool of waters remaining on beach or reef after recession of tide

Topography—physical features of the ocean floor, such as mounds or ridges

Total length—the longest measurable distance from the outermost portion of a fish's snout lengthwise to the outermost portion of the tail fin

Toxicant—any chemical with adverse health effects

Tradewinds—air masses moving from subtropical high pressure belts toward the equator. They are northeasterly in the Northern Hemisphere and southeasterly in the Southern Hemisphere

Transition Zone—an area of mixing between the cold, low-salinity, highly productive subarctic water and the warmer, more saline and less productive subtropical water

Trawl—an active type of fishing gear that us pulled through the water, and the target species are scooped by by the forward open end of the net, and funneled back to a closed end (cod end), where they are effectively captured

Trophic level—a step in the transfer of food or energy within a chain

Tropical—the geographic region found in the low latitudes (30° north of the equator to 30° south of the equator) characterized by a warm climate

Tropical cyclone—a warm core low pressure system which develops over tropical, and sometimes subtropical, waters, and has an organized circulation. Depending on sustained surface winds, the system is classified as a tropical disturbance, a tropical depression, a tropical storm, or a hurricane or typhoon

Troposphere—the lowest layer of the atmosphere within which there is a steady drop in temperature with increasing altitude and within which nearly all cloud formations occur and weather conditions manifest themselves

Tsunami—series of waves of extremely long wave length and long period generated in a body of water by an impulsive disturbance caused by an earthquake, a submarine landslide, or a submarine volcanic eruption. Tsunamis are not caused by or related to tides and therefore "tidal wave" is a misnomer

Tsuyu—see "baiu"

Tubercles—knob-like bumps on the bodies of some species of cetaceans

Tunicates—any of various chordate marine animals of the subphylum Tunicata or Urochordata having a cylindrical or globular body enclosed in a tough outer covering (i.e., sea squirts and salps)

Turbidity—the thickness or opaqueness of water caused by the suspension of matter

Tursiops—the genus of bottlenose dolphins comprised of the common bottlenose dolphin (*Tursiops truncatus*) and the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*)

Typhoon—a tropical cyclone with sustained winds of 74 miles per hour (65 knots) or greater in the western North Pacific Ocean. This same tropical cyclone is known as a hurricane in the eastern North Pacific and North Atlantic Ocean, and as a cyclone in the Indian Ocean

Ultrasonic—sounds above the human hearing range

Unisexual—individuals that are both male and female

Upwelling—upward movement or rising of deep, usually nutrient- and oxygen-rich, water to the surface; may be caused by wind-forcing, divergent currents, or density differences

Uro-genital area—portion of ventral surface around and near the excretory and genital orifices

Vagile—wandering, free motile, mobile

Vagrant—a wanderer, in the sense of an animal moving outside the usual limits of distribution for its species or population

Ventral—relating to the underside (or belly side) of an animal

Vertebrates—animals with a backbone

Vestimentiferan—any of various marine tubeworms, including the giant tubeworms, of the phylum Vestimentifera, that lack a digestive system, depend on chemoautotrophic bacteria for nutrients, and inhabit areas close to deep sea hydrothermal vents or areas of cold water seeps on continental margins

Viviparous—type of development in which the young are born alive after having been nourished in the uterus by blood from the placenta

Vulnerable species (IUCN Red List)—a species that is considered to be facing a high risk of extinction in the wild

Water column—a vertical column of seawater extending from the surface to the sea bottom

Water mass—a body of water that can be identified by a specific temperature or salinity

Watershed—a land area that delivers water into a stream or river system. Also called a *drainage basin*

Weaning—the end of the lactation period; the process of changing from milk to a solid diet in juvenile mammals

West Pacific—that part of the Pacific Ocean found west of the 180° longitude line

Western North Atlantic—the part of the Atlantic Ocean found north of the Equator and west of the mid-ocean ridge (or roughly the area between Iceland and Greenland); synonymous with Northwest Atlantic Ocean

Wetland—an area inundated by water (either freshwater or saltwater) frequently enough to support vegetation that requires saturated soil conditions for growth and reproduction; generally includes swamps, marshes, springs, seeps, or wet meadows

Whale lice—amphipod crustaceans of the Family Cyanidae; adapted for living in crevices and other secure places on the skin of cetaceans (for example, gray whales), on which whale lice largely feed

Whistle—a narrow band frequency sound produced by some toothed whales and used for communication; they typically have energy below 20 kHz

Young-of-the-year (YOY)—a juvenile fish less than 1 year old

Zonation—the occurrence of single species or groups of species in recognizable bands that might delineate a range of water depth or a range of height in the intertidal zone

Zoobenthos—animals living in or on the sea bed

Zooplankton—diverse group of non-photosynthesizing organisms that drift freely in the water or its surface; zooplankton are composed of a wide range of invertebrates, including larval forms of fish and shellfish

Zooxanthallae—single-celled algae that live symbiotically within certain types of coral; it is the presence of these organisms that gives coral its color