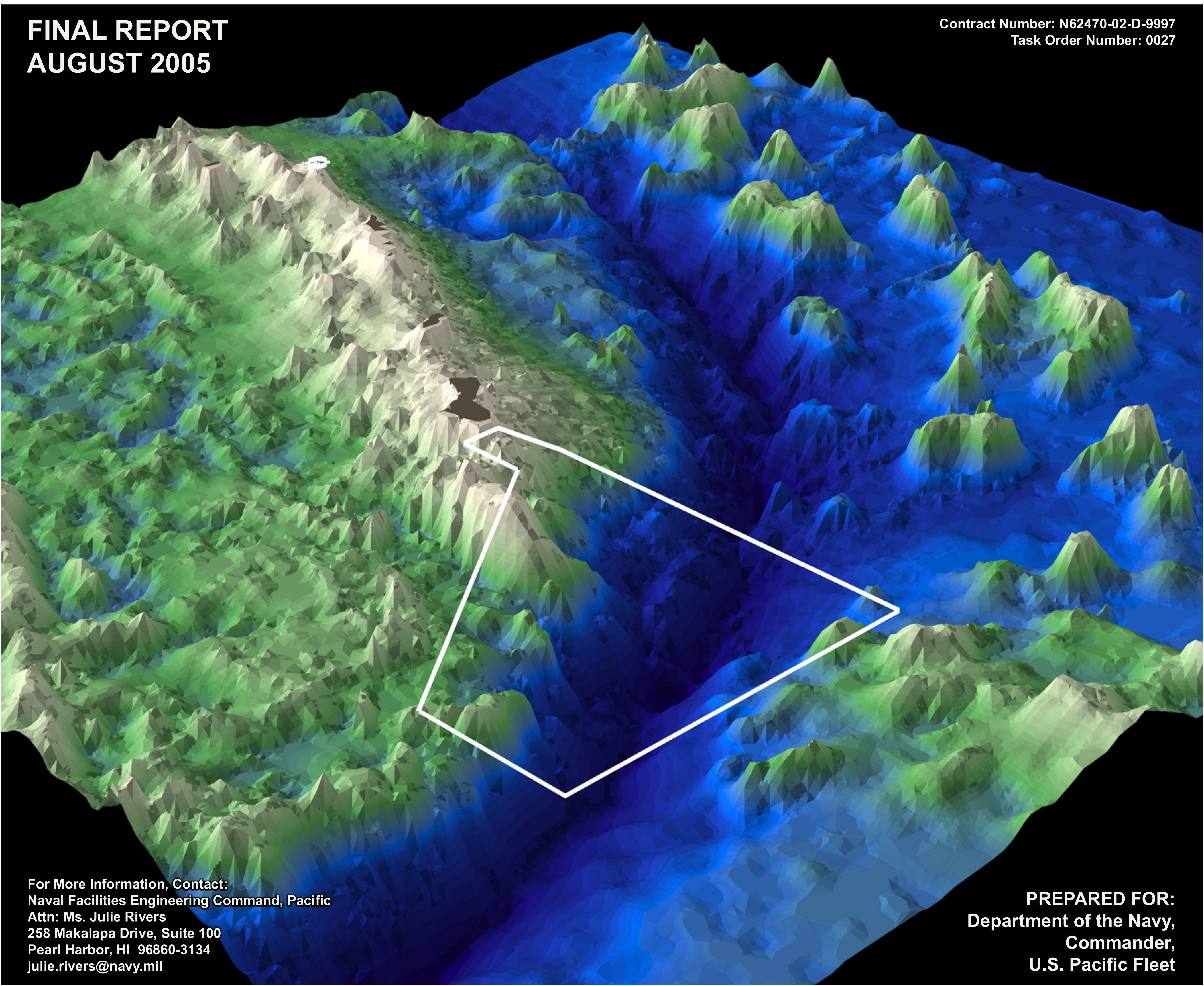
MARINE RESOURCES ASSESSMENT FOR THE MARIANAS OPERATING AREA



FINAL REPORT
AUGUST 2005

Contract Number: N62470-02-D-9997
Task Order Number: 0027

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PREPARED FOR:
Department of the Navy,
Commander,
U.S. Pacific Fleet

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Cover Image: Three-Dimensional View of Northern Mariana Islands Bathymetry. Geo-Marine, Inc.

Title Page Photograph: Sunset at Saipan Island, Northern Mariana Islands. Ken Deslarzes, Geo-Marine, Inc.

STATEMENT OF PURPOSE

The Navy Commander, U.S. Pacific Fleet (COMPACFLT) implemented the Marine Resources Assessment (MRA) Program to establish a comprehensive source for information (which could include published information and consultations with regional and/or subject matter experts) concerning the protected and managed resources found in its various marine operating areas (OPAREAs). The information found within an MRA is vital for environmental planning and for use in environmental compliance documentation, for example the description of the affected environment. An MRA is not intended to be used in the place of a National Environmental Policy Act (NEPA) document. MRAs are reviewed by subject matter experts familiar with the region.

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EXECUTIVE SUMMARY

The Department of the Navy (DoN) is committed to demonstrating environmental stewardship while executing its national defense mission. The United States (U.S.) Navy (Navy) is responsible for compliance with a suite of federal environmental and natural resources laws and regulations that apply to the marine environment, including the National Environmental Policy Act (NEPA), the Marine Mammal Protection Act (MMPA), the Endangered Species Act (ESA), the Magnuson-Stevens Fishery Conservation and Management Act/Sustainable Fisheries Act (MSFCMA/SFA), and Executive Order (EO) 13089 on Coral Reef Protection. The Navy Commander, U.S. Pacific Fleet (COMPACFLT) implemented the marine resources assessment (MRA) program to develop a comprehensive compilation of data and literature concerning the protected and managed marine resources found in its various operating areas (OPAREA). The information in this MRA is vital for planning purposes and for various types of environmental documentation such as biological and environmental assessments (EA) that must be prepared in accordance with the NEPA, MMPA, ESA, and MSFCMA/SFA.

This MRA documents and describes the marine resources in the U.S. Pacific Fleet military ranges and training areas located in the waters off of Guam, Tinian, and Farallon de Medinilla, including Warning Area W-517. The MRA report for these areas, which is collectively known as the Marianas MRA study area, is provided in both paper and electronic form.

The geographical representation of marine resource occurrences in the Marianas MRA study area is a major constituent of this MRA. A geographic information system (GIS) was used to store, manipulate, analyze, and display the spatial data and information accumulated for the Marianas MRA study area. Ninety-six GIS-generated map figures are included in this assessment. Metadata (documentation of the GIS data) were also prepared for each GIS file associated with this MRA report.

The introduction to the report discusses the purpose and need of the MRA, the location of the study area, the environmental legislation that is applicable to the study area, and the methodology used to assess the marine resources of the study area. The introduction is followed by an overview of the marine environment and habitats found in the study area. Here the report describes the physical environment, physical and biological processes, and living organisms associated with the various habitats of the study area. Detailed maps are provided to depict the physical environment, nearshore benthic habitats, and human-made substrates (artificial reefs, shipwrecks, and fish aggregating devices [FADs]).

The MRA report next provides detailed information on marine mammals, sea turtles, fishes, and invertebrates of the study area. The discussion on marine mammals focuses on the occurrences of marine mammals in the study area differentiating the threatened and endangered marine mammals from the non-threatened and non-endangered species. The MRA section on sea turtles provides a general description of the life history of sea turtles, an account of the sea turtles that occur in the study area, and detailed information on the dynamics of each sea turtle species within the study area. Detailed seasonal occurrence maps (dry versus wet seasons) are provided for the marine mammals and sea turtles.

The chapter on fish and fisheries provides detailed information on fishes and invertebrates by essential fish habitat (EFH) management unit (bottom, pelagic, crustacean, and coral reef ecosystem). An overview of the fisheries in the study area discusses the pelagic, bottomfish, and reef fisheries, as well as ports, fishing areas, and fishing tournaments. For each location of the study area, detailed figures depict the EFH for all life stages of bottomfish and designated habitats of particular concern (HAPC), the EFH for all life stages of pelagic fishes, the EFH for all life stages of crustaceans, and the EFH for currently and potentially harvested coral reef taxa and designated HAPC.

The MRA report also includes a review of the marmite boundaries in the study area (territorial waters, contiguous zone, and exclusive economic zone [EEZ]), navigable waterways and commercial shipping lanes, managed marine areas (MMAs), and recreational self contained underwater breathing apparatus (SCUBA) diving sites. The MRA report ends with recommendations on what work needs to be done to address data gaps and enhance the current knowledge on the marine resources of the study area

REPORT ORGANIZATION

This report consists of eight chapters and four appendices:

Chapter 1 Introduction—provides an explanation of the purpose and need of the MRA, defines the location of the study area, reviews the relevant environmental legislation, and describes the methodology used in the MRA.

Chapter 2 Physical Environment and Habitats—describes the environment (climate and weather, marine geology, oceanic circulation, hydrography), biological oceanography (primary and secondary production), and benthic and coastal habitats and associated organisms of the Marianas MRA study area.

Chapter 3 Species of Concern—covers marine mammals and sea turtles found in the Marianas MRA study area. The section on marine mammals first discusses the sound production and reception by marine mammals and the associations marine mammals have with the different habitats in the MRA study area. The section goes on to present the occurrences of marine mammals in the study area differentiating the threatened and endangered marine mammals from the non-threatened and non-endangered species. The section on sea turtles provides a general description of the life history of sea turtles (including description, status, habitat preferences, and distribution), an account of the sea turtles that occur in the study area, and detailed information on the dynamics of each sea turtle species within the study area (including behavior and life history).

Chapter 4 Fish and Fisheries—discusses the general occurrence of fishes and invertebrates in the study area and defines the EFH. Fish and invertebrate species are then presented by management units covering the bottom, pelagic, crustacean, and coral reef ecosystem management unit species. For each management unit species, the report includes a discussion of the distribution, habitat preference, life history, EFH designations, and HAPC designations. The chapter also discusses fisheries in the study area (pelagic, bottomfish, and reef fisheries; ports; fishing areas; and fishing tournaments).

Chapter 5 Additional Considerations—provides information on maritime boundaries, navigable waterways and commercial shipping lanes, MMAs (local and federal), and SCUBA diving sites.

Chapter 6 Recommendations—identifies what needs to be done to fill data gaps and fully assess the marine resources of the Marianas MRA study area. The recommended work is prioritized using a cost/benefit approach.

Chapter 7 List of Preparers—lists all individuals who helped prepare this MRA.

Chapter 8 Glossary—includes definitions of the terms used in the MRA.

Appendix A—contains source information for marine mammal and sea turtle data, data confidence levels, map projection information, and map figures illustrating the sighting survey effort of those surveys used in the Marianas MRA study area and vicinity.

Appendix B—marine mammal occurrence maps.

Appendix C—sea turtle occurrence maps.

Appendix D—EFH maps.

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TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

Page

TABLE OF CONTENTS
(Continued)

Page

TABLE OF CONTENTS
(Continued)

Page

APPENDICES

LIST OF FIGURES

LIST OF FIGURES
(Continued)

LIST OF TABLES

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LIST OF ACRONYMS AND ABBREVIATIONS

%	Percent
°	Degree(s)
°C	Degree(s) Celsius
μm	Micron(s)
μp	Micropascal(s)
3D	Three-dimensional
AAFB	Andersen Air Force Base
AIW	Antarctic Intermediate War
AVHRR	Advanced Very High-resolution Radiometer
BMUS	Bottomfish Management Unit Species
C	Carbon
CCD	Carbonate Compensation Depth
CDW	Circumpolar Deep Water
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CHCRT	Currently Harvested Coral Reef Taxa
chl *a*	Chlorophyll *a*
cm	Centimeter(s)
cm/yr	Centimeter(s) Per Year
CMUS	Crustacean Management Unit Species
CNMI	Commonwealth of the Northern Mariana Islands
CODAR	Coastal Ocean Dynamics Radars
COMNAVMARIANAS	Commanding Officer, United States Naval Forces Marianas
COMPACFLT	Commander, United States Pacific Fleet
COTS	Crown-of-thorn starfish
CRE FMP	Coral Reef Ecosystem Fishery Management Plan
CRE MUS	Coral Reef Ecosystem Management Unit Species
CRE	Coral Reef Ecosystem
CRED	Coral Reef Ecosystem Division
CWA	Clean Water Act
CZCS	Coastal Zone Color Scanner
CZMA	Coastal Zone Management Act
d	Day
DAWR	Division of Aquatic and Wildlife Resources
dB re 1μPa-m	Decibels at the Reference Level of One Micropascal at One Meter
dB	Decibel
DFW	Division of Fish and Wildlife
DoD	Department of Defense
DoI	Department of the Interior
DoN	Department of the Navy
DSL	Deep Scattering Layer
EA	Environmental Assessment
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
ENSO	El Niño/Southern Oscillation
EO	Executive Order
EPA	Environmental Protection Agency
ERA	Ecological Reserve Area
ESA	Endangered Species Act
ESRI	Environmental Systems Research Institute, Inc.
FAA	Federal Aviation Administration
FAD	Fish Aggregating Device
FAO	Food and Agriculture Organization

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

FCMA	Fishery Conservation and Management Act
FDM	Farallon de Medinilla
FM	Frequency-modulated
FMC	Fishery Management Council
FMP	Fishery Management Plan
FR	Federal Register
FSM	Federated States of Micronesia
FWPCA	Federal Water Pollution Control Act
g	Grams
GIS	Geographic Information System
GMI	Geo-Marine, Inc.
GPS	Global Positioning System(s)
ha	Hectare(s)
HAPC	Habitat Area(s) of Particular Concern
HTML	Hyper Text Markup Language
Hz	Hertz
IGFA	International Game Fish Association
IUCN	International Union for Conservation of Nature and Natural Resources
IWC	International Whaling Commission
kg	Kilogram
kHz	Kilohertz
km	Kilometer(s)
km^2	Square kilometer(s)
kp	Kilopascal
kph	Kilometers Per Hour
LBA	Leaseback Area
lbs	Pounds
LCAC	Landing Craft, Air Cushion
LCPW	Lower Circumpolar Water
m	Meter(s)
m/sec	Meter(s) Per Second
m/sec	Meters Per Second
m^2	Square Meter(s)
m^3	Cubic Meter(s)
MCSST	Multi-Channel Sea Surface Temperature
mg	Milligram
$mgC/m^2/d$	Milligram(s) of Carbon Per Square Meter Per Day
MHHW	Mean Higher High Water
MHW	Mean High Water
mi	Mile(s)
min	Minute(s)
ml/l	Milliliters Per Liter
MLLW	Mean Lower Low Water
MLW	Mean Low Water
mm	Millimeter(s)
MMA	Marine Managed Area
MMC	Marine Mammal Commission
MMPA	Marine Mammal Protection Act
MMS	Minerals Management Service
mmu	Minimum Mapping Unit
MPA	Marine Protected Area
MPPRCA	Marine Plastic Pollution Research and Control Act
MPRSA	Marine Protection, Research, and Sanctuaries Act

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

MRA	Marine Resources Assessment
msec	Millisecond(s)
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
MSL	Mean Sea Level
MU	Marine Unit
MUS	Management Unit Species
NASA	National Aeronautic and Space Administration
Navy	United States Navy
NEC	North Equatorial Current
NEFSC	Northeast Fisheries Science Center
NEPA	National Environmental Policy Act
NHP	National Historic Park
NM	Nautical Mile(s)
NMFS	NOAA Fisheries (National Marine Fisheries Service)
NMML	National Marine Mammal Laboratory
NOAA	National Oceanic and Atmospheric Administration
NOS	National Oceanic Service
NPDW	North Pacific Deep Water
NPEC	North Pacific Equatorial Current
NPIW	North Pacific Intermediate Water
NPS	National Park Service
NPS	National Park System
NPSG	North Pacific Subtropical Gyre
NRFCC	National Recreational Fisheries Coordination Council
NWR	National Wildlife Refuge
NWRS	National Wildlife Refuge System
OBIS	Ocean Biogeographic Information System
OCS	Outer Continental Shelf
OPA	Oil Pollution Act
OPAREA	Operating Area
OPAREA	Operating Area
OPIS	Ocean Planning and Information System
PDF	Portable Document Format
PDO	Pacific Decadal Oscillation
PHCRT	Potentially Harvested Coral Reef Taxas
PI	Principal Investigator
PIFSC	Pacific Islands Fisheries Science Center
PIFSC	Pacific Islands Fisheries Science Center
PIRO	Pacific Islands Regional Office
PMUS	Pelagic Management Unit Species
POP	Platforms of Opportunity Program
ppt	Parts Per Thousand
psu	Practical Salinity Unit(s)
RFRCP	Recreational Fishery Resources Conservation Plan
S.D.	Standard Deviation
SCD	Silicate Compensation Depth
SCUBA	Self Contained Underwater Breathing Apparatus
sec	Second(s)
SFA	Sustainable Fisheries Act
SLP	Sea Level Pressure
SPREP	South Pacific Regional Environment Program
SPUE	Sightings Per Unit Effort
SST	Sea Surface Temperature

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

SWFSC	Southwest Fisheries Science Center
TIN	Triangular Irregular Network
TTS	Temporary Threshold Shifts
TU	Terrestrial Unit
U.N.	United Nations
U.S.	United States
U.S.C.	United States Code
UNEP	United Nations Environment Programme
USCG	United States Coast Guard
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USVI	United States Virgin Islands
WPRFMC	Western Pacific Regional Fishery Management Council
WWI	World War I
WWII	World War II
XML	Extensible Markup Language

1.0 INTRODUCTION

The Navy's COMPACFLT contracted this MRA to initiate collection of data and information concerning the protected and commercial marine resources found in U.S. Pacific Fleet military ranges and training areas located in the waters off of Guam and the Commonwealth of the Northern Mariana Islands (CNMI). For the purposes of this MRA, the military areas assessed will be considered as one unit that is hereafter referred to as "the Marianas MRA study area" or more simply as "the study area."

1.1 PURPOSE AND NEED

The goal of this MRA is to describe and document the marine resources in the Marianas MRA study area, including both protected and commercial marine species. This MRA provides a compilation of the most recent data and information on the occurrence of these resources in the study area. A synopsis of environmental and habitat data and in-depth discussions of the species of concern found in the study area and surrounding region are included. The locations of EFH and other areas of interest, such as MMAs and SCUBA diving sites, are also addressed in this assessment. In addition, this report identifies data gaps and prioritizes recommendations for future research in the study area.

Beyond the Navy's immediate mission in the study area is the Department of Defense's (DoD) mission to prevent pollution, protect the environment, and protect natural, historic, and cultural resources (DoN 1999). The assembled information in this MRA will serve as a baseline from which the Navy may evaluate future actions and consider adjustments to training exercises or operations in order to mitigate potential impacts to protected and commercial marine resources. This assessment will contribute to the Fleet's Integrated Long-Range Planning Process and represents an important component in the Fleet's ongoing compliance with U.S. federal mandates that aim to protect and manage resources in the marine environment. All species and habitats that are potentially affected by the Navy's maritime exercises and are protected by U.S. federal resource laws or executive orders are considered in this assessment.

A search and review of relevant literature and data was conducted to provide information on the relevant features of the marine environment (coastal and oceanic), the occurrence patterns of protected species, and the distribution of EFHs and fishing activities in the study area and vicinity. To describe the physical environment and habitats at Guam and the CNMI, physiographic, bathymetric, geologic, hydrographic, and oceanographic data for the region are presented and locations of benthic communities (e.g., live/hardbottom and coral reefs), artificial habitats (e.g., artificial reefs and shipwrecks), and submerged aquatic vegetation are identified. All available sighting, stranding, satellite tracking, nesting, and critical habitat data for marine mammals and sea turtles were compiled and interpreted to predict the occurrence patterns of these protected species in the study area and vicinity. Seasonal variations in occurrence patterns have been identified, mapped, and described along with the likely causative factors (behavioral, climatic, or oceanographic). Characteristics of these species, such as their behavior and life history, relevant to the evaluation of potential impacts of Navy operations are included. Also reviewed were the locations of EFHs, fishing activities, U.S. maritime boundaries, commercially navigable waterways, MMAs, and SCUBA diving sites. This report summary of the marine resources occurring in the Marianas MRA study area is provided in both paper and electronic form.

1.2 LOCATION OF STUDY AREA

The Marianas MRA study area is located in the western North Pacific Ocean more than 1,600 kilometers (km) south of Japan and 2,400 km east of the Philippines (**Figure 1-1**). The CNMI is a chain of 16 islands that extends 730 km from Farallon de Pajaros in the north to Rota in the south, and encompasses a total land area of 510 square kilometers (km^2). The largest islands in the CNMI are Saipan, Rota, and Tinian, which account for 65 percent (%) of the Commonwealth's land area and are home to 99% of its population. The U.S. Territory of Guam lies immediately to the south of the CNMI, and is the largest and southernmost island in the Mariana Islands archipelago (PBEC 1985). The Marianas MRA study area includes military training areas and ranges in the near vicinity of the following islands: Guam, Tinian, and Farallon de Medinilla (FDM). At Guam, four distinct areas were assessed: 1) Apra Harbor; 2) Agat Bay

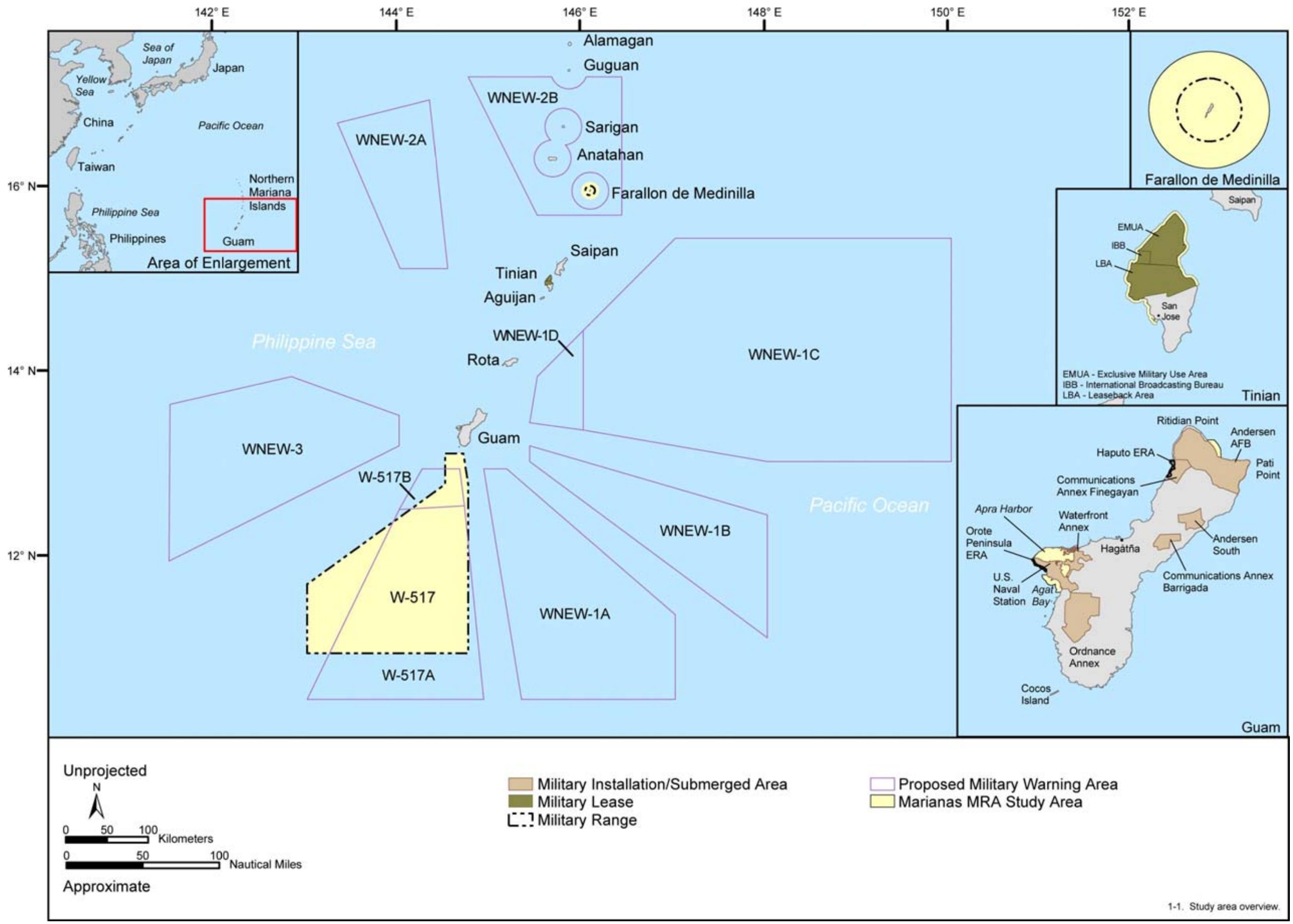

Figure 1-1. Guam and the Commonwealth of the Northern Mariana Islands (CNMI), northwest Pacific Ocean: Study area, military installations, military submerged areas (Haputo Ecological Reserve Area [ERA], Orote Peninsula ERA), military leases, military warning areas, and military ranges. Source data: DoN (2000, 2002).

(out to 1 km from shore); 3) waters off Andersen Air Force Base east of Ritidian Point (out to 1 km from shore); and 4) Warning Area W-517 (located 7.4 km due south of Cocos Island). Around Tinian, the Marianas MRA study area includes nearshore waters (out to 0.4 km from shore) surrounding the northern two-thirds of the island. At FDM, the study area includes all waters surrounding the island out to 10 km from shore, including all waters within the 5 km radius Navy Target Range (**Figure 1-1**). In addition to the current military training areas and ranges found within the Marianas MRA study area, there are nine proposed military warning areas that surround the Guam and CNMI islands (**Figure 1-1**). These proposed warning areas may become active in the future if activated by the Federal Aviation Administration (FAA).

Guam is the westernmost U.S. territory and is the largest, most populated island in Micronesia, the group of more than 2,000 islands scattered between Hawai'i and the Philippines. Guam is a strategic stopping point for ships and aircraft. Apra Harbor is one of the largest protected deepwater harbors in the central Pacific Ocean. Given its position with respect to the Far East and its recent development, the island has become a political, economic, and military stronghold of national and international significance (GlobalSecuirty.org 2004a).

Tinian is the second most populated island in the CNMI and is located 129 km north of Guam. The U.S. military leases more than two-thirds of the island. Training on Tinian occurs within the Military Lease Area, with limited activities in San Jose Harbor. The study area, which surrounds the northern two-thirds of Tinian, runs from San Jose Harbor on the west side of the island to the southern boundary of the Leaseback Area (LBA) on the east side of the island (GlobalSecurity.org 2004b).

Ninety percent of the CNMI population (62,392 inhabitants in 2000; CNMI Department of Commerce 2001) lives on Saipan, the administrative center of the CNMI. Saipan is the largest island of the CNMI (20 km long and 9 km wide). It has a rough topography and its highest point, Mount Tagpochau (474 meters [m] high), is an extinct volcano. Saipan is located approximately 200 km north of Guam, 5,150 km west of Hawai'i, and 2,012 km east of Japan. The Port of Saipan inaugurated in 1999 is a world-class commercial port facility and primary seaport of the CNMI that can accommodate deep draft vessels (Romero 1999; Commonwealth Ports Authority 2004). During 2004, 20 military vessels made a port call in Saipan including the USS Frank Cable (196 m long submarine tender) and USS Blue Ridge (194 m long Command Ship) (Commonwealth Ports Authority 2004; DoN 2003, 2005). Ships of the Military Sealift Command and Maritime Prepositioning Ship Squadron Three anchor off Saipan (DoN 2004). These ships are loaded with equipment, supplies, and ammunition to support a Marine Expeditionary Brigade of 17,000 during one month (DoN 2003).

FDM is an uninhabited, 81 hectare (ha) island that stands about 85 m above sea level. The island is currently being leased to the U.S. military by the CNMI. The lease agreement allows U.S. military use of the island as a target range until 2075. FDM plays a special and unique role in national defense and its location provides a suitable environment that can support established training requirements. In addition, the air and sea space at FDM provides sufficient room for the many different attack profiles necessary to replicate training operations in the CNMI. FDM is the Pacific Fleet's only U.S.-controlled range available for live-fire training for forward-deployed naval forces. The Pacific Fleet has been conducting military activities in this range since 1976 (GlobalSecurity.org 2004c).

1.3 APPLICABLE LEGISLATION

The primary environmental laws that govern Navy activities in the marine environment include NEPA, MMPA, ESA, and the MSFCMA. In addition to these acts, there are several other federal mandates and EOs that deal with resource conservation and management in ocean waters under U.S. jurisdiction. Following are chronological lists of the many laws and regulations that the Navy must consider when conducting maritime operations.

1.3.1 Federal Resource Laws

- The **Sikes Act** of 1960 (16 U.S. Code [U.S.C.] §§ 670a et seq.) provides for cooperation by the Departments of the Interior and Defense with State agencies in planning, development, and maintenance of fish and wildlife resources on military reservations throughout the U.S. This is accomplished through the creation of integrated natural resource management plans (INRMP), which are long-term planning documents that provide recommendations on managing natural resources. As required by the Sikes Act Improvement Act of 1997, the INRMP must, to the extent appropriate and applicable, provide for: 1) fish and wildlife management, land management, forest management, and fish- and wildlife-oriented recreation; 2) fish and wildlife habitat enhancement or modification; 3) wetland protection, enhancement, and restoration, where necessary for support of fish, wildlife, or plants; 4) integration of, and consistency among, the various activities conducted under the plan; 5) establishment of specific natural resources management goals and objectives and time frames for proposed actions; 6) sustainable use by the public of natural resources to the extent that the use is not inconsistent with the needs of fish and wildlife resources; 7) public access to the military installation that is necessary or appropriate for the sustainable use of natural resources, subject to requirements necessary to ensure safety and military security; 8) enforcement of applicable natural resource laws (including regulations); 9) no net loss in the capability of the installation's lands to support the military mission of the installation; and 10) such other activities as the military has determined appropriate.

- The **National Environmental Policy Act** (NEPA) of 1969 (42 U.S.C. §§ 4321 et seq.) established national policies and goals for the protection of the environment. The NEPA aims to encourage harmony between people and the environment, to promote efforts to prevent or eliminate damage to the environment and the biosphere, and to enrich the understanding of ecological systems and natural resources important to the country. Thus, environmental factors must be given appropriate consideration in all decisions made by federal agencies.

  The NEPA is divided into two sections: Title I outlines a basic national charter for protection of the environment, while Title II establishes the Council on Environmental Quality (CEQ), which monitors the progress made towards achieving the goals set forth in Section 101 of the NEPA. Other duties of the CEQ include advising the President on environmental issues and providing guidance to other federal agencies on compliance with the NEPA.

  Section 102(2) of the NEPA contains "action-forcing" provisions that ensure that federal agencies act according to the letter and the spirit of the law. These procedural requirements direct all federal agencies to give appropriate consideration to the environmental effects and cumulative impacts of their decision-making and to prepare detailed environmental statements on recommendations or reports on proposals for legislation and other major federal actions significantly affecting the quality of the environment.

  Future studies and/or actions requiring federal compliance which may utilize the data contained in this MRA should be prepared in accordance with Section 102(2)(c) of the NEPA, the CEQ regulations on implementing NEPA procedures (40 Code of Federal Regulations [CFR] 1500-1508), and the Department of the Navy (DoN) regulations on implementing NEPA procedures (32 CFR 775).

- The **Marine Mammal Protection Act** (MMPA) of 1972 (16 U.S.C. §§ 1361 et seq.) established a moratorium on the "taking" of marine mammals in waters or on lands under U.S. jurisdiction. The MMPA defines taking as "harassing, hunting, capturing, killing, or attempting to harass, hunt, capture, or kill any marine mammal" (16 U.S.C. 1312[13]). It also prohibits the importation into the U.S. of any marine mammal or parts or products thereof, unless it is for the purpose of scientific research or public display, as permitted by the Secretary of the Interior or the Secretary of Commerce. In the 1994 amendments to the MMPA, two levels of "harassment" were defined. Harassment is defined as any act of pursuit, torment, or annoyance that has the potential to injure a marine mammal or marine mammal stock in the wild (Level A), or any act that has the potential to disturb a marine mammal or marine mammal stock in the wild by disrupting behavioral patterns, including, but not limited to migration, breathing, nursing, breeding, feeding, or sheltering (Level B). In 2003, the National Defense Authorization Act for Fiscal Year 2004 altered the MMPA's definition of Level A and B harassment in regards to military readiness and scientific research activities conducted by or on behalf of the Federal Government. Under these changes, Level A harassment was redefined as any act that injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild. Level B harassment was redefined as any act that disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns, including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering, to a point where such behavioral patterns are abandoned or significantly altered.

Section 101(a)(5)(A) of the MMPA directs the Secretary of Commerce, upon request, to authorize the unintentional taking of small numbers of marine mammals incidental to activities (other than commercial fishing) when, after notice and opportunity for public comment, the Secretary: (1) determines that total takes during a five-year (or less) period have a negligible impact on the affected species or stock, and (2) prescribes necessary regulations that detail methods of taking and monitoring and requirements for reporting. The MMPA provides that the moratorium on takes may be waived when the affected species or population stock is at its optimum sustainable population and will not be disadvantaged by the authorized takes (i.e., be reduced below its maximum net productivity level). Section 101(a)(5)(A) also specifies that the Secretary has the right to deny permission to take marine mammals if, after notice and opportunity for public comment, the Secretary finds: (1) that applicable regulations regarding taking, monitoring, and reporting are not being followed, or (2) that takes are, or may be, having more than a negligible impact on the affected species or stock.

- The **Marine Protection, Research, and Sanctuaries Act** (MPRSA) (33 U.S.C. §§ 1401 et seq.), often referred to as the "Ocean Dumping Act," was also enacted in 1972, two days after passage of the MMPA. The MPRSA regulates the dumping of toxic materials beyond U.S. territorial waters and provides guidelines for the designation and regulation of marine sanctuaries. MPRSA Titles I and II prohibit persons or vessels subject to U.S. jurisdiction from transporting any material out of the U.S. for the purpose of dumping it into ocean waters without a permit. The term "dumping," however, does not include the intentional placement of devices in ocean waters or on the sea bottom when the placement occurs pursuant to an authorized federal or state program.

- The **Coastal Zone Management Act** (CZMA) of 1972 (16 U.S.C. §§ 1451 et seq.) established a voluntary national program through which U.S. states and territories can develop and implement coastal zone management plans (USFWS 2003a). The National Oceanic and Atmospheric Administration (NOAA), under the Secretary of Commerce, administers this act. States and territories use coastal zone management plans "to manage and balance competing uses of and impacts to any coastal use or resource" (NOAA 2000). A coastal zone management plan must be given federal approval before the state or territory can implement the plan (USFWS 2003a). The plan must include, among other things, defined boundaries of the coastal zone, identified uses of the area that the state/territory will regulate, a list of mechanisms that will be employed to control the regulated uses, and guidelines for prioritizing the regulated uses. Currently, there are 34 U.S. states and territories with federally approved coastal zone management plans. These states and territories manage 153,500 km (99.9%) of U.S. shoreline along the Atlantic, Pacific, and Arctic Oceans as well as the Great Lakes (NOAA 2003). Guam and the CNMI both have federally approved coastal zone management plans.

  The CZMA also instituted a Federal Consistency requirement, which provides Federal agencies with restrictions concerning their behavior in relation to state and territory managed coastal zones. Federal agency actions that affect any land or water use or natural resource of the coastal zone (e.g., military operations, outer continental shelf lease sales, dredging projects) must be "consistent to the maximum extent practicable" with the enforceable policies of a state or territory's coastal management program (Coastal Zone Act Reauthorization Amendments of 1990). The Federal Consistency requirement was enacted as a mechanism to address coastal effects, to ensure adequate Federal consideration of state and territory coastal management programs, and to avoid conflicts between states/territories and Federal agencies by fostering early consultation and coordination (NOAA 2000). Within each state or territory coastal zone management plan is a list of the Federal agency activities for which Consistency Determinations must be prepared. Under certain circumstances, the President is authorized to exempt specific activities from the Federal Consistency requirement if they determine that the activities are in the paramount interest of the U.S.

- The **Endangered Species Act** (ESA) of 1973 (16 U.S.C. §§ 1531 et seq.) established protection over and conservation of threatened and endangered species and the ecosystems upon which they depend. An "endangered" species is a species that is in danger of extinction throughout all or a significant portion of its range, while a "threatened" species is one that is likely to become endangered within the foreseeable future throughout all or in a significant portion of its range. All federal agencies are required to implement protection programs for threatened and endangered species and to use their authority to further the purposes of the ESA. The NOAA Fisheries (National Marine Fisheries Service [NMFS]) and U.S. Fish and Wildlife Service (USFWS) jointly administer the ESA and are also responsible for the listing (i.e., the labeling of a species as either threatened or endangered) of all "candidate" species. A "candidate" species is one that is the subject of either a petition to list or status review, and for which the NMFS or USFWS has determined that listing may be or is warranted (NMFS 2004). The NMFS is further charged with the listing of all "species of concern" that fall under its jurisdiction. A "species of concern" is one about which the 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 ESA (NMFS 2004).

  A species may be a candidate for listing as a threatened or endangered species due to any of the following five factors: (1) current/imminent destruction, modification, or curtailment of its habitat or range; (2) overuse of the species for commercial, recreational, scientific, or educational purposes; (3) high levels of disease or predation; (4) inadequacy of existing regulatory mechanisms; or (5) other natural or human-induced factors affecting its continued existence.

  The major responsibilities of the USFWS and NMFS under the ESA include: (1) the identification of threatened and endangered species; (2) the identification of critical habitats for these species; (3) the implementation of research programs and recovery plans for these species; and (4) the consultation with other federal agencies concerning measures to avoid, minimize, or mitigate the impacts of their activities on these species (Section 7 of the ESA). Further duties of the USFWS and NMFS include regulating "takes" of listed species on public or private land (Section 9) and granting incidental take permits to agencies that may unintentionally "take" listed species during their activities (Section 10a).

  The ESA allows the designation of geographic areas as critical habitat for threatened or endangered species. The physical and biological features essential to the conservation of a threatened or endangered species are included in the habitat designation. Designation of critical habitat affects only federal agency actions and federally funded or permitted activities.

  There are 32 species of marine mammals (29 cetaceans, 2 pinnipeds, and 1 sirenian), 5 species of sea turtles, and a multitude of bird, fish, and invertebrate species with potential occurrence in the Marianas MRA study area. Of these, 6 cetaceans, 1 pinniped, 1 sirenian, and 5 sea turtle species are listed as either threatened or endangered (**Table 1-1**). For the marine mammals, the NMFS has jurisdiction over cetaceans (e.g., whales, dolphins, and porpoises) while the USFWS has jurisdiction over pinnipeds (e.g., seals and sea lions) and sirenians (e.g., manatees and dugongs). The NMFS has jurisdiction over sea turtles while they are in the water and the USFWS has jurisdiction over sea turtles on land (including eggs, hatchlings that are on the beach, and nesting females).

  Fishes classified as species of concern in the MRA study area are the humphead wrasse (*Cheilinus undulatus*) and the bumphead parrotfish (*Bolbometopon muricatum*). These species are discussed in Chapter 4.0 under the "status" sections of the EFH designations.

- The **Fishery Conservation and Management Act** (FCMA) of 1976 (16 U.S.C. §§ 1801 et seq.), later renamed the **Magnuson-Stevens Fishery Conservation and Management Act** (MSFCMA), established a 200 nautical miles (NM) fishery conservation zone in U.S. waters and a network of regional Fishery Management Councils (FMCs). The FMCs are comprised of federal and state officials, including the NMFS, which oversee fishing activities within the fishery management zone. The act also establishes national standards (e.g., optimum yield, scientific information, allocations, efficiency, and costs/benefits) for fishery conservation and management. In 1977, the multifaceted

Table 1-1. The threatened and endangered species with potential occurrence in the Marianas Marine Resource Assessment (MRA) study area. Marine mammals taxonomy follows Rice (1998) for pinnipeds and sirenians and IWC (2004) for cetaceans except for the North Pacific right whale, which was revised by Rosenbaum et al. (2000). Sea turtle taxonomy follows Pritchard (1997). [[1]Although the species as a whole is listed as threatened, the Mexican Pacific nesting stock of the green turtle is listed as endangered. A risk-averse approach requires the assumption that at-sea animals encountered in the study area may come from the Mexican Pacific population and are therefore endangered]

Marine Mammals		
North Pacific right whale	*Eubalaena japonica*	Endangered
Humpback whale	*Megaptera novaeangliae*	Endangered
Sei whale	*Balaenoptera borealis*	Endangered
Fin whale	*Balaenoptera physalus*	Endangered
Blue whale	*Balaenoptera musculus*	Endangered
Sperm whale	*Physeter macrocephalus*	Endangered
Hawaiian monk seal	*Monachus schlauinslandi*	Endangered
Dugong	*Dugong dugon*	Endangered
Sea Turtles		
Green turtle	*Chelonia mydas*	Threatened[1]
Hawksbill turtle	*Eretmochelys imbricata*	Endangered
Loggerhead turtle	*Caretta caretta*	Threatened
Olive ridley turtle	*Lepidochelys olivacea*	Threatened
Leatherback turtle	*Dermochelys coriacea*	Endangered

regional management system began allocating harvesting rights, with priority given to domestic enterprises. Since a substantial portion of fishery resources in offshore waters was allocated for foreign harvest, these foreign allocations were eventually reduced as domestic fish harvesting and processing industries expanded under the domestic preference authorized by the MSFCMA. At that time, exclusive federal management authority over U.S. domestic fisheries resources was vested in the NMFS.

The authority to place observers on commercial fishing and processing vessels operating in specific geographic areas is also provided by the MSFCMA. The data collected by the National Observer Program, which is overseen by the NMFS, is often the best means to get current data on the status of many fisheries. Without observers and observer programs, there would not be sufficient fisheries data for effective management. Observer programs also satisfy requirements of the ESA and MMPA by documenting incidental fisheries bycatch of federally protected species, such as marine mammals and sea turtles.

- In 1977, Congress addressed the heightened concern over water pollution by amending the **Federal Water Pollution Control Act** (FWPCA) of 1948 (33 U.S.C. §§ 1251 et seq.). The 1977 amendments, known as the Clean Water Act (CWA), extensively amended the FWPCA. For a synopsis of FWPCA initiatives prior to 1977, consult USFWS (2003b), which documents the history of the FWPCA since its origin.

The CWA took the first step towards establishing a comprehensive solution to the country's serious water pollution problems (EPA 2003). Through standards, technical tools, and financial assistance, the CWA works towards the accomplishment of two goals: (1) to make U.S. waters fishable and swimmable and (2) to eliminate contaminant discharge into such waters. Under the authority of the Environmental Protection Agency (EPA), the act sets water quality standards for all pollutants, requires a permit for the discharge of pollutants from a point source, and funds sewage treatment plant construction (EPA 2003). Section 403 of the CWA sets out permit guidelines specific to the discharge of contaminants into the territorial sea, the contiguous zone, and waters further offshore (USFWS 2003b). The Chief of Engineers and the Secretary of the Army must approve discharges of dredged or fill material into all waters of the U.S., including wetlands. In addition to regulating pollution in offshore waters, the CWA, under the amendment known as the Water Quality Act of 1987, also requires state and federal agencies to devise programs and management plans that aim to maintain the biological and chemical integrity of estuarine waters. In estuaries of national significance, NOAA is permitted to conduct water quality research in order to evaluate state and federal management efforts. Sensitive estuarine habitats, such as seagrass beds and wetlands, are protected from pollution under this act.

- Like the CWA, the **Marine Plastic Pollution Research and Control Act** (MPPRCA) of 1987 (33 U.S.C. §§ 1901 et seq.) also regulates the discharge of contaminants into the ocean. Under this federal statute, the discharge of any plastic materials (including synthetic ropes, fishing nets, plastic bags, and biodegradable plastics) into the ocean is prohibited. The discharge of other materials, such as floating dunnage, food waste, paper, rags, glass, metal, and crockery, is also regulated by this act. Ships are permitted to discharge these types of refuse into the water, but they may only do so when beyond a set distance from shore, as prescribed by the MPPRCA. An additional component of this act requires that all ocean-going, U.S. flag vessels greater than 12.2 m in length, as well as all manned, fixed, or floating platforms subject to U.S. jurisdiction, keep records of garbage discharges and disposals (NOAA 2004).

- Passage of the **Oil Pollution Act** (OPA) of 1990 (33 U.S.C. §§ 2701 et seq.) further increased the protection of our nation's oceans. In addition to amending the CWA, this act details new policies relating to oil spill prevention and cleanup methods. Any party that is responsible for a vessel, offshore facility, or deepwater port that could potentially cause an oil spill must maintain proof of financial responsibility for potential damage and removal costs. The act details which parties are liable in a variety of oil spill circumstances and what damage and removal costs must be paid. The President has the authority to use the Oil Spill Liability Trust Fund to cover these costs when necessary. Any cost for which the fund is used must be in accordance with the National Contingency Plan, which is an oil and hazardous substance pollution prevention plan established by the CWA (USFWS 2003b). Federal, state, Indian tribe, and foreign trustees must assess the natural resource damages that occur from oil spills in their trusteeships and develop plans to restore the damaged natural resources. The act also establishes the Interagency Coordinating Committee on Oil Pollution Research, whose purpose is to research and develop plans for natural resource restoration and oil spill prevention.

- During the reauthorization of the MPRSA in 1992, Title III of the MPRSA was designated the **National Marine Sanctuaries Act** (16 U.S.C. §§ 1431 et. seq.). Title III authorizes the Secretary of Commerce to designate and manage areas of the marine environment with nationally significant aesthetic, ecological, historical, or recreational value as national marine sanctuaries. The primary objective of this law is to protect marine resources, such as coral reefs, sunken historical vessels, or unique habitats while facilitating all compatible public and private uses of these resources. National marine sanctuaries, similar to underwater parks, are managed according to management plans, prepared by the NOAA on a site-by-site basis. The NOAA is the agency responsible for administering the National Marine Sanctuary Program.

- In 1996, the MSFCMA was reauthorized and amended by the **Sustainable Fisheries Act** (SFA). The SFA provides a new habitat conservation tool in the form of the EFH mandate. The EFH mandate requires that the regional FMCs, through federal Fishery Management Plans (FMPs), 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 the 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 term "fish" is defined in the SFA as "finfish, mollusks, crustaceans, and all other forms of marine animals and plant life other than marine mammals and birds." The regulations for implementing EFH clarify that "waters" include all aquatic areas and their biological, chemical, and physical properties, while "substrate" includes the associated biological communities that make these areas suitable fish habitats (50 CFR 600.10). Habitats used at any time during a species' life cycle (i.e., during at least one of its life stages) must be accounted for when describing and identifying EFH (NMFS 2002).

Authority to implement the SFA is given to the Secretary of Commerce through the NMFS. The SFA requires that the EFH be identified and described for each federally managed species. The identification must include descriptive information on the geographic range of the EFH for all life stages, along with maps of the EFH for life stages over appropriate time and space scales. Habitat requirements must also be identified, described, and mapped for all life stages of each species. The NMFS and regional FMCs determine the species distributions by life stage and characterize associated habitats, including HAPC. The SFA requires federal agencies to consult with the NMFS on activities that may adversely affect EFH. For actions that affect a threatened or endangered species, its critical habitat, and its EFH, federal agencies must initiate both ESA and EFH consultations.

In 2002, the EFH Final Rule was authorized, which simplified EFH regulations (NMFS 2002). Significant changes delineated in the EFH Final Rule are: (1) clearer standards for identifying and describing EFH, including the inclusion of the geographic boundaries and a map of the EFH, as well as guidance for the FMCs to distinguish EFH from other habitats; (2) more guidance for the FMCs on evaluating the impact of fishing activities on EFH and clearer standards for deciding when FMCs should act to minimize the adverse impacts; and (3) clarification and reinforcement of the EFH consultation procedures (NMFS 2002). The process by which federal agencies can integrate MSFCMA EFH consultations with ESA Section 7 consultations is described in NMFS (2002).

1.3.2 Executive Orders

- **EO 12114 on Environmental Effects Abroad of Major Federal Actions** (32 CFR 187) was passed in 1979 to further environmental objectives consistent with U.S. foreign and national security policies by extending the principles of the NEPA to the international stage. Under EO 12114, federal agencies that engage in major actions that significantly affect a non-U.S. environment must prepare an EA of the action's effects on that environment. This is similar to an environmental impact statement (EIS) or EA developed under the NEPA for environments in the U.S. Certain actions, such as intelligence activities, disaster and emergency relief actions, and actions that occur in the course of an armed conflict, are exempt from this order. Such exemptions do not apply to major federal actions that significantly affect an environment that is not within any nation's jurisdiction, unless permitted by law. The purpose of the order is to force federal agencies to consider the effects their actions have on international environments.

- **EO 12962 on Recreational Fisheries** (60 Federal Register [FR] 30769) was enacted in 1995 to ensure that federal agencies strive to improve the "quantity, function, sustainable productivity, and distribution of U.S. aquatic resources" so that recreational fishing opportunities nationwide can increase. The overarching goal of this order is to promote the conservation, restoration, and enhancement of aquatic systems and fish populations by increasing fishing access, education and outreach, and multi-agency partnerships. The National Recreational Fisheries Coordination Council (NRFCC), co-chaired by the Secretaries of the Interior and Commerce, is charged with overseeing federal actions and programs that are mandated by this order. The specific duties of the NRFCC include: (1) ensuring that the social and economic values of healthy aquatic systems, which support recreational fisheries, are fully considered by federal agencies; (2) reducing duplicative and cost-inefficient efforts among federal agencies; and (3) disseminating the latest information and technologies to assist in the conservation and management of recreational fisheries. In June 1996, the NRFCC developed a comprehensive Recreational Fishery Resources Conservation Plan (RFRCP) specifying what member agencies would do to achieve the order's goals (NMFS 1999). In addition to defining federal agency actions, the plan also ensures agency accountability and provides a comprehensive mechanism to evaluate achievements. A major outcome of the RFRCP has been the increased utilization of artificial reefs to better manage recreational fishing stocks in U.S. waters (USFWS 2003c).

- **EO 13089 on Coral Reef Protection** (60 FR 30769) was issued in 1998 "to preserve and protect the biodiversity, health, heritage, and social and economic value of U.S. coral reef ecosystems and the marine environment." The EO directs all federal agencies to protect coral reef ecosystems to the extent feasible and instructs particular agencies to develop coordinated science-based plans to restore damaged reefs as well as mitigate current and future impacts on reefs, both in the U.S. and around the globe (Agardy 2000). This order also establishes the interagency U.S. Coral Reef Task Force, co-chaired by the Secretary of the Interior and the Secretary of Commerce through the Administrator of the NOAA.

- **EO 13158, Marine Protected Areas** (65 FR 34909) of 2000 is a furtherance of EO 13089. It created the framework for a national system of marine protected areas (MPAs). MPAs are defined in EO 13158 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." This EO strengthened governmental interagency cooperation in protecting the marine environment. It also calls for strengthening management of these existing areas, creating new ones, and preventing harm to marine ecosystems by federally approved, conducted, or funded activities (Agardy 2000). Currently, the NOAA is redefining the criteria used to designate MPAs and has recently reclassified all existing MPAs as "marine managed areas." A more in-depth discussion on the NOAA's process of redefining MPAs is included in Chapter 5.

1.4 METHODOLOGY

1.4.1 Literature and Data Search

A thorough and systematic search for relevant scientific literature and data was conducted. Once identified, information vital to the production of this MRA report was obtained, reviewed, and catalogued. Of the available scientific literature (both published and unpublished), the following types of documents were utilized in the assessment: journals, periodicals, bulletins, monographs of scientific and professional societies, theses, dissertations, project reports, endangered species recovery plans, stock assessment reports, EISs, FMPs, and other technical reports published by government agencies, private businesses, or consulting firms. The scientific literature was also consulted during the search for geographic location data (geographic coordinates) on the occurrence of marine resources within the study area.

To investigate the physical environment and habitats of the study area, to summarize the occurrence patterns of marine mammals and sea turtles, to depict areas identified as EFH and HAPC, and to determine the locations of maritime boundaries, commercially navigable waterways, marine managed areas, and diving sites, information and literature were collected from the following sources:

- Academic and educational/research institutions: University of Guam Marine Laboratory, Scripps Institute of Oceanography, Texas A&M University, University of Hawai'i, James Cook University, New England Aquarium, Centre de Recherches Insulaires et Observatoire de l'Environment, Smithsonian Institution, Waikiki Aquarium, The Nature Conservancy-Pacific Island Countries Program;

- University on-line databases: DIALOG (e.g., Oceanic Abstracts, Enviroline, Pollution Abstracts, Aquatic Sciences and Fisheries Abstracts, Life Science Collection, Zoological Record Online, Water Resources Abstracts, National Technical Information Service, Federal Register, Dissertation Abstracts, BIOSIS Previews), First Search (e.g., BIODigest, BiolAgrindex, GenSciIndex, the Government Printing Office), Cambridge Abstracts;

- The Internet, including various databases and related websites: NOAA, NOAA Fisheries, Ocean Biogeographic Information System (OBIS), Ocean Planning and Information System (OPIS), U.S. Geological Survey (USGS), U.S. Coast Guard (USCG), General Dynamics Advanced Information Systems, Veridian Corporation, Elsevier, Allen Press, Blackwell-Science, Pacific Islands Fisheries Science Center (NOAA Fisheries-PIFSC), FishBase, ReefBase, Reef Environment Education Foundation, Food and Agriculture Organization (FAO), FR, Pacific Daily News, Marine Turtle Newsletter, Proceedings of the Annual Sea Turtle Symposium, University of Florida Sea Turtle

Bibliography, WhaleNet, InnerCity Oz, the National Sea Grant Library, Ingenta, AVISO, the International Union for the Conservation of Nature and Natural Resources (IUCN);

- International agencies and commissions: International Whaling Commission (IWC), United Nations Environment Programme (UNEP), Pacific Regional Environment Programme (formerly known as the South Pacific Regional Environment Programme [SPREP]);

- U.S. federal agencies: DoD; DoN: Naval Facilities Engineering Command, Pacific; DoN: Naval Pacific Meteorological and Oceanography Center, Navy Exchange Dive Center Guam; Marine Mammal Commission (MMC); Minerals Management Service (MMS); National Aeronautic and Space Administration (NASA); National Park Service (NPS); NOAA Fisheries: Pacific Islands Regional Office (PIRO), Office of Protected Resources, Office of Habitat Conservation, Southwest Fisheries Science Center (SWFSC), PIFSC; NOAA: National Ocean Service (NOS), Sustainable Seas Expedition, National MPA Center, National Marine Mammal Laboratory (NMML), Western Pacific Regional Fishery Management Council (WPRFMC), National Data Buoy Center; USFWS: Refuges Division, Ecological Field Services Office, Guam National Wildlife Refuge;

- U.S. commonwealth and territory agencies: Guam Bureau of Statistics and Plans, Guam Division of Aquatic and Wildlife Resources (DAWR), Guam Environmental Protection Agency, CNMI Coastal Resources Management Office, CNMI Division of Fish and Wildlife (DFW), CNMI Division of Environmental Quality; and

- Local dive shops and tour operators: Dive Rota, Micronesian Divers Association, and Guam Tropical Dive Station.

1.4.2 Spatial Data Representation—Geographic Information System

The geographical representation of marine resource occurrences in the Marianas MRA study area was a major constituent of this MRA report. The marine resources data and information accumulated for this project were accessed from a wide variety of sources, were in disparate formats, covered a broad range of time periods, and represented differing levels of accuracy as well as quality assurance. The spatial or geographical component that was common to all data sets allowed the widely dissimilar data to be visualized in a meaningful manner. Without this common data characteristic, graphical display of such disparate data would have been difficult, if not impossible, to achieve.

A GIS was used to store, manipulate, analyze, and visualize the spatial data and information accumulated for the study area. For this project, Environmental Systems Research Institute, Inc.'s (ESRI) ArcView® version 3.2 GIS software was used to create the majority of map figures and ArcView® version 8.2 was used to create the metadata as well as some features of the three-dimensional map figures. ArcView® was chosen for this project due to its widespread use, ease of operation, and its ability to create multiple views and layouts within the same project file.

The geographic locations of important marine resources in the study area were derived from four types of sources (in order of reliability): source data, scanned source maps, source information, and information adapted from published maps. The “source data,” which include geographic coordinates and GIS shapefiles, were first scrutinized for data quality. If the data were in coordinate form, they were then converted to decimal degrees, if necessary, and text fields were renamed or added for ease of manipulation. Once standardized, the source data were imported into the GIS software. Some of the data were only available as graphical representations or “source maps.” These data were scanned, imported into ArcView®, and geo-referenced using the Image Analysis extension, with significant information being digitized into a shapefile format. Materials acquired as Adobe® Portable Document Format (PDF) files were also treated as scanned source maps (i.e., they were geo-referenced and pertinent information was digitized), since they were already in a digital form. A third type of source, “source information,” encompasses information that was neither taken from a scanned map nor was available in coordinate form. For example, maps displaying non-coordinate data, information given via personal communication, or information extracted from a literature description are referenced as source information. In certain cases, source maps and/or information had to be interpreted to be usable in the GIS environment. Maps displaying geographic information that was interpreted or altered from the original source map/information are noted in the figure caption as being "adapted from" that source.

The source type and associated references for all marine resources data presented in the map figures are listed in each figure's caption. The full reference citations for map source data or information may be found in the Literature Cited section of each MRA chapter. The two primary types of spatial information used in the Marianas MRA were coordinate data and scanned maps. These two source types are associated with differing levels of data reliability or confidence (**Appendix A-1** contains a further explanation of data confidence). Numerical or authentic data are associated with the highest level of reliability, while data obtained by scanning source maps are less reliable.

Problems were encountered when data sets were combined during the development of the map figures. Source data were not in a standard format, there was no standard naming convention for species names, and some data sets included missing or unlabeled data fields. To mitigate these difficulties, many steps were taken to standardize and control the quality of the numerical data, especially for the marine mammal and sea turtle data. Prior to using the data, a master database was created in Microsoft® Access where the data format was standardized so that the data could be merged and later used in the GIS. To accomplish this, data were manipulated to match data set records with a set of standard field names. In some cases, the latitude and longitude had to be converted to decimal degrees with accuracy to the fourth decimal place. Species' common names were added to the database to replace the multiple species codes that accompanied the original data. The different types of codes used for species names in the original data sets were not always consistent from one data set to the next. Compiling a comprehensive list of species names increased the chances of plotting all sightings for a given species on the map figures. To maintain the integrity of the original data, all fields and records were kept without alteration. When necessary, fields were created to store supplemental information or data that was altered from the original source. No original data fields were deleted and all added fields are signified by the "GMI_" prefix (GMI: Geo-Marine, Inc.). For example, source fields were added to the main data set to indicate the origin of the data and are shown in the field as "GMI_source."

GIS data are displayed as layers or "themes" for which scale, extent, and display characteristics can be specified. Multiple themes are represented on an individual map figure. Throughout the project, data imported into ArcView® had to be maintained in the most universal, least transformed manner in order to avoid conflict between theme coordinate systems and projections. In the GIS, the most flexible spatial data format is the unprojected geographic coordinate system, which uses decimal-degree latitude and longitude coordinates (**Appendix A-2** contains more information on map projections). The decimal-degree format is the only coordinate system format that allows unlimited, temporary, custom projection and re-projection in ArcView® and is, therefore, the least restrictive spatial data format. The printed maps and electronic GIS map data for this MRA report are unprojected and are not as spatially precise (in terms of distance, area, and shape) as a projected map. Consequently, the maps should not be used for measurement or analysis.

Once the marine resources data were imported and stored in the GIS, maps were created representing multiple layers of either individual or combined data. Maps in this report are presented in several different forms and scales, depending upon the marine resource in question. Full-page maps of the entire study area region, from FDM to the southern boundary of Warning Area W-517, are at the approximate scale of 1:3,289,000. At this scale, it is difficult to visualize the distributions of marine resources that are located in nearshore environments. As a result, a number of maps include zoomed in views of Guam, Tinian, and FDM so that the locations of certain coastal resources in Apra Harbor, Agat Bay, off Andersen Air Force Base, and around Tinian and FDM can be more easily viewed. The maps in this MRA report are presented in both kilometers and nautical miles.

The ability to display and analyze multiple data themes or layers simultaneously is one of the advantages to using a GIS rather than other graphic software. Customizations were made to the software in Avenue®, ESRI's proprietary macro-language, to automate the more repetitive map-making tasks as well as the processing and analysis of large volumes of data.

1.4.2.1 Maps of the Physical Environment—Oceanography and Habitats

Bathymetric data from Sandwell et al. (2004) were sampled at 2 minute (min) resolution and were acquired as geographic coordinates giving depth below mean sea level. Depth data were imported into the Spatial Analyst module of ArcView®, which interpolated and contoured the data at 50 m intervals for waters shallower than 100 m and at 500 m intervals for waters deeper than 500 m. Selected isobaths from the resulting two-dimensional contours are shown on the bathymetry figures and on various maps throughout the MRA report.

To illustrate the three-dimensional (3D) bathymetry of the Marianas MRA study area, triangular irregular networks (TINs), which interpolate intermediate data values between surveyed data points, were created using the available bathymetry data and processing those data in the ArcGIS® 3D Analyst extension. The 2 min bathymetric sounding data sampled from Sandwell et al. (2004) were used to create the TIN, which depicts the 3D bathymetry of the study area (**Figures 2-1** and **2-4**). The TINs were viewed in the ArcGIS® 8.3 ArcScene™ extension to model the 3D display. ArcScene® allows the 3D display to be manipulated (i.e., rotated, tilted, zoomed, classified, and overlaid with data). The most authentic display was exported directly from an ArcScene® view as a graphic file (.tif), which was then imported into ArcView® for the final map layout.

Seasonal averages of sea surface temperature (SST) were obtained from the NASA and compiled from weekly averaged Advanced Very High-resolution Radiometer (AVHRR) images, which contain multi-channel sea surface temperature (MCSST) pixel data for the years 1981 to 2001. Seasonal averages of chlorophyll *a* (chl *a*) concentrations were also obtained from the NASA and compiled from monthly averaged Coastal Zone Color Scanner (CZCS) images taken from 1978 to 1986 to provide a proxy of primary productivity for the study area. Seasons were defined with the same monthly derivations used throughout the MRA report (dry=December through June, rainy=July through November).

Multiple sources of data and information were used in the creation of maps for the oceanic and coastal habitats located in the Marianas MRA study area and vicinity. The maps displaying benthic communities, chemosynthetic communities, and artificial habitats (**Figures 2-3**, **2-13**, and **2-14**) are good examples of multiple data sources used in the creation of a single map. These maps were created using scanned images, coordinate data, GIS shapefiles, and other information available in the scientific literature and technical reports.

1.4.2.2 Biological Resource Maps—Species of Concern

Marine mammal and sea turtle occurrence data were accumulated from every available source; however, it was impossible to obtain every data source in existence for the Marianas MRA study area. An overview of all existing marine mammal and sea turtle data sources is found in **Appendix A-3**. Available marine mammal and sea turtle data displayed on the maps included in this MRA are listed in **Table A-1**. The data described in **Table A-1** include occurrence data from marine surveys, opportunistic sighting programs, and stranding records. Miscellaneous sighting and stranding data available from the scientific literature were also used in this MRA. These literature-based records represented the vast majority of occurrence data that were available for marine mammals. Not included in **Table A-1** are occurrence data from incidental fisheries bycatch records, release and recapture programs, and nesting surveys, as these types of data either were not available for inclusion at this time or did not possess the necessary detail required for inclusion in the GIS. The combined source data mentioned above were vital to the creation of occurrence polygons for protected species potentially occurring in the Marianas MRA study area.

When working with the marine mammal and sea turtle data, several assumptions were made. First, it was assumed that the species identifications given were correct. This assumption was necessary since the reliability of species identifications from one dataset to the next was not always known. For the sake of consistency, reliability of species identification was not considered in the plotting of any marine mammal or sea turtle data. Although it was assumed that the species identifications were correct, it could not always be assumed that the geographic coordinates in any data set, when provided, were correct. Several of the available marine mammal and sea turtle data sets lacked geographic coordinates, and determination of the locations required educated predictions based upon the physical description of locales. An underlying premise used during the map creation process was that a conservative approach to delineating occurrence patterns of marine mammals and sea turtles was necessary since all 5 sea turtle species and several of the marine mammal species are either threatened or endangered.

The data for individual and groups of species were used to create occurrence polygons for marine mammal and sea turtle species. Four types of occurrence information may be displayed on each turtle or mammal map: areas of **expected occurrence** (areas encompassing the expected distribution of a species based on what is known of its habitat preferences, life history, and the available sighting and stranding data), areas of **concentrated occurrence** (subareas of a species' expected occurrence where there is the highest likelihood of encountering that species; this designation is based primarily on areas of concentrated sightings and preferred habitat), areas of **low/unknown occurrence** (areas where a species is believed to be rare or the likelihood of encountering that species is not known), and areas labeled **occurrence not expected in study area** (areas within the Marianas MRA study area where a species is not expected to be encountered).

1.4.2.3 Biological Resource Maps—Fish and Fisheries

Maps displaying the EFH for all life stages of marine fish, crustaceans, invertebrates, and sessile benthos found within the study area and vicinity were created from official FMP habitat descriptions and maps produced by the WPRFMC. None of the EFH data were available in a usable electronic format. As a result, the locations of EFH and HAPC were determined by developing polygons encompassing the bathymetric ranges for each life stage. The EFH for each life stage found within the study area are presented together on one map for each Management Unit Species (MUS) and for each family and/or families in the Coral Reef Ecosystem (CRE). The EFH maps depict each of the associated life stages (for MUS and individual families in the Currently Harvested Coral Reef Taxa [CHCRT]: eggs, larvae, juvenile, adult; for CHCRT/Potentially Harvested Coral Reef Taxa [PHCRT]: all life stages). The EFH maps do not have seasonal designations as the FMPs presented EFH information according to life history stages, not seasons.

1.4.2.4 Maps of Additional Considerations

Information regarding the locations of maritime boundaries, commercially navigable waterways, MMAs, and SCUBA diving sites in the Marianas MRA study area was gathered from a wide array of sources. Maps displaying the U.S. maritime boundaries, major commercial shipping lanes, and MMAs were created using GIS shapefiles produced by federal and commonwealth/territory agencies, academic institutions, and privately owned companies. Recreational diving sites in the study area and vicinity were depicted using geographic data and maps available from SCUBA diving guides, a Navy EIS, local dive operators, and the CNMI Coastal Resources Management Office.

1.4.2.5 Metadata

The creation of metadata files was a large component of the GIS aspect of this assessment. All GIS files used to produce maps contained within this assessment have associated metadata. Since most of the GIS files contained in this report were collected from other agencies, it was requested that those agencies send metadata or source information along with the donated shapefiles or databases they created.

Metadata is information about GIS data. Metadata for geographical data may include the source of the data, its creation date and format, its projection, scale, resolution, and accuracy, and its reliability with regard to some standard. Metadata also consists of properties and documentation. Properties are derived from the data source, while documentation is entered by a person. ArcCatalog® stores metadata in extensible markup language (XML), so the same metadata can be viewed in many different ways using different style sheets. By default, ArcCatalog® automatically creates and updates metadata, which can then be stored within a geodatabase. Metadata for a folder can also consist of a well-formed hyper text markup language (HTML) file describing its contents.

1.4.3 Inherent Problems with Marine Survey Data

When attempting to use aerial and shipboard survey data as a major indicator of a species' occurrence, it is necessary to first recognize the inherent problems associated with each survey type. One of the main drawbacks of surveys in the marine environment is that aerial and shipboard surveys count the number of animals at the water's surface, where species such as cetaceans and sea turtles spend relatively little time. Since sea turtles spend over 90% of the time underwater, it has been estimated that marine surveys undersample (underestimate) the total number of sea turtles in a given area by as much as an order of magnitude (Shoop and Kenney 1992; Renaud and Carpenter 1994). Although scientists have devised mathematical formulas to account for animals not seen at the surface, the diving behavior of one individual may be different from that of other members of the same species. Even though marine mammals and sea turtles are obligated to come to the surface to breathe, many individuals will not surface within an observer's field of view. This is of particular concern when attempting to sight species that dive for extended periods of time, do not possess a dorsal fin, and are known to exhibit cryptic behavior, such as beaked whales and sperm whales (Würsig et al. 1998; Barlow 1999). Beaked whales are often solitary individuals, which makes their sightability much different from a species that regularly occurs in large groups, such as dolphins in the genus *Stenella* (Scott and Gilbert 1982).

Sighting conditions also affect the sightability of marine mammals and sea turtles. Sighting frequencies vary due to the amount of sun glare on the water's surface, the sea state, and the water clarity. Both sea state and glare have statistically significant effects on sighting frequency (Scott and Gilbert 1982; Thompson 1984). When water clarity is poor, animals are difficult to see below the water's surface, and only those animals at the water's surface that are extremely close to the observer are usually identifiable.

Problems also arise when attempting to select an optimal and efficient survey method for sampling marine mammals and sea turtles. Since most surveys are multi-species surveys, the sampling design, although likely cost- and labor-efficient, cannot be considered optimal for each species (Scott and Gilbert 1982). The altitude at which marine mammal aerial surveys are flown is much higher than is desirable to sight sea turtles (which are typically much smaller than cetaceans). Shipboard surveys designed for sighting marine mammals are adequate for detecting large sea turtles but usually not the smaller-sized turtles. Their relatively small size, diving behavior, and startle responses to vessels and aircraft make smaller sea turtles difficult to sight or visually observe from a ship. The youngest age-classes, which often inhabit waters far from land, are extremely difficult to spot and identify to species.

In addition, marine surveys are unable to assist scientists in accurately describing the seasonal occurrence of marine mammals and sea turtles in extremely large areas, such as the Pacific Ocean. The occurrence of marine mammals and sea turtles in an area often changes on a seasonal basis in response to changes in water temperature, the movement and availability of prey, or an individual's life history requirements, such as reproduction; therefore, the number of sightings on a specific date over a specific trackline may not be representative of the number of individuals occurring in the entire area over the course of an entire season or year. As a result, sighting frequency is often a direct result of the level of survey effort expended in a given area. Other difficulties with marine surveys include weather, time, and logistical constraints. For example, the operating cost for a large research vessel is approximately $10,000 per day (Forney 2002).

As a result of these problems, there have been no large-scale surveys in the western North Pacific Ocean designed to specifically address information needs relative to marine mammals and sea turtles. Scientists have, however, conducted smaller-scale aerial, marine tow, SCUBA, and beach surveys designed specifically to sight sea turtles in the nearshore waters around Guam and the CNMI. These surveys have not only allowed scientists to determine high-use foraging and nesting areas, they have also provided scientists with sufficient information in order to estimate trends in sea turtle abundance over time.

1.4.4 Inherent Problems with Stranding Data

How closely the distribution of marine mammal and sea turtle stranding records mirrors the actual occurrence of a species in a given region is often not known. Sick animals may strand well beyond their normal range and carcasses may travel long distances before being noticed by observers. Stranding frequency in a given area is as much a function of nearshore and offshore current regimes and coastal zone patrol efforts as it is a function of the stranded species' actual pattern of occurrence. Since coastal species will strand more frequently than oceanic species, due to their closer proximity to shore, stranding frequencies should not be used when attempting to compare the occurrence of a coastal versus an oceanic stock in a certain area. Comparisons cannot be made between species of differing sizes and social structures, as strandings of large-bodied species and groups of individuals are much more likely to be reported than strandings of small-bodied species or single individuals. An additional problem with the use of stranding data involves the inability of reporters to identify carcasses as a certain species. For example, only the most experienced marine mammal scientists are likely able to differentiate between the several species of beaked whale in the genus *Mesoplodon*.

1.5 REPORT ORGANIZATION

This report consists of eight major chapters and associated appendices. Chapter 1—Introduction provides background information on this project, an explanation of its purpose and need, a review of relevant environmental legislation, and a description of the methodology used in the assessment. Chapter 2—Physical Environment and Habitats describes the physical environment of the study area, including the marine geology (physiography, bathymetry, and bottom sediments), physical oceanography (circulation and currents), hydrography (surface temperature and salinity), biological oceanography (plankton), and habitat complexity. It also discusses the distribution of nearshore habitats (e.g., rocky and sandy shore), benthic habitats (e.g., coral reefs, artificial reefs, shipwrecks), and submerged aquatic vegetation in the study area and surrounding region. Chapter 3—Species of Concern covers two protected taxa found in the study area: marine mammals and sea turtles. For these species, detailed narratives of their morphology, status, habitat preferences, distribution (including migratory patterns), behavior, life history, and acoustics and hearing (if known) have been provided. Chapter 4—Fish and Fisheries investigates fish, EFH, and fishing activities (commercial and recreational) that occur within the study area. Chapter 5—Additional Considerations provides information on U.S. maritime boundaries, navigable waterways and commercial shipping lanes, MMAs, and SCUBA diving sites. Chapter 6—Recommendations suggests future avenues of research that may fill the data gaps identified in this project and prioritizes research needs from a cost-benefit approach. Chapters 7 and 8 are the List of Preparers and Glossary, respectively. Appendix A includes supplementary materials referred to in the Introduction (including a list of marine mammal and sea turtle occurrence data sources) while Appendices B and C contain occurrence map figures that are described or referenced in the marine mammal and sea turtle sections (3.1 and 3.2, respectively) of Chapter 3. Appendix D includes maps for all fishery management units (e.g., pelagic fish, crustaceans, bottomfish) and ecosystems (e.g., CRE) that have designated EFH within the study area.

This report is written in a format and reference style similar to that found in *The Chicago Manual of Style*, 14th Edition. Cited literature appears at the end of each chapter except in Chapter 3, Species of Concern, where the cited literature appears at the end of each chapter section.

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2.0 PHYSICAL ENVIRONMENT AND HABITATS

The islands of the Mariana archipelago lie between latitude 13 degrees (°) N and 20°N and are approximately 5,800 km west of Hawai'i, 2,250 km south of Japan, and 7,600 km north of Sydney, Australia (DoN 1998; DoN 2003a, 2003b). The archipelago extends roughly 800 km from Guam in the south to the uninhabited island of Farallon de Pajaros in the north (DoN 1998) and is divided into three relatively parallel arcs. The outer frontal arc is composed of the more southerly limestone islands while the inner, or active arc, extends to the north to form the only active volcanic islands in Micronesia (Eldredge 1983).

The Marianas MRA study area and vicinity (study area) extend from the high tide shore line along the islands of Guam, Tinian, and FDM to over 11,000 m of water depth in the Marianas Trench. The study area includes several dominant physiographic features including the Marianas Trench, seamounts, and active submarine volcanoes.

2.1 CLIMATE AND WEATHER

The tropical climate of the study area is influenced by easterly trade winds and can be described as warm and humid throughout the year, although rainfall and wind exhibit distinct seasonal patterns (Eldredge 1983). Average temperatures range from 29° to 32° Celsius (C) during the day and drop to 21° to 24°C overnight (Eldredge 1983; DoD 1999). The months of January through March are generally the coolest months of the year, with May and June being the warmest. Throughout the year, relative humidity ranges from 65 to 75% in the afternoon and increases at night to 85 to 100%. Annual rainfall ranges from 1,775 to 2,285 millimeters [mm] per year with the more southerly (more tropical) islands in the study area receiving higher levels of rainfall than the more northern islands. The study area experiences two distinct seasons, a dry and a rainy season, separated by brief periods of transitional weather (Eldredge 1983; DoD 1999). Climatic anomalies influencing the study area include El Niño/Southern Oscillation (ENSO), La Niña, and the Pacific Decadal Oscillation (PDO) (Trenberth 1997; Giese and Carton 1999; Sugimoto et al. 2001; Mantua 2002; NOAA 2005a, 2005b).

During normal conditions, trade winds blowing west across the tropical Pacific pile up warm water in the west Pacific (~0.5 m sea surface height difference between Indonesia and Ecuador) (Conlan and Service 2000; NOAA 2005a, 2005b). The equatorward flow of the eastern boundary Peru Current along the South America coastline and the easterly trade winds cause the offshore transport of cool surface water (Ekman layer) (Pickard and Emery 1982; NOAA 2005b) visualized as a large "cold tongue" extending westward across the Equatorial Pacific. The removed surface water is replaced by upwelled cold and nutrient-rich water which favors increased primary productivity and higher trophic levels (including fisheries). Under these normal conditions, rainfall is scare in the eastern Pacific and is concentrated over the warmest water in the west Pacific.

2.1.1 Seasons

The dry season (December to June) is characterized by strong and consistent tradewinds blowing from the east to northeast at 24 to 40 km per hour (kph) (Eldredge 1983; DoD 1999; Paulay 2003). Winds are heaviest during the late morning and afternoon and are lightest during the night. On average less than 20% of the study area's rain falls during the dry season and thunderstorms are rare (Eldredge 1983; DoD 1999).

During the rainy season (July through November), the study area experiences heavy winds and rains, with squalls and gales becoming more common (Eldredge 1983; DoD 1999). Rain falls during more than 75% of the days. More than 60% of the annual rainfall is received in the study area during the rainy season.

Tropical cyclones commonly traverse the study area from August to November with the peak typhoon season extending from July through October (Elsner and Liu 2003). Typhoons are tropical cyclones with maximum sustained surface wind speeds greater or equal to 33 meters per second (m/sec) and less than

65 m/sec (JTWC 1998). Super typhoons have sustained surface winds with speeds greater than 65 m/sec from 1960 to 2001, there were on average 2.7 to 3.5 typhoons per year in the northwestern Pacific Ocean (JTWC 2005). Typhoons have occurred on Guam in every month of the year (Paulay personal communication).

Storm surge, winds, salt stress, and heavy rainfall generated by tropical cyclones can cause a number of damages to marine and terrestrial resources (Schlappa 2004). The storm surge (difference between the mean tide level and the tide level during the tropical cyclone) and excessive rainfalls caused by tropical cyclones can cause flooding, a change in the nearshore salinity, the erosion and sedimentation of marine resources, destruction of shoreline structures, and terrestrial and marine habitat destruction. Strong winds and salt stress can cause the defoliation and uprooting of trees which in turn will cause a pulse of debris and nutrients affecting both terrestrial and marine resources (Schlappa 2004). Typhoons have impacted algal and coral communities of the Mariana Islands (Randall and Eldredge 1977; Paulay 2003). In waters shallower than 30 m, windward exposed fore reefs of the Mariana Islands rarely include fragile growth forms (including tabular growth forms) because of the recurrent typhoon wave damage (Paulay 2003; Schlappa 2004). *Acropora* as a genus is abundant in this depth zone (Paulay personal communication).

2.1.2 El Niño/Southern Oscillation, La Niña

The ENSO is the result of interannual swings in sea level pressures in the tropical Pacific between the eastern and western hemispheres (Conlan and Service 2000). ENSO events typically last 6 to 18 months, and can initiate large shifts in the global atmospheric circulation. El Niño occurs when unusually high atmospheric pressure develops over the western tropical Pacific and Indian Oceans and low sea level pressures develop in the southeastern Pacific (Trenberth 1997; Conlan and Service 2000). El Niño means The Little Boy or Christ child in Spanish, and was originally defined by fisherman off the western coast of South America with the onset of unusually warm waters occurring near the beginning of the year. This name was used for the tendency of the phenomenon to arrive around Christmas. During El Niño conditions, the trade winds weaken in the central and west Pacific which impedes the east to west surface water transport and the upwelling of cold water along South America and causes the SST to increase across the mid to eastern Pacific (Donguy et al. 1982). In the western equatorial Pacific, SST is lower than in non-El Niño years (Kubota 1987) and rainfall patterns shift eastward across the Pacific as the strength of the tradewinds weakens, resulting in increased (sometimes extreme) rainfall in the southern U.S. and Peru and drought conditions in the west Pacific (Conlan and Service 2000).

La Niña and El Niño are opposite phases of the ENSO cycle (NOAA 2005a). La Niña is a condition in which the tradewinds strengthen and push the warmer surface waters back to the western tropics. Under these conditions, the thermocline in the western Pacific deepens and becomes shallower in the eastern Pacific resulting in abnormally cold SST along the equatorial Pacific. Often with La Niña, the climatic effects are the opposite of those encountered during an El Niño warming event (e.g., higher SST in the western equatorial Pacific, high production along Pacific upwelling coasts, and heavy rainfall in Australia and Indonesia) (NOAA 2005a).

The study area experiences considerable changes during El Niño or La Niña events. While the average annual rainfall in Guam does not appear to be affected during an El Niño event (93 to 100% of average conditions), the Northern Mariana Islands experience substantial differences in annual rainfall. During an El Niño, the Northern Mariana Islands experience conditions in which only 84 to 88% of average seasonal rains fall in the dry season and the beginning of the rainy season (January to September), and rainfall exceeds the average values during the rainy season (104% of historical averages) (Pacific ENSO Applications Center 1995). In addition, there is a general weakening of the Hadley circulation (in which warm air rises from the equator and travels to the north and south, sinking at 30°). This weakening reduces the strength of the high pressure system located over the western equatorial Pacific and the overall SST in the region increases (Kubota 1987). Further, typhoons in the western Pacific basin are more frequent during warm ENSO periods although their tracks are oriented northwest and away from the study area (Saunders et al. 2000; Elsner and Liu 2003).

During La Niña, Guam experiences a deficit in rain during the dry and rainy season (86% and 87% of historical averages, respectively) (Pacific ENSO Applications Center 1995). During June to September rainfall amounts exceed historical averages (104% of average). The Northern Mariana Islands also experience a surplus of rainfall throughout the year during La Niña (104 to 139% of historical averages with excess rainfall peaking in March, April and May) (Pacific ENSO Applications Center 1995).

2.1.3 Pacific Decadal Oscillation

The PDO is a long-term climatic pattern capable of altering SST, surface wind, and sea level pressure (SLP) (Mantua 2002; Mantua and Hare 2002). The PDO is a long-lived El Niño-like pattern of Pacific climate variability and experiences both warm and cool phases. However, the PDO has three main characteristics separating it from ENSO events. First, PDO events can persist for 20 to 30 years which contrasts with the relatively short duration of ENSOs (up to 18 months). Second, climatic effects of the PDO are more prominent in ecosystems outside the tropics. Third, the mechanisms controlling the PDO are unknown, while those forces creating ENSO variability have been resolved (Mantua and Hare 2002). During warm phases of the PDO, the western tropical Pacific experiences periods of increased SLP while the opposite is true during cold periods of the PDO. However, the effect of the PDO is weak in tropical areas, such as the Marianas OPAREA, and thus climatic anomalies are most likely due to ENSO forcings (Mantua 2002; Mantua and Hare 2002).

2.2 MARINE GEOLOGY

The study area is located at the intersection of the Philippine and Pacific crustal plates, atop what is believed to be the oldest seafloor on the planet dating to the Jurassic era (Handschumacher et al. 1988). The collision of the two plates has resulted in the subduction of the Pacific Plate beneath the Philippine Plate forming the Mariana Trench (Kennett 1982; **Figure 2-1**). The Mariana Trench is over 2,270 km long and 114 km wide. The deepest point in the trench and on Earth, Challenger Deep (11,034 m; 11°22'N, 142°25'E), is found 544 km southwest of Guam in the southwestern extremity of the trench (Fryer et al. 2003).

The seafloor of the study area region is characterized by the Mariana Trench, the Mariana Trough, ridges, numerous seamounts, hydrothermal vents, and volcanic activity. Two volcanic arcs, the West Mariana Ridge (a remnant volcanic arc than runs from approximately 21°N 142°E to 11°30'N 141°E) and the Mariana Ridge (an active volcanic arc) are separated by the Mariana Trough (Baker et al. 1996; **Figure 2-1**). The Mariana Trough formed when the oceanic crust in this region began to spread between the ridges as recently as four million years ago. Currently the Mariana Trough is spreading at a rate of less than 1 centimeter per year (cm/yr) in the northern region and at rates up to 3 cm/yr in the center of the trough (Yamazaki et al. 1993). The Mariana archipelago is located on the Mariana Ridge, 160 to 200 km west of the Mariana Trench subduction zone. The Mariana archipelago is comprised of fifteen volcanic islands: Guam, Rota, Tinian, Saipan, FDM, Aguijan, Anatahan, Sarigan, Guguan, Alamagan, Pagan, Agrigan, Asuncion, Maug, and Farallon de Pajaros (listed from south to north) (**Figure 2-2**). Approximately 800 km separate Guam from Farallon de Pajaros (Eldredge 1983; DoN 1998; DoN 2003a).

The islands north of FDM are located on an active volcanic arc ridge axis and were formed between 1.3 and 10 million years ago (Randall 1985, 1995, 2003; Fryer personal communication). The six southern islands (Guam to FDM) are on the old Mariana fore-arc ridge axis and formed about 43 million years ago (Eocene) (Randall 1985, 2003; Birkeland 1997). The young volcanic active ridge axis is offset 25 to 35 km west of the southern arc ridge axis (Randall 1995). The islands on the southern ridge consist of a volcanic core covered by thick coralline limestone (up to several hundreds of meters) (DoN 2003a). The subsidence of the original volcanoes in the southern islands allowed for the capping of the volcanoes by limestone. Limestone covers the northern half of Guam (limestone plateau height: 90 to 180 m above mean sea level [MSL]) while volcanic rock and clay are exposed on the southern half of the island (DoD 1999). Tinian consists of rocky shoreline cliffs and limestone plateaus with no apparent volcanic rock (DoD 1999). Similar to Tinian, the uplifted limestone substrate of FDM is bordered by steep cliffs (DoN 2004).

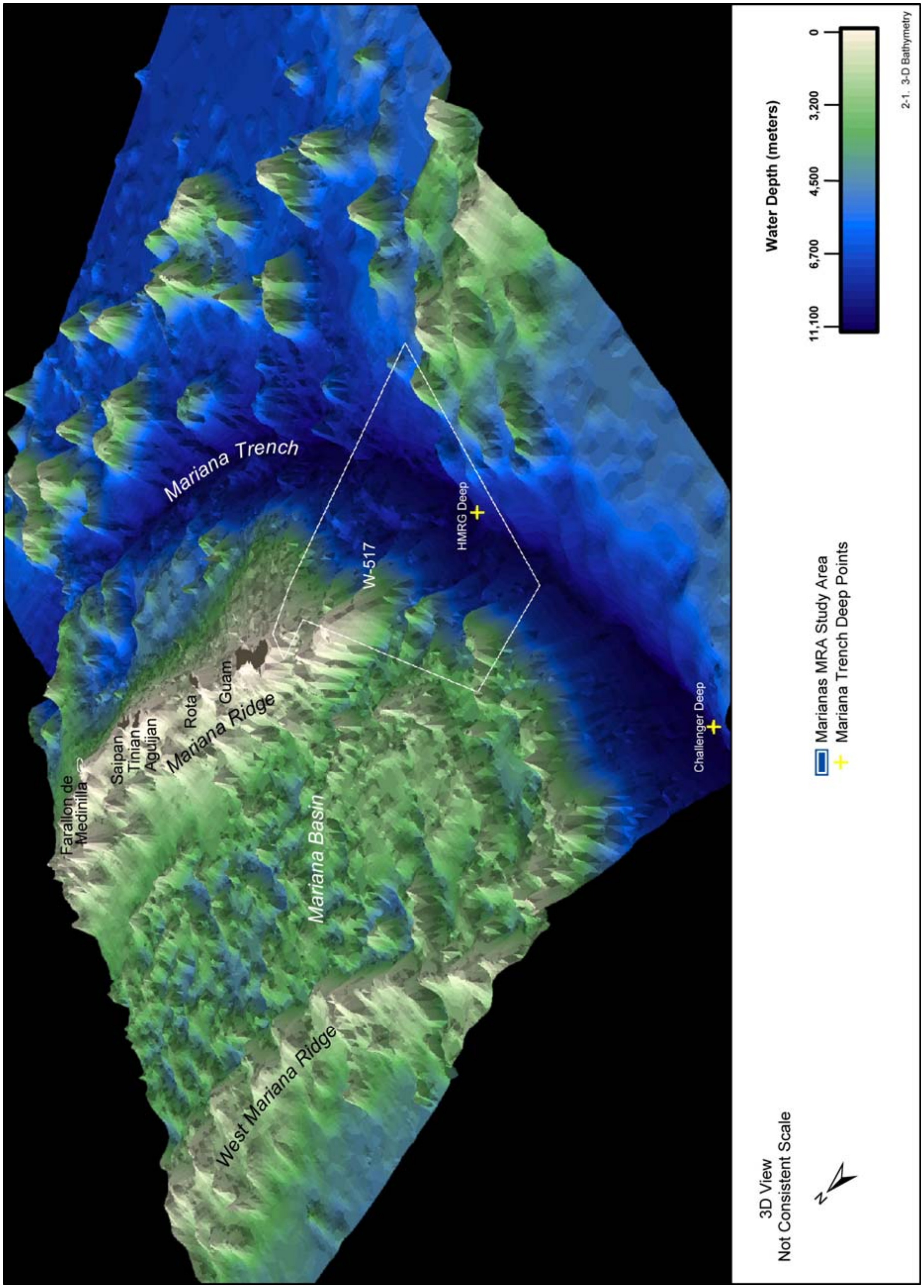

Figure 2-1. Three-dimensional bathymetry and major physiographic features of the Marianas MRA study area and vicinity. Source data: Fryer et al. (2003) and Sandwell et al. (2004).

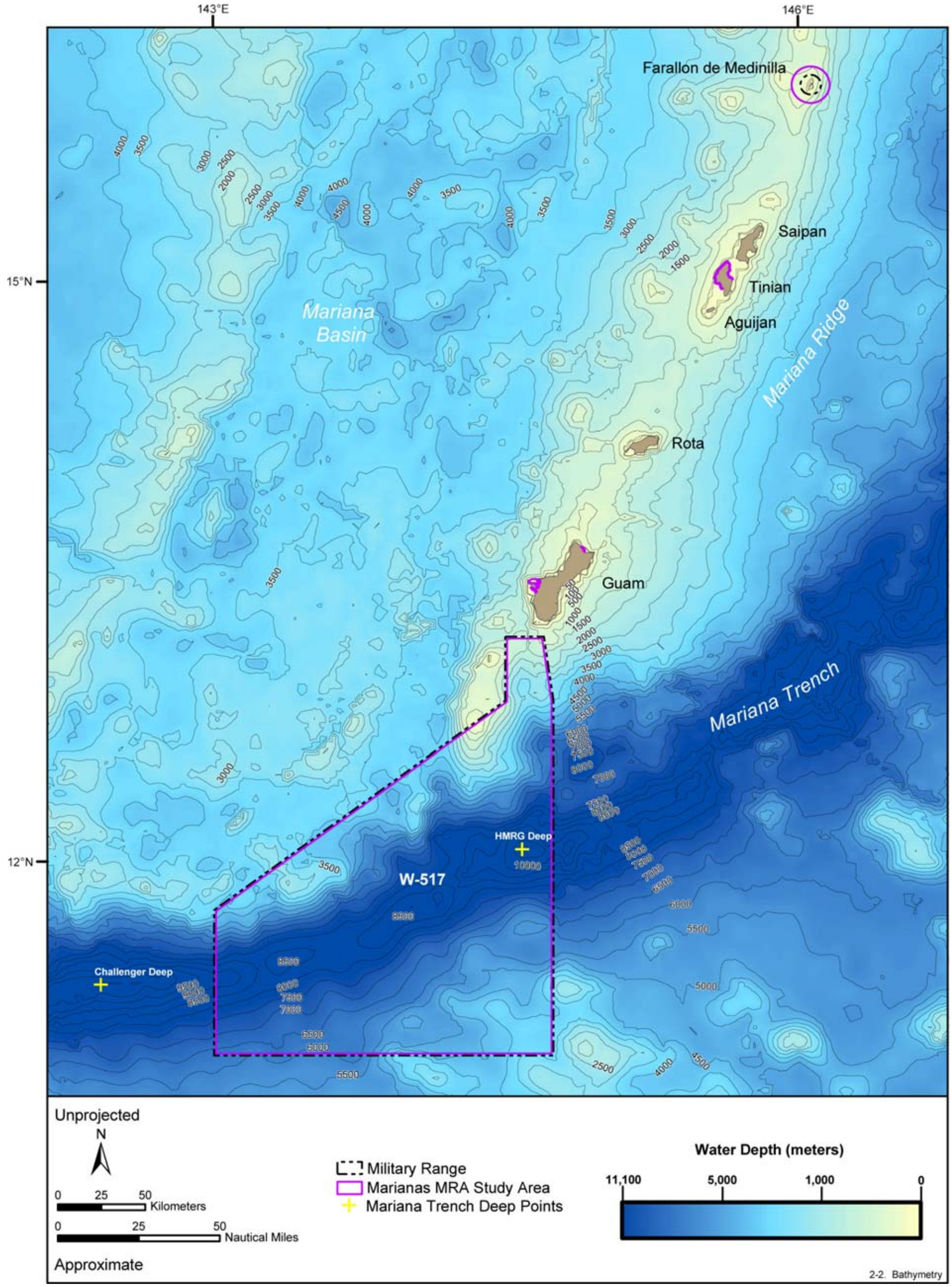

Figure 2-2. Bathymetry of the Marianas MRA study area and vicinity. Source data: Fryer et al. (2003) and Sandwell et al. (2004).

In contrast, volcanoes north of FDM have not subsided below sea level, do not have limestone caps, and remain active (Baker et al. 1996) with the latest major known eruption (Anatahan; 16°22’N, 145°40’E) occurring in July 2005 when ash reached an elevation in excess of 12,000 m (Smithsonian Institute 2003; Volcano Live 2005). Guguan, Alamagan, Pagan (two active volcanoes), Agrigan, Asuncion, and Farallon de Pajaros have documented volcanic activity spanning from 1883 to 1967 (DoN 2003a; USGS 2005a). Ruby Volcano and Esmeralda Bank are submarine volcanoes found east of Saipan and Tinian (USGS 2005a). Ruby Volcano erupted in 1966 (Johnson 1973) and then again in 1995 as the surrounding area experienced submarine explosions, fish kills, a sulfurous odor, bubbling water, and volcanic tremors (Smithsonian Institute 1995).

The study area experiences numerous shallow to intermediate depth (<300 km) normal-fault events indicative of a region that is stretching (Zhang and Lay 1992), resulting in low magnitude earthquakes (DoN 2003a, 2003b; USGS 2004; **Figure 2-2**). Further, the subduction of the Pacific Plate under the Philippine Plate causes abundant seismic activity in the study area, with occasional intense and destructive earthquakes (magnitudes greater than 7 on the Richter scale) (EERI 1993; USGS 2004, 2005b).

As the Pacific plate descends into the interior of the Earth, fluids driven off lower the melting temperature of the mantle permitting partial melting of the mantle to separate (Fryer 1996). This material is less dense and rises to the surface to form seamounts (Fryer 1996; Mottl et al. 2004). Seamounts in the study area are of two distinct varieties: volcanoes and mud volcanoes. Volcanoes are formed along the spreading axis in the Mariana Trough in which molten rock from the interior of the Earth rises to the surface in the form of magma to construct the seamount conical structure. These seamounts are often associated with hydrothermal communities (Embley et al. 2004). An example of a volcanic seamount in the study area is Ruby Volcano (15°37’N, 145°32’E) last believed to erupt in May 1995 (Smithsonian Institute 1995; **Figure 2-3**). Mud volcanoes are formed in a band behind the axis of the Mariana Trench. They are formed when water generated by the dehydration of the subducting Pacific plate (due to increased pressure and temperature) ascends to the mantle of the overlying crust and creates low-density rock capable of rising and extruding to the seafloor. Mud volcanoes tend to have a central conduit that feeds serpentinite mud, which comprises the bulk of the seamount structure (Mottl et al. 2004) and are the location of several macrofaunal communities (Fryer et al. 1999).

2.3 MARINE ENVIRONMENTS

2.3.1 Oceanic Waters

Oceanic waters in this MRA refers to the portion of the study area found in water depths exceeding 200 m, which is the area beyond the “shelf break” where there is a sharp break in the slope of the insular shelf (Kennett 1982; Thurman 1997).

2.3.1.1 Physiography and Bathymetry

The boundary, or transition, between a continent and the ocean basin is referred to as the continental margin (Kennett 1982). In general, two types of continental margins are found on the globe: passive and active. Passive continental margins are usually found in the Atlantic Ocean, and consist of three major physiographical regions that transition from one to another with depth: the continental shelf, the continental slope, and the continental rise. Passive margins are not correlated with the boundaries of continental plates but rather strictly distinguish the transition from continent to ocean (Kennett 1982). Passive margins can also be considered stable as they are not associated with seismic or volcanic activity.

Active margins border the Pacific Ocean and are characterized by the rapid transition from a shelf to a slope to a deep trench (Kennett 1982). In this study area, the margin is known as a Mariana-type, or island-arc margin, which exhibits a shallow marginal basin separating the continent from an island-arc and trench system (Kennett 1982). Additional examples of island-arc margins include Japan

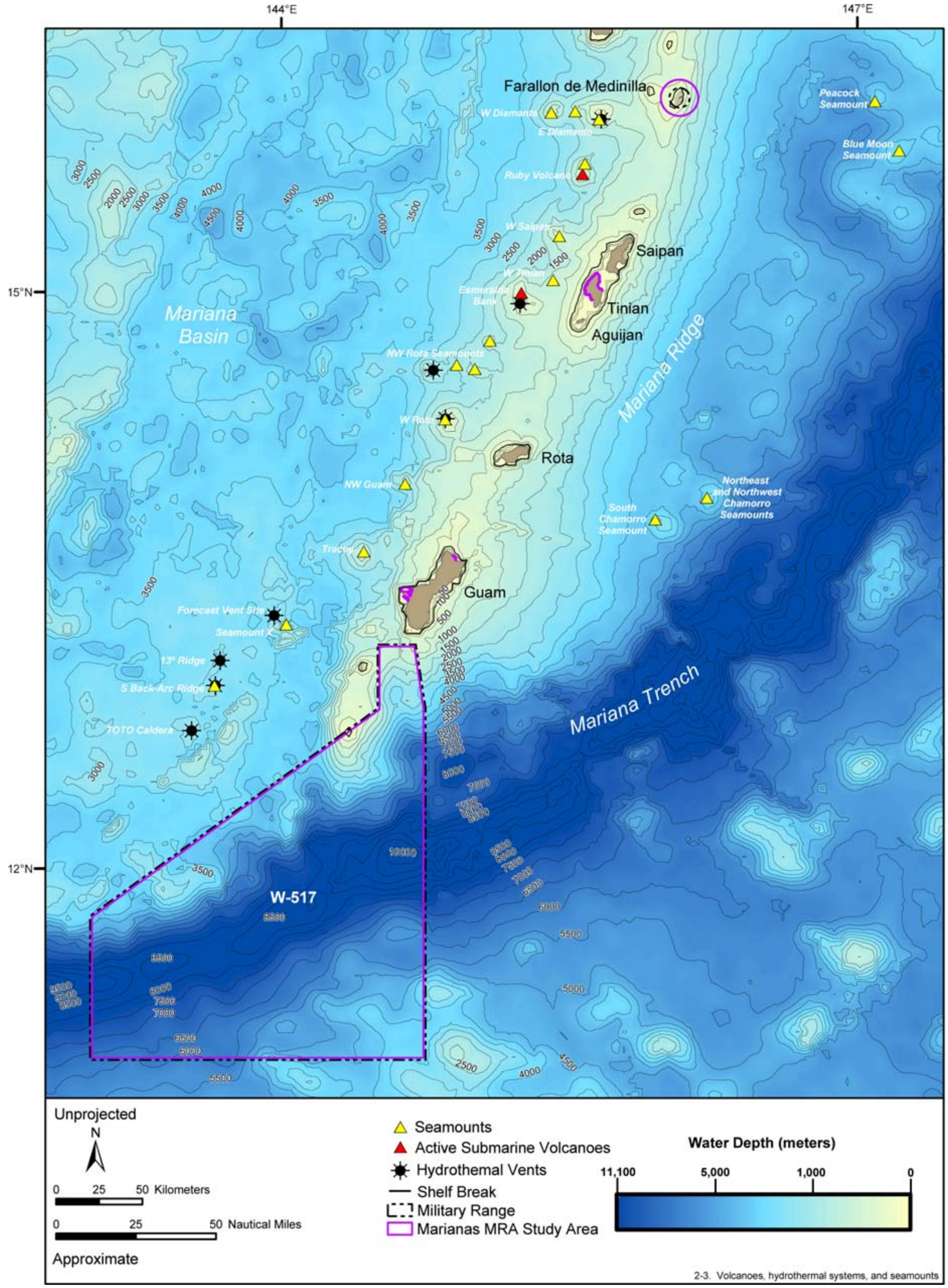

Figure 2-3. Seamounts, active submarine volcanoes, and hydrothermal vents located in the Marianas MRA study area and vicinity. Source data: Kojima (2002), Fryer et al. (2003), Embley et al. (2004), Mottl et al. (2004), and Sandwell et al. (2004).

and the Aleutian Islands of Alaska. Unlike passive margins, active continental margins do mark the boundary between two crustal plates. Due to the collision of the crustal plates, active margins are associated with deep oceanic trenches, the formation of seamounts, seismic activity, and volcanism.

The bathymetry of the study area can be divided into three main areas: the Mariana Trough, the Mariana Ridge, and the Mariana Trench.

Mariana Trough—The Mariana Trough (or Basin) spans the region to the west of the Mariana Ridge in the region of the study area (**Figure 2-2**). The basin formed as the crustal plate spread between the West Mariana Ridge and the Mariana Ridge. The Mariana Trough attains its widest spread (approximately 250 km) at about 18°N (Yamazaki et al. 1993). The spreading center is located on the eastern side of the basin. The spreading of the seafloor between the two ridges is believed to have begun approximately 6 million years ago. The area between the two ridges is a flat plain averaging approximately 3,500 m in depth and is spreading at a rate of 0.3 to 1.0 cm/yr in the northern region (Taylor and Martinez 2003; Yamazaki et al. 1993).

Mariana Ridge—The Mariana Ridge consists of both active and extinct volcanoes. The latter are the islands of Guam, Rota, Tinian, Saipan, and FDM (**Figure 2-2**). In general these islands are surrounded by shallow fringing reefs with the occasional boulder breaking the water surface. There are barrier reefs on the leeside of the islands of Guam and Saipan and a large shoal area 2 km north of FDM at a water depth of 36.5 m (Randall 1979; Eldredge 1983). The Mariana Ridge formed as active volcanoes emerged from the ocean floor over the subducting Pacific Plate. As the subduction zone moves to the east, the Mariana Ridge will eventually subside and become submerged beneath the surface of the Pacific Ocean (Thurman 1997).

Mariana Trench—The major physiographic feature of the study area is the Mariana Trench. The trench runs from approximately 11°N, 141°E to 25°N, 143°E in an arc-like pattern extending over 2,270 km in length (**Figures 2-1** and **2-2**). The trench is the result of the collision and subduction of two crustal plates, the faster moving Pacific Plate and the slower moving Philippine Plate. Water depths in the trench range from 5,000 to 11,000 m with the deepest locations being southwest of Guam and becoming shallower northward (north of 14°N, the Mariana trench shallows to a depth less than 9 km; Fryer et al. 2003; **Figures 2-1** and **2-2**). Located within the trench is Challenger Deep (11,034 m; 11°22'N, 142°25'E) and HMRG Deep (10,732 m; 11°50'N, 144°30'E) (Fryer et al. 2003; **Figures 2-1** and **2-2**). Water mass characteristics at varying depths within the trench suggest that the waters of the Mariana Trench are not significantly different from those found on the abyssal plain north of the Marshall Islands (2,000 km to the east) (Mantyla and Reid 1978).

2.3.1.2 Bottom Substrate

The bottom substrate covering the seafloor in the study area is primarily volcanic or marine in nature (Eldredge 1983). Large flats of the seafloor are covered with a pavement-like covering of volcanic mud. Patches of *Globigerina* ooze, the calcareous shells of foraminiferan cells, also form large patches on the seafloor. Closer to island land masses are regions of coral debris, formed from the skeletons of corals comprising the fringing and barrier reefs found throughout the Mariana archipelago (Eldredge 1983). The Mariana Trench seafloor is comprised mostly of reddish-brown, pumiceous sand and silty clays (Ogawa et al. 1997). Sediment cores of the Mariana Trench seafloor also contain radiolarians, pollen, sponge spicules, diatoms, and benthic foraminiferans (Ogawa et al. 1997).

2.4 PHYSICAL OCEANOGRAPHY

2.4.1 Circulation

The water column can be divided into three separate water masses: a surface layer, an intermediate layer of rapidly changing temperature referred to as the thermocline, and a deepwater layer (Pickard and Emery 1982). Wind and water density differences drive the circulation of water masses in the ocean. Surface currents are primarily driven by the wind (wind-driven circulation), which affects the upper 100 m of the water column. Variations in temperature and salinity will cause changes in water density which in turn drives the thermohaline circulation capable of moving water masses at all levels of the water column (Pickard and Emery 1982).

The general oceanic circulation surrounding the study area and the Mariana Islands is little known as few studies have investigated the major current pattern around the islands (Eldredge 1983). Due to the lack of observational data in the study area, only broad, more generalized patterns can be identified. The following is a discussion of circulation patterns that influence the study area including sea surface circulation, deepwater circulation, and the North Pacific Subtropical Gyre (NPSG).

2.4.1.1 Surface Currents

Surface currents in the study area are heavily influenced by the North Pacific Equatorial Current (NPEC) which flows westward between 8 and 15°N eventually turning to the north to form the Kuroshio current off of Japan (Pickard and Emery 1982; Wolanski et al. 2003; **Figure 2-4a**). The North Equatorial Current (NEC) is driven by the trade winds along the equator (**Figure 2-4b**). The trade winds force the NEC through the study area. This results in a net sea surface transport to the west/northwest at an average speed of 0.1 to 0.2 m/sec (Uda 1970; Wolanski et al. 2003).

However, it also should be noted that the Mariana Islands lie to the southeast of the heaviest tropical cyclone activity in the Pacific Ocean and current patterns in the study area can be influenced by tropical cyclones during the rainy season (July through November). As such, the passage of tropical cyclones (Eldredge 1983), El Niño (Lagerloef et al. 1999), and oceanic cyclonic eddies through the area (Wolanski et al. 2003) have resulted in a reversal of surface current flow in the study area.

The large mass of the islands within the study area may be capable of producing small eddies (net eastward coastal flow of several cm s^{-1}) on the lee side of the islands capable of returning fish and coral larvae and eggs to the fringing reefs surrounding most of the islands. While the formation of these eddies have not been largely investigated throughout the study area, these eddies may provide the explanation as to why people lost at sea to the west side of the Mariana Islands are not advected to the west by the NEC as predicted by Coast Guard models (Wolanski et al. 2003).

Many of the islands within the study area are surrounded by fringing coral reefs (Eldredge 1983; Spalding et al. 2001). There are a number of fine scale currents within the reef and between the reef and shore (Jones et al. 1974; Eldredge et al. 1977; Marsh et al. 1982). However these fine scale current patterns are complex and there is a lack of observational data to accurately predict these current patterns (Eldredge 1983). In Guam, Marsh et al. (1982) found that incoming waves travel shoreward over the reef flats (Tumon Bay, Pago Bay) and slowly turn to form longshore currents. These currents flow along the shoreline for distances up to 1,500 m, eventually turn seaward, and then exit through cuts in the reef margin (Marsh et al. 1982).

2.4.1.2 Deepwater Currents/Water Masses

The colder, mid-depth and bottom waters of the study area do not originate in local waters. Rather, some of the water travels a great distance prior to reaching the study region, including waters originating in the North Pacific and the Antarctic Sea (Pickard and Emery 1982). In fact, the water found in the Mariana Trough and Mariana Trench originates from Lower Circumpolar Water (LCPW) and North Pacific Deep Water (NPDW) and is influenced by the overlying Antarctic Intermediate Water (AIW) (Kawabe et al. 2003; Siedler et al. 2004).

The NPDW is formed in the northern Pacific as cold water from the North Pacific mixes with high silica bottom sources (Siedler et al. 2004). The low salinity and high silica content is the signature of the NPDW water mass. After sinking into the deep subarctic, this water travels from the northeast Pacific with a general westward propagation south of the Hawaiian Islands. The NPDW extends to the western edge of the Mariana Trough at a depth to 2,000 to 3,500 m, where net transport of the water mass is southward (Kawabe et al. 2003; Siedler et al. 2004).

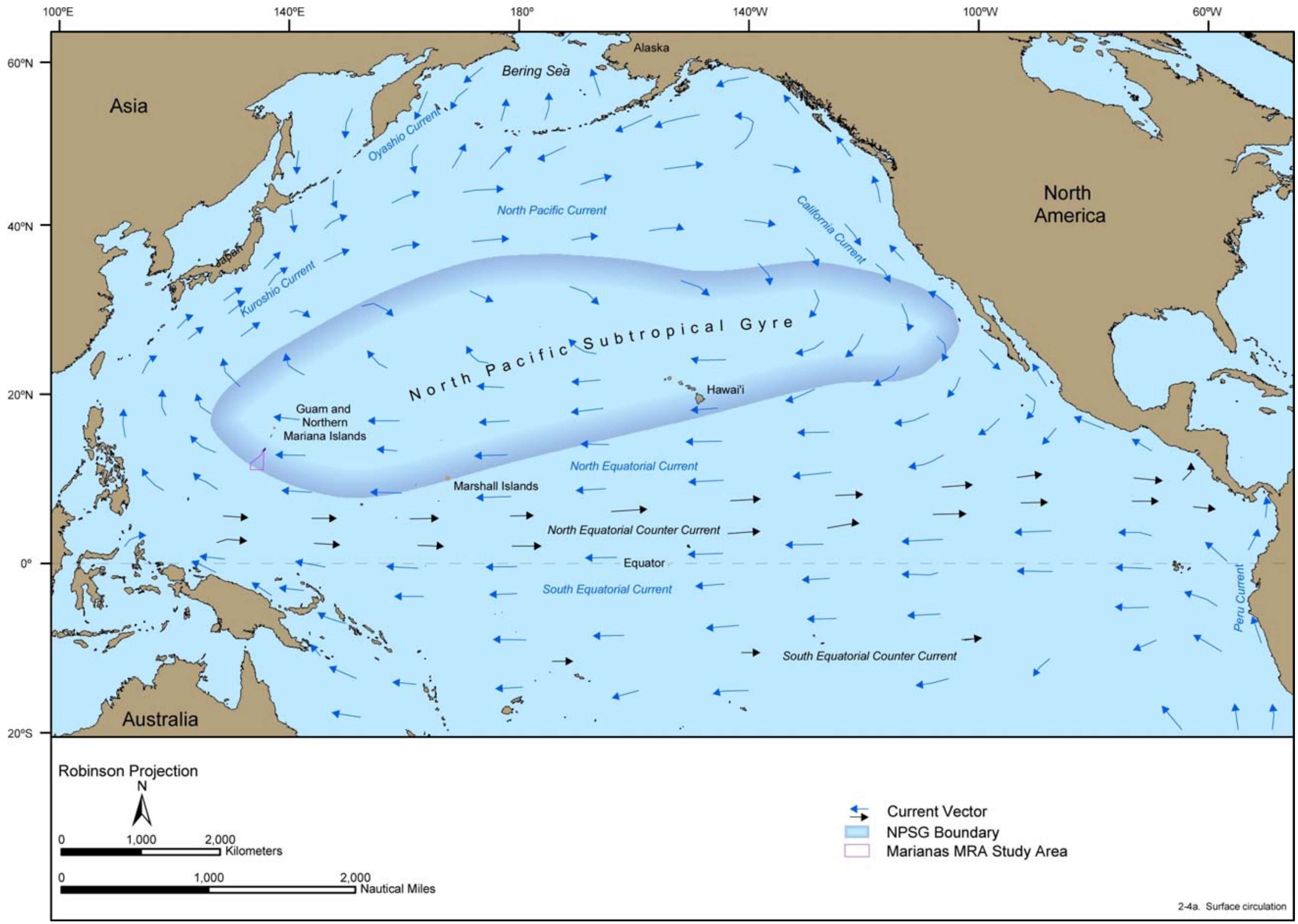

Figure 2-4a. Surface circulation of the Pacific Ocean and outline of the North Pacific Subtropical Gyre. Source information: Pickard and Emery (1982) and Karl (1999).

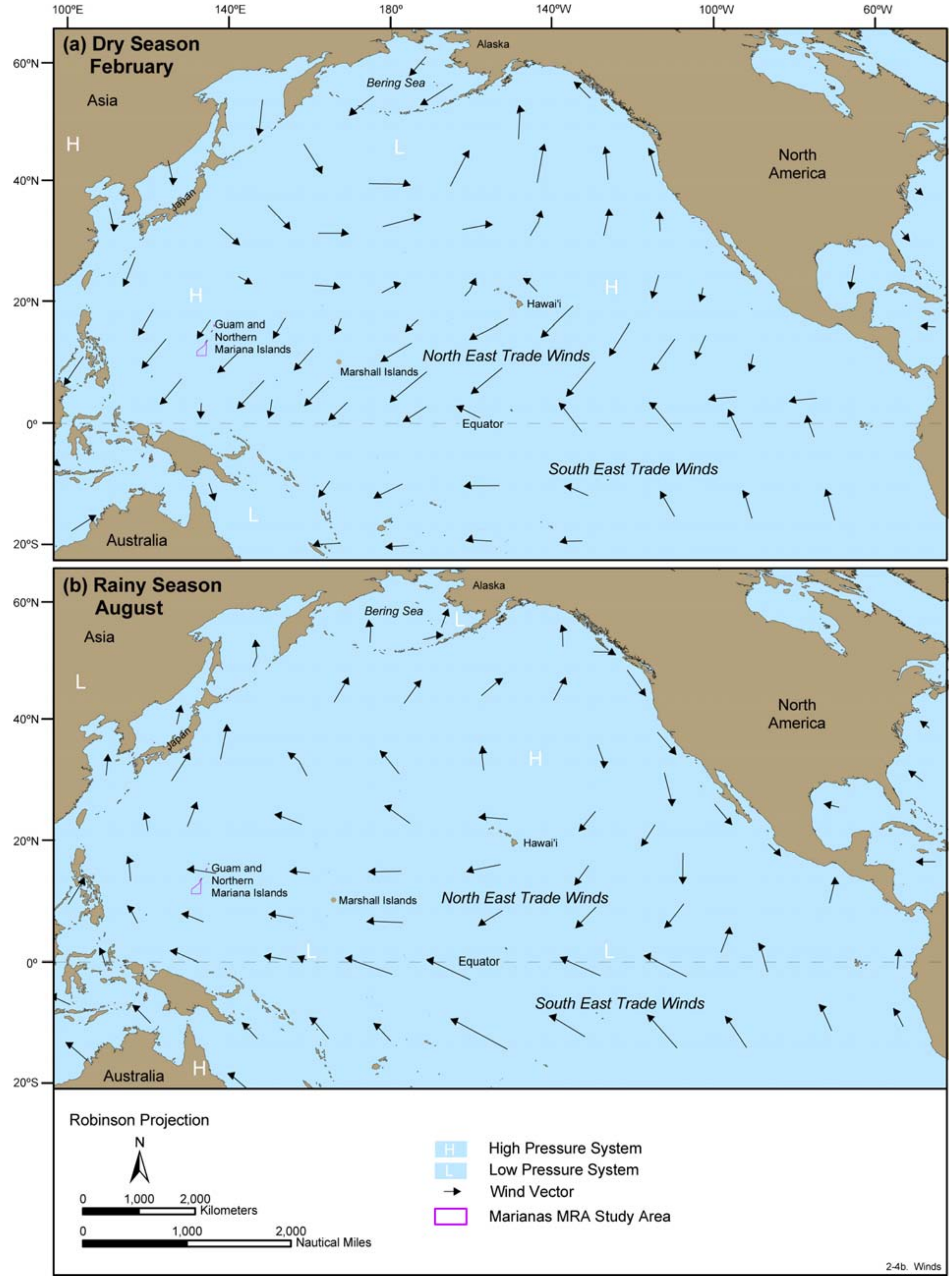

Figure 2-4b. Winds and mean atmospheric highs and lows of the northern Pacific Ocean during the (a) dry season and (b) rainy season. Source information: Pickard and Emery (1982).

LCPW is also referred to in the literature as Circumpolar Deep Water (CDW) (Pickard and Emery 1982). Part of the LCPW flows from the South Pacific across the equator, westward around the Marshall Islands and into the Mariana Trough and Trench (Mantyla and Reid 1978; Kawabe et al. 2003; Siedler at al. 2004). Seafloor ridges prevent the densest water of the LCPW and NPDW from reaching the Mariana Trench. Otherwise, the water characteristics in the Mariana Trench are identical to abyssal water found north of the Marshall Islands (2,000 km east). At depths ranging from 5,585 to 10,933 m, the Mariana Trench seawater temperature ranges from 1.5° to 2.5°C, salinity is approximately 34.7 parts per thousand (ppt), and dissolved oxygen concentrations are about 4 milliliters per liter (ml/l) (Mantyla and Reid 1978).

2.4.1.3 North Pacific Subtropical Gyre

Approximately half of all primary production is supported by phytoplankton found in the oceans (Falkowski 1994). In the marine environment oceanic provinces, or subtropical gyres, occupy 40% of the earth's surface, are located far from land, and account for the majority of primary production (Karl 1999). The Marianas study area lies within the western region of the NPSG, the most extensive gyre on Earth.

Despite being the largest ecosystem on the planet, the NPSG is remote, poorly sampled, and not well understood (Karl 1999). The NPSG extends from 15 to 35°N and 135°E to 135°W, and is bounded by the North Pacific Current to the north, the NEC to the South, the California Current to the East, and the Kuroshio Current to the west. In total, the NPSG encompasses 2 X 10^7 km^2, creating the planet's largest circulation pattern. Geologically, the NPSG is a very old region in which the present boundaries have existed since the Pliocene (10^7 years ago) (McGowan and Walker 1985) and is considered a climax community in which the climate affects the seascape, which in turn controls the community structure and dynamics (Karl 1999).

The NPSG is comprised of warm (>24°C) surface water containing low nutrient levels, low standing stocks of living organisms, and a persistent deep-water chlorophyll maximum (Karl 1999). The water column can be divided vertically into two distinct regions including a light-saturated nutrient-limited layer at the surface (0 to 70 m) and a light-limited nutrient-rich layer at depth (>70 m). Surface circulation in the gyre is wind driven, and the overall anti-cyclonic rotation of the NPSG isolates the water within the gyre, restricting exchange with adjacent current systems (Karl 1999).

Due to the isolated waters within the gyre, the NPSG is thought to be a semi-enclosed, stable, and relatively homogenous habitat; however, increasing evidence suggests that the NPSG exhibits substantial physical, chemical and biological variability on a variety of time and space scales (Karl 1999). For example, regions of the NPSG show extensive mesoscale variability via the formation of discreet eddies, near-inertial motions, and internal tides (Venrick 1990). In addition, during winter months, tropical cyclones pass through the NPSG, moving from west to east, deepening the mixed layer and injecting nutrient rich water into the surface waters fueling ephemeral blooms of phytoplankton (Karl 1999).

2.4.2 Hydrography

Hydrography refers to the scientific study of the measurement and description of the physical features of bodies of water. The following sections describe in detail the temperature of water at the ocean surface, the vertical structure of temperature within the water column, and the horizontal and vertical distribution of the salinity in the study area.

<u>Sea Surface Temperature</u>—The waters of the study area undergo an annual cycle of temperature change, however this temperature flux is only a few degrees each year, as would be expected from a tropical climate (**Figure 2-5**). The temperature throughout the year ranges from about 25° to 31°C with an annual mean temperature of 27° to 28°C for the years ranging from 1984 to 2003 (NOAA 2004a). Temperatures increase during the summer and autumn months with peak temperatures occurring in September/October.

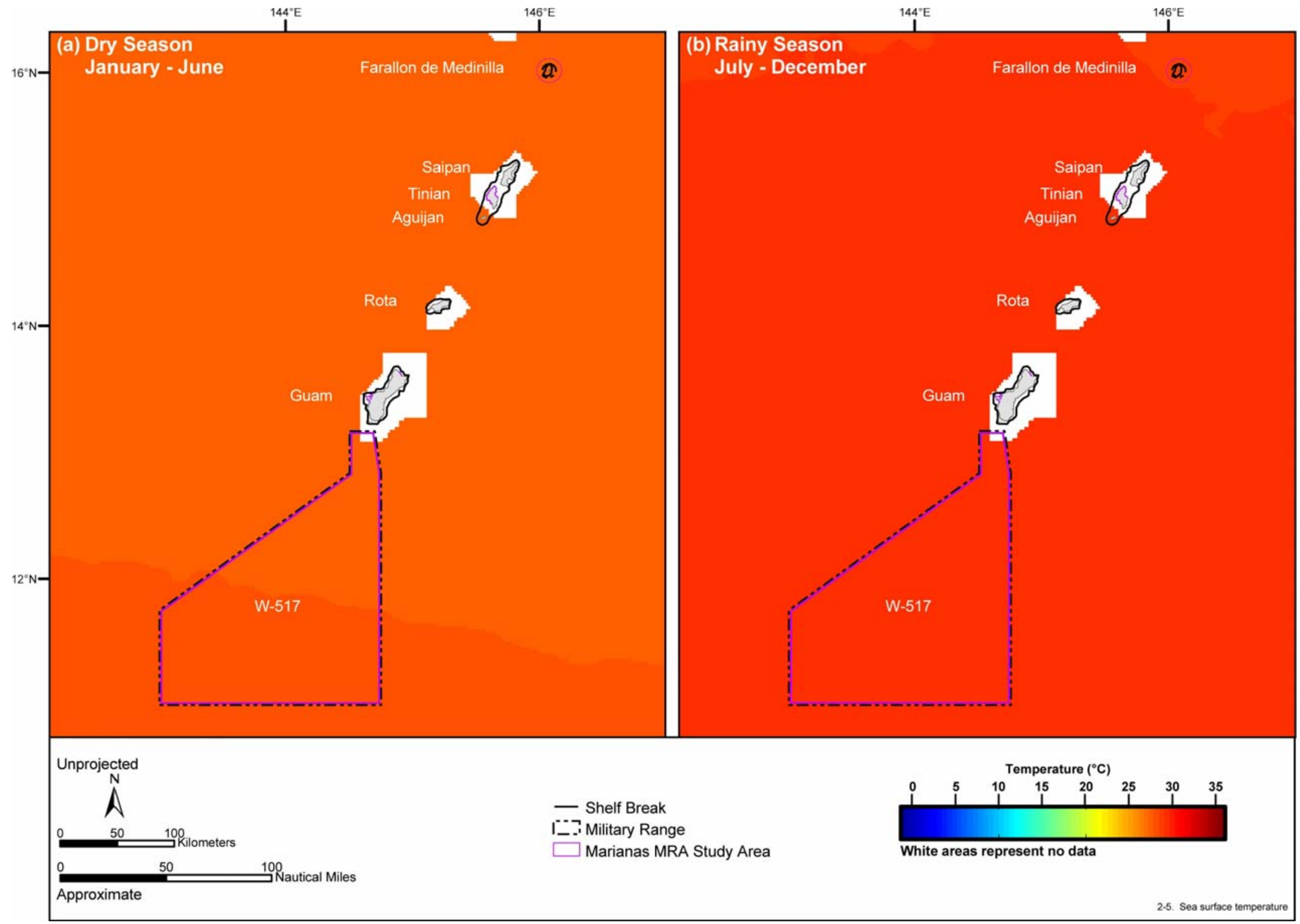

Figure 2-5. Mean seasonal sea surface temperature in the Marianas MRA study area and vicinity during the (a) dry season and (b) rainy season. The white areas surrounding Guam and the CNMI islands are areas where sea surface temperature data were unavailable. Source data: NASA (2000).

SST along the reef flats near the shoreline have been reported to average 2°C higher than those reported in nearshore waters and may reach temperatures as high as 34°C during periods of extensive low tide (Eldredge 1983).

Increases in SST caused by El Niño events can influence the distribution pattern of fishes (Lehodey et al. 1997). Further, prolonged high SST will cause the bleaching of corals, coral mortality and induce the outbreak of coral diseases within the study area (Harvell et al. 1999; Paulay and Benayahu 1999; Richmond et al. 2002).

Thermocline—The water column in the Marianas MRA study area contains a well-mixed surface layer ranging from 90 to 125 m. Immediately below the mixed layer is a rapid decline in temperature to the cold deeper waters. Unlike more temperate climates, the thermocline in the study area is relatively stable, rarely turning over and mixing the more nutrient waters of the deeper ocean in to the surface layer.

Salinity—The study area lies in a region near the equator of low surface salinity bound to the north and south by regions of higher salinity (Pickard and Emery 1982). Surface salinity is lower towards the southern end of the Mariana archipelago and increases towards the north. At a depth of 100 to 200 m, there is a spike in salinity that corresponds with the input of high saline tropical waters (Eldredge 1983). Below this region, the salinity drops to a minimum (approximately 34.5 ppt) and corresponds to the influx of North Pacific Intermediate Water (NPIW). NPIW is formed as cold, fresh, dense water sinks below the more saline water in the north subarctic Pacific Ocean and can be recognized by its overall lower salinity and location within the water column (500 to 700 m depth) (Eldredge 1983).

2.5 BIOLOGICAL OCEANOGRAPHY

The physical environment of an area can directly affect the distribution of marine life found within. In this section, the major groups of organisms found in the Marianas MRA study area are discussed with particular reference to their geographical distribution and any physical mechanisms that may affect their distribution. The organisms that comprise the base of the food web and those to which all other oceanic organisms depend, the plankton, will be specifically discussed here while discussions of the larger species found in the study area may be found in subsequent chapters.

2.5.1 Primary Production

Primary production is a rate at which the biomass of organisms changes and is defined as the amount of carbon fixed by organisms in a fixed volume of water through the synthesis of organic matter using energy derived from solar radiation or chemical reactions (Thurman 1997). The major process through which primary production occurs is photosynthesis. The intensity and quality of light, the availability of nutrients, and seawater temperature all influence primary productivity as generated through photosynthesis (Valiela 1995). Chemosynthesis will also be mentioned in this section since it is another form of primary production occurring at hydrothermal vent communities along ocean spreading centers in the study area.

2.5.1.1 Photosynthesis

Photosynthesis is a chemical reaction that converts solar energy from the sun into chemical energy stored within organic molecules by combining water, carbon dioxide, and light energy to form sugar and oxygen. In the oceanic system, the majority of photosynthesis is carried out by phytoplankton utilizing a suite of light harvesting compounds to convert solar energy into chemical energy, the most common being chl *a* (Thurman 1997). Rates of photosynthetic production can vary from between less than 0.1 milligram (mg) of carbon (C) per square meter (m^2) per day (d) in low primary productivity (oligotrophic) regions, such as the western equatorial Pacific, to more than 10 $mgC/m^2/d$ in highly productive areas (Thurman 1997).

The western Pacific, including the study area, can be considered an oligotrophic region. The water column surrounding the study area is composed of nutrient depleted surface area overlying a deeper nutrient rich layer (Rodier and LeBorgne 1997). As such, standing stocks of phytoplankton biomass (Radenac and Rodier 1996) and concentrations of chl *a* are low throughout the study area (less than 0.1 mg per cubic meter [m^3]) (NASA 1998; **Figure 2-6**). In regions in which overall nutrient concentrations are low, the phytoplankton communities are dominated by small nanoplankton and picoplankton (Le Bouteiller et al. 1992; Higgins and Mackey 2000). This is true for the study area, as phytoplankton communities in the western Pacific are dominated by cyanobacteria (*Synechococcus* spp.), prochlorophytes, haptophytes, and chlorophytes (Higgins and Mackey 2000). These cells are less than one micron (µm) in size and comprise 60% of the total chl *a* measured (Le Bouteiller et al. 1992).

Two regions of enhanced chl *a* (up to 0.06 mg/m^3) can be identified in the study area off the southwest coast of Guam and in the region surrounding the islands of Tinian and Saipan (**Figure 2-6**). These regions of enhanced chl *a* persist through both the rainy and dry seasons, with higher chl *a* concentrations occurring during the rainy season. Reasons for these regions of higher chl *a* levels are not completely understood but may be a product of the island mass interacting with currents. This island mass effect has been previously observed for other islands located in oligotrophic or stratified regions including the Scilly Isles in the Celtic Sea (Simpson et al 1982), the Marquesas islands (Martinez and Maamaatuaiahutapu 2004), and the islands of Hawai'i (Gilmartin and Revelante 1974) in which currents passing by the islands or through channels in island chains created turbulence mixing bringing more nutrient rich waters to the surface. This mixing may be capable of occurring along the Mariana island chain creating isolated areas of increased production. In addition, an anticyclonic eddy is formed off the southwestern coast of Guam in the same region as the increased chl *a* (Wolanski et al 2003; **Figure 2-6**). It is likely that phytoplankton is becoming trapped within the eddy and is not advected to the west, allowing for an accumulation of biomass and chl *a* in the region. The remainder of the study area experiences chl *a* levels below 0.045 mg/m^3 throughout the year (NASA 1998; **Figure 2-6**). ENSO appears to have little, if any, effect on primary production in the western tropical Pacific (Mackey et al 1997; Higgins and Mackey 2000).

2.5.1.2 Chemosynthesis

Another potentially significant source of biological productivity does not occur in the light of the surface, but rather at great depths within the ocean. In some locations, including the Mariana Trough, hydrothermal springs can support vast benthic communities (Hessler and Lonsdale 1991; Hashimoto et al. 1995; Galkin 1997). Many organisms live in association with bacteria capable of deriving energy from hydrogen sulfide that is dissolved in the hydrothermal vent water (Thurman 1997). Since these bacteria are dependant upon the release of chemical energy, the mechanism responsible for this production is called chemosynthesis. Little is known regarding the significance of bacterial productivity on the ocean floor on a global scale. Hydrothermal indicators and vents have been found within the study area (Embley et al. 2004) and locations are described in further detail in subsequent sections.

2.5.2 Secondary Production

Secondary production refers to the production (change in biomass) of organisms that consume primary producers, i.e., the production of bacteria and animals through heterotrophic processes (Scavia 1988; Strayer 1988). Detailed descriptions of protected species as consumers of primary production including marine mammals and sea turtles, as well as species such as corals and seagrasses are found in later sections of this chapter or later chapters of this MRA. In this section, marine zooplankton is discussed.

Marine zooplankton are aquatic organisms ranging in size from 20 µm to large shrimp (>2,000 µm) (Parsons et al. 1984), and can be separated into two distinct categories based upon their dependence to coastal proximity. Oceanic zooplankton includes organisms such as salps and copepods typically found at a distance from the coast and over great depths in the open sea. Neritic zooplankton (found in waters overlying the island shelves), include such species as fish and benthic invertebrate larvae, and are usually only found short distances from the coast (Uchida 1983).

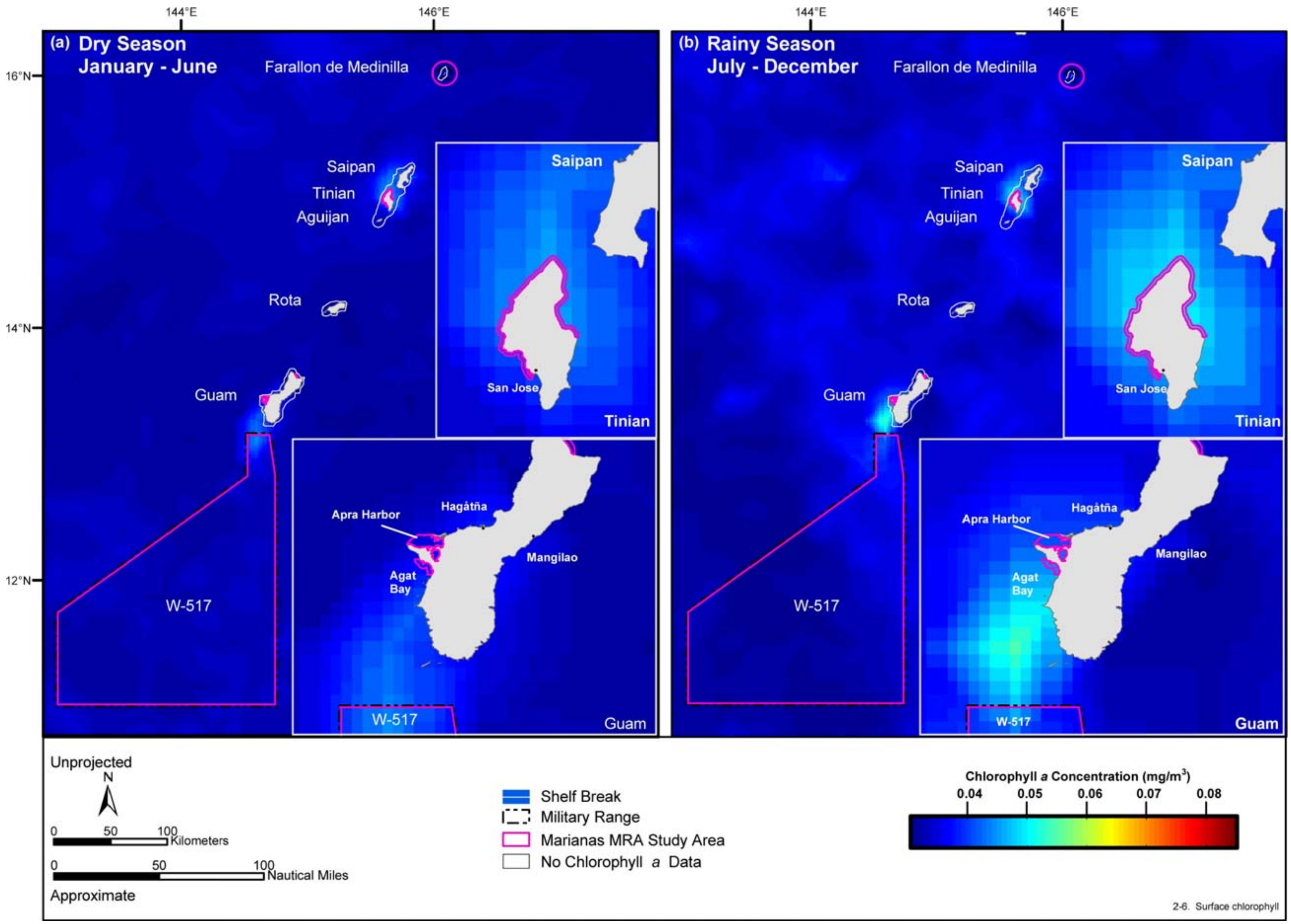

Figure 2-6. Mean seasonal surface chlorophyll *a* concentrations in the Marianas MRA study area and vicinity during the (a) dry season and (b) rainy season. Source data: NASA (1998).

The NEC, which provides the bulk of water passing the Mariana archipelago, is composed primarily of plankton-poor water. Detailed information on the oceanic zooplankton community in the waters of the Marianas MRA study area is practically nonexistent (Uchida 1983). Rather, data gathered in waters surrounding the study area must be explored to gain insight into the zooplankton communities within the study area. Total zooplankton biomass at the surface examined for the western Pacific and adjacent seas found that zooplankton biomass was the lowest within the NEC, reaching concentrations of only 1.35 grams (g) wet weight/m^2 (Vinogradov and Parin 1973). Vinogradov and Parin (1973) also surveyed zooplankton biomass in the tropical Pacific, and at their station nearest the study area (13°31'N, 139°58'E), zooplankton biomass was very low (11.7 mg/m^3).

Studies on the neritic plankton have centered around Apra Harbor and Piti Reef on Guam. However, the majority of studies have been performed in conjunction with more general environmental surveys, and thus no long-term surveys have been conducted. In general, abundance of zooplankton is highly variable with respect to location and time (both throughout the day and month to month) (Uchida 1983). In Apra Harbor, the commercial port contains the highest levels of zooplankton abundance and is dominated by copepods (Uchida 1983). Other organisms in the harbor include fish larvae, decapod zoeae (free-swimming larvae), and pteropods (Uchida 1983). In Tanapag Harbor, Saipan, the diurnal zooplankton community is dominated by copepods and the nocturnal zooplankton community by larval crustaceans (Uchida 1983).

2.6 Benthic Habitats

Deep sea benthic habitats include seamounts, hydrothermal vents, the abyssal plain, and trenches. The bottom sediments covering the sea floor in much of the study area are volcanic or marine in nature (Eldredge 1983). In the Marianas Trench, the seabed is composed mostly of sand and clays (Ogawa et al. 1997). Sediments found on the narrow shelves along the Marianas archipelago are a combination of volcanic and calcareous sediments derived from calcareous animal skeletons (Eldredge 1983).

2.6.1 Seamounts

Seamounts are undersea mountains that rise steeply from the ocean floor to an altitude greater than 1,000 m above the ocean basin (Thurman 1997). Generally, seamounts tend to be conical in shape and volcanic in origin, although some seamounts are formed by tectonic movement and converging plates (Rogers 1994). The study area contains seamounts of both types. The seamount topography is a striking difference to the surrounding flat, sediment covered abyssal plain, and the effects seamounts can impart on local ocean circulation are complex and poorly understood (Rogers 1994). However, around seamounts increased levels of phytoplankton, primary production, and pelagic and demersal fish (Zaika and Kovalev 1984; Fedorov and Chistikov 1985; Greze and Kovalev 1985; Parin et al. 1985; Rogers 1994) are correlated with current pattern alterations and Taylor columns (circulation vortices) (Darnitsky 1980; Boehlert and Genin 1987; Rogers 1994).

The large ranges in depth, hard substrate, steep vertical gradients, cryptic topography, variable currents, clear oceanic waters, and geographic isolation all combine to make seamounts a unique habitat for both deep-sea and shallow water organisms (Rogers 1994). Thus, seamounts are capable of supporting a wide range of organisms (Wilson and Kaufman 1987). To date, Richer de Forges et al. (2000) conducted the most extensive species identification on seamounts. Richer de Forges et al. (2000) found a range of 108 to 516 species of fish and macro-invertebrates from three areas of seamounts in the southwest Pacific (Tasman Sea, Coral Sea). Approximately one third of species found were new to science and potentially endemic. The number of species encountered versus the sampling effort showed that more species are probably present on the seamounts they investigated. Richer de Forges et al. (2000) noted that there were significant differences in the species composition between groups of seamounts found at a same latitude and approximately 1,000 km apart. Such differences in seamount communities suggest that species dispersal is limited to clustered seamounts and that seamount species have localized distributions (Richer de Forges et al. 2000).

2.6.2 Hydrothermal Vents

Deep-sea hydrothermal vents occur in areas of crustal formation near mid-ocean ridge systems both in fore-arc and back-arc areas (Humphris 1995). Seawater permeating and entrained through the crust and upper mantle is superheated by hot basalt and is chemically altered to form hydrothermal fluids as it rises through networks of fissures in newly-formed seafloor (Humphris 1995; McMullin et al. 2000). The temperature of the hydrothermal fluid is characteristically 200° to 400°C in areas of focused flows and less than 200°C in areas of diffuse flow. Other than being hot, hydrothermal fluids are typically poor in oxygen content, and contain toxic reduced chemicals including hydrogen sulfide and heavy metals (McMullin et al. 2000). As the hot hydrothermal fluids come in contact with seawater overlying the vent, heavy metals precipitate out of the fluid and accumulate to form chimneys and mounds. In complete darkness, under the high ambient pressure of the deep sea, in nutrient-poor conditions, and under extreme thermal and chemical conditions, metazoans (multicellular animals) are able to adapt and colonize these sites. Chemosynthetic bacteria use the reduced chemicals of the hydrothermal fluid (hydrogen sulfide) as an energy source for carbon fixation and generate a chemosynthetic-based primary production. In turn, vent organisms (metazoans) consume the chemosynthetic bacteria or form symbiotic relationships with them, and use numerous morphological, physiological, and behavioral adaptations to flourish in this extreme deep-sea environment. These chemosynthetic organisms produce communities typically characterized by a high biomass and low diversity.

A number of hydrothermal vents have been located in the study area (**Figure 2-3**). 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 (Kojima 2002; Embley et al. 2004) with the potential for more systems yet to be discovered. Hydrothermal vents located in the Mariana Trough experience high levels of endemism due to their geographic isolation from other vent systems, with at least 8 of the 30 identified genera only known to occur in western Pacific hydrothermal vent systems (Hessler and Lonsdale 1991; Paulay 2003). Hydrothermal vents at Esmeralda Bank, one of the active submarine volcanoes in the Marianas MRA study area, span an area greater than 0.2 km^2 on the seafloor and expel water with temperatures exceeding 78°C (Stüben et al. 1992). West of Guam and on the Mariana Ridge, there 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; **Figure 2-3**). The gastropod *Alviniconcha hessleri* is the most abundant chemosynthetic organism found in hydrothermal vent fields of the Mariana Trough. Vestimentiferan tube worms are also found in these sites west of Guam (Kojima 2002).

2.6.3 Abyssal Plain

The Mariana Trough is comprised of a large relatively flat abyssal plain with water depths ranging approximately from 3,500 to 4,000 m (Thurman 1997; **Figure 2-2**). Very little data regarding the Mariana Trough within the study region has been investigated. However, in general abyssal plains can be described as large and relatively flat regions covered in a thick layer of fine silty sediments with the topography interrupted by occasional mounds and seamounts (Kennett 1982; Thurman 1997). It is host to thousands of species of invertebrates and fish (Mariana Trench 2003).

2.6.4 Mariana Trench

The seafloor contains numerous hydrothermal vents formed by spreading tectonic plates (Mariana Trench 2003). Away from the hydrothermal vents, the seafloor is covered with soft brown sediments devoid of rock formations (Kato et al. 1998). Sediments that lack carbonate and silica shells appear to be dissolving, suggesting that the ocean floor lies below the carbonate compensation depth (CCD) and at or near the silicate compensation depth (SCD) (Ogawa et al. 1997). In addition, sediments appear to be affected by local currents, which can transport sandy or silty sediments along the trench floor (Ogawa et al. 1997). The trench is host to numerous hydrothermal vent systems supporting a wide variety of chemosynthetic organisms. In addition, the deep waters of the Mariana Trench support barophilic organisms capable of surviving in the cold, dark, high pressure environment. One mud sample taken from Challenger Deep by oceanographers yielded over 200 different microorganisms (Mariana Trench 2003).

2.7 COASTAL HABITATS

Coastal habitats of the study area encompass part of the subneritic zone, which extends from the shoreline at high tide to the edge of the insular shelf (200 m isobath) (Kennett 1982; Thurman 1997). The following discussion of shoreline habitats will focus on the intertidal zone (region of shoreline covered by water between the high and low tidal extremes), coral communities and reefs, softbottom habitats (sand beaches, mudflats, and sand flats), lagoons (semi-enclosed bays found around the islands), seagrass beds, mangroves, and artificial reefs. Since the tidal range in the study area is less than 1 m (Paulay 2003), the shoreline intertidal zone is very narrow around the Mariana Islands.

Biodiversity is high throughout the subneritic zone due to the high variability existing within the habitat (Thurman 1997). Organisms residing on or in the benthos (epifauna and infauna, respectively) can be greatly affected by sedimentation, sediment resuspension, vertical mixing, regeneration (recycling of nutrients), and light penetration (turbidity) (Valiela 1995).

2.7.1 Intertidal Zone

Within the intertidal zone, the shoreline can be divided into three subzones: the high-tide zone, the mid-tide zone, and the low-tide zone. In the high-tide zone, benthic organisms are covered by water only during the highest high tides. Organisms in this zone spend the majority of the day exposed to the atmosphere. In the mid-tide zone, benthic organisms spend approximately half of the time submerged. Organisms residing in this zone are exposed during periods of low tides, but are covered with water during all high tides. Organisms in the low-tide zone are submerged most of the time but may be exposed to the air during the lowest of low tides.

The islands within study area are volcanic in nature and thus the overall geology reflects this origin (Eldredge 1983). The intertidal regions along the majority of the coastlines of islands in the study area are rocky in nature (Rock 1999). Coastlines within the study area are generally lined with rocky intertidal areas, steep cliffs and headlands, and the occasional sandy beach or mudflat (Eldredge 1983). The water erosion of rocky coastlines in the study area has produced wave-cut cliffs (produced by undercutting and mass wasting), and sea-level benches (volcanic and limestone and wave-cut notches at the base of the cliffs (Eldredge 1979, 1983). Large blocks and boulders often buttress the foot of these steep cliffs in the Marianas. Wave-cut terraces also occur seaward of the cliffs (Eldredge 1983; Myers 1999).

2.7.2 Coral Communities and Reefs

Islands within the study area (Guam to FDM) support reefs (biogenic or hermatypic coral reefs) as do islands north of FDM (Anatahan, Sarigan, Guguan, Alamagan, Maug, and Farrallon de Pajaros) (Birkeland et al. 1981; Eldredge 1983; Randall et al. 1984; Randall 1985; Randall and Siegrist 1988; Birkeland 1997; Green 1997; Paulay et al. 1997, 2001; Houk 2001; Paulay 2003; Starmer 2005). Reefs are also found on offshore banks including Tatsumi Reef located 2 km southeast of Tinian, Arakane Bank located 325 km west-northwest of Saipan, Pathfinder Bank located 275 km west of Anahatan, and Supply Reef located 18.5 km northwest of Maug Island (Starmer 2005). The degree of reef development depends on a number of environmental controls including the age of the islands, volcanic activity, the availability of favorable substrates and habitats, weathering caused by groundwater discharge, sedimentation and runoff accentuated by the overgrazing of feral animals, and varying levels of exposure to wave action, trade winds, and storms (Eldredge 1983; Randall 1985, 1995; Randall et al. 1984; Paulay 2003; Starmer 2005). The southern islands (Guam to FDM) are inactive volcanic islands that have subsided and are covered by massive limestone deposits dating back more than 40 million years (Birkeland 1997; 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 (Randall 1995; Birkeland 1997; Paulay 2003).

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 Marianas as gametes and planulae by the NEC (Randall 1995). Overall, the reefs of the Marianas 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 Hawai'i. There are 377 scleractinian species in Marianas (Randall 2003) versus 60 in Hawai'i (Maragos and Gulko 2002). Of the 377 scleractinian corals of the Marianas, 276 species harbor zooxanthellae and 101 species do not (Randall 2003).

There are fewer hard coral (reef building) species and genera in the northern islands compared to the southern islands: 159 species and 43 genera in the northern islands, versus 256 species and 56 genera in southern islands (Randall 1995; Randall 2003; Abraham et al. 2004). The same is true for other reef dwelling organisms. For example, there is greater species diversity of fishes and mollusks on the southern than on the northern islands (Birkeland 1997). These estimates of numbers of species could increase as a function of sampling effort and percentage of reef habitats surveyed at each location.

Corals reported in the general study area are found on shallow reefs and upper fore reefs (<75 m water depth), and deeper fore reef habitats (>75 m water depth) (Randall 2003). 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). In 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).

Most of the shorelines in the general study area are karstic and bordered by limestone cliffs (Randall 1979; Eldredge 1983; Siegrist and Randall 1992; Amesbury et al. 2001; Paulay et al. 2001, 2003). In a few areas, the shorelines consist of volcanic substrates (Randall 1979; Paulay et al. 2003). On windward shores in the general study area, 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 few 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 (Randall 1979; Paulay et al. 2003).

Following are summaries of the distribution, composition, and condition of reefs in the study area. The NCCOS/NOAA (2005) delineations of shallow-water benthic habitats of Guam and the CNMI were used to provide the overall distribution of reefs within the study area. The depiction of benthic habitats (including reefs) of Guam, Tinian, and FDM presented in **Figures 2-7** through **2-9** are approximate due to the low resolution (1 acre minimum mapping unit [MMU]) and hierarchical mapping method (see NCCOS/NOAA 2005 for detailed information on their mapping methods). Future benthic habitat mapping of Guam and the CNMI would benefit from higher resolution techniques and site-specific input on reef structure and coral coverage from local experts. The site specific information on coral cover provided in this report is based on peer-reviewed publications and reports. In areas where coral cover was not reported in the literature we approximated coral cover using NCCOS/NOAA (2005).

2.7.2.1 Regional Distribution, Composition, and Condition

Reefs located in the MRA study area are found on Guam (Agat Bay, Apra Harbor, and Ritidian Point area), Tinian (along the upper two thirds of the island shoreline), and FDM (**Figure 1-1**). Reefs of the Orote Peninsula Ecological Reserve Area (ERA) and the Haputo ERA in Guam are not specifically within the MRA study area but are nevertheless of interest here since the Orote ERA is within the boundaries of the U.S. Naval Station, Guam, and the Haputo ERA is under the control of the Commanding Officer, U.S. Naval Forces Marianas (COMNAVMARIANAS) (DoN 1984, 1986; **Figure 1-1**).

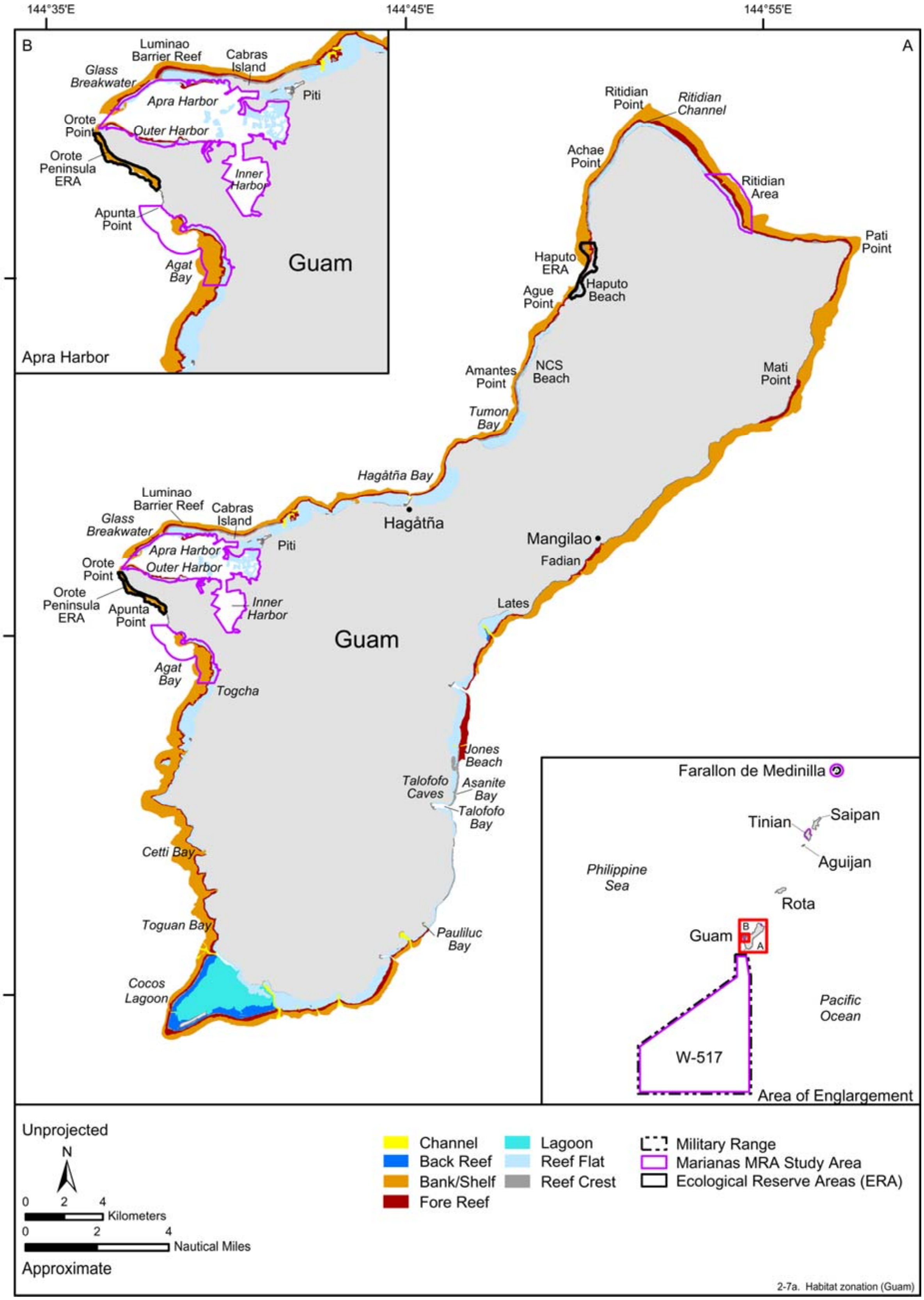

Figure 2-7a. Nearshore benthic habitats of the Marianas MRA study area, Guam: Habitat zonation. Source data: NCCOS/NOAA (2005).

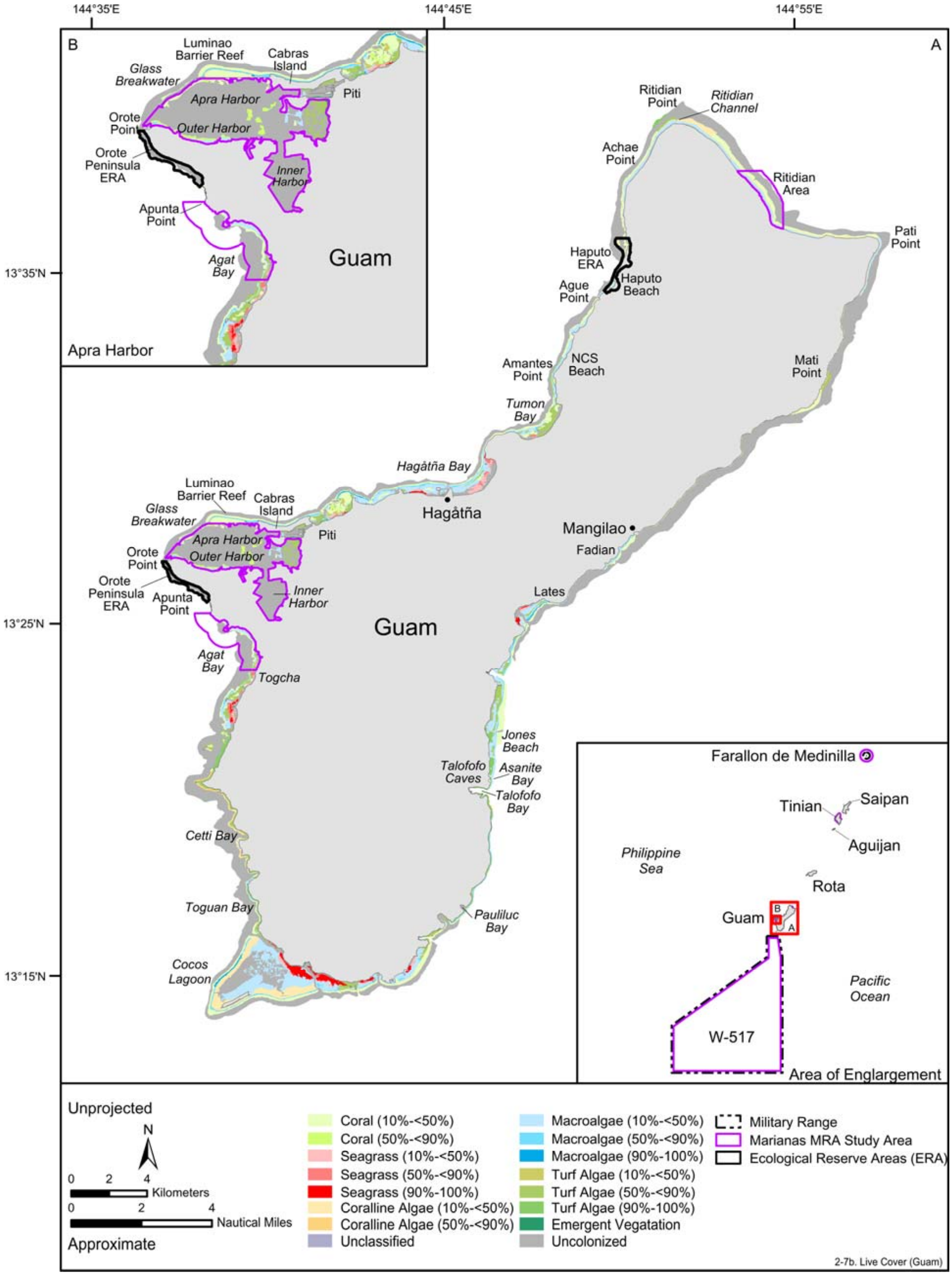

Figure 2-7b. Nearshore benthic habitats of the Marianas MRA study area, Guam: Live cover. Source data: NCCOS/NOAA (2005).

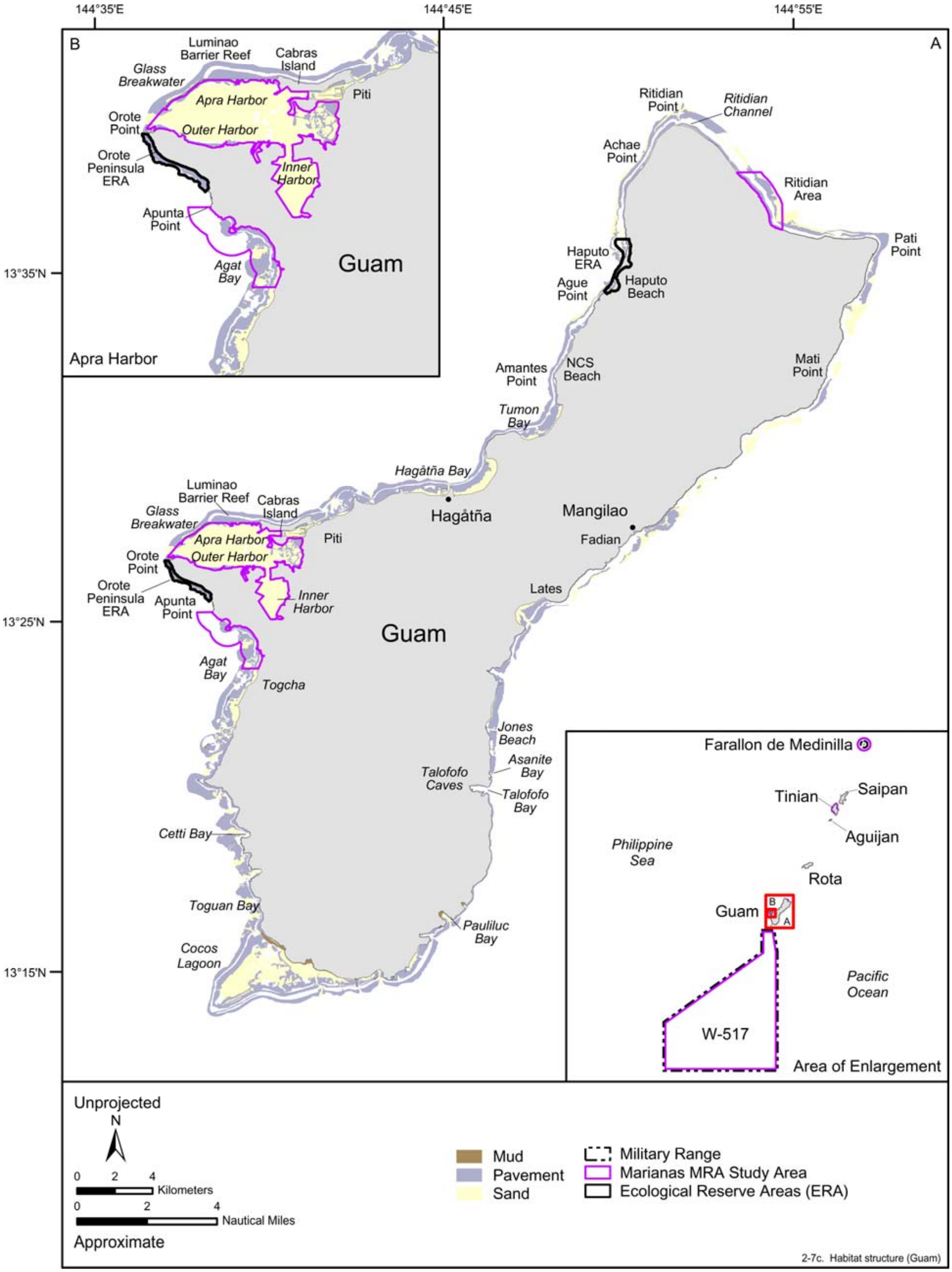

Figure 2-7c. Nearshore benthic habitats of the Marianas MRA study area, Guam: Geomorphological structure. Source data: NCCOS/NOAA (2005).

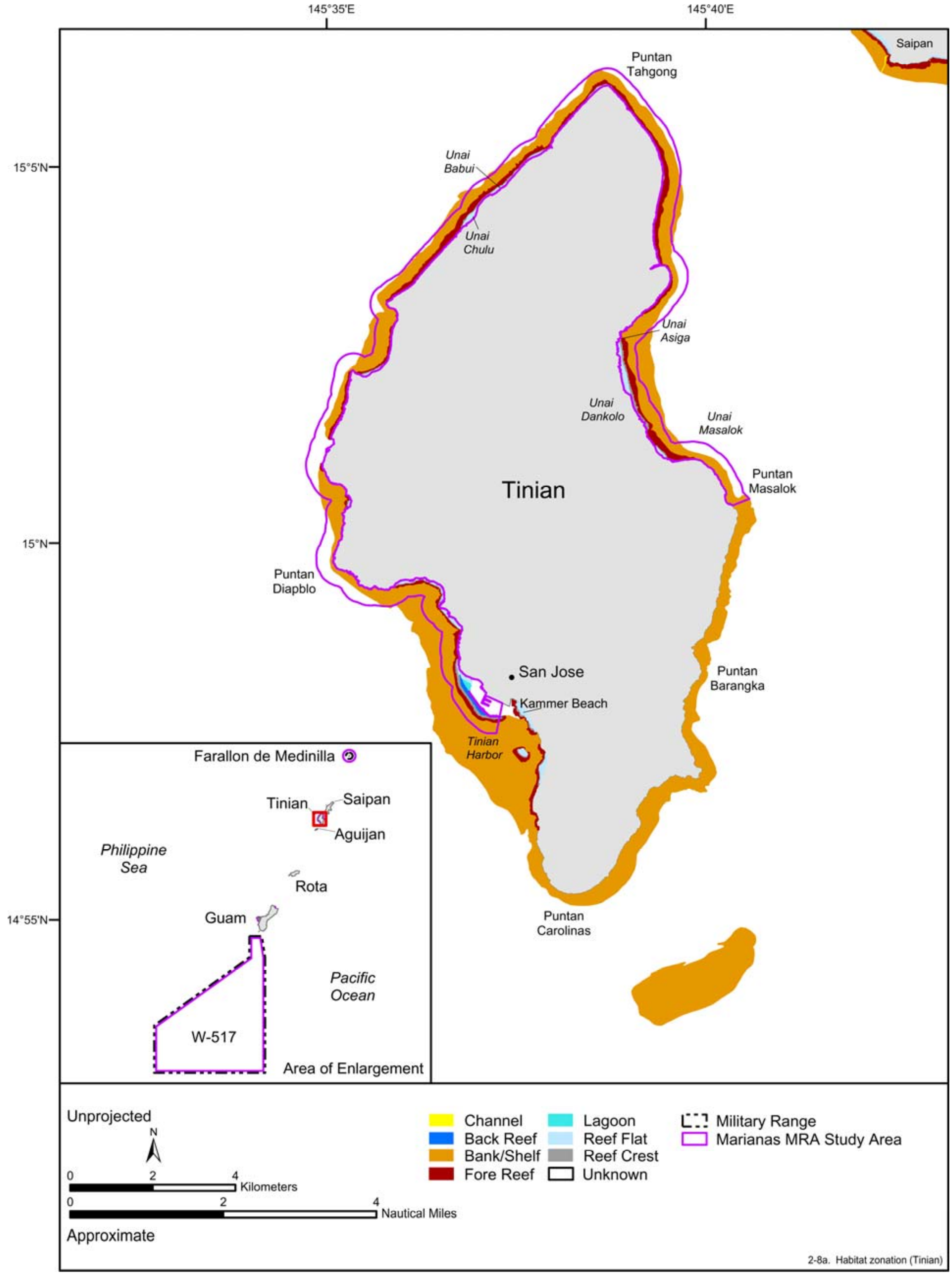

Figure 2-8a. Nearshore benthic habitats of the Marianas MRA study area, Tinian: Habitat zonation. Source data: NCCOS/NOAA (2005).

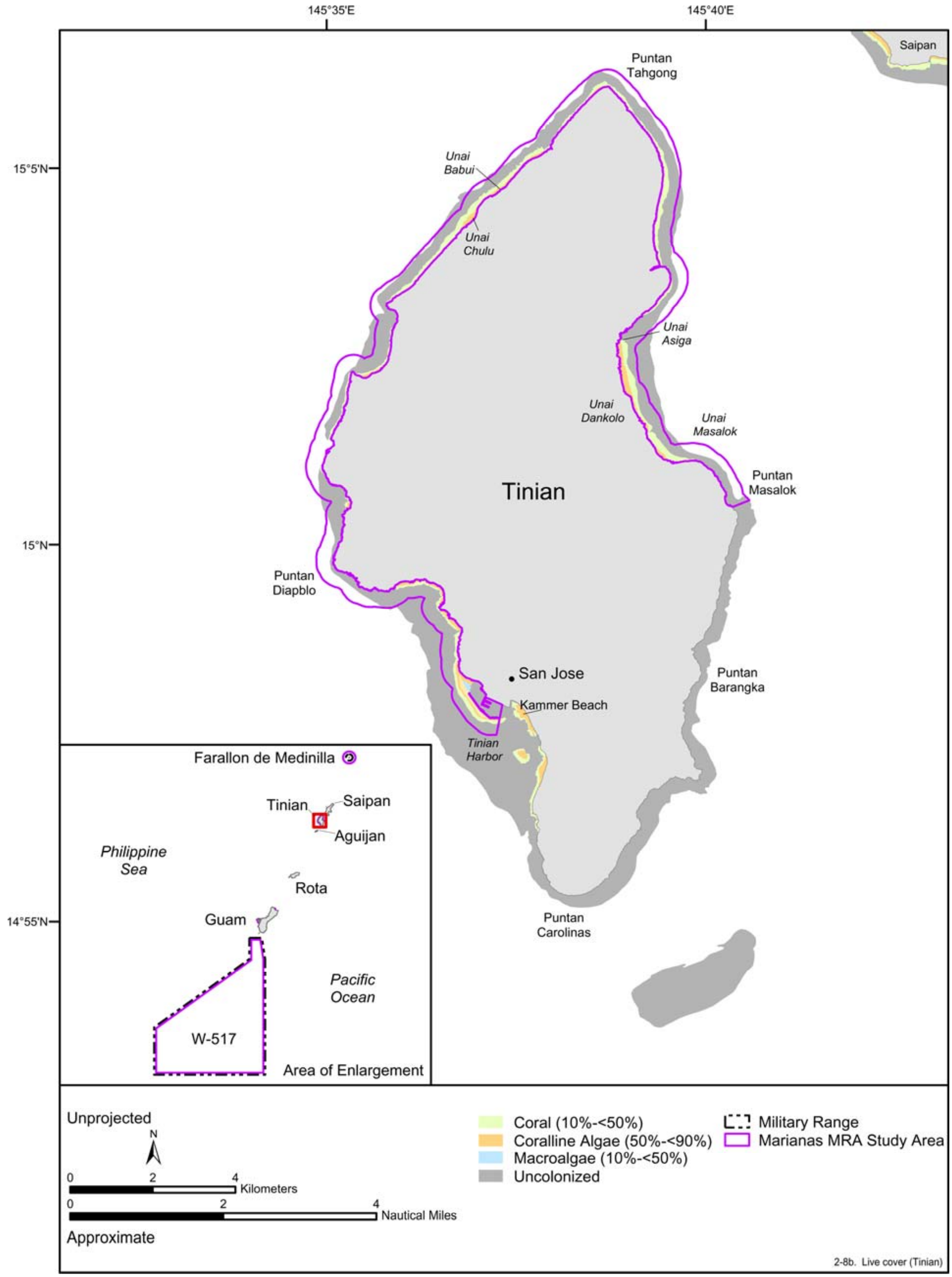

Figure 2-8b. Nearshore benthic habitats of the Marianas MRA study area, Tinian: Live cover. Source data: NCCOS/NOAA (2005).

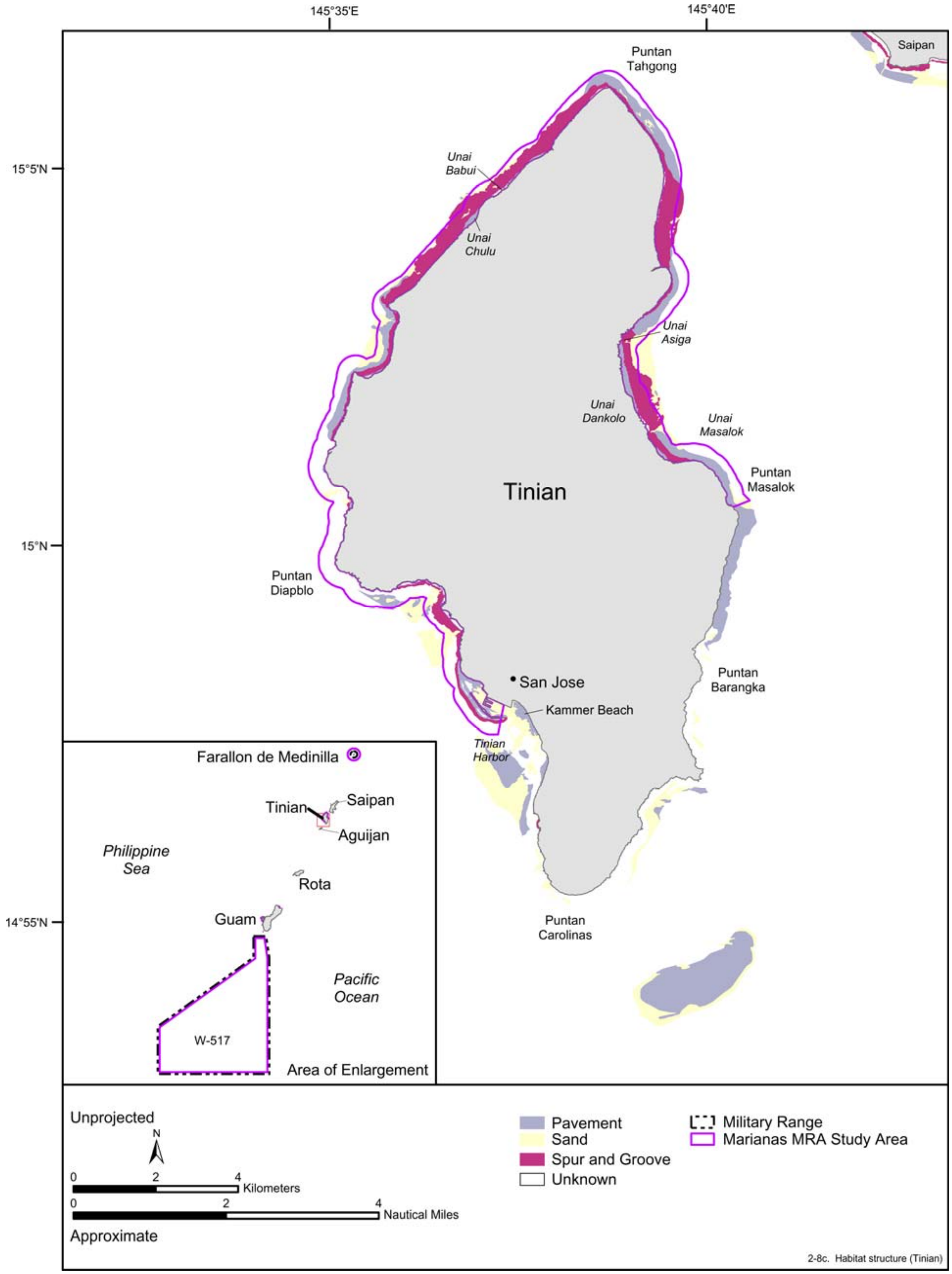

Figure 2-8c. Nearshore benthic habitats of the Marianas MRA study area, Tinian: Geomorphological structure. Source data: NCCOS/NOAA (2005).

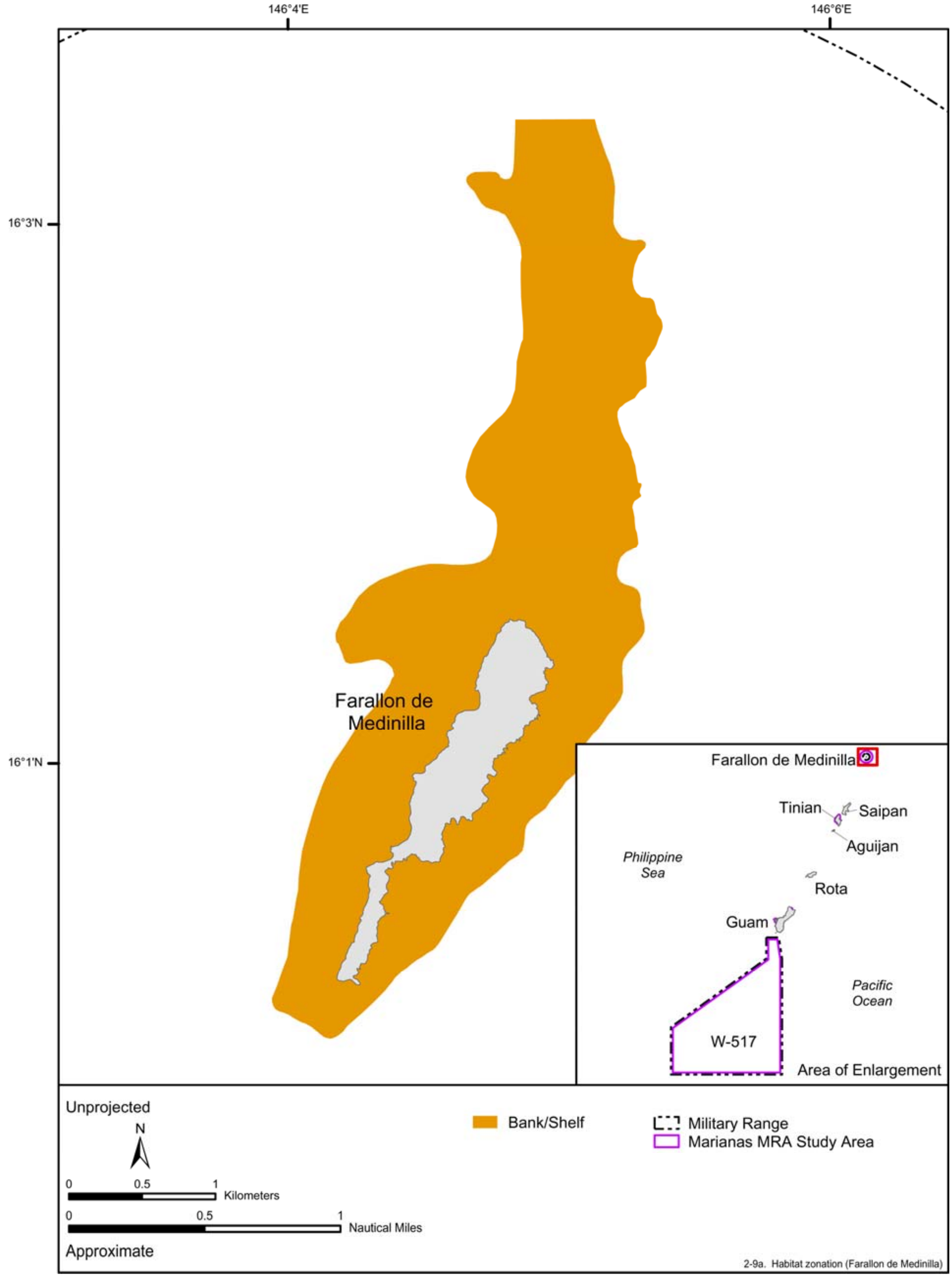

Figure 2-9a. Nearshore benthic habitats of the Marianas MRA study area, Farallon de Medinilla: Habitat zonation. Source data: NCCOS/NOAA (2005).

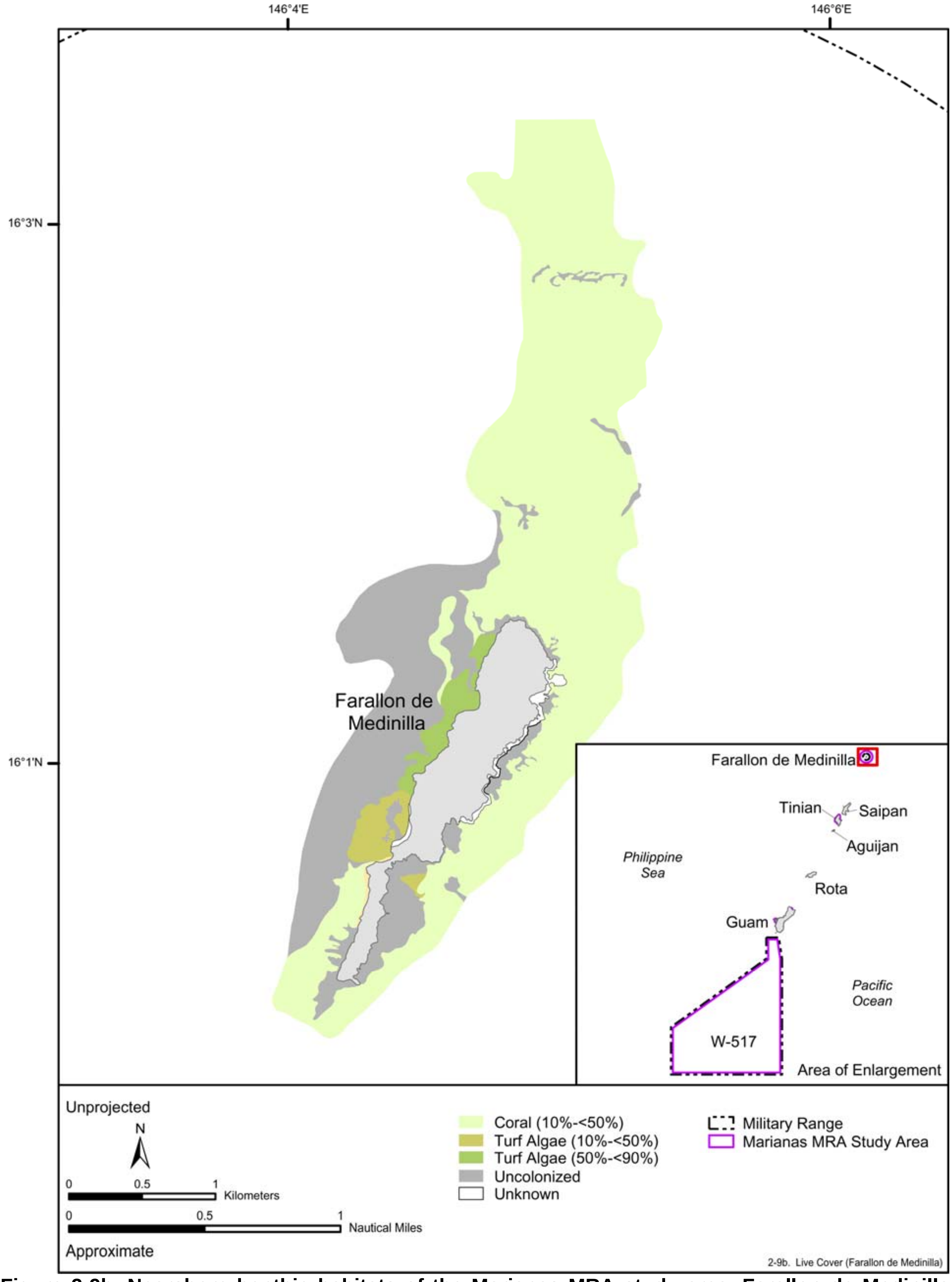

Figure 2-9b. Nearshore benthic habitats of the Marianas MRA study area, Farallon de Medinilla: Live cover. Source data: NCCOS/NOAA (2005).

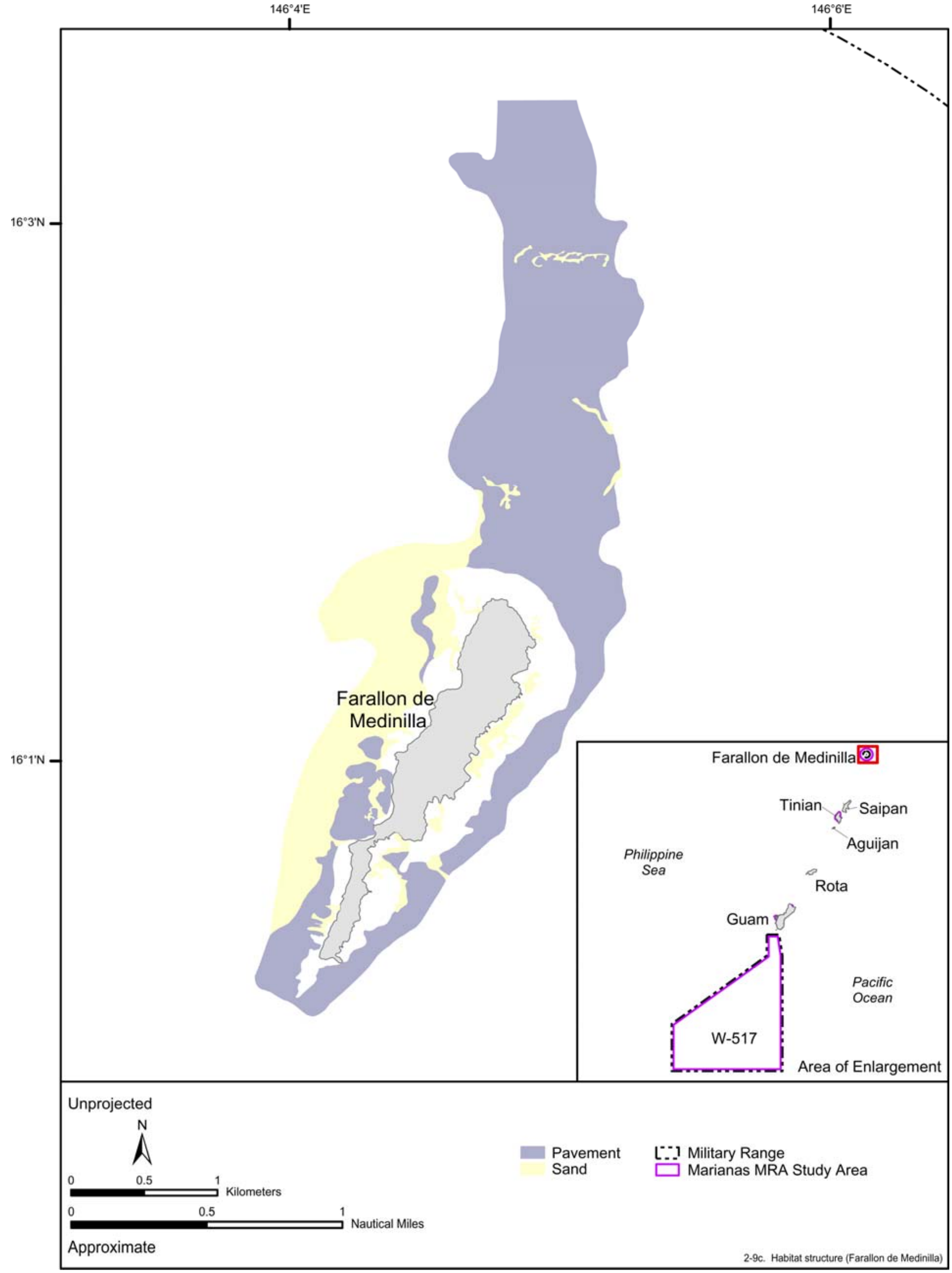

Figure 2-9c. Nearshore benthic habitats of the Marianas MRA study area, Farallon de Medinilla: Geomorphological structure. Source data: NCCOS/NOAA (2005).

Coral communities and reefs are dynamic and changing ecosystems subject to natural and human-induced disturbances. Natural disturbances that have had significant impacts on coral communities and reefs in the Mariana Islands include storm-related damage caused by frequent typhoons, ENSO events, outbreaks of the crown-of-thorns starfish (COTS) (*Acanthaster planci*, a corallivorous predator), freshwater runoff, recurrent earthquakes, and volcanic activity (Richmond 1994; Birkeland 1997; Paulay 2003; Abraham et al. 2004; Bonito and Richmond Submitted). 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 (Birkeland 1997; Houk 2001; Richmond and Davis 2002; Starmer et al. 2002; Paulay 2003; Quinn and Kojis 2003; DoN 2003a; Abraham et al. 2004).

Natural Disturbances—Coral communities and reefs on the eastern, windward side of the islands are exposed to dominant winds, strong wave action, and storms (including typhoons). Corals found above the 30 m isobath on windward coasts are conditioned to withstand heavy wave action and will recover if damaged (Randall 1985; Birkeland 1997; Paulay personal communication). Typhoons can cause substantial damages to corals on windward coasts (Paulay personal communication). Corals in this exposed area of the reef typically include encrusting or massive growth forms of corals as well as columnar, platy and branching growth forms. Exposed windward reef fronts are dominated by three growth forms of *Acropora*: corymbose (colonies are composed of horizontal branches and short to moderate vertical branchlets that terminate in a flat top), digitate (colonies are composed of short, non-anastomosing branches like the fingers of a hand), and caespitose (bushy, branching, possibly fused branches) (Paulay personal communication). There are currently more acroporids on reefs at Unai Dankolo than in sheltered bays of Lau Lau Bay (southeastern Saipan) or Sasanhaya Bay (southwestern Rota) (Houk personal communication). Reef growth in the CNMI at wave exposed sites is more conditioned by the availability of a suitable habitat and an underlying substrate than by wave action (Randall 1985; Houk personal communication).

The disruption of the trade wind pattern during ENSO events has caused sea level to drop in the Mariana Islands and exposed shallow corals and other reef organisms over a prolonged time which has caused mass mortality (Birkeland 1997). Further, ENSO events have produced unusually high seawater temperature which may have caused coral bleaching (Richmond and Davis 2002). The bleaching of corals has been recorded in the Marianas since 1994, and some bleaching events have caused coral mortality (Paulay and Benahayu 1999; Richmond and Davis 2002; Starmer et al. 2002). In 1994, corals bleached on all reefs of Guam (Paulay and Benahayu 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. The chronic outbreaks and predation of COTS on corals (including *Acropora*, *Montipora*, *and Pocillopora*) have also caused coral mortality. 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* (Quinn and Kojis 2003; Bonito and Richmond Submitted; Paulay personal communication). Weather and wave action-exposed reefs (e.g., Unai Dankolo, Tinian) appear to be more resilient to COTS outbreaks compared to reefs in sheltered bays (e.g., Lau Lau Bay, Saipan; Sasanhaya Bay, Rota) (Houk personal communication).

Other sources of coral mortality and degradation are freshwater runoff and seismic and volcanic activity. Freshwater runoff naturally affects reefs in the study area during the rainy season (Richmond and Davis 2002). Areas particularly affected by sedimentation following heavy rainfall include the Ugum River watershed (southeast Guam), the south coast of Guam, Lau Lau Bay (southeastern Saipan), and Opyan Beach (southern Saipan) (Houk 2001; Richmond and Davis 2002; Abraham et al. 2004). Reefs in the islands north of FDM are likely to have been impacted by frequent and recent seismic and volcanic activity (Birkeland 1997; USGS 2004, 2005b). The southern islands (Guam to FDM) have not been impacted by recent volcanic activity but by recurrent seismic activity as witnessed in 1993 in Guam (EERI 1993; Birkeland 1997).

Human-Induced Disturbances—The increased land-clearing and construction of coastal roads, housing, and tourism-related facilities have caused the increased erosion, sedimentation and runoff (particularly during heavy rainfall) impacting coral cover and recruitment in Guam and the CNMI and is the main source of human-induced impacts on coral communities and reefs in the study area (Richmond 1994; Birkeland 1997; Houk 2001; Richmond and Davis 2002; Starmer et al. 2002; Paulay 2003; Abraham et al. 2004). Sedimentation affects both coral cover and diversity. Sedimentation-impacted sites can further be degraded by the compounding effects of overfishing of herbivorous fishes and starfish (Houk 2001; Abraham et al. 2004). Polluted runoff (nutrients from sewage, fertilizers, agriculture, and animal waste), sedimentation, and overfishing have impacted reefs off the most urbanized areas.

2.7.2.2 Coral Communities and Reefs of 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; Paulay personal communication). The depiction of benthic habitats (including reefs) of Guam presented in **Figures 2-7a**, **2-7b**, and **2-7c** is approximate and would benefit from higher resolution mapping and site-specific input on reef structure and coral coverage from local experts.

Reefs in the southern half of Guam have always been subject to more naturally-occurring sedimentation than in the northern half of the island because of the difference of erosional products (volcanic in the south versus limestone in the north) (Richmond and Davis 2002). Coral cover and diversity are currently higher on reefs located along the northeastern coast of Guam (Richmond and Davis 2002). Historical surveys suggest that diversity was actually higher in the south before anthropogenic impacts severely impacted those reefs (Paulay personal communication). The NCCOS/NOAA (2005) survey of shallow-water benthic habitats of Guam determined that the overall coral cover around Guam ranged from 10 to 90% (**Figure 2-7b**). Most the reefs surrounding Guam have a coral cover ranging 10 and 50%. NCCOS/NOAA (2005) delineates four of the areas of Guam where coral cover ranges from 50 to 90%: an area off Mergagan Point on the northeastern end of the island, an area off Pagat Point on the eastern side of the island, an area immediately south of Togacha Bay also on the eastern side of the island, and Apra Harbor.

The fringing reef is interrupted in several locations along the coastline by bays, channels, and areas where the insular shelf is colonized by seagrass (**Figures 2-7a**, **2-7b**, and **2-7c**). 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 from Ague Point to Haputo Beach (NCCOS/NOAA 2005). 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 (NCCOS/NOAA 2005).

Natural and human-induced disturbances affecting the reefs of Guam have caused a significant decline of coral cover and recruitment since the 1960s (Richmond 1994). Coral cover on many fore reef slopes on Guam has decreased from over 50% to less than 25% (Birkeland 1997). There are, however, several reefs of Guam where coral cover remains high, including Apra Harbor, Agat Bay, Orote ERA, and Haputo ERA.

Hagåtña and Tumon Bays are centers for tourism and incur a high level of tourism-related impacts on water quality and marine resources. 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 cause physical damages on reefs (Richmond and Davis 2002; Starmer et al. 2002; Abraham et al. 2004). Anchor damage on reefs occurs at popular dive and fishing sites (Abraham et al. 2004). It is estimated that over half a million SCUBA dives are done each year on Guam and concentrated in five main dive sites: Tokai Maru (Apra Harbor), the Cormoran (Apra Harbor), The Crevice

(Orote peninsula), Blue Hole (Orote peninsula), and Hap's Reef (Agat Bay) (Birkeland 1997; Hanauer 2001). Vessel groundings (recreational and commercial vessels) are also a source of physical impacts on reefs in the Marianas (Richmond and Davis 2002; Starmer et al. 2002).

Apra Harbor—Apra Harbor is a deep lagoon located at the western end of Guam (Paulay et al. 1997; **Figures 1-1**, **2-7a**, **2-7b**, and **2-7c**). 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, the 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; USGS 1978), the Apra Harbor lagoon is unique to the Marianas 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 (Paulay et al. 1997; DoD 1999; DoN 2003b; Paulay 2003; Smith personal communication). Coral cover in the outer harbor is greater than what is depicted in **Figure 2-7b**. **Figure 2-7b** is based on the NCCOS/NOAA (2005) delineation (Paulay personal communication; Smith personal communication); whereas, Paulay et al. (1997) observed "well-developed reefs with some of the highest coral cover on Guam" within Apra Harbor. Further, there are numerous deeper reef shoals in Apra Harbor that are missing from **Figure 2-7a** (Paulay personal communication). The bottom of Apra Harbor is a complex environment that includes substantially more reef than depicted in **Figures 2-7b** and **2-7c** (Paulay personal communication).

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 range from 50 to 90% (Paulay 2003; NCCOS/NOAA 2005). There are mounds at deeper depths 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 (DoD 1999; Smith 2004; NCCOS/NOAA 2005). 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). Reefs located further in the harbor (excluding the Inner Apra Harbor) have been severely impacted by freshwater runoff, sedimentation, and polluted discharges (DoD 1999; Richmond and Davis 2002). Corals in the Inner Apra Harbor (including *P. rus* and *P. damicornis*) encrust sheet pilings, rocks, and concrete debris (DoD 1999).

There are no corals on the seafloor of the Inner Apra Harbor or the inner portion of the Entrance Channel to the Inner Apra Harbor (Smith personal communication). The closest area to the Inner Apra Harbor where corals occur on the seafloor is in the outer reaches of the Entrance Channel of the Inner Apra Harbor. In this area corals consist of *P. rus* and *P. cylindrica* (Smith personal communication). Corals are also found on sheet piles in the Entrance Channel of the Inner Apra Harbor and the outer reaches of the Inner Apra Harbor.

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 found 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 compared to 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 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, in 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) intrinsically 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 that are typical of Apra Harbor (including *P. rus*, *P. cylindrica*, *Pavona venosa*, *Pavona divaricata*, *Psammocora contigua*, *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 (NCCOS/NOAA 2005). Also, a narrow strip of seagrass borders the entire fore reef from the end of the breakwater to Piti Reef (NCCOS/NOAA 2005). In addition to this data from the National Centers for Coastal Ocean Science (NCCOS/NOAA 2005), 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 that the reef flat and the reef front were areas of the reefs where corals were concentrated. However, considering the recent and severe impacts of corallivorous predators and storms on the corals of Guam, the surveys of 1980 and 1981 are probably not representative of current reef conditions (coral diversity and cover) (Birkeland 1997; Abraham et al. 2004). There is no new information to describe these reef areas; therefore the following description from Randall et al. (1982) is discussed. 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 reef pavement (0.6 m deep), a reef margin, and a reef slope. There were very few corals and coral cover on the reef pavement and reef margin was minute (0 to 1.1% coral cover) with coral cover on the reef pavement less than 0.3%. Coral genera on the reef pavement included *Porites* and *Pocillopora*. On the reef margin, there 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. There were five physiographic zones 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 pavement (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 ERA—The Haputo ERA 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) (**Figures 1-1**, **2-7a**, **2-7b**, and **2-7c**). The marine portion of the Haputo ERA covers a 29 ha area (DoN 1986). The following information on the Haputo ERA marine community is taken from Amesbury et al. (2001).

The Haputo ERA coastline is characterized by exposed and narrow supratidal exposed benches (less than 5 m wide, raised 0.5 to 1.5 m above sea level) alternating with vertical cliffs. There are six main macrohabitats supporting corals in the Haputo ERA 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 the three shallow macrohabitats. Corals, however, have the greatest diversity in shallow water on Double Reef. Coral cover ranged from 37 to 64% in the Haputo ERA. Coral cover is higher along transects taken at an 8 m depth compared to those taken at 15 m, and coral species with the highest coverage in the Haputo ERA 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 ERA. 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 ERA correspond to approximately 60% of the coral species known on Guam, and the 204 fish species, 22% of the fish known on Guam. The marine portion of the Haputo ERA is therefore an area of relatively high biodiversity, yet because of overfishing, the fish in the Haputo ERA 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 reef pavement has been honeycombed by echinoids.

The shallow fore reef substrate within the Haputo ERA 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 ERA 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 ERA, 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) which makes it distinctive compared to other locations of Guam. Elsewhere on Guam abundant large massive corals are largely of *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.). Since 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. Crevices and caverns within the reef front create a favorable habitat for sponges.

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 having affected the back reef (Amesbury et al. 2001).

<u>Ritidian Area</u>—The MRA study area on the northern shore of Guam found between Tarague Cave and the Tarague Channel (Ritidian area) is bordered by a nearshore narrow fringing reef made of coralline algae (NCCOS/NOAA 2005; **Figures 2-7a**, **2-7b**, and **2-7c**). Landward of the fringing reef is 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) (NCCOS/NOAA 2005).

<u>Orote Peninsula ERA</u>—The Orote Peninsula ERA is located at the eastern end of Guam (**Figures 1-1**, **2-7a**, **2-7b**, and **2-7c**). As per Paulay et al. (2001), the following is a description of the coral and reef communities found within the Orote peninsula. The Orote peninsula ERA is characterized by steep karstic cliffs plunging abruptly onto a steep fore reef macrohabitat. Erosional processes and seismic events caused large boulders to become detached from the karstic cliffs and land on the fore reef pavement. There are strong currents 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. There are two fringing reefs, 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, there are accumulations of large boulders originating from the cliff. The cliff reef substrate is highly bioeroded by boring echinoids (*Echinometra*), and there is a low diversity of corals in this macrohabitat comprised primarily of *Montipora*, *Pocillopora*, and *Millepora platyphylla*. The sessile benthos here is primarily composed of sponges. The abundance of sponges at this location is substantially higher than many other places on Guam (Paulay personal communication).

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 compared to most locations of Guam. For the majority, the western tip of Orote Island can be considered a high energy environment. 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. This area once supported a large aggregation of Bumphead parrotfish (*Bulbometopon muricatum*) (Davis personal communication).

Paulay et al. (2001) defined the Orote reef slope as a depth zone between the Orote cliff reef and the Orote drop-off. This is the largest macrohabitat of the Orote peninsula ERA. The 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*, *Pocillopora*), and the large boring sponge *Spirastrella vagabunda*. Yet, there are three microhabitats that 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 are located off Neye Island, Apuntua Point, and Barracuda Rock and support higher coral diversity, higher fish diversity and biomass compared to typical locations of Guam, and many soft corals rarely observed on Guam. In this microhabitat, Paulay et al. (2001) found the largest population of *Plerogyra sinuosa* (bubble coral) and the only sighting of *Madracis kirbyi* known on Guam.

The fore reef pavement 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 observation 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 (Hanauer 2001). This cave contains sessile species and fishes known only to this location on Guam. In the 1970s, the Blue Hole contained many more gorgonians and much more macrofauna than it does today. Since then, recreational divers have taken much of the gorgonians as souvenirs (Birkeland 1997). The cave contains the gorgonians *Viminella* sp., *Keroides* sp., *Heliania spiniescens*, and *Briareum excavatum* which have only been observed around the lip of the cave and on the Orote Drop Off (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 drop off. Paulay et al. (2001) has also identified an undescribed sponge *Callyspongia* aff. *carens*.

<u>Agat Bay</u>—Agat Bay is located at the eastern end of Guam (**Figures 1-1**, **2-7a**, **2-7b**, and **2-7c**). Paulay et al. (2001) recently surveyed coral reefs from Orote Point to the northern half of Agat Bay. This survey contains information on the reefs specific to the MRA study area, i.e., the coastal area contained between Togcha Beach and Apuntua Point (Agat Bay area).

The Agat Bay shoreline is characterized by sandy beaches and small limestone outcrops. The sand on Agat Bay consists of dredge spoils from the Inner Apra Harbor deposited on the shore here following World War II (WWII). As a result, the sand contains abundant shells of *Timoclea* sp., a bivalve specific to Apra Harbor.

There is a silty sand plain found in the middle of Agat Bay at water depths ranging from 5 to 30 m (Paulay et al 2001; NCCOS/NOAA 2005). Sand channels and reef substrate interdigitate with patch reefs and reef substrate rising more than 2 m above the sand channels. At 30 m, few patch reefs are found on the dominant sand cover. The epifauna on the sand substrate has a low diversity.

The reef flat from Tipalao Bay through Dadi Beach contains 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 were directly related to the distance from shore. Corals found along the inner reef flat include *Porites australiensis*, *Porites lutea*, and *Leptastrea purpurea*. The coral along the outer reef flat is more diverse than the inner reef flat and includes the species *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. There is a high biodiversity of marine fauna at Neye Island with the coral cover and diversity high on this particular reef flat. Coral cover is dominated by large *Porites* microatolls and eleven *Acropora* species. There is low algal cover and high coralline algae cover, and 34 species of echinoderms have been identified.

2.7.2.3 Coral Communities and Reefs of Tinian

Barrier reefs, fringing reefs, and a broad shelf area (1,000 m wide) are found off the Tinian Harbor (Eldredge 1983; NCCOS/NOAA 2005; **Figures 2-8a**, **2-8b**, and **2-8c**). The largest amount of coral cover is probably found along the outer edges of the reef (fore reef and terrace) (Starmer et al. 2002). Fringing and fore reefs (less than 200 m wide) occur immediately next to the western shoreline of Tinian (NCCOS/NOAA 2005). 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 occupies 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 southern extremity of the study area on the eastern Tinian coast), no fringing reefs are found and the shelf is composed of coralline algae. Furthermore, there are no fringing reefs 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 (**Figures 2-8a**, **2-8b**, and **2-8c**). Fringing reefs reoccur past Puntan Carolinas (NCCOS/NOAA 2005). An oval-shaped, offshore, submerged reef (3.5 km by 1 km) composed primarily of coralline algae is located approximately 2.7 km southeast off the southern most point of Tinian (NCCOS/NOAA 2005). NCCOS/NOAA (2005) determined that the overall coral cover around Tinian ranged 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 compared to Kammer Beach due to fewer coral predator-resistant species (Quinn and Kojis 2003).

Unai Chulu, Unai Babui, and Unai Dangkolo are three beach areas and nearshore reefs within the MRA study area that have been evaluated for amphibious training landing exercises (Marine Research Consultants 1999). Unai Chulu and Unai Babui are located on the northwestern side of Tinian and Unai Dangkolo 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 (NCCOS/NOAA 2005). 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 when compared to 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 more developed at Unai Babui.

A fringing reef borders the Unai Dangkolo white carbonate beach (NCCOS/NOAA 2005). 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 (NCCOS/NOAA 2005). Surveys conducted in 1994, however, report 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, there is a spur-and-groove system down to a depth of 10 m, seaward of which the benthos is comprised of carbonate pavement. Both the spur-and-groove system and the fore reef pavement are densely populated by corals (36 species of corals). The passage of a typhoon in December 1997 severely altered the reef flat coral community diversity and cover. 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 NCCOS/NOAA (2005) reflects the change in reef flat composition. Since NCCOS/NOAA (2005) show relatively abundant coral cover on the reef front, the fore reef has possibly retained some of its pre-December 1997 characteristics. The impacts of corallivorous predators on corals have most likely altered the coral composition and cover on the fore reef (Quinn and Kojis 2003).

2.7.2.4 Coral Communities and Reefs of Farallon de Medinilla

In contrast with the other southern Mariana Islands, the study area at FDM does not include fringing or fore reefs (**Figures 2-9a**, **2-9b**, and **2-9c**). Rather, it has 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 (NCCOS/NOAA 2005; Smith personal communication). In 2004, 81 species of corals were observed on reefs at FDM (DoN 2005). 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 (DoN 2005). Most of the coastline of FDM is bordered by steep karstic cliffs which for the most part extend 6 to 9 m below the waterline (DoN 2005). Cliffs on the western shoreline extend more than 20 m below the waterline. There are numerous underwater caves 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. 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 (DoN 2005).

Near the cliff edge on the reef terrace of the eastern side of FDM, there is less than 5% coral cover (DoN 2005). Further offshore, there 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 comprised 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*. There are large aggregations of the long-spined urchin *Echinotrix diadema* (hundreds to thousands of individuals) seen both on 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 (DoN 2005).

Since 1971, FDM has been a target site for live-fire military exercises (ship-to-shore gunfire, aerial gunnery and bombing) (DoN 2005). The majority of the ordnance found underwater at FDM during reef assessments conducted since 1999 occur at the northwestern end of the island (DoN 2005).

2.7.3 Softbottom Habitats

Softbottom habitats are those habitats in which the benthos is covered with a layer of fine sediment (Nybakken 1997). Commonly identified habitats are beaches, sand flats, and mudflats (**Figures 2-7** through **2-9**). Sand flats differ from sand beaches in that beaches are intertidal pile-ups along coasts, while sandflats can be found anywhere away from the coasts. Softbottom habitats can occur on a sloped seafloor and not only on a flat, horizontal surface (Paulay personal communication).

The topography of a mud flat is flatter than that of a sand flat, as mudflats require less wave energy to form (Nybakken 1997). Mud flats are also more stable than their sand counterparts, and are more conducive to the establishment of permanent infaunal burrowing communities (Nybakken 1997). The Puerto Rico Mudflats of Saipan (15°13'N, 145°43'E) and mudflats in and around the Apra Harbor mangrove system are substantial (Scott 1993; Stinson et al. 1997; Paulay personal communication) and are important feeding grounds for migratory shorebirds (Scott 1993; **Figures 2-7** through **2-9**).

Softbottom substrates in coastal regions of the study area are not common. This is due to the fact that the intertidal and subtidal regions are often characterized by limestone pavement interspersed with coral colonies and submerged boulders (Kolinski et al. 2001). Shorelines are often rocky with interspersed sand beaches or mud flats (Eldredge 1983; PBEC 1985).

On the island of Guam, the majority of the coastline is comprised of rocky intertidal regions. Interspersed among this rocky shoreline are 58 beaches composed of calcareous or volcanic sands (Eldredge 1983). On Rota, the rare beaches are found scattered among limestone patches and are composed of rubble and sand (Eldredge 1983). The submarine topography surrounding Tinian and Aguijan can be described as limestone pavement with interspersed coral colonies and submarine boulders (Kolinski et al. 2001). While the island of Aguijan contains no beaches (Kolinski et al. 2001), the island of Tinian contains 13 beaches (10 located 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, **Figure 2-7c**) and are comprised mainly of medium to course grain calcareous sands, gravel, and coral rubble ("coral-algal-mollusk rubble") (Eldredge 1983; Kolinski et al. 2001). 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. The coastal area of FDM contains two small intertidal beaches that are inundated by high tide on the northeastern and western coastlines. Offshore of FDM, at approximately 20 m, a softbottom, sandy slope extends downward onto the abyssal plain (DoN 2003a). Most of the other islands in the Marianas also have sandy slopes below the fore reef, typically starting at 30 to 40 m, with some variation (Paulay personal communication).

2.7.4 Estuarine Habitats

Estuaries are bodies of water along coasts and are formed where there is an interaction between freshwater, saltwater, land, and the atmosphere (Day et al. 1989). Estuaries are among the most productive natural systems on earth, producing more food per acre than the richest farmland (RAE/ERF 1999). A minority of fish and shellfish species depend on estuaries, although these are often very abundant and economically important species. Estuaries provide a vital buffer between land and open water, filtering pollution and protecting surrounding lands from flooding (RAE/ERF 1999). The dominant feature of the estuarine environment is the fluctuating salinity. By definition, a salinity gradient (from fresh to saline) exists at some time in an estuary (Nybakken 1997).

There are many types of estuaries in the world. The most common type is the coastal plain estuary which is formed when rising sea levels invade low-lying coastal river valleys. Examples of coastal plain estuaries are the Chesapeake Bay and the mouths of the Hudson and Delaware Rivers on the east coast of the U.S. (Nybakken 1997). Tectonic estuaries are formed when land subsides, allowing water to flood coastal regions. One example of a tectonic estuary is San Francisco Bay (Nybakken 1997). Fjords, a third type of estuary, are formed when a valley that has been deepened by a glacier is submerged by oceanic waters. Fjords are characterized by a shallow sill that restricts water exchange with the ocean and the deeper waters of the fjord. Finally, the lagoon is an estuarine habitat formed along a coastline behind a sandbar or reef. Within the study area, estuarine habitats are found in lagoons, embayments, and river mouths.

Steep slopes and complex shorelines of the Mariana Islands (Guam to FDM) form relatively sheltered coastal bays characterized by silty sediments and turbid waters. Often, these bays are associated with riverine freshwater discharge (Myers 1999). Bordering estuaries and coastal embayments throughout the world are unique plant associations. In temperate and subpolar regions, this association is found in the form of a salt marsh. A salt marsh develops wherever sediment has accumulated to form a transition area between aquatic and terrestrial ecosystems (Nybakken 1997). They are composed of beds of intertidal rooted vegetation which are alternately inundated and drained by the tides (Day et al. 1989). While salt marshes can occasionally form in tropical regions along salt flats, they are not known to occur in the study area (Day et al. 1999). Rather, mangroves, the tropical equivalent of salt marshes, occur within the study area. Mangroves often line the shores of coastal embayments and the banks of rivers to the upper tidal limits in tropical environments, especially where the slope is gentle (Myers 1999). Mangroves possess large roots that spread laterally and consolidate sediments, eventually transforming local mudflats into dry land (Myers 1999). The extensive root system and nutrient rich waters found in mangroves make them among the richest of nursery grounds for marine life (Scott 1993; Myers 1999).

On Guam, estuarine habitats occur in areas of tidal intrusion or brackish water, and consist primarily of mangroves and the lower channels of rivers that are inundated by tides ranging from 75 to 90 cm in amplitude (Scott 1993). Nine of the Guam's 46 rivers that empty into the ocean have true estuarine habitats with elevated salinity levels extending upstream (Scott 1993). While estuarine habitats in the CNMI are not as widely studied, there are a number of bays and lagoons that probably function as estuarine habitats. Further discussion of the estuarine environments located within the study area including sand flats, mud flats, lagoons, and mangroves can be found within this chapter.

2.7.5 Lagoons

A lagoon within the study area can be described as a semi-enclosed bay found between the shoreline and the landward edge of a fringing reef or barrier reef (NCCOS/NOAA 2005; Paulay personal communication). By geomorphological definition, true lagoons lie only behind barrier reefs, while moats (a shallow analogue of lagoons) can lie behind fringing reefs (Paulay personal communication). A lagoon is formed when a sandbar (or barrier reef) is built up parallel to the coastline and cuts off the inland waters to the sea, creating a shallow region of water. A lagoon typically contains three distinct zones: freshwater zone, transitional zone, and saltwater zone (Thurman 1997). Yet, most tropical reef-associated lagoons are not brackish and lack significant freshwater influence (Paulay personal communication).

The study area contains numerous relatively shallow lagoons (depth ranging from 1 to 15 m) and one deep lagoon, Apra Harbor (PBEC 1985; Paulay et al. 1997; NCCOS/NOAA 2005; **Figures 2-7** through **2-9**). The bottoms of the lagoons are mostly sandy and flat or undulatory. Coral rubble, coral mounds (patch reefs), seagrass, and algae are found within the lagoons. Coral mounds tend to be more abundant in the outer lagoons and are widely scattered or absent in the inner lagoons (PBEC 1985; NCCOS/NOAA 2005).

Apra Harbor, the only deep lagoon on Guam and the busiest port in the Mariana Islands, is enclosed by the Glass Breakwater (**Figure 2-7a**). 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 (USGS 1978; Paulay et al. 2002; **Figure 2-7a**). A similar situation occurs on the eastern coastline with fringing reefs occurring along the eastern coastline from Fadian Point to Cocos Lagoon (USGS 1978; **Figure 2-7a**).

The western coastline of Saipan is lined with sandy beaches protected by a barrier reef which forms Tanapag and Saipan Lagoons (Scott 1993). Tanapag Lagoon is a typical high-island barrier reef lagoon. Tanapag Lagoon is located on the northwestern coast of Saipan. Also, on the western coastline of Saipan, the barrier reefs form two additional lagoons, creating the largest lagoonal system in the Mariana Islands, Garapan Lagoon and Chalan Kanoa Lagoon (Chandron 1988; Duenas and Associates 1997; Trianni and Kessler 2002). The maximum width of Saipan Lagoon is 100 m, and the maximum depth is 14 m in the Tanapag Harbor channel, although average depth is only 3 m (PBEC 1985; Trianni and Kessler 2002).

The islands of Tinian and Rota lack complex lagoon systems. The island of Tinian is surrounded by reefs, but lacks a true lagoon complex. The lagoons of Tinian, save two (off of the Leprosarium at the southwestern edge of the leaseback area (LBA; see **Figures 1-1** and **2-8a**), and the northern region of the Tinian Harbor area), are all adjacent to military leases (USGS 1980; NCCOS/NOAA 2005).

Saipan has five small lagoons located on the western side of the island and two lagoons along the eastern coastline (USGS 1980; PBEC 1985; NCCOS/NOAA 2005). 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 (PBEC 1985; NCCOS/NOAA 2005).

2.7.6 Seagrass Beds

Seagrasses are vascular (flowering) plants adapted to living in a saline environment and grow completely submerged (Phillips and Menez 1988). Seagrasses are unique as they are land plants that spend their entire life cycle underwater. Seagrasses grow in muddy or sandy substrates and can develop into extensive undersea meadows (Phillips and Menez 1988). Seagrass beds are among the most highly productive ecosystems in the world and are an important ecosystem of shallow-water tropical regions (Nybakken 1997). Beds are often used as protective habitats or nursery grounds for many organisms that live in/on sandy or muddy bottoms, in the surrounding waters, or on the plants themselves (Phillips and Menez 1988; Daniel and Minton 2004). While seagrasses are consumed by only a few species (including dugongs, sea turtles, mollusks, and some urchins), many organisms feed on the epiphytic algae growing on the plant structure (Nybakken 1997).

Seagrass beds are widely distributed within the study area. Both Guam and Saipan have extensive seagrass meadows surrounding the coastlines (NCCOS/NOAA 2005; **Figure 2-10**), including extensive beds 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 Cocos Lagoon on Guam (Eldredge et al. 1977; Daniel and Minton 2004). Rota is known to posses a small seagrass bed off its southern shore (Abraham et al. 2004). Tinian possesses seagrass beds along the northwestern, the northeastern, the southwestern and the eastern coastlines (DoN 2003a). Seagrasses are more scattered on the island of Saipan, with seagrass beds reported along Tanapag Beach (along the northwest coast) and in the Puerto Rico Mudflats (northwest shoreline, south of Tanapag Beach) (Tsuda et al. 1977; Scott 1993). Seagrasses have vanished off the southern coast of Saipan (Abraham et al. 2004). There is no record of seagrass beds occurring on the islands north of Saipan (Tsuda 2003).

Currently, three species of seagrasses (*Enhalus acoroides, Halodule uninervis, and Halophila minor*) are known to occur in the Mariana Islands (Tsuda et al. 1977). *Enhalus acoroides*, also referred to as tape grass, possesses long leaves (30 to 150 cm long and 1 to 2 cm wide), 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 (Phillips and Menez 1988; Daniel and Minton 2004). *Halodule uninervis* possesses leaves ranging from 6 to 15 cm long (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 (0.7 to 1.4 cm long, 3 to 5 mm wide) and is found in sheltered areas on muddy or sandy substrate in the upper subtidal zone (Phillips and Menez 1988).

2.7.7 Mangroves

Mangroves are a type of wetland that borders estuaries or shores protected from the open ocean (Scott 1993). They are composed of salt-tolerant trees and other plant species and they provide critical habitat for both marine and terrestrial life. Species diversity is usually high in mangroves, and like seagrasses, can act as a filter to remove sediments before they can be transported onto an adjacent coral reef (Scott 1993; Nybakken 1997; Thurman 1997).

Mangrove forests are native to the Marianas study area, however, are only present on the islands of Guam and Saipan (**Figure 2-10**), with the mangroves of Guam being the most extensive and diverse,

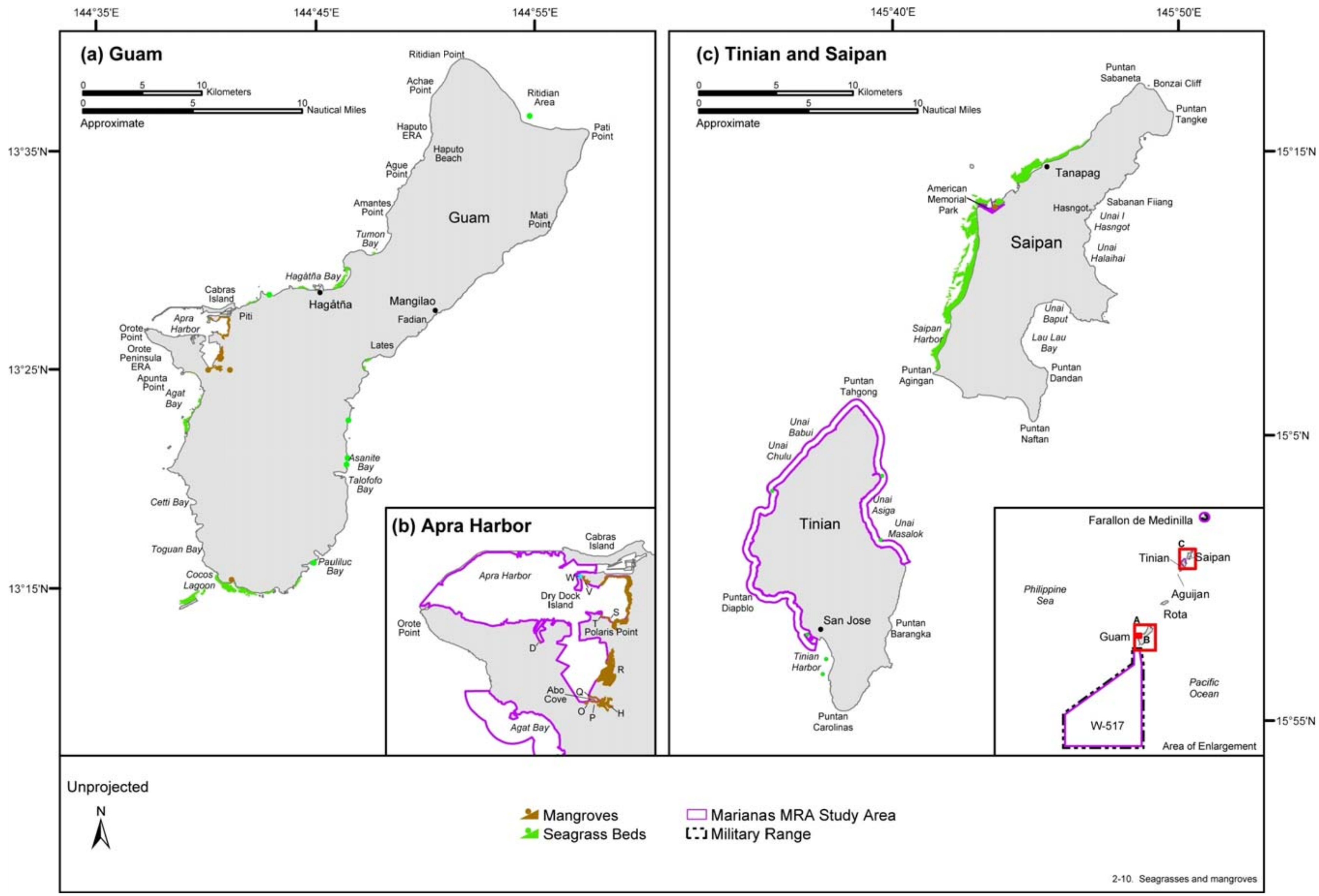

Figure 2-10. Distribution of seagrass and mangrove communities in the Marianas MRA study area and vicinity (a) Guam, (b) Apra Harbor, (c) Tinian and Saipan. Source data: Jones et al. (1974), Scott (1993), DoN (1999, 2003), and NCCOS/NOAA (2005).

totaling approximately 70 ha (Scott 1993). There are 50.7 ha of mangrove forests on ten sites within the Navy lands on Guam (DoN 1999b; **Figure 2-10**). The largest of these mangrove sites (35.9 ha) is site R located along the eastern shoreline of the Apra Inner Harbor (DoN 1999b). This site mainly consists of *Rhizophora mucronata*. Four sites near Abo Cove at the southern tip of the Inner Apra Harbor (Sites H, O, P, and Q) amount to 12.4 ha of mangrove forests (**Figure 2-10**). Site H contains *R. mucronata* and *Avicennia alba*. Sites O, P and Q contain *R. mucronata*. There are two mangrove sites near Dry Dock Island (Sites V and W) and two more sites near Polaris Point (Sites S and T) (**Figure 2-10**). Mangrove site S (0.6 ha) consists of *Rhizophora* sp., and site T (0.4 ha) of *Rhizophora* sp. and *A. marina*. Mangroves species found at site V (1.2 ha) are *A. marina*, *Rhizophora* sp., and *Bruguiera gymnorrhiza*. Site W is populated by *A. marina*, *Xylocarpus moluccensis*, and *B. gymnorrhiza* (DoN 1999b). Along the southern shore of the para Harbor, there is a mangrove area at site D which consists of *R. mucronata* and *A. alba* and covers a 0.7 ha area (DoN 1999b). Achang Bay Mangroves is centered on Achang Bay at the southern end of Guam. This area is the only sizable area of mangrove forest in southern Guam (*R. mucronata, B. gymnorrhiza, A. marina, R. apiculata*) (Wilder 1976). The forest is owned by the government of Guam and is a 20 to 60 m wide strip lining the shore.

Mangroves in the CNMI are restricted to Saipan. These mangroves are comprised of a single species (*Bruguiera gymnorrhiza*) and can only be found in a few small stands (Scott 1993) in two locations: Puerto Rico Mudflats and American Memorial Park. Puerto Rico Mudflats (15°13’N, 145°43’E) is a series of mudflats bounded by a national park (American Memorial Park; NPS 2004) and a landfill. Within these mudflats is a broken fringe of mangrove trees. The largest stands of mangroves are found north of the landfill.

2.7.8 Artificial Habitats

Artificial habitats (shipwrecks, artificial reefs, jetties, pontoons, docks, and other man-made structures) are physical alterations to the naturally-occurring marine environment. In addition to artificial structures intentionally or accidentally placed on the seafloor, FADs are suspended in the water column and anchored on the seafloor to attract fish. FADs have come to be referred to as any floating object physically placed in the water column solely intended to attract fish (Klima and Wickham 1971; Bohnsack et al. 1991, Blue Water 2002). Artificial structures provide a substrate upon which a marine community can develop (Fager 1971). Navigational, meteorological, and oceanographic buoys suspended in the water column potentially function like artificial habitats. Epibenthic organisms will settle on artificial substrates (including algae, sponges, corals, barnacles, anemones, and hydroids) to eventually provide a biotope suitable for large motile invertebrates (e.g., starfish, lobster, crabs) and demersal and pelagic fishes (Fager 1971; Bohnsack et al. 1991).

2.7.8.1 Artificial Reefs

An artificial reef consists of one or more submerged structures of natural or man-made origin that are purposefully deployed on the seabed to influence the physical, biological, or socioeconomic processes related to living marine resources (Baine 2001). Artificial reefs are defined both physically, by the design and arrangement of materials used in construction, and functionally according to their purpose (Seaman and Jensen 2000). A large number of items are used for the creation of artificial reefs including natural objects, such as wood (weighted tree trunks) and shells; quarry rock; or man-made objects, like vehicles (automobile bodies, railroad cars, and military tanks), aircraft, steel-hulled vessels (Liberty ships, landing ship tanks, barges, and tug boats), home appliances, discarded construction materials (concrete culverts), scrap vehicle tires, oil/gas platforms, ash byproducts (solid municipal incineration, and coal/oil combustion), and prefabricated concrete structures (reef balls) (Artificial Reef Subcommittee 1997). The purpose of deploying artificial reefs in the marine environment is to: (1) enhance commercial fishery production/harvest; (2) enhance recreational activities (fishing, SCUBA diving, and tourism); (3) restore/enhance water and habitat quality; (4) provide habitat protection and aquaculture production sites; and (5) control fish mortality (Seaman and Jensen 2000).

Dedicated artificial reefs are currently found in two locations of the study area: Agat Bay, Guam and Apra Harbor, Guam (**Figure 2-11**). 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, Inc. 2005). In 1944, the 76th Naval Construction Battalion (SEABEES) built the Glass Breakwater which forms the north and northwest sides of Apra Harbor (Thompson 2005). The enormous seawall is made of 1.5 million m^3 of soil and coral extracted from Cabras Island (Thompson 2005). The Glass Breakwater is the largest artificial substrate in the Marianas.

To date, no additional artificial reefs have been established in the study area. The passage of tropical cyclones and typhoons have probably damaged and/or displaced the reefs placed in Cocos Lagoon (Gutierrez personal communication). The installation of artificial reefs around Guam is currently prohibited (Gutierrez personal communication).

2.7.8.2 Shipwrecks

Many shipwrecks are found within the study area including grounded vessels and military wreckage (**Figure 2-11**). 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 Marianas 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 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 (NOAA 2004b).

As of October 2003, 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: 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). Shipwrecks of interest along Guam include the *Cormoran*, a German gunboat scuttled in Apra Harbor during World War I (WWI) to prevent it from falling into enemy hands (Rock 1999; Hanauer 2001). Lying next to the *Cormoran* in Apra Harbor is the *Tokai Maru*, a 134 m long Japanese freighter sunk by a Navy submarine during WWII. Also located in Apra Harbor are a tanker and a "junkyard" comprised of bulldozers, pieces of the oceanliner *Cariba*, and other scrap (Rock 1999; Hanauer 2001). Located off of Cocos Island at the southern tip of Guam is the wreck site of a seventeenth century Spanish galleon (Hanauer 2001).

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). 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

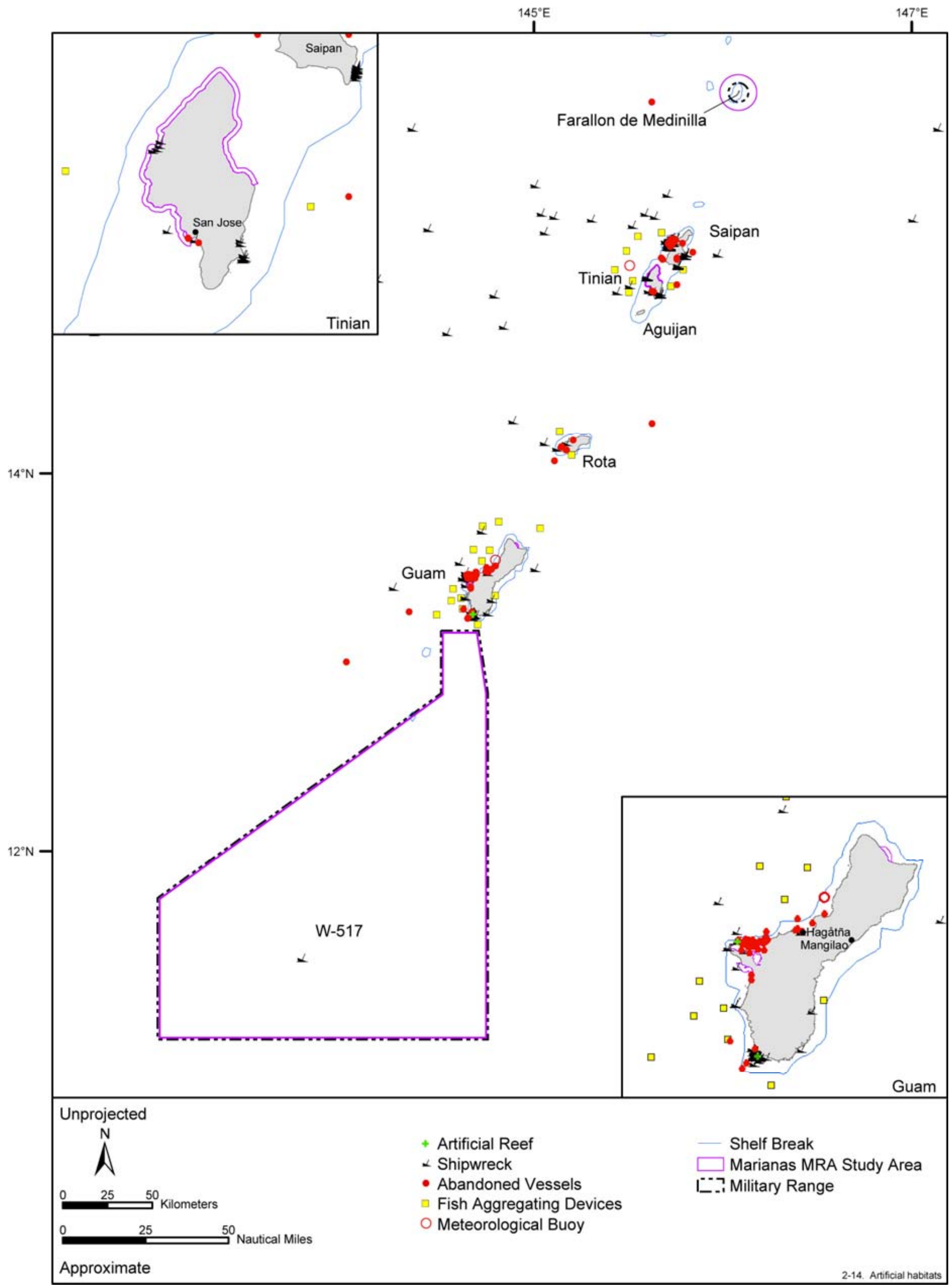

Figure 2-11. Distribution of artificial reefs, shipwrecks, and fish aggregating devices in the Marianas MRA study area and vicinity. Source data: Eldredge (1979), Veridian Corporation (2001), NOAA (2004c), DAWR (2004), and CNMI DFW (2005).

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, located 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).

2.7.8.3 Fish Aggregating Devices

FADs consist of single or multiple floating devices (Samples and Hollyer 1989) connected to the ocean floor by ballast or anchors. Usually prefabricated, FADs are designed to attract fish species to them (Klima and Wickham 1971). Even though a naturally floating log attracts fish, it is not considered a FAD because humans did not intentionally place it in the ocean (Blue Water 2002). Two fundamentally different types of FADs have been employed since the 1970s: large floating FADs and small mid-water FADs. Large FADs have been deployed in water depths exceeding 1,800 m for ocean pelagic commercial and recreational fisheries. Small FADs have been used in more nearshore and coastal environments for recreational fisheries in water depths ranging from 15 to 30 m (Rountree 1990).

The first FADs deployed within the study area were constructed by connecting three 55-gallon drums together (Chapman 2004). Four of these FADs were deployed between 1979 and 1980. All were lost within five months of deployment. The Northern Marianas Islands first deployed five FADs in conjunction with the Pacific Tuna Development Foundation in 1980. Four of the five were lost within the first six months (Chapman 2004). Currently, Guam maintains 16 FADs within 20 NM of the shoreline (Chapman 2004; DAWR 2004; **Figure 2-11**). Lost FADs are replaced within two weeks (Chapman 2004). The Northern Marianas 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; CNMI DFW 2005).

Buoys—A buoy is a floating platform used for navigational purposes or supporting scientific instruments that measure environmental conditions. Currently two meteorological buoys capable of measuring wave energy, wave direction, and sea surface temperature are active and located in the study area (**Figure 2-11**). One of these buoys supports oceanographic instruments and is owned by the Scripps Institution of Oceanography (La Jolla, California), and is located off of Guam at 13°21'15" N, 144°47'20" E in 200 m of water depth (CDIP 2005; NDBC 2005; StormSurf 2005). The other buoy is located off the coast of Saipan (15°06’N, 145°30’E) and serves a meteorological purpose (StormSurf 2005; **Figure 2-11**). CRED (Coral Reef Ecosystem Division – NOAA Pacific Islands Fisheries Science Center) has deployed and currently maintains subsurface instrument arrays on all of the islands in the study area, and has surface buoys on Rota, Saipan, Pagan, Maug (Michael Parke personal communication).

2.8 LITERATURE CITED

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3.0 SPECIES OF CONCERN

This chapter provides detailed information for marine mammals and sea turtles, which are species of particular interest to the Navy due to their protected status and potential to be impacted by Navy activities.

Marine mammals are the taxon group with the largest number of federally protected species in the Marianas MRA study area. Section 3.1 of this chapter provides information on the 32 marine mammal species with confirmed or possible occurrence in the study area and vicinity. All marine mammals are protected by the MMPA; 7 large whale species, the Hawaiian monk seal, and the dugong are additionally listed as endangered under the ESA. An overview of marine mammals, as well as a brief introduction to acoustics and hearing, which is useful in consideration of any potential anthropogenic impacts to these animals, is included. A detailed narrative has been prepared for each marine mammal species, consisting of a species description, status, habitat preferences, distribution (including a focus on the Marianas MRA study area), behavior and life history, as well as an account of its vocalizations and hearing capabilities (when available). Maps depicting the seasonal occurrence records and the predicted occurrence extent of each marine mammal species in the study area and vicinity are found in **Appendix B** (**Figures B-1** through **B-24**).

Five sea turtle species have the potential to occur in the Marianas MRA study area and all are threatened or endangered. Section 3.2 of this chapter consists of an overview on sea turtle biology and life history and provides basic information on the hearing capabilities of these animals. Each of the sea turtle species is then described in detail by its physical description, status, habitat preferences, distribution (including a focus on the Marianas MRA study area), and behavior and life history. Maps depicting the seasonal occurrence records and the predicted occurrence extent of each sea turtle species in the study area and vicinity are found in **Appendix C** (**Figures C-1** through **C-6**).

The locations of literature citations in Chapter 3 differ from other MRA chapters. Literature cited in the marine mammal section is found at the end of Section 3.1 while literature cited in the sea turtle section is found at the end of Section 3.2. Map figures associated with the species described in Chapter 3 are located in **Appendices B** and **C**.

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3.1 MARINE MAMMALS

3.1.1 Introduction

More than 120 species of marine mammals occur worldwide (Rice 1998). The term “marine mammal” is purely descriptive, referring to mammals that carry out all or a substantial part of their foraging in marine, or in some cases, freshwater environments. Marine mammals as a group are comprised of various species from three orders (Cetacea, Carnivora, and Sirenia).

The vast majority of the 32 marine mammal species with confirmed or possible occurrence in the Marianas study area are cetaceans (whales and dolphins). Cetaceans are divided into two major suborders: Mysticeti and Odontoceti (baleen and toothed whales, respectively). Toothed whales use teeth to capture prey, while baleen whales use baleen plates to filter their food from the water. Beyond contrasts in feeding methods, there are also life history and social organization differences between baleen and toothed whales (Tyack 1986).

3.1.1.1 Adaptations to the Marine Environment: Sound Production and Reception

Marine mammals display a number of anatomical and physiological adaptations to an aquatic environment that are discussed in detail by Pabst et al. (1999). Sensory changes from the basic mammalian scheme have also taken place in response to the different challenges an aquatic environment imposes. Sound travels faster and further in water than in air and is, therefore, an important sense. Touch and sight are also well developed in whales and dolphins (Wartzok and Ketten 1999).

Marine mammal vocalizations often extend both above and below the range of human hearing; vocalizations with frequencies lower than 18 Hertz (Hz) are labeled as infrasonic and those higher than 20 kiloHertz (kHz) as ultrasonic. Baleen whales primarily use the lower frequencies, producing tonal sounds in the frequency range of 20 to 3,000 Hz, depending on the species. Clark and Ellison (2004) suggested that baleen whales use low frequency sounds not only for long-range communication, but also as a simple form of echo ranging, using echoes to navigate and orient relative to physical features of the ocean. The toothed whales produce a wide variety of sounds, which include species-specific broadband “clicks” with peak energy between 10 and 200 kHz, individually variable “burst pulse” click trains, and constant frequency or frequency-modulated whistles ranging from 4 to 16 kHz (Wartzok and Ketten 1999). The general consensus is that the tonal vocalizations (whistles) produced by toothed whales play an important role in maintaining contact between dispersed individuals, while broadband clicks are used during echolocation (Wartzok and Ketten 1999). Burst pulses have also been strongly implicated in communication, with some scientists suggesting that they play an important role in agonistic encounters (McCowan and Reiss 1995), while others have proposed that they represent “emotive” signals in a broader sense, possibly representing graded communication signals (Herzing 1996). Sperm whales, however, are known to produce only clicks, which are used for both communication and echolocation (Whitehead 2003).

Data on the hearing abilities of cetaceans are sparse, particularly for the larger cetaceans such as the baleen whales. The auditory thresholds of some of the smaller odontocetes have been determined in captivity. It is generally believed that cetaceans should at least be sensitive to the frequencies of their own vocalizations. Comparisons of the anatomy of cetacean inner ears and models of the structural properties and the response to vibrations of the ear’s components in different species provide an indication of likely sensitivity to various sound frequencies. The ears of small toothed whales are optimized for receiving high-frequency sound, while baleen whale inner ears are best in low to infrasonic frequencies (Ketten 1992, 1997).

General reviews of cetacean sound production and hearing may be found in Richardson et al. (1995), Edds-Walton (1997), Wartzok and Ketten (1999), and Au et al. (2000). For a discussion of acoustic concepts, terminology, and measurement procedures, as well as underwater sound propagation, Urick (1983) and Richardson et al. (1995) are recommended.

3.1.1.2 Marine Mammal Distribution—Habitat and Environmental Associations

Marine mammals inhabit most marine environments, from deep ocean canyons to shallow estuarine waters. They are not randomly distributed. Marine mammal distribution is affected by demographic, evolutionary, ecological, habitat-related, and anthropogenic factors (Bowen et al. 2002; Bjørge 2002; Forcada 2002; Stevick et al. 2002).

Movements are often related to feeding or breeding activity (Stevick et al. 2002). A migration is the periodic movement of all, or significant components of an animal population from one habitat to one or more other habitats and back again. Migration is an adaptation that allows an animal to monopolize areas where favorable environmental conditions exist for feeding, breeding, and/or other phases of the animal's life history. Some baleen whale species, such as humpback whales, make extensive annual migrations to low-latitude mating and calving grounds in the winter and to high-latitude feeding grounds in the summer (Corkeron and Connor 1999). These migrations undoubtedly occur during these seasons due to the presence of highly productive waters and associated cetacean prey species at high latitudes and of warm water temperatures at low latitudes (Corkeron and Connor 1999; Stern 2002). The timing of migration is often a function of age, sex, and reproductive class. Females tend to migrate earlier than males and adults earlier than immature animals (Stevick et al. 2002; Craig et al. 2003). Not all baleen whales, however, migrate. Some individual fin, Bryde's, minke, and blue whales may stay year-round in a specific area.

Cetacean movements can also reflect the distribution and abundance of prey (Gaskin 1982; Payne et al. 1986; Kenney et al. 1996). Cetacean movements have also been linked to indirect indicators of prey, such as temperature variations, sea-surface chlorophyll *a* concentrations, and features such as bottom depth (Fiedler 2002). Oceanographic conditions such as upwelling zones, eddies, and turbulent mixing can create regionalized zones of enhanced productivity that are translated into zooplankton concentrations, and/or entrain prey.

As noted by MacLeod and Zuur (2005), however, even in the best studied marine mammal species, determining the fundamental reasons behind the linkage between habitat variables and distribution can be problematic, and often requires extensive datasets. For example, though topography might increase primary productivity, and as a result, provide a local increased availability of prey, not every marine mammal species is necessarily concentrated in that area. Additional factors may be involved, such as habitat segregation between other species that share the same ecological niche (MacLeod and Zuur 2005). The degree of similarity in diet between two or more predators that occur in the same habitat will affect the level of competition between these predators. Competition between predators can result in the exclusion of one or more of them from a specific habitat. For example, MacLeod et al. (2003) suggested that an example of niche segregation might be that *Mesoplodon* occupy a separate dietary niche from bottlenose whales (*Hyperoodon*) and Cuvier's beaked whales (*Ziphius*), though they share the same distribution. In contrast, *Hyperoodon* and *Ziphius* appear to occupy very similar dietary niches but have geographically segregated distributions, with *Hyperoodon* occupying cold-temperate to polar waters and *Ziphius* occupying warm-temperate to tropical waters.

Since most toothed whales do not have the fasting capabilities of the baleen whales, toothed whales probably follow seasonal shifts in preferred prey or are opportunistic feeders, taking advantage of whatever prey happens to be in the area. Small-scale hydrographic fronts may act as convergence zones. Bottlenose dolphins have demonstrated a spatial association with the area near the surface features of tidal intrusion fronts, which could be related to increased foraging efficiency resulting from the accumulation of prey in the frontal region (Mendes et al. 2002).

Occurrence of cetaceans outside the area with which they are usually associated may reflect fluctuations in food availability. Some studies have correlated shifts in the distribution of some baleen whale and toothed whale populations with ecological shifts in prey patterns after intense fishing efforts by commercial fisheries in the western North Atlantic (Payne et al. 1986, 1990; Kenney et al. 1996). DeMaster et al. (2001) predicted, based upon current data on human population growth and marine mammal fisheries interactions, that in the future, the most common type of competitive interaction would be ones in which a fishery has an adverse effect on one or more marine mammal populations without necessarily overfishing the target species of the fishery.

Climatic fluctuations have produced a growing concern about the effects of climate change on marine mammal populations (MacGarvin and Simmonds 1996; IWC 1997; Evans 2002; Würsig et al. 2002). Large-scale climatic events and long-term temperature change may affect the distribution and abundance of marine mammal species, either impacting them directly or indirectly through alterations of habitat characteristics and distribution or prey availability (Kenney et al. 1996; IWC 1997; Harwood 2001; Greene and Pershing 2004). In the Pacific Ocean, climate variability has been linked to the PDO and the ENSO. The PDO is a long-term climatic pattern capable of altering SST, winds, and SLP over the Pacific Basin (Mantua 2002; Mantua and Hare 2002) and has been linked to cycles in fishery production (e.g. Hare 1996). In years when the PDO Index is positive, the central North Pacific experiences anomalously cold SSTs, while the Western coast of the United States experiences anomalously cold temperatures. When the PDO index is negative, the opposite occurs. The PDO is weak in tropical areas, such as the Marianas MRA study area, and thus climatic anomalies are most likely due to ENSO forcings (Mantua 2002; Mantua and Hare 2002). The ENSO is the result of interannual swings in sea level pressures in the tropical Pacific between the eastern and western hemispheres (Conlan and Service 2000). ENSO events typically last 6 to 18 months, and can initiate large shifts in the global atmospheric circulation. In the western equatorial Pacific, SST is lower than in non-El Niño years (Kubota 1987), and rainfall patterns shift eastward across the Pacific as the strength of the tradewinds weakens, resulting in increased (sometimes extreme) rainfall in the southern U.S. and Peru and drought conditions in the western Pacific (Conlan and Service 2000). While the ENSO can have dramatic effects on rainfall, atmospheric circulation, and SST, it appears to have little, if any, effect on primary production in the western tropical Pacific (Mackey et al. 1997; Higgins and Mackey 2000). For further information regarding the PDO and the ENSO, refer to Chapter 2. Gregr and Trites (2001) noted difficulties in interpreting climate change impacts in working with habitat prediction models, including that using incorrect spatial scales might fail to detect a shift in habitat usage.

3.1.2 Marine Mammals of Guam and the Commonwealth of the Northern Mariana Islands

Marine mammals are not well-documented in Micronesia. The first compilation of available information for 19 species of marine mammals from Micronesia was provided by Eldredge (1991) with additional records in Eldredge (2003). Taking into consideration marine mammal distribution and habitat preferences, the list is expanded to 32 marine mammal species with confirmed or with possible occurrence records in Guam and the Commonwealth of the Northern Mariana Islands. The vast majority (29) are cetaceans (whales, dolphins, and porpoises) (**Table 3-1**). The dugong very rarely strays into this area, and no pinniped species is known to be a regular inhabitant of the Micronesia region (Reeves et al. 1999). There are rare reports of seals at these islands; however, species identification could not be verified. Eldredge (1991) called attention to the possibility that Hawaiian monk seals and northern elephant seals wander far enough from their normal ranges to appear at the Marshall or Gilbert Islands in the Micronesia region.

The Marianas study area lies within an oceanic province with generally very low levels of primary productivity (see **Figure 2-6**). Any local hotspots in production may attract all components of the local food chain. Strong interactions between the local oceanography and topography exist in the study area. The Marianas MRA study area is comprised of a series of seamounts. Seamount topography has been previously correlated with enhanced production due to the formation of vortices capable of mixing nutrients to the surface and entraining phytoplankton in the overlying waters (reviewed by Rogers 1994). For an in depth examination of seamounts, refer to Chapter 2.

In addition, the passage of the NEC through the Mariana archipelago is capable of creating regions of enhanced turbulence. Passage of the current of the NEC can initiate the formation of eddies on the lee side of the islands (Wolanski et al. 2003); these are capable of entraining phytoplankton and creating localized regions of enhanced primary production visible as increased concentrations of chl *a* in the surface waters (see the lee side of Guam, **Figure 2-6**). In addition, passage of currents through a narrow channel (as found between the islands of Tinian and Saipan) can create localized zones of

Table 3-1. Marine mammal species of the Marianas MRA study area. Taxonomy follows Rice (1998) for pinnipeds and sirenians and IWC (2004) for cetaceans, except for the North Pacific right whale, which was revised by Rosenbaum et al. (2000). [Regular = A species that occurs as a regular or normal part of the fauna of the area, regardless of how abundant or common it is; Rare = A species that only occurs in the area sporadically; Extralimital = A species that does not normally occur in the area, but for which there are one or more records that are considered beyond the normal range of the species; *****includes more than one species, but nomenclature is still unsettled].

	Scientific Name	Status	Occurence
Order Cetacea			
Suborder Mysticeti (baleen whales)			
Family Balaenidae (right whales)			
North Pacific right whale	*Eubalaena japonica*	Endangered	Rare
Family Balaenopteridae (rorquals)			
Humpback whale	*Megaptera novaeangliae*	Endangered	Regular
Minke whale	*Balaenoptera acutorostrata*		Rare
Sei whale	*Balaenoptera borealis*	Endangered	Extralimital
Fin whale	*Balaenoptera physalus*	Endangered	Rare
Blue whale	*Balaenoptera musculus*	Endangered	Rare
Bryde's whale	*Balaenoptera edeni/brydei**		Regular
Suborder Odontoceti (toothed whales)			
Family Physeteridae (sperm whale)			
Sperm whale	*Physeter macrocephalus*	Endangered	Regular
Family Kogiidae (pygmy sperm whales)			
Pygmy sperm whale	*Kogia breviceps*		Regular
Dwarf sperm whale	*Kogia sima*		Regular
Family Ziphiidae (beaked whales)			
Cuvier's beaked whale	*Ziphius cavirostris*		Regular
Blainville's beaked whale	*Mesoplodon densirostris*		Regular
Ginkgo-toothed beaked whale	*Mesoplodon ginkgodens*		Rare
Hubbs' beaked whale	*Mesoplodon carlhubbsi*		Extralimital
Longman's beaked whale	*Indopacetus pacificus*		Regular
Family Delphinidae (dolphins)			
Rough-toothed dolphin	*Steno bredanensis*		Regular
Common bottlenose dolphin	*Tursiops truncatus*		Regular
Indo-Pacific bottlenose dolphin	*Tursiops aduncus*		Extralimital
Pantropical spotted dolphin	*Stenella attenuata*		Regular
Spinner dolphin	*Stenella longirostris*		Regular
Striped dolphin	*Stenella coeruleoalba*		Regular
Short-beaked common dolphin	*Delphinus delphis*		Rare
Risso's dolphin	*Grampus griseus*		Regular
Melon-headed whale	*Peponocephala electra*		Regular
Fraser's dolphin	*Lagenodelphis hosei*		Regular
Pygmy killer whale	*Feresa attenuata*		Regular
False killer whale	*Pseudorca crassidens*		Regular
Killer whale	*Orcinus orca*		Regular
Short-finned pilot whale	*Globicephala macrorhynchus*		Regular
Order Carnivora			
Suborder Pinnipedia (seals, sea lions, walruses)			
Family Phocidae (true seals)			
Hawaiian monk seal	*Monachus schauinslandi*	Endangered	Extralimital
Northern elephant seal	*Mirounga angustirostris*		Extralimital
Order Sirenia			
Family Dugongidae (dugongs)			
Dugong	*Dugong dugon*	Endangered	Extralimital

turbulent flow capable of mixing nutrients into the surface layer to fuel primary production (Gilmartin and Revelante 1974; Simpson et al. 1982; Martinez and Maamaatuaiahutapu 2004) (**Figure 2-6**). This "island effect" on productivity is covered in further detail in Chapter 2.

Gannier (2002) reviewed cetacean occurrence in various locations of the tropical Pacific and provided a general assessment. Areas without a significant continental shelf domain do not shelter large densities of bottlenose dolphins. A stable component of four oceanic or semi-oceanic species is present in all areas: spinner and pantropical spotted dolphins, Risso's dolphin, and pilot whale. Spinner and pantropical spotted dolphins are among the two most frequent species in all areas. A general rule is that in most tropical areas, spinner dolphins and pantropical spotted dolphins are the most common cetacean species (Jefferson personal communication).

3.1.2.1 Marine Mammal Occurrences

As noted earlier, marine mammal occurrence in this region is not well-documented. **Appendix A-3** discusses the paucity of marine mammal data for this area, and Chapter 6 provides recommendations on how to address these data gaps, particularly in offshore waters such as W-517. The distribution of available marine mammal records is presented for the dry (December through June) and rainy seasons (July through November) in the maps in **Appendix B**. An occurrence record does not reflect the number of marine mammals; due to the social nature of cetaceans, multiple individuals of a species are often sighted at the same time at the same location. It should be noted that the number of marine mammal observations in this area is a function of the level of effort to collect this information, rather than just the actual marine mammal abundance in the area. This is evident in viewing the relatively few available sighting and stranding records for marine mammals in the Marianas study area (**Figure B-1**).

A listing and description of data sources used to determine each species' occurrence in the Marianas study area is found in **Appendix A-3**, while the process used to create the map figures is described in Section 1.4.2.2. On the map figures, various types of shading and terminology designate the occurrence of marine mammals in the Marianas study area. "Expected occurrence" (area shaded in dark blue) is defined as the area encompassing the expected distribution of a species based on what is known of its habitat preferences, life history, and the available sighting and stranding data. "Concentrated occurrence" (area shaded in green) is the subarea of a species' expected occurrence where there is the highest likelihood of encountering that species; the designation is based primarily on areas of concentrated sightings and preferred habitat. "Low/unknown occurrence" (light blue area) is where the likelihood of encountering a species is rare or not known. "Occurrence not expected in the Marianas study area" (white, unmarked area) is the area where a species encounter is not expected to occur.

In this MRA, the 200 m isobath was used as a surrogate for the location of the shelf break surrounding the islands. The oceanic waters surrounding the Marianas study area do not contain a true continental shelf, and therefore no true shelf break, the region in which there is a sharp break in the slope of the island shelf (Kennett 1982; Thurman 1997). Rather, the Mariana archipelago is composed of a series of volcanic islands that have broken the sea surface (Eldredge 1983) where the offshore bottom topography is steep and slopes rapidly reaching the ocean basin floor (4,000 m) within tens of kilometers (see **Figures 2-1** and **2-2**).

Each marine mammal species is listed below with its description, status, habitat preference, distribution (including location and seasonal occurrence in the Marianas MRA study area), behavior and life history, and information on its acoustics and hearing ability. Species appearance within the text begins with threatened and endangered marine mammals, while the remaining species follow the taxonomic order as presented in **Table 3-1**.

3.1.2.2 Threatened and Endangered Marine Mammals of Guam and the Commonwealth of the Northern Mariana Islands

There are eight marine mammal species that are listed as endangered under the ESA with confirmed or possible occurrence in the study area: North Pacific right whale, humpback whale, sei whale, fin whale, blue whale, sperm whale, Hawaiian monk seal, and the dugong. Most of the cetacean species are expected to occur in the study area. There are very rare sightings of the dugong here and no confirmed records for the North Pacific right whale or Hawaiian monk seal.

Information Specific to the Marianas MRA Study Area—The expected occurrence for endangered marine mammals is based primarily on the occurrence of the sperm whale but the humpback whale's occurrence patterns were also considered. Throughout the year, endangered marine mammals in the Marianas MRA study area are expected to occur seaward of the shelf break into open ocean waters (**Figure B-2**). This is based on expected occurrence of the sperm whale in this area. There is a low or unknown occurrence of endangered marine mammals from the coastline (excluding harbors and coastlines) to the shelf break, except during June through September when there is no possible occurrence of endangered marine mammals (specifically, the humpback whale) in lagoons (**Figure B-2**).

♦ North Pacific Right Whale (*Eubalaena japonica*)

Description—Until recently, right whales in the North Atlantic and North Pacific were classified together as a single species, referred to as the "northern right whale." Genetic data indicate that these two populations represent separate species: the North Atlantic right whale (*Eubalaena glacialis*) and the North Pacific right whale (*Eubalaena japonica*) (Rosenbaum et al. 2000).

Right whales have a robust body shape; overall body color is black, although many individuals also have irregular white patches on their undersides (Reeves and Kenney 2003). There is no dorsal fin on the broad back. The largest recorded North Pacific right whales are an 18.3 m female and a 16.4 m male (Omura et al. 1969); North Pacific right whales are larger than their North Atlantic counterparts (Reeves and Kenney 2003). The head is nearly one-third of the total body length. The jawline is arched and the upper jaw is very narrow in dorsal view. The head is covered with irregular whitish patches called "callosities," which have whale lice attached.

Status—The North Pacific right whale is perhaps the world's most endangered large whale species (Perry et al. 1999; IWC 2001). North Pacific right whales are classified as endangered both under the ESA and on the IUCN Red List (Reeves et al. 2003). There are insufficient genetic or resighting data to address whether there is support for the traditional separation into eastern and western stocks (Brownell et al. 2001); however, Clapham et al. (2004) noted that north-south migratory movements support the hypothesis of two largely discrete populations of right whales in the eastern and western North Pacific. No reliable population estimate presently exists for this species; the population in the eastern North Pacific is considered to be very small, perhaps only in the tens of animals (NMFS 2002; Clapham et al. 2004), while in the western North Pacific, the population may number at least in the low hundreds (Brownell et al. 2001; Clapham et al. 2004). There is no designated critical habitat for the North Pacific right whale (NMFS 2002).

Habitat Preferences—Feeding habitat for right whales is defined by the presence of sufficiently high densities of prey, especially calanoid copepods (Reeves and Kenney 2003). Development of those patches is essentially a function of oceanic conditions, such as SST, stratification, bottom topography, and currents, which concentrate zooplankton, and concentration is probably enhanced by the behavior of the organisms themselves (Beardsley et al. 1996; Tynan et al. 2001). The shift in Bering Sea right whale occurrences from deep waters in the mid-twentieth century to the mid-shelf region in the late 1900s was attributed to changes in the availability of optimal zooplankton patches, possibility relating to climatic forcing (variability in oceanic conditions caused by changes in atmospheric patterns) (Tynan et al. 2001). Sightings in the Bering Sea are clustered in relatively shallow water (waters with a bottom depth of 50 to 80 m) (Tynan et al. 2001). However, North Pacific right whales also have been sighted in waters with bottom depths as deep as 1,700 m (Carretta et al. 1994). The IWC (2001) noted a surprising absence of evidence for coastal calving grounds, since right whales in the North Atlantic and in the Southern Hemisphere have calving grounds located in shallow bays, lagoons, or in waters over the continental shelf.

Distribution—Right whales occur in sub-polar to temperate waters. The North Pacific right whale historically occurred across the Pacific Ocean north of 35°N, with concentrations in the Gulf of Alaska, eastern Aleutian Islands, south-central Bering Sea, Sea of Okhotsk, and the Sea of Japan (Omura et al. 1969; Scarff 1986; Clapham et al. 2004). Presently, sightings are extremely rare, occurring primarily in the Okhotsk Sea and the eastern Bering Sea (Brownell et al. 2001). Prior to 1996, right whale sightings were very rare in the eastern North Pacific (Scarff 1986; Brownell et al. 2001). Recent summer sightings of right whales in the eastern Bering Sea represent the first reliable consistent observations in this area since the 1960s (Tynan et al. 2001; LeDuc 2001). Right whales were probably never common along the west coast of North America (Scarff 1986; Brownell et al. 2001).

Historical whaling records provide virtually the only information on North Pacific right whale distribution. During the summer, whales were found in the Gulf of Alaska, along both coasts of the Kamchatka Peninsula, the southeastern Bering Sea, and in the Okhotsk Sea (Clapham et al. 2004). The whales were most widely dispersed in fall and spring, with whales occurring in mid-ocean waters and extending from the Sea of Japan to the eastern Bering Sea. In winter, right whales were found in the Ryukyu Islands (south of Kyushu, Japan), the Bonin Islands, the Yellow Sea, and the Sea of Japan. Historical concentrations of sightings in the Bering Sea together with the recent sightings indicate that this region remains an important summer habitat for eastern North Pacific right whales (Tynan et al. 2001). Scarff (1986) hypothesized those right whales that summer in the eastern North Pacific mate, calve, and overwinter in the mid-Pacific or in the western North Pacific.

Current distribution patterns and migration routes of these whales are not known (Scarff 1986; NMFS 2002). The extent to which right whales in the eastern North Pacific engage in north-south migrations is unknown (Scarff 1986). There is very little information on the winter distribution of right whales in the eastern North Pacific. The location of calving grounds for the eastern North Pacific population is unknown (Scarff 1986; NMFS 2002; Clapham et al. 2004). There are no records of newborn or very young calves in the eastern North Pacific, which appears to reflect a true absence of coastal calving grounds at least within historic times (Scarff 1986). Neither the west coast of North America nor the Hawaiian Islands constituted a major calving ground for right whales within the last 200 years (Scarff 1986). No coastal calving grounds for right whales have been found in the western North Pacific either (Scarff 1986). Mid-ocean whaling records of right whales in the winter suggest that right whales may have wintered and calved far offshore in the Pacific (Scarff 1986, 1991; Clapham et al. 2004). Such pelagic calving would appear to be inconsistent with the records of nearshore calving grounds in other locales for the other right whale species.

Feeding grounds for North Pacific right whales are also poorly known. Based on historical whaling records and some recent sightings, the principal feeding grounds were most likely in the Sea of Okhotsk, central and eastern Bering Sea, and Gulf of Alaska. All of these feeding areas are much further offshore than the well-studied North Atlantic habitats. The eastern Bering Sea is used for foraging (NMFS 2002). Right whales in the eastern Pacific have been observed each summer since 1996 in the eastern Bering Sea in roughly the same location (Goddard and Rugh 1998; Moore et al. 2000; Tynan et al. 2001).

Right whales can make long-range movements. For example, radio-tagged North Atlantic right whales make extensive movements, traveling into waters with bottom depths as great as 4,200 m (Knowlton et al. 1992; Mate et al. 1997). One individually-identified right whale was documented to make a two-way trans-Atlantic migration from the eastern coast of the U.S. to a location in northern Norway (Jacobsen et al. 2004). Clapham et al. (2004) noted seasonal movements in their review of North Pacific right whale records: a general northward migration in spring from lower latitudes (March through May); major concentrations above 40°N in summer (May through August); sightings diminish and occur further south in fall (September through October); few animals are recorded anywhere during the winter (November through February).

- Information Specific to the Marianas MRA Study Area—There are no confirmed records of the North Pacific right whale in the Micronesia region; however, Reeves et al. (1999) noted the remote possibility of encountering this species here. The highly endangered status of this species necessitates an extremely conservative determination of its occurrence in the Marianas study area (Jefferson personal communication). There is a low or unknown occurrence of right whales from the coastline to seaward of the Marianas study area (**Figure B-3**). Sightings have been made both in waters on and seaward of the shelf off the Hawaiian Islands (Herman et al. 1980; Rowntree et al. 1980; Salden and Mickelsen 1999); the predicted occurrence for the Marianas study area reflects the possibility that right whales might be encountered close to shore, as well as in much deeper waters. Right whales are not expected to make their way into lagoons or busy harbors such as Apra Harbor (Jefferson personal communication). Right whale occurrence patterns are assumed to be similar throughout the year.

Behavior and Life History—In the North Pacific, few individuals are observed and they are usually alone (Brownell et al. 2001). The only exception is an area of the southeastern Bering Sea where small groups of right whales (at least five, and possibly seven individuals, but no calves) have been sighted in several successive years (Tynan et al. 2001). Right whales have been observed in association with humpback whales in Hawaiian waters (Herman et al. 1980; Salden and Mickelsen 1999).

Right whales in the North Pacific probably reach sexual maturity at a body length of 14.5 to 15.5 m for males and 15 to 16 m for females, which corresponds to an age of approximately 10 years (Omura et al. 1969). Calves are born during December through March after 12 to 13 months of gestation (Best 1994). Weaning occurs at 8 to 17 months (Hamilton et al. 1995). There is usually a three-year cycle (calving interval) between calves in the North Atlantic (Kraus et al. 2001).

North Pacific right whales probably feed almost exclusively on calanoid copepods (*Canalus marshallae*), a type of zooplankton. High concentrations of copepods have been recorded in zooplankton samples collected in 1997 and 1999 near right whales in the North Pacific. North Pacific right whales have also been observed feeding on an extensive coccolithophore bloom of *Emiliania huxleyi* (Tynan et al. 2001). When feeding, a right whale skims prey from the water (Pivorunas 1979). Feeding can occur throughout the water column (Watkins and Schevill 1976, 1979; Goodyear 1993; Winn et al. 1995).

Dives of 5 to 15 min or even longer have been reported (Winn et al. 1995; Mate et al. 1997; Baumgartner and Mate 2003). Baumgartner and Mate (2003) found that the average depth of a North Atlantic right whale dive was strongly correlated with both the average depth of peak copepod abundance and the average depth of the bottom mixed layer's upper surface. North Atlantic right whale feeding dives are characterized by a rapid descent from the surface to a particular depth between 80 and 175 m, remarkable fidelity to that depth for 5 to 14 min, and then rapid ascent back to the surface (Baumgartner and Mate 2003). Longer surface intervals have been observed for reproductively active females and their calves (Baumgartner and Mate 2003).

Acoustics and Hearing—North Pacific right whale calls are classified into five categories: (1) up; (2) down-up; (3) down; (4) constant; and (5) unclassified (McDonald and Moore 2002). The 'up' call is the predominant type (McDonald and Moore 2002; Mellinger et al. 2004). Typically, the 'up' call is a signal sweeping from about 90 Hz to 150 Hz in 0.7 sec (McDonald and Moore 2002; Wiggins et al. 2004; Parks and Tyack 2005). Right whales commonly produce calls in a series of 10 to 15 calls lasting 5 to 10 mins, followed by silence lasting an hour or more; some individuals do not call for periods of at least four hours (McDonald and Moore 2002). This calling pattern is similar to the 'moan cluster' reported for North Atlantic right whales by Matthews et al. (2001). Vocalization rates of North Atlantic right whales are also highly variable, and individuals have been known to remain silent for hours (Gillespie and Leaper 2001). Sound production is common in surface active groups of the North Atlantic right whale (Parks and Tyack 2005).

Frequencies of these vocalizations are between 50 and 500 Hz (Matthews et al. 2001; Laurinolli et al. 2003); typical sounds are in the 300 to 600 Hz range with up- and down-sweeping modulations (Vanderlaan et al. 2003). Vanderlaan et al. (2003) found that lower (<200 Hz) and higher (>900 Hz) frequency sounds are relatively rare. Source levels for pulsive calls of North Atlantic right whales are 172 to 187 dB (decibels) with a reference pressure of one micropascal at one meter (dB re 1 μPa-m) (Thomson and Richardson 1995; Parks and Tyack 2005). Other sound types produced by North Atlantic right whales have a source level ranging from 137 to 162 dB re 1 μPa-m for tonal calls and 174 to 192 dB re 1 μPa-m for broadband gunshot sounds (Parks and Tyack 2005).

Morphometric analyses of the inner ear of right whales resulted in an estimated hearing frequency range of approximately 10 Hz to 22 kHz, based on established marine mammal models (Parks et al. 2004). Research by Nowacek et al. (2004) on North Atlantic right whales suggests that received sound levels of only 133 to 148 dB re 1 μPa-m for the duration of the sound exposure are likely to disrupt feeding behavior; the authors did note, however, that a return to normal behavior within minutes of when the source is turned off would be expected.

- Humpback Whale (*Megaptera novaeangliae*)

Description—Humpback whale adults are 11 to 16 m in length and are more robust than other rorquals. The body is black or dark gray, with very long (about one-third of the body length) flippers that are usually white (Jefferson et al. 1993; Clapham and Mead 1999). The head is larger than in other rorquals. The flukes have a concave, serrated trailing edge; the ventral side is variably patterned in black and white. Individual humpback whales may be identified using these patterns (Katona et al. 1979).

Status—Humpback whales are classified as endangered under the ESA. There is no designated critical habitat for this species in the North Pacific.

Recent information from photo-identification studies and genetic work suggests that there are probably three stocks or populations in the North Pacific: Eastern, Central, and Western North Pacific stocks (Baker et al. 1998; Calambokidis et al. 2001; Carretta et al. 2004). Calambokidis et al. (2001) further suggested that up to six subpopulations of humpback whales in the North Pacific Ocean might be recognized. The Western North Pacific stock is the stock considered to occur in the Marianas study area (Jefferson personal communication); it is classified as a strategic stock by NOAA Fisheries (Angliss and Lodge 2004). The Western North Pacific stock of humpback whales is clearly the smallest of the various North Pacific stocks. Using mark-recapture analysis of photo-identification data, Calambokidis et al. (1997) derived an estimate of 400 whales for the Western North Pacific stock in 1993, although this estimate is probably biased downwards. The minimum population estimate for the Western North Pacific stock of humpback whales is considered to be 367 individuals (Angliss and Lodge 2004).

The Central North Pacific stock, which is the one that is best studied, overwinters in waters of the main Hawaiian Islands and summers in British Columbia and Alaskan waters (Baker et al. 1986; Calambokidis et al. 2001). Site fidelity to feeding areas is very high, but there is at least occasional interchange among different breeding areas (Salden et al. 1999; Calambokidis et al. 2001). Most individuals that breed in Hawai'i travel to waters of Alaska to feed (Calambokidis et al. 2001). The Hawaiian breeding group shares some genetic inter-relatedness with the group that breeds off the coast of Mexico (Baker et al. 1998) and even off Japan (Salden et al. 1999; Darling and Mori 1993), but it is rare enough that these are still considered to be separate management stocks.

Habitat Preferences—Although humpback whales typically travel over deep, oceanic waters during migration, their feeding and breeding habitats are mostly in shallow, coastal waters over continental shelves (Clapham and Mead 1999). Shallow banks or ledges with high sea-floor relief characterize feeding grounds (Payne et al. 1990; Hamazaki 2002). The habitat requirements of wintering humpbacks appear to be determined by the conditions necessary for calving. Breeding grounds are in tropical or subtropical waters, generally with shelter created by islands or reefs. Optimal calving conditions are warm water (24° to 28°C) and relatively shallow, low-relief ocean bottom in protected areas (behind reefs) apparently to take advantage of calm seas, to minimize the possibility of predation by sharks, or to avoid harassment by males (Smultea 1994; Craig and Herman 2000; Clapham 2000). Females with calves occur in significantly shallower waters than other groups of whales, and breeding adults use deeper, more offshore waters (Smultea 1994; Ersts and Rosenbaum 2003).

Distribution—Humpback whales are globally distributed in all major oceans and most seas. They generally are found during the summer on high-latitude feeding grounds and during the winter in the tropics and subtropics around islands, over shallow banks, and along continental coasts, where calving occurs. Most humpback whale sightings are in nearshore and continental shelf waters; however, humpback whales frequently travel through deep water during migration (Clapham and Mattila 1990; Calambokidis et al. 2001).

North Pacific humpback whales are distributed primarily in four more-or-less distinct wintering areas: the Ryukyu and Ogasawara (Bonin) Islands (south of Japan), Hawai'i, the Revillagigedo Islands off Mexico, and along the coast of mainland Mexico (Calambokidis et al. 2001). In the central North Pacific, whales use Hawaiian waters as a major breeding ground in winter and spring (December through March). There is known to be some interchange of whales among different wintering grounds, and matches between Hawai'i and Japan, and Hawai'i and Mexico have been found (Salden et al. 1999; Calambokidis et al. 2000, 2001; **Figure 3-1**). However, it appears that the overlap is relatively small between the Western North Pacific humpback whale population and Central and Eastern North Pacific populations (Darling and Mori 1993; Calambokidis et al. 2001).

There is also some trans-oceanic interchange between the North Pacific and South Pacific breeding populations (Medrano-Gonzalez et al. 2001). Baker et al. (1993) hypothesized that the most likely route for such interbreeding of northern and southern humpback whales is the equatorial waters of the eastern Pacific Ocean. This apparently occurs through geographic overlap of some individuals from both ocean basins off the Central American coast (Acevedo and Smultea 1995). However, this is probably a relatively rare occurrence.

In addition to Japanese waters, humpbacks have been documented in recent years off Taiwan and the Philippines (Yamaguchi et al. 2002), although it is not known if whales are breeding in these latter areas or simply using them as stopover points. The waters of the Ogasawara (Bonin) Islands off Japan are considered to be one of the main wintering grounds for humpback whales of the western North Pacific population (Mori et al. 1998). Mori et al. (1998) suggested that calving might actually take place in waters with slightly higher temperatures than the waters of the Ogasawara Islands, for example, in the lower latitudes along the Ogasawara Islands rim, possibly extending from the Kazan Retto to the Northern Mariana Islands. The historical winter range in the western North Pacific included the waters around Taiwan, Hainan Island, and the Mariana and Marshall islands (Darling and Mori 1993). Although Townsend (1935) indicated that many humpbacks were caught off the Marianas in earlier years, preliminary surveys of Taiwan and Saipan suggest that humpback whales are no longer common there and have not generally reinhabited this part of the range (Darling and Mori 1993). Darling and Mori (1993) suggested that the recent humpback whale sightings off Saipan might indicate that the range of the population is currently expanding, or alternatively, these could just be a few wayward individuals. In addition, humpback whales have recently been observed in the Babuyan Islands off the northern Philippines, raising the question as to whether this also may have been part of their traditional wintering range (Yamaguchi et al. 2002).

During summer months, North Pacific humpback whales feed in a nearly continuous band from southern California to the Aleutian Islands, Kamchatka Peninsula, and the Bering and Chukchi seas (Calambokidis et al. 2001; **Figure 3-1**). There is much interchange of whales among different feeding grounds, although some site fidelity is the rule. Whales migrate between the Mexican breeding ground and feeding grounds along the west coast of the continental U.S., using a corridor along the coast of Baja California (**Figure 3-1**). The primary feeding range of the Western North Pacific humpback stock is not known. Mark recoveries from whaling operations suggest connections with summering areas in the Okhotsk and Bering seas, off Kamchatka, and the Aleutian Islands (Nishiwaki 1966; Ohsumi and Masaki 1975). There are recent photo-identification matches to the Gulf of Alaska, southeast Alaska, and the Pacific Northwest (Calambokidis et al. 2001). However, there are also indications of genetic associations of Ogasawara humpbacks with the North American coastline (Baker et al. 1998), and some Western North Pacific humpbacks apparently feed off British Columbia (Darling et al. 1996; Calambokidis et al. 1997). Clearly, the picture is not a simple one. The paucity of photo-identification data for the Aleutian Islands, Bering and Okhotsk seas, and Kamchatcka waters may be somewhat masking the true identity of the primary feeding grounds, but this remains to be

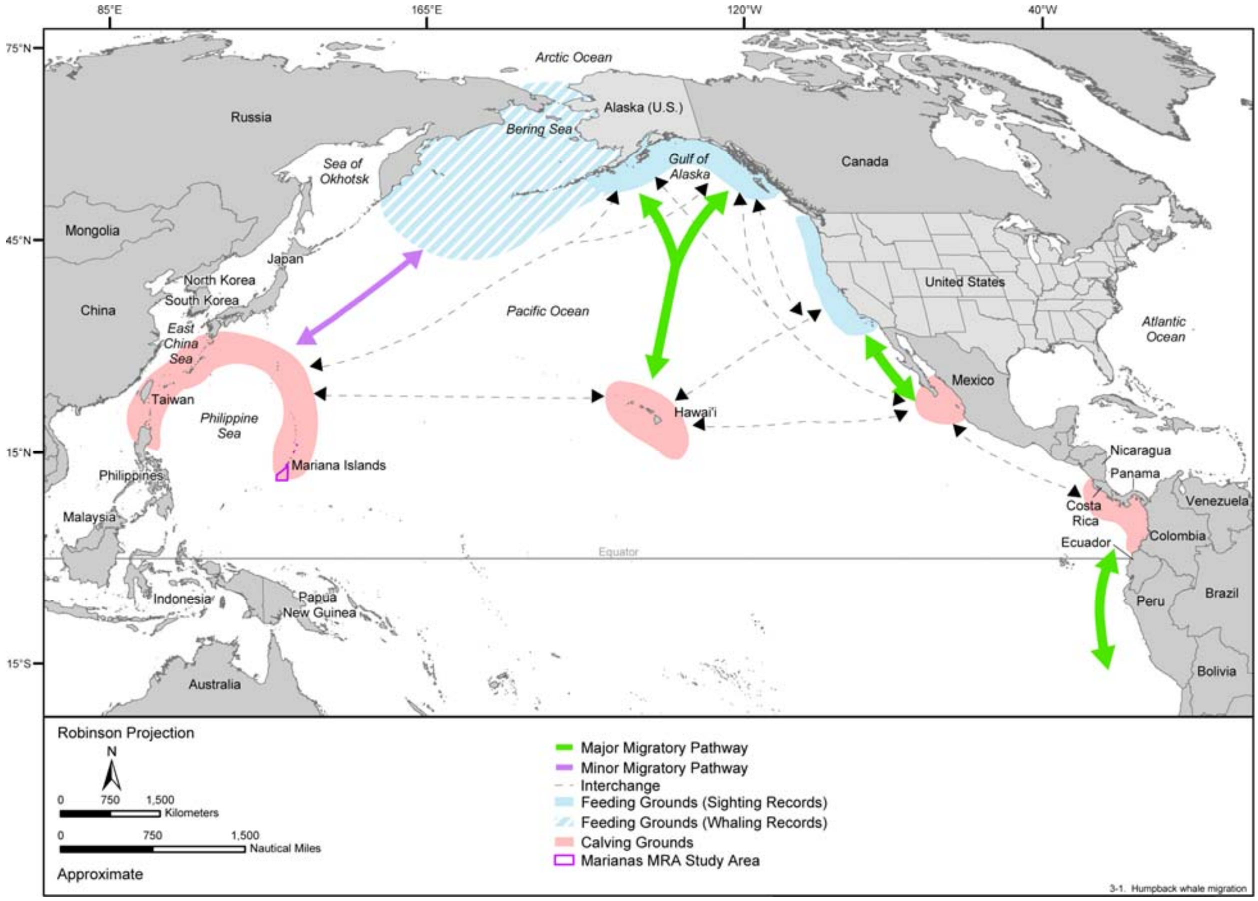

Figure 3-1. General major and minor migratory patterns of humpback whales in the North Pacific Ocean. Humpback whales migrate between summer feeding grounds in temperate or near-polar waters and winter calving grounds in shallow tropical waters. Regions depicted with solid shading are defined by current observations of seasonal return by naturally marked individuals. Regions depicted with striped shading are defined by historical patterns of distribution during periods of commercial whaling. Few individuals have been sighted on both the Hawaii and Mexico calving grounds during alternate years indicating a possible interchange betweeen the two seasonal subpopulations. Interchange is also possible between the Japan and Hawai'i calving grounds. Source information: Baker et al. (1990) and Calambokidis et al. (2000, 2001).

tested. Also, it seems reasonable to assume that the aggregation of humpbacks that feeds around Kodiak Island (Waite et al. 1999) may represent largely individuals from the Western North Pacific stock.

The humpback whale has one of the longest migrations known for any mammal; individuals can travel nearly 8,000 km from feeding to breeding areas (Clapham and Mead 1999). The exact migration corridor of whales moving between the Hawaiian breeding ground and the Alaskan feeding ground is not known, although it is clear that whales migrate through deep, oceanic waters. Similarly, the specific migration route of whales between Japanese breeding grounds and the apparent Aleutian Island/Bering Sea/Gulf of Alaska feeding grounds is not clear. Migratory transits between Hawai'i and southeastern Alaska have been documented to take as little as 36 to 39 days (Gabriele et al. 1996; Calambokidis et al. 2001). Based on Japanese whaling records, the migratory sequence of arrival on the Ryukyu Islands grounds is that immature whales arrive first, following by adult males and non-pregnant females, while late pregnant females and those with newborn calves arrive last (Nishiwaki 1966).

- Information Specific to the Marianas MRA Study Area—There is a low or unknown occurrence of humpback whales from the coastline (excluding harbors and lagoons) in the Marianas study area and vicinity (**Figure B-4**). These occurrence patterns are applicable throughout the year, except June through September when this species is not expected in the area. The winter range of the Western North Pacific stock of humpback whales extends, at least occasionally, into this region (Taitano 1991; Darling and Mori 1993). Humpback whales in other locales during the breeding season are typically found in insular shelf waters, but can also be found in deeper waters during the breeding season. For example, humpback whale calls were detected from whales located to the northeast and east of the Puerto Rican Trench over deep water (>6,000 m) and far from any banks or islands (Swartz et al. 2002).

  Reeves et al. (1999) suggested that the Marianas might be south of the normal breeding range, but clearly some whales do move into the study area in the breeding season (**Figure B-4**). There are several recent records of humpback whales in the Marianas Islands, at Guam, Rota, and Saipan during January through March (Darling and Mori 1993; Eldredge 1991, 2003). February and March are the months when humpback whales are most often sighted in the Marianas (Anonymous 2004). The breeding season extends well into the spring; whalers took humpback whales through the month of May in the southern Marianas (Eldredge 1991).

Behavior and Life History—Humpback whales are arguably the most social of all the baleen whales. Group size can range from single individuals to large groups of up to 20 or more whales. These groups are, however, typically small and unstable, with the exception of mother/calf pairs (Clapham and Mead 1999). On the feeding grounds, relatively large numbers of humpbacks may be observed within a limited area to feed on a rich food source. While large aggregations are often observed, it is not clear if there are stable associations between individuals, or if this is simply a reflection of a concentration of animals brought together by a common interest in locally abundant prey (Clapham 2000). On the breeding grounds, small groups of males may occur, competing for access to females (Tyack and Whitehead 1983; Baker and Herman 1984; Pack et al. 1998). On rare occasions, competitive groups have been observed on the feeding grounds (Weinrich 1995).

Humpback whales feed on a wide variety of invertebrates and small schooling fishes. The most common invertebrate prey are euphausiids (krill); the most common fish prey are herring, mackerel, sand lance, sardines, anchovies, and capelin (Clapham and Mead 1999). These whales are lunge feeders, taking in huge batches of prey items as they lunge laterally, diagonally, or vertically through patches of prey (Clapham 2002). Feeding behavior is highly diverse, and humpbacks employ unusual behaviors, such as bubble netting, to corral prey (Jurasz and Jurasz 1979; Weinrich et al. 1992). This is the only species of baleen whale that shows some evidence of cooperation when feeding in large groups (D'Vincent et al. 1985). Humpback whales are not typically thought to feed on the wintering grounds; however, Salden (1989) observed apparent feeding by a juvenile humpback whale off Hawai'i.

Female humpbacks become sexually mature at 4 to 9 years of age (Clapham 1996). Gestation is approximately one year. Calves are weaned before one year of age. Calving intervals are usually 2 to 3 years, although occasionally females give birth to calves in successive years (Clapham 1996). Males compete for access to receptive females by aggressive, sometimes violent interactions, as well as vocal displays (Clapham 1996; Pack et al. 1998).

Humpback whale diving behavior depends on the time of year (Clapham and Mead 1999). In summer, most dives last less than 5 min; those exceeding 10 min are atypical. In winter (December through March), dives average 10 to 15 min; dives of greater than 30 min have been recorded (Clapham and Mead 1999). Although humpback whales have been recorded to dive as deep as 500 m (Dietz et al. 2002), on the feeding grounds they spend the majority of their time in the upper 120 m of the water column (Dolphin 1987; Dietz et al. 2002). Humpback whales on the wintering grounds dive deeply; Baird et al. (2000) recorded dives deeper than 100 m.

Acoustics and Hearing—Humpback whales are known to produce three classes of vocalizations: (1) “songs” in the late fall, winter, and spring by solitary males; (2) social sounds made within groups on the wintering (calving) grounds; and (3) sounds made on the feeding grounds (Thomson and Richardson 1995).

The best-known types of sounds produced by humpback whales are songs, which are thought to be breeding displays used only by adult males (Helweg et al. 1992). Singing is most common on breeding grounds during the winter and spring months, but is occasionally heard outside breeding areas and out of season (Matilla et al. 1987; Clark and Clapham 2004). Humpback song is an incredibly elaborate series of patterned vocalizations, which are hierarchical in nature (Payne and McVay 1971). There is geographical variation in humpback whale song, with different populations singing different songs, and all members of a population using the same basic song. However, the song evolves over the course of a breeding season, but remains nearly unchanged from the end of one season to the start of the next (Payne et al. 1983).

Social calls are from 50 Hz to over 10 kHz with the highest energy below 3 kHz (Silber 1986). Female vocalizations appear to be simple; Simão and Moreira (2005) noted little complexity. The male song, however, is complex and changes between seasons. Components of the song range from under 20 Hz to 4 kHz and occasionally 8 kHz, with source levels of 144 to 174 dB re 1 μPa-m, with a mean of 155 dB re 1 μPa-m. Au et al. (2001) recorded high-frequency harmonics (out to 13.5 kHz) and source level (between 171 and 189 dB re 1 μPa-m) of humpback whale songs. Songs have also been recorded on feeding grounds (Mattila et al. 1987; Clark and Clapham 2004). The main energy lies between 0.2 and 3.0 kHz, with frequency peaks at 4.7 kHz. “Feeding” calls, unlike song and social sounds, are highly stereotyped series of narrow-band trumpeting calls. They are 20 Hz to 2 kHz, less than 1 sec in duration, and have source levels of 175 to 192 dB re 1 μPa-m. The fundamental frequency of feeding calls is approximately 500 Hz (D’Vincent et al. 1985).

No tests on humpback whale hearing have been made. Houser et al. (2001) produced the humpback audiogram (using a mathematical model). The predicted audiogram indicates sensitivity to frequencies from 700 Hz to 10 kHz, with maximum relative sensitivity between 2 and 6 kHz.

♦ Sei Whale (*Balaenoptera borealis*)

Description—Adult sei whales are up to 18 m in length and are mostly dark gray in color with a lighter belly (Jefferson et al. 1993). There is a single prominent ridge on the rostrum and a slightly arched rostrum with a downturned tip (Jefferson et al. 1993). The dorsal fin is prominent and very falcate. Sei whales are extremely similar in appearance to Bryde’s whales, and it is difficult to differentiate them at sea and even in some cases, on the beach (Mead 1977).

Status—Sei whales are listed as endangered under the ESA; they are also designated as endangered by the IUCN Red List (Reeves et al. 2003). The IWC designates the entire North Pacific Ocean as one sei whale stock unit (Donovan 1991), although some evidence exists for multiple stocks (NMFS 1998a; Carretta et al. 2004). There are no abundance estimates available for this species in this area.

The taxonomy of the baleen whale group formerly known as sei and Bryde’s whales is currently confused and highly controversial (see Reeves et al. 2004 for a recent review, also see the Bryde’s whale species account below for further explanation).

Habitat Preferences—Sei whales are most often found in deep, oceanic waters of the cool temperate zone. They appear to prefer regions of steep bathymetric relief, such as the continental shelf break, canyons, or basins situated between banks and ledges (Kenney and Winn 1987; Schilling et al. 1992; Gregr and Trites 2001; Best and Lockyer 2002). These areas are often the location of persistent hydrographic features, which may be important factors in concentrating zooplankton, especially copepods. On the feeding grounds, the distribution is largely associated with oceanic frontal systems (Horwood 1987). In the North Pacific, sei whales are found feeding particularly along the cold eastern currents (Perry et al. 1999). Characteristics of preferred breeding grounds are unknown.

Distribution—Sei whales have a worldwide distribution, but are found primarily in cold temperate to subpolar latitudes, rather than in the tropics or near the poles (Horwood 1987). Sei whales are also known for occasional irruptive occurrences in areas followed by disappearances for sometimes decades (Horwood 1987; Schilling et al. 1992; Clapham et al. 1997).

Sei whales spend the summer months feeding in the subpolar higher latitudes and returns to the lower latitudes to calve in winter. There is some evidence from whaling catch data of differential migration patterns by reproductive class, with females arriving at and departing from feeding areas earlier than males (Horwood 1987; Perry et al. 1999). For the most part, the location of winter breeding areas remains a mystery (Rice 1998; Perry et al. 1999).

In the North Pacific, sei whales are thought to occur mainly south of the Aleutian Islands. They are present all across the temperate North Pacific north of 40°N (NMFS 1998a) and are seen at least as far south as 20°N (Horwood 1987). In the east, they range as far south as Baja California, Mexico, and in the west, to Japan and Korea (Reeves et al. 1998). As noted by Reeves et al. (1999), reports in the literature from any time before the mid-1970s are suspect, because of the frequent failure to distinguish sei from Bryde's whales, particularly in tropical to warm temperate waters where Bryde's whales are generally more common than sei whales.

- Information Specific to the Marianas MRA Study Area—Sei whales are not expected to occur in the Marianas study area. Two "sei" whales were tagged in the general vicinity of the Northern Mariana Islands (1,515 km northwest of Riidian Point, Guam) during January 1972 (Masaki 1972; Ohsumi and Masaki 1975). These two individuals were later killed a few hundred kilometers south of the western Aleutian Islands during June 1972 (Ohsumi and Masaki 1975; Horwood 1987). These were possibly misidentifications of Bryde's whales (Jefferson personal communication).

Behavior and Life History—Sei whales are typically found in groups of one to five individuals (Leatherwood et al. 1976). The sei whale is atypical of rorquals in that it primarily "skims" its food (though it does some "gulping" as other rorquals do) (Pivorunas 1979). In the North Pacific, sei whales take a diversity of prey, including calanoid copepods, krill, fish, and squid (Nemoto and Kawamura 1977). Sei whales typically follow a reproductive cycle of two years: a gestation period of about 10 to 12 months and a lactation period of 6 to 9 months (Gambell 1985).

Acoustics and Hearing—Sei whale vocalizations have been recorded only on a few occasions. They consist of paired sequences (0.5 to 0.8 sec, separated by 0.4 to 1.0 sec) of 7 to 20 short (4 milliseconds [msec]) frequency-modulated (FM) sweeps between 1.5 and 3.5 kHz; source level is not known (Thomson and Richardson 1995). While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

- Fin Whale (*Balaenoptera physalus*)

Description—The fin whale is the second-largest whale species, with adults reaching 24 m in length (Jefferson et al. 1993). Fin whales have a very sleek body, with a pale, V-shaped chevron on the back, just behind the head. The dorsal fin is prominent, but with a shallow leading edge and is set back two-thirds of the body length from the head (Jefferson et al. 1993). The head color is asymmetrical, with a lower jaw that is white on the right and black or dark gray on the left. Fin and sei whales are very similar in appearance, which has resulted in confusion about the distribution of both species (NMFS 1998a).

Status—Fin whales are classified as endangered under the ESA and are designated as endangered by the IUCN Red List (Reeves et al. 2003). There is no designated critical habitat for this species in the North Pacific. The IWC recognizes two management stocks in the North Pacific: a single widespread stock in the North Pacific and a smaller stock in the East China Sea (Donovan 1991). There are no abundance estimates available for the fin whale in this area.

Habitat Preferences—The fin whale is found in continental shelf and oceanic waters (Gregr and Trites 2001; Reeves et al. 2002). Globally, this species tends to be aggregated in locations where populations of prey are most plentiful, irrespective of water depth, though those locations may shift seasonally or annually (Payne et al. 1986, 1990; Kenney et al. 1997; Notarbartolo-di-Sciara et al. 2003). Fin whales in the North Pacific spend the summer feeding along the cold eastern boundary currents (Perry et al. 1999). Littaye et al. (2004) determined that fin whale distribution in the Mediterranean Sea was linked to frontal areas and upwelling, within large zooplankton patches.

Distribution—Fin whales are broadly distributed throughout the world's oceans, usually in temperate to polar latitudes, and less commonly in the tropics (Reeves et al. 2002). Fin whales are distributed across the North Pacific during the summer (May through October) from the southern Chukchi Sea (69°N) south to the Subarctic Boundary (approximately 42°N) and to 30°N in the California Current (Mizroch et al. 1999). They have been observed during the summer in the central Bering Sea (Moore et al. 2000). During the winter (November through April), fin whales are sparsely distributed from 60°N south to the northern edge of the tropics, near which it is assumed that mating and calving take place (Mizroch et al. 1999). However, some fin whales have been sighted as far north as 60°N all winter (Mizroch et al. 1999). Recoveries of marked whales demonstrate long migrations from low-latitude winter grounds to high-latitude summer grounds, and extensive longitudinal movements both in-season and between years, within and between the main summer concentration areas (Mizroch et al. 1999). There is also some evidence of a resident population of fin whales in the Gulf of California, Mexico (Tershy et al. 1993). Such cases indicate that not all members of the species necessarily make the long, north/south migrations that are typical of the species.

- Information Specific to the Marianas MRA Study Area—There are no occurrence records for the fin whale in the Marianas study area and vicinity, but this area is within the known distribution range for this species. The endangered status of this large whale species was heeded when determining its occurrence. There is a low or unknown occurrence of the fin whale seaward of the 50 m isobath. This takes in consideration the possibility of encountering this species in both coastal and oceanic waters, knowing that fin whales can occur over the continental shelf and in oceanic waters (**Figure B-5**). Occurrence patterns are expected to be the same throughout the year.

Behavior and Life History—Fin whales feed by "gulping" (Pivorunas 1979). In the North Pacific, fin whales appear to prefer krill and large copepods, followed by schooling fish such as herring, walleye pollock, and capelin (Nemoto and Kawamura 1977). Single fin whales are most common. A fin whale was sighted off Hawai'i in association with an adult humpback whale (Mobley et al. 1996), while a group of 8 to 12 fin whales 400 km south of Hawai'i was in a mixed-species aggregation with dolphins (Balcomb 1987).

Female fin whales in the North Pacific mature at 8 to 12 years of age (Boyd et al. 1999). Peak calving is in October through January (Hain et al. 1992) after a gestation period of approximately 11 months. Weaning may occur at 6 months (Boyd et al. 1999). The calving interval for fin whales ranges between two to three years (Agler et al. 1993).

Fin whale dives are typically 5 to 15 min, separated by sequences of 4 to 5 blows at 10 to 20 sec intervals (CETAP 1982; Stone et al. 1992; Lafortuna et al. 2003). Kopelman and Sadove (1995) found significant differences in blow intervals, dive times, and blows per hour between surface-feeding and non-surface-feeding fin whales. Croll et al. (2001) determined that fin whales dived to 97.9 m (± standard deviation [S.D.] 32.59) with a duration of 6.3 (±S.D. 1.53) min when foraging and to 59.3 m (±S.D. 29.67) with a duration of 4.2 (±S.D. 1.67) min when not foraging. Fin whale dives exceeding 150 m and coinciding with the diel migration of krill were reported by Panigada et al. (1999).

Acoustics and Hearing—Infrasonic, pattern sounds have been documented for fin whales (Watkins et al. 1987). Fin whales produce a variety of sounds with a frequency range up to 750 Hz. The long, patterned 15 to 30 Hz vocal sequence is most typically recorded; only males are known to produce these (Croll et al. 2002). The most typical fin whale sound is a 20 Hz infrasonic pulse (actually an FM sweep from about 23 to 18 Hz) with durations of about 1 sec and can reach source levels of 184 to 186 dB re 1 µPa-m (maximum up to 200) (Thomson and Richardson 1995; Charif et al. 2002). Croll et al. (2002) recently suggested that these long, patterned vocalizations might function as male breeding displays, much like those that male humpback whales sing. While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

♦ Blue Whale (*Balaenoptera musculus*)

Description—Blue whales are the largest living animals. Blue whale adults in the northern hemisphere reach 22.9 to 28 m in length (Jefferson et al. 1993). The rostrum of a blue whale is broad and U-shaped, with a single prominent ridge down the center (Jefferson et al. 1993). The tiny dorsal fin is set far back on the body and appears well after the blowholes when the whale surfaces (Reeves et al. 2002). This species is blue-gray with light (or sometimes dark) mottling.

Status—Blue whales are classified as endangered under the ESA and endangered by the IUCN Red List (Reeves et al. 2003). The blue whale was severely depleted by commercial whaling in the twentieth century (NMFS 1998b). There is no designated critical habitat for this species in the North Pacific. The stock structure of blue whales in the North Pacific is uncertain (NMFS 1998b). There might be as many as five populations of blue whales in the North Pacific (NMFS 1998b).

Habitat Preferences—Blue whales inhabit both coastal and oceanic waters in temperate and tropical areas (Yochem and Leatherwood 1985). Feeding grounds have been identified in coastal upwelling zones off the coast of California (Croll et al. 1998; Fiedler et al. 1998; Burtenshaw et al. 2004), Baja California (Reilly and Thayer 1990), and off southern Australia (Gill 2002). Blue whales also feed in cool, offshore, upwelling-modified waters in the eastern tropical and equatorial Pacific (Reilly and Thayer 1990; Palacios 1999). Moore et al. (2002) determined that blue whale call locations in the western North Pacific were associated with relatively cold, productive waters and fronts.

Distribution—Blue whales are distributed from the ice edges to the tropics in both hemispheres (Jefferson et al. 1993). Blue whales as a species are thought to summer in high latitudes and move into the subtropics and tropics during the winter (Yochem and Leatherwood 1985). Data from both the Pacific and Indian Oceans, however, indicate that some individuals may remain in low latitudes year-round, such as over the Costa Rican Dome (Wade and Friedrichsen 1979; Reilly and Thayer 1990). The productivity of the Costa Rican Dome may allow blue whales to feed during their winter calving/breeding season and not fast, like humpback whales (Mate et al. 1999).

The range of the blue whale is known to encompass much of the North Pacific Ocean, from Kamchatka (Russia) to southern Japan in the west, and from the Gulf of Alaska south to at least Costa Rica in the east (NMFS 1998). The only (presumably) reliable sighting report of this species in the central North Pacific was a sighting made from a scientific research vessel about 400 km northeast of Hawai'i in January 1964 (NMFS 1998). Blue whale call locations in the western North Pacific suggest that there is an association between whale distribution and the Emperor Seamounts, the steep continental slope off the Kamchatka Peninsula, and the Aleutian Island chain (Moore et al. 2002). Moore et al. (2002) noted a seasonal progression of call-location concentrations over the seamounts in winter, the Kamchatka Peninsula and seamounts in spring, the Kamchatka Peninsula and waters between the seamounts and Aleutian Islands in summer, and the seamounts again in fall. Blue whale calls have been recorded off Midway and O'ahu (Northrop et al. 1971; Thompson and Friedl 1982; McDonald and Fox 1999); these provide evidence of blue whales occurring within several hundred kilometers of these islands (NMFS 1998b). The recordings made off O'ahu showed bimodal peaks throughout the year, suggesting that the animals were migrating into the area during summer and winter (Thompson and Friedl 1982; McDonald and Fox 1999). Evidence of blue whales in the Micronesia region is almost entirely lacking, except for near the Solomon Islands (Reeves et al. 1999).

- Information Specific to the Marianas MRA Study Area—There are no occurrence records for the blue whale in the Marianas study area and vicinity, but this area is within the known distribution range for this species. There is a low or unknown occurrence of the blue whale seaward of the 50 m isobath. This takes into consideration the endangered status of this species, the probability of encountering this species in both coastal and oceanic waters, and the unknown possibility that this species might occur in this area (**Figure B-6**). Occurrence patterns are expected to be the same throughout the year, reflecting our lack of knowledge and the possibility of year-round residents, but with a higher probability during winter and the adjacent months from November to May (Jefferson personal communication).

Behavior and Life History—Blue whales are found singly or in groups of two or three (Yochem and Leatherwood 1985). As noted by Wade and Friedrichsen (1979), apparently solitary whales are likely part of a large dispersed group. Blue whales, like other rorquals, feed by "gulping" (Pivorunas 1979) almost exclusively on krill (Nemoto and Kawamura 1977). Female blue whales reach sexual maturity at 5 to 15 years of age (Yochem and Leatherwood 1985). There is usually a two-year interval between calves. Calving occurs primarily during the winter (Yochem and Leatherwood 1985).

The usual duration of blue whale dives is 3 to 20 min (Wynne and Schwartz 1999). Croll et al. (2001) determined that blue whales dived to an average of 140.0 m (±S.D. 46.01) and for 7.8 (±S.D. 1.89) min when foraging and to 67.6 m (±S.D. 51.46) and for 4.9 (±S.D. 2.53) min when not foraging. Calambokidis et al. (2003) deployed tags on blue whales and collected data on dives as deep as 300 m.

Acoustics and Hearing—Blue whale vocalizations are long, patterned low-frequency sounds with durations up to 36 sec (Thomson and Richardson 1995) repeated every 1 to 2 min (Mellinger and Clark 2003). Their frequency range is 12 to 400 Hz, with dominant energy in the infrasonic range at 12 to 25 Hz (Ketten 1998; Mellinger and Clark 2003). Source levels are up to 188 dB re 1 μPa-m (Ketten 1998; McDonald et al. 2001). During the Magellan II Sea Test (at-sea exercises designed to test systems for antisubmarine warfare), off the coast of California in 1994, blue whale vocalization source levels at 17 Hz were estimated in the range of 195 dB re 1 μPa-m (Aburto et al. 1997). Vocalizations of blue whales appear to vary among geographic areas (Rivers 1997), with clear differences in call structure suggestive of separate populations for the western and eastern regions of the North Pacific (Stafford et al. 2001). While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

- Sperm Whale (*Physeter macrocephalus*)

Description—The sperm whale is the largest toothed whale species. Adult females can reach 12 m in length, while adult males measure as much as 18 m in length (Jefferson et al. 1993). The head is large (comprising about one-third of the body length) and squarish. The lower jaw is narrow and underslung. The blowhole is located at the front of the head and is offset to the left (Rice 1989). Sperm whales are brownish gray to black in color with white areas around the mouth and often on the belly. The flippers are relatively short, wide, and paddle-shaped. There is a low rounded dorsal hump and a series of bumps on the dorsal ridge of the tailstock (Rice 1989). The surface of the body behind the head tends to be wrinkled (Rice 1989).

Status—Sperm whales are classified as endangered under the ESA and are designated as vulnerable by the IUCN Red List (Reeves et al. 2003). There is no designated critical habitat for this species in the North Pacific. For management purposes, the IWC has divided the North Pacific into two management regions defined by a zig-zag line which starts at 150°W at the equator, is at 160°W between 40° to 50°N, and ends up at 180°W north of 50°N (Donovan 1991).

It should be noted that the sperm whale's ESA status as endangered is somewhat political, and the species is actually in no immediate danger of global extinction (unlike some species, such as the North Pacific right whale, which clearly are). Although many sperm whale populations have been depleted to varying degrees by past whaling activities, sperm whales remain one of the more globally common great whale species. In fact, in some areas, they are actually quite abundant. As just a single example, there are estimated to be about 21,200 to 22,700 sperm whales in the eastern tropical Pacific Ocean (Wade and Gerrodette 1993).

Habitat Preferences—Sperm whales show a strong preference for deep waters (Rice 1989), especially areas with high sea floor relief. Sperm whale distribution is associated with waters over the continental shelf edge, over the continental slope, and into deeper waters (Hain et al. 1985; Kenney and Winn 1987; Waring and Finn 1995; Gannier 2000; Gregr and Trites 2001; Waring et al. 2001). However, in some areas, such as off New England, on the southwestern and eastern Scotian Shelf, or the northern Gulf of California, adult males are reported to quite consistently use waters with bottom depths less than 100 m and as shallow as 40 m (Whitehead et al. 1992; Scott and Sadove 1997; Croll et al. 1999; Garrigue and Greaves 2001). Worldwide, females rarely enter the shallow waters over the continental shelf (Whitehead 2003).

Sperm whale concentrations have been correlated with high secondary productivity and steep underwater topography (Jaquet and Whitehead 1996). Sperm whales are more frequently found in certain geographic areas, which whalers learned to exploit (e.g., whaling "grounds" such as the Azores Islands) encompassing 300 to 1,500 km^2 (Townsend 1935). These main sperm whaling grounds are usually correlated with areas of increased primary productivity caused by upwelling (Jaquet et al. 1996). Sperm whales in the Gulf of Mexico aggregate along the continental slope in or near cyclonic (cold-core) eddies (Biggs et al. 2000; Davis et al. 2002). These eddies are mesoscale features with locally enhanced plankton stocks (Wormuth et al. 2000). Data suggest that sperm whales appear to adjust their movements to stay in or near cold-core rings (Davis et al. 2000, 2002). This would demonstrate that sperm whales shift their movements in relation to prey concentrations. Off the eastern U.S., sperm whales are found in regions of pronounced horizontal temperature gradients, along the edges of the Gulf Stream and warm-core rings (Waring et al. 1993; Griffin 1999; Jaquet et al. 1996). It is likely that these habitats are regions where oceanographic conditions are optimal for the aggregation of prey, such as squid. Waring et al. (2003) conducted a deepwater survey south of Georges Bank in 2002 and examined fine-scale habitat use by sperm whales. Sperm whales were located in waters characterized by a SST of 23.2º to 24.9ºC and a bottom depth of 325 to 2,300 m (Waring et al. 2003). In the eastern tropical Pacific, sperm whale habitat use is significantly related to SST and depth of the thermocline (Polacheck 1987). Gregr and Trites (2001) reported that female sperm whales off British Columbia were relatively unaffected by the surrounding oceanography.

Distribution—Sperm whales are found from tropical to polar waters in all oceans of the world between approximately 70°N and 70°S (Rice 1998). Females use a subset of the waters where males are regularly found. Females are normally restricted to areas with SSTs greater than approximately 15ºC, whereas males, and especially the largest males, can be found in waters as far poleward as the pack ice with temperatures close to 0ºC (Rice 1989). The thermal limits on female distribution correspond approximately to the 40º parallels (50º in the North Pacific) (Whitehead 2003).

- <u>Information Specific to the Marianas MRA Study Area</u>—Globally, sperm whales are typically distributed in waters over the shelf break and continental slope. Sperm whales are expected to occur seaward of the shelf break into waters with bottom depths analogous to the open ocean (>200 m) expected in the Marianas study area and vicinity (**Figure B-7**). Whaling records demonstrate sightings year-round around the Marianas (Townsend 1935). In some locales, sperm whales also may be found in waters less than 100 m deep (Scott and Sadove 1997; Croll et al. 1999). To account for the possibility of encountering this species in shallow waters, there is a low or unknown sperm whale occurrence from the 50 m isobath to the shelf break (**Figure B-7**). This occurrence prediction is based on the possibility of this typically deepwater species being found in insular shelf waters that are in such close proximity to deep water. As in other areas where sperm whales are found in shelf waters, this is likely due to prey occurrence. There are two stranding records for this area (Kami and Lujan 1976; Eldredge 1991, 2003). In June 2001, a group of sperm whales that included a newborn calf was sighted off the west coast of Guam (Eldredge 2003). Sperm whale occurrence patterns are assumed to be similar throughout the year. North of the map extent in **Figure B-7** is one sighting of 3 sperm whales made 8.3 km north of Anatahan during March 2003 (Vogt 2004).

Behavior and Life History—Female sperm whales live a highly social life, while large male sperm whales typically occur alone or in pairs, at times joining groups of adult females for breeding (Whitehead 2003). Female and immature sperm whales form groups that move together in a coordinated fashion over periods of days (Whitehead 2003). Mean group size is approximately 20 to 30 individuals, although there is much variation (Whitehead 2003). For a review of sperm whale social organization, see Whitehead and Weilgart (2000) and Whitehead (2003). Mating behavior is observed from winter through summer and calving during spring through fall. Gestation is 14 to 15 months, lactation is approximately 2 years, and the typical inter-birth interval is 4 to 7 years. Sperm whales prey on large mesopelagic squid and other cephalopods as well as demersal fishes and occasionally benthic invertebrates (Rice 1989; Clarke 1996).

Sperm whales forage during deep dives that routinely exceed a depth of 400 m and 30 min duration (Watkins et al. 2002). Sperm whales are capable of diving to depths of over 2,000 m with durations of over 60 min (Watkins et al. 1993). Sperm whales spend up to 83% of daylight hours underwater (Jaquet et al. 2000; Amano and Yoshioka 2003). Males do not spend extensive periods of time at the surface (Jaquet et al. 2000). In contrast, females spend prolonged periods of time at the surface (1 to 5 hours [hrs] daily) without foraging (Whitehead and Weilgart 1991; Amano and Yoshioka 2003). The average swimming speed is estimated to be 0.7 m/sec (Watkins et al. 2002). Dive descents averaged 11 min at a rate of 1.52 m/sec, and ascents averaged 11.8 min at a rate of 1.4 m/sec (Watkins et al. 2002).

Acoustics and Hearing—Sperm whales produce short-duration (generally less than 3 sec), broadband clicks. These clicks range in frequency from 100 Hz to 30 kHz, with dominant energy in two bands (2 to 4 kHz and 10 to 16 kHz). Generally, most of the acoustic energy is present at frequencies below 4 kHz, although diffuse energy up to past 20 kHz has been reported (Thode et al. 2002). The source levels can be up to 236 dB re 1 µPa-m (Møhl et al. 2003). Thode et al. (2002) suggested that the acoustic directivity (angular beam pattern) from sperm whales must range between 10 and 30 dB in the 5 to 20 kHz region. The clicks of neonate sperm whales are very different from usual clicks of adults in that they are of low directionality, long duration, and low-frequency (centroid frequency between 300 and 1,700 Hz) with estimated source levels between 140 and 162 dB re 1 µPa-m (Madsen et al. 2003). Clicks are heard most frequently when sperm whales are engaged in diving/foraging behavior (Whitehead and Weilgart 1991; Miller et al. 2004; Zimmer et al. 2005). These may be echolocation clicks used in feeding, contact calls (for communication), and orientation during dives. When sperm whales are socializing, they tend to repeat series of clicks (codas), which follow a precise rhythm and may last for hours (Watkins and Schevill 1977). Codas are shared between individuals of a social unit and are considered to be primarily for intragroup communication (Weilgart and Whitehead 1997; Rendell and Whitehead 2004).

The anatomy of the sperm whale's ear indicates that it hears high-frequency sounds (Ketten 1992). Anatomical studies also suggest that the sperm whale has some ultrasonic hearing, but at a lower maximum frequency than many other odontocetes (Ketten 1992). The sperm whale may also possess better low-frequency hearing than some other odontocetes, although not as extraordinarily low as many baleen whales (Ketten 1992). Auditory brainstem response in a neonatal sperm whale indicated highest sensitivity to frequencies between 5 and 20 kHz (Ridgway and Carder 2001).

- Hawaiian Monk Seal (*Monachus schauinslandi*)

Description—Hawaiian monk seals are similar in body shape to female and young elephant seals, with a moderately robust, spindle-shaped body and short muzzle. Adults are 2.1 to 2.4 m in length and weigh 170 to 240 kilograms [kg], with females growing slightly larger than males (Gilmartin and Forcada 2002). Other than this size difference, there is little noticeable sexual dimorphism. Coloration of Hawaiian monk seals is drab, generally a yellow-brown to silvery gray color with slight countershading and some small ventral white patches.

Status—The Hawaiian monk seal is listed as endangered under the ESA and depleted under the MMPA (Ragen and Lavigne 1999). The Hawaiian monk seal population is a NOAA Fisheries strategic stock (Carretta et al. 2004). Hawaiian monk seals are managed as a single stock, although there are six main reproductive subpopulations at French Frigate Shoals, Laysan Island, Lisianski Island, Pearl and Hermes Reef, Midway Island, and Kure Atoll (Ragen and Lavigne 1999; Carretta et al. 2004). Genetic comparisons between the Northwestern and main Hawaiian Islands seals have not yet been conducted, but observed interchange of individuals among the regions is extremely rare, suggesting that these may be more appropriately designated as separate stocks; further research is needed (Carretta et al. 2004).

The best estimate of the total population size is 1,304 individuals (Carretta et al. 2004). In 2001, there were an estimated 52 seals in the main Hawaiian Islands (Baker and Johanos 2004; Carretta et al. 2004); the vast majority of the population occurs in the Northwestern Hawaiian Islands. The trend in abundance for the population over the past 20 years has mostly been negative (Baker and Johanos 2004; Carretta et al. 2004). A self-sustaining subpopulation in the main Hawaiian Islands may improve the monk seal's long-term prospects for recovery (MMC 2003; Baker and Johanos 2004; Carretta et al. 2004).

Critical habitat for the Hawaiian monk seal is designated from the shore out to 37 m (20 fathoms) in 10 areas of the Northwestern Hawaiian Islands (NMFS 1988) (**Figure 3-2**).

Habitat Preferences—Breeding habitat for the Hawaiian monk seal primarily consists of short, sandy beaches, although hard substrate beach areas and exposed reef are used at some islands (Gilmartin 1983). Dry sand areas above the high tide line are preferred (Kenyon 1973; Gilmartin 1983). The breeding beaches are characterized by shallow, protected water adjacent to the shoreline, which may limit access by large predatory sharks (Westlake and Gilmartin 1990). Foraging habitat is commonly restricted to waters of less than 100 m in depth near the breeding atolls and seamounts (Parrish et al. 2000; Stewart 2004). The inner reef waters adjacent to the islands are critical to weaned pups learning to feed, as the pups move laterally along the shoreline, but do not appear to travel far from shore during the first few months after weaning (Gilmartin 1983). Feeding has been observed in reef caves (Gilmartin 1983). Recent studies have shown that adult seals at French Frigate Shoals forage at depths of 300 to 500 m in deepwater coral beds (Parrish et al. 2002), and 2 to 3 year-olds feed at much shallower depths of 10 to 30 m (Parrish et al. 2005). However, juveniles feed in water sand fields with a bottom depth of 50 to 100 m on the atoll's outer slope (Parrish et al. 2005).

Local environmental conditions affect trends in abundance of specific monk seal subpopulations, with areas sharing similar ecological characteristics having similar trends (Schmelzer 2000). Climate-driven changes in oceanic productivity could be decisive in reducing (or enhancing) monk seal reproduction and survival. Juvenile seals feed over deepwater sand fields, and oceanographic conditions are thought to influence survivorship of these seals (Parrish et al. 2005). Polovina et al. (1994) speculated that climate changes in the central North Pacific cause declines in lobster recruitment, which contributed to declines in the numbers of monk seal pups. More recent work suggests that El Niño conditions may actually benefit Hawaiian monk seals by making prey more available and resulting in weaned pups with larger axillary girths (and therefore, presumably, better nutritional condition) (Antonelis et al. 2003). Further research is needed to fully understand the implications of climate change on this species.

Distribution—The Hawaiian monk seal occurs only in the central North Pacific. Until recently, this species occurred almost exclusively at remote atolls in the Northwestern Hawaiian Islands where six major breeding colonies are located: French Frigate Shoals, Laysan and Lisianski Islands, Pearl and

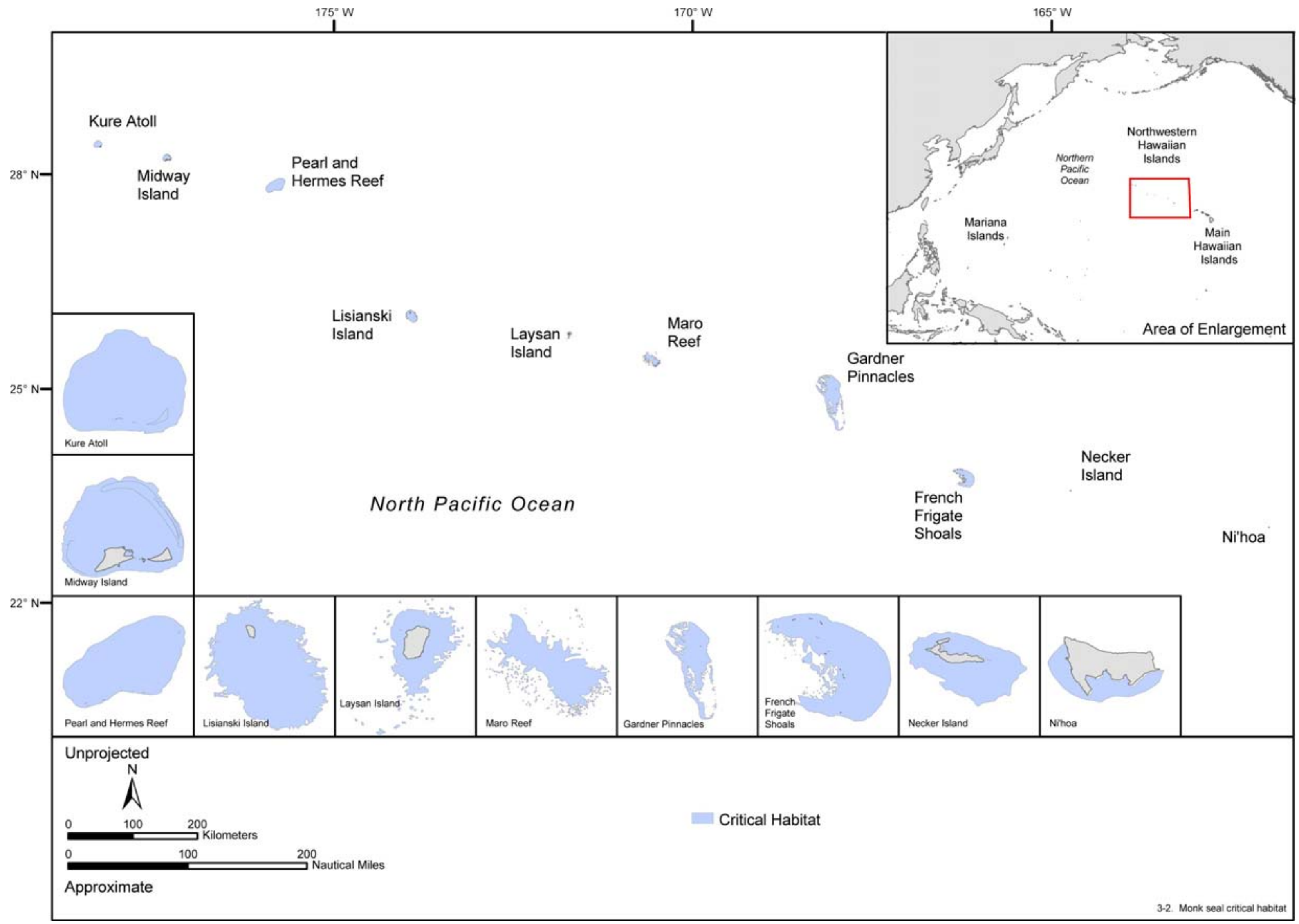

Figure 3-2. Designated critical habitat for the Hawaiian monk seal. Critical habitat is all beach areas, including all beach crest vegetation to its deepest extent inland, lagoon waters, and ocean waters out to a depth of 37 m around the Northwestern Hawaiian Islands. References to beaches or beach areas includes all sand spits and islets. Source data: NOS (2001). Source information: NMFS (1988).

Hermes Reef, and Midway and Kure Atoll. In the last decade, however, sightings of Hawaiian monk seals in the main Hawaiian Islands have increased considerably (Baker and Johanos 2004; Carretta et al. 2004). Most monk seal haulout events in the main Hawaiian Islands have been on the western islands of Ni'ihau and Kaua'i (Baker and Johanos 2004; Carretta et al. 2004), although sightings or births have now been reported for all of the main Hawaiian Islands, including Lehua Rock and Kaula Rock (MMC 2003; Baker and Johanos 2004). These sightings include "surplus" males that were relocated from the main breeding islands to reduce the problem of mobbing of breeding females (Zevin 1995; Baker and Johanos 2004). Births of Hawaiian monk seal pups have been recorded in the main Hawaiian Islands, including Kaua'i and Ni'ihau (Baker and Johanos 2004). Hawaiian monk seals wander to Mar Reef and Gardner Pinnacles and have occasionally been sighted on nearby island groups, such as Johnston Atoll, Wake Island, and Palmyra Atoll (Rice 1998).

Hawaiian monk seals show very high site fidelity to natal islands, with only about 10% of individuals moving to another island in their lifetime (Gilmartin and Forcada 2002). While monk seals do move between islands, long-distance movements are not common. Seals move distances of up to 250 km on a regular basis, but distances of more than 1,000 km have not been documented (DeLong et al. 1984; Ragen and Lavigne 1999).

- Information Specific to the Marianas MRA Study Area—There are no confirmed records of Hawaiian monk seals in the Micronesia region; however, Reeves et al. (1999) and Eldredge (1991; 2003) have noted occurrence records for seals (unidentified species) in the Marshall and Gilbert islands. The monk seal is not known to make long-distance movements; however, its numbers are increasing in the main Hawaiian Islands as individuals expand their range from the Northwestern Hawaiian Islands, so extralimital occurrences are possible. The highly endangered status of this species necessitates mentioning the possibility of encountering this species in the Marianas study area (Jefferson personal communication).

Behavior and Life History—Unlike many other pinniped species, Hawaiian monk seals are not very gregarious on land and are more-or-less solitary when at sea. The monk seal also appears to be intolerant of human presence; occurrence trends at Kure Atoll, Midway Atoll, and French Frigate Shoals appear to be determined by the pattern of human disturbance from military or USCG activities (Kenyon 1973; MMC 2003; Baker and Johanos 2004; Carretta et al. 2004). Likewise in the main Hawaiian Islands, seals tend to frequent remote areas where human access is limited (MMC 2003).

Although births are documented year-round, pupping occurs during a protracted breeding season mostly from February to August, with a peak in April to June (Gilmartin and Forcada 2002; Stewart 2004). Sometimes groups of males exhibit an aggressive behavior called "mobbing," in which they gang together and attempt to mate with, and by doing so, injure and often kill, adult females and immature seals of both sexes (Starfield et al. 1995). This behavior seems to occur to a far greater extent in those subpopulations where there are more males than females.

Molting takes place once a year between April and December. Hawaiian monk seals have a "catastrophic molt" in which large patches of skin and fur are shed. This type of molt is considered to be very energetically expensive.

Hawaiian monk seals feed opportunistically on a wide variety of at least 40 species of benthic and demersal fishes, cephalopods, and spiny lobster (MacDonald 1982; Goodman-Lowe 1998; Parrish et al. 2000). Juveniles feed on small, cryptic, benthic prey items (Parrish et al. 2005). Monk seals also interact with various fisheries, such as longlines and the lobster fishery (Nitta and Henderson 1993; Carretta et al. 2004). Hawaiian monk seals were previously not thought to be deep divers, with most known dives in the 10 to 40 m depth range (DeLong et al. 1984; Ragen and Lavigne 1999). However, deeper dives to at least 121 m (DeLong et al. 1984) and to over 500 m (Parrish et al. 2002) have recently been recorded.

Acoustics and Hearing—There is no information available regarding underwater sounds produced by Hawaiian monk seals. In-air sounds include: (1) a soft liquid bubble at 100 to 400 Hz; (2) a loud, brief guttural expiration below 800 Hz during short-distance agonistic encounters; (3) a roar, also to 800 Hz, for long-distance threat; and (4) a belch cough made by males when patrolling (Miller and Job 1992). Pups emit a <1.4 kHz call; Job et al. (1995) reported that there is apparent lack of vocal recognition of pups by adult females. An underwater audiogram obtained for the Hawaiian monk seal showed relatively poor hearing sensitivity, as well as a narrow range of best sensitivity and a relatively low upper frequency limit (Thomas et al. 1990a). The data demonstrated best underwater hearing at 12 to 28 kHz and 60 to 70 kHz (Thomas et al. 1990a). It should be noted that this audiogram is based on a single animal whose hearing curve has some characteristics that suggest its responses may have been affected by disease or age (Reeves et al. 2001).

♦ Dugong (*Dugong dugon*)

Description—The dugong is a sirenian that has a fluked tail (like dolphins and whales) and no dorsal fin (Marsh 2002). In general, dugongs are more streamlined than manatees (Jefferson et al. 1993). The maximum known size is 3.3 m in length, with a weight of 400 kg (Jefferson et al. 1993). The head is squarish, and the tusks of mature males and some old females erupt on either side of the mouth (Marsh 2002). The eyes are very small. The flippers are short, and unlike in manatees, lack nails (Marsh 2002).

Status—The dugong is listed as endangered under the ESA throughout its entire range (USFWS 2003) and is designated as vulnerable by the IUCN Red List (Marsh et al. 2003). A total of 27 individuals were counted during the course of the 2003 aerial survey at Palau, the only location in the Micronesia region with a dugong population (Davis 2004).

Habitat Preferences—The dugong generally frequents coastal waters, but unlike the manatee, it strictly occurs in marine waters. This species tends to concentrate in wide, shallow protected bays; wide, shallow, mangrove channels; and in the lees of large inshore islands (Marsh et al. 2003). These areas are coincident with sizeable seagrass beds (Marsh et al. 2003). Shallow waters, such as tidal sandbanks and estuaries, have also been reported sites for calving (USFWS 2003). Dugongs are also regularly observed in deeper water further offshore in areas where the continental shelf is wide, shallow and protected (Marsh et al. 2003). This distribution reflects that of deepwater seagrasses, such as *Halophila spinulosa* (Anderson 1994; Marsh et al. 2003). Dugong feeding trails have been observed at depths of up to 33 m off northeastern Queensland, Australia (Marsh et al. 2003).

Dugongs are able to undertake long-distance movements. Whiting (1999) reported dugongs, including calves, at Ashmore Reef on the Sahul Banks at the edge of the Australian continental shelf. Although Ashmore Reef is only 140 km from the Indonesian island of Roti; the Timor Trough, which is 2,000 m in depth, separates these locations (Marsh et al. 2003). The capacity of dugongs to cross deep ocean trenches (up to 4 km in depth) is also supported by recent reports of dugongs at Aldabra Atoll, which is located 425 km from Madagascar; dugongs had not previously been observed at this atoll (Marsh et al. 2003). These movements are likely habitat-driven, which is further supported by movements of large numbers of dugongs in western Australia following a tropical cyclone that reduced the availability of prey plants in one area (Gales et al. 2004).

Distribution—The dugong's historic distribution is believed to have been broadly coincident with the tropical Indopacific distribution of its food plants, the seagrasses of the families Potamogetonaceae and Hydrocharitaceae (Husar 1978). Currently, the dugong has a large range that spans at least 37 countries and territories and includes tropical and subtropical coastal and inland waters from east Africa to Vanuatu, between about 26° and 27° north and south of the equator (Nishiwaki et al. 1979; Marsh et al. 2003). This distribution is disjunct, reflecting habitat availability and human activities. Over most of its range, the dugong is known only from incidental sightings, accidental drownings, and the anecdotal reports of fishermen (Marsh 2002). In the Micronesia area, dugongs occur only in Palau (part of the western Caroline Islands), except for occasional sightings around Yap and Guam (USFWS 2003; Davis 2004). The dugong population around the Palau Islands is the closest location (1,076 km) of regular occurrence of dugongs to the Mariana Islands. The dugong population at Palau is one of the few still known to persist in an isolated archipelago (Brownell et al. 1981).

- Information Specific to the Marianas MRA Study Area—The dugong is not expected to occur in the Marianas study area during any time of the year. The endangered status of this species necessitates mentioning these extralimital occurrences in the Marianas study area. Nishiwaki et al. (1979) reviewed dugong distribution worldwide and concluded that this species likely never occurred in the Mariana Islands. There have been extralimital sightings recorded in this area, including a sighting in Cocos Lagoon at the southern end of Guam in 1974 (Anonymous 1974; Randall et al. 1975); Eldredge (1991, 2003) erroneously noted the year to be 1975. Several sightings were made in 1985 (date unspecified) of a dugong along the southeastern coast of Guam (Eldredge 1991, 2003). As noted earlier, Palau is the closest location (1,076 km) of regular occurrence of the dugong to the Mariana Islands. Dugongs are known to travel over deep waters for long distances; they can occur in both shallow and deep waters.

Behavior and Life History—Most dugongs are sighted alone or in groups of two animals (Marsh 2002; Davis 2004). Large aggregations of up to several hundred animals are regularly seen at some locations, feeding on seagrass meadows (Marsh 2002; Lanyon 2003). Dugongs are slow-growing mammals, with females only reaching sexual maturity after 6 to 17 years and producing a single calf every 2.5 to 5 years (Marsh et al. 2002). The estimated gestation period is about 13 months; calves are nursed for at least 13 months (Marsh 1995). Dugongs start eating seagrasses soon after birth (Marsh et al. 2002). Dugongs are benthic feeding specialists; depending on the species of seagrass being consumed, dugongs target either the leaves alone or uproot the entire plant and consume the leaves, roots, and rhizomes, leaving distinct feeding scars (Preen 1995a; Marshall et al. 2003). Seagrasses of the genera *Halophila* and *Halodule* are preferred (Marsh 2002). Marine algae are also eaten. In northern Australia, Whiting (2002) documented long-term feeding by dugongs on algal-covered rocky reefs in the intertidal zone. It is not known whether algae form a minor part of their diet or if dugongs only feed on algae when seagrasses are scarce (Whiting 2002). Dugongs are known to occasionally supplement their herbivorous diet with macro-invertebrates (Preen 1995b). The highly specialized dietary requirements of the dugong suggest that only certain seagrass meadows may be suitable as dugong habitat (Preen 1995a). Maximum recorded dive depth for a tagged dugong is 20.5 m, although as noted earlier, maximum dive depths of up to 33 m are inferred from feeding scars in seagrass meadows (Chilvers et al. 2004). Maximum dive time at depths greater than 1.5 m is 12.3 min (Chilvers et al. 2004). Typical mean dive duration for depths less than 3 m from the water's surface is 2.7 $\pm$ 0.17 min (Chilvers et al. 2004).

Acoustics and Hearing—Dugongs produce complex sounds such as chirp-squeaks, barks, and trills (Anderson and Barclay 1995). Chirp-squeaks are in the 3 to 18 kHz range and last approximately 60 msec (Anderson and Barclay 1995). Trills last as long as 2,200 msec and are within the 3 to 18 kHz frequency band (Anderson and Barclay 1995). Barks are broadband signals of 500 to 2,200 Hz lasting 30 to 120 msec (Anderson and Barclay 1995). No hearing data are available for this species (Ketten 1998).

3.1.2.3 Non-Threatened and Non-Endangered Marine Mammal Species of Guam and the Northern Mariana Islands

There are 21 non-endangered/non-threatened marine mammal species: two baleen whale species, 18 toothed whale species, and one pinniped species. For most of the marine mammal species occurring in the Guam and the Northern Mariana Islands, there are few occurrence records. Many species in this area are known only from stranding records or are suspected to occur in the area. For species with few records, this may be a result of difficulty in visually detecting the species, identifying it, or due to extralimital occurrences of the species.

- Minke Whale (*Balaenoptera acutorostrata*)

Description—The minke whale is the smallest balaenopterid species in the western North Atlantic, with adults reaching lengths of just over 9 m (Jefferson et al. 1993). The head is extremely pointed, and the median head ridge is prominent. The dorsal fin is tall (for a baleen whale), recurved, and is located about two-thirds of the way back from the snout tip (Jefferson et al. 1993). The minke's coloration is distinct: dark gray dorsally, white beneath, with streaks of intermediate shades on the sides (Stewart and Leatherwood 1985). The most distinctive light marking is a brilliant white band across each flipper of northern hemisphere minke whales (Stewart and Leatherwood 1985).

Status—The IWC recognizes three stocks of minke whales in the North Pacific: one in the Sea of Japan/East China Sea, one in the rest of the western Pacific west of 180º N, and one in the remainder of the Pacific (Donovan 1991). Smith (2003) suggested that there are only three breeding groups in the western Northern Pacific, and that at least one of these (group W) breeds in the vicinity of the Bonin-Japan Trench during winter. This would presumably correlate to minke whales observed around the Marianas, but it should be noted that this is still very speculative, and is based primarily on modeling results (with few supporting data).

The minke whale is designated as near threatened on the IUCN Red List (Reeves et al. 2003). There are no abundance estimates for this species in this area; Horwood (1990) noted that densities of minke whales throughout the North Pacific are low.

Habitat Preferences—The minke whale generally occupies waters over the continental shelf, including inshore bays and estuaries (Mitchell and Kozicki 1975; Ivashin and Vitrogov 1981; Murphy 1995; Mignucci-Giannoni 1998; Calambokidis et al. 2004). However, based on whaling catches and surveys worldwide, there is also a deep-ocean component to the minke whale's distribution (Slijper et al. 1964; Horwood 1990; Mitchell 1991; Mellinger et al. 2000; Roden and Mullin 2000). Dorsey et al. (1990) noted minke whales feeding in locations of strong tidal currents in inshore waters.

Distribution—Minke whales are distributed in polar, temperate, and tropical waters (Jefferson et al. 1993); they are less common in the tropics than in cooler waters. Minke whales are present in the North Pacific from near the equator to the Arctic (Horwood 1990). The summer range extends to the Chukchi Sea (Perrin and Brownell 2002). In the winter, minke whales are found south to within 2° of the equator (Perrin and Brownell 2002). The distribution of minke whale vocalizations (specifically, "boings") suggests that the winter breeding grounds are the offshore tropical waters of the North Pacific Ocean (Rankin and Barlow 2003). There is no obvious migration from low-latitude, winter breeding grounds to high-latitude, summer feeding locations in the western North Pacific, as there is in the North Atlantic (Horwood 1990); however, there are some monthly changes in densities in both high and low latitudes (Okamura et al. 2001). In the northern part of their range, minke whales are believed to be migratory, wherease they appear to establish home ranges in the inland waters of Washington and along central California (Dorsey et al. 1983) and exhibit site fidelity to these areas between years (Borggaard et al. 1999).

- <u>Information Specific to the Marianas MRA Study Area</u>—There are no occurrence records for this species in the Marianas study area and vicinity, but this area is within the known distribution range for this species. There is a low or unknown occurrence of the minke whale here from the coastline (excluding harbors and lagoons) to seaward of the Marianas study area and vicinity. Taken into consideration were both sightings in shallow waters in some locales around the world, as well as the anticipated oceanic occurrence of this species (**Figure B-8**). Occurrence patterns are expected to be the same throughout the year, but with a higher probability during winter and the adjacent months from November to May (Jefferson personal communication).

Behavior and Life History—Minke whales are sighted alone or in small groups (Perrin and Brownell 2002). Mating is thought to occur in winter or early spring, but has never been observed (Stewart and Leatherwood 1985). Stern (1992) described a general surfacing pattern of minke whales consisting of about four surfacings interspersed by short-duration dives averaging 38 sec. After the fourth surfacing, there was a longer duration dive ranging from approximately 2 to 6 min. Minke whales are "gulpers," like the other rorquals (Pivorunas 1979). Hoelzel et al. (1989) reported on different feeding strategies used by minke whales. In the North Pacific, major food items include krill, Japanese anchovy, Pacific saury, and walleye Pollock (Perrin and Brownell 2002).

Acoustics and Hearing—Recordings in the presence of minke whales have included both high- and low-frequency sounds (Beamish and Mitchell 1973; Winn and Perkins 1976; Mellinger et al. 2000). Mellinger et al. (2000) described two basic forms of pulse trains that were attributed to minke whales: a "speed up" pulse train with energy in the 200 to 400 Hz band, with individual pulses lasting 40 to 60 msec, and a less-common "slow-down" pulse train characterized by a decelerating series of pulses with energy in the 250 to 350 Hz band.

Recorded vocalizations from minke whales have dominant frequencies of 60 to greater than 12,000 Hz, depending on vocalization type (Thomson and Richardson 1995). Recorded source levels, depending on vocalization type, range from 151 to 175 dB re 1 µPa-m (Ketten 1998). Gedamke et al. (2001) recorded a complex and stereotyped sound sequence ("star-wars vocalization") in the Southern Hemisphere that spanned a frequency range of 50 Hz to 9.4 kHz. Broadband source levels between 150 and 165 dB re 1 µPa-m were calculated. "Boings" recorded in the North Pacific have many striking similarities to the star-wars vocalization, in both structure and acoustic behavior. "Boings", recently confirmed to be produced by minke whales and suggested to be a breeding call, consist of a brief pulse at 1.3 kHz, followed by an amplitude-modulated call with greatest energy at 1.4 kHz, with slight frequency modulation over a duration of 2.5 sec (Rankin and Barlow 2003). While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

♦ Bryde's Whale (*Balaenoptera edeni/brydei*)

Description—Bryde's whales can be easily confused with sei whales. Bryde's whales usually have three prominent ridges on the rostrum (other rorquals generally have only one) (Jefferson et al. 1993). The Bryde's whale's dorsal fin is tall and falcate and generally rises abruptly out of the back. Adults can be up to 15.5 m in length (Jefferson et al. 1993), but there is a smaller species that rarely reaches over 10 m in length (Jefferson personal communication).

It is not clear how many species of Bryde's whales there are, but genetic analyses suggest the existence of at least two species (Rice 1998; Kato 2002). The taxonomy of the baleen whale group formerly known as sei and Bryde's whales is currently confused and highly controversial (see Reeves et al. 2004 for a recent review). It is clear that there are at least three species in this group, the antitropically-distributed sei whale, the tropically-distributed standard form Bryde's whale (probably referable to *Balaenoptera brydei*), and the "dwarf Bryde's whale" (probably referable to *Balaenoptera edeni*), which inhabits tropical waters of the Indo-Pacific (Yoshida and Kato 1999). However, the nomenclature is not resolved, due to questions about the affinities of the type specimens of *Balaenoptera brydei* and *Balaenoptera edeni*.

Status—The IWC recognizes three management stocks of Bryde's whales in the North Pacific: Western North Pacific, Eastern North Pacific, and East China Sea (Donovan 1991). The Bryde's whale is designated as data deficient on the IUCN Red List (Reeves et al. 2003). This "species" is expected to be the most common baleen whale species in the Mariana Islands (Jefferson personal communication).

Clearly, the standard-form Bryde's whale occurs in the area of the Mariana Islands, and the sei whale may also occur there, at least extralimitally. It is possible that the dwarf Bryde's whale may also occur there, although current data suggest a more equatorial distribution for most of the records.

Habitat Preferences—Bryde's whales are found both offshore and near the coasts in many regions. Off eastern Venezuela, Bryde's whales are often sighted in the shallow waters between Isla Margarita and Peninsula de Araya, as well as into waters where there is a steep slope, such as the Cariaco Trench (Notarbartolo di Sciara 1982). Along the Brazilian coast, distribution and seasonal movements of the Bryde's whale appear to be influenced by the behavior, distribution, and abundance of Brazilian sardine (*Sardinella brasiliensis*) schools that approach the coast to spawn in shallow waters (Zerbini et al. 1997). In the Gulf of Mexico, all Bryde's whale sightings have been near the shelf break in DeSoto Canyon (Davis and Fargion 1996; Jefferson and Schiro 1997; Davis et al. 2000). Whaling catches also have shown that the Bryde's whale is not always a coastal species (Ohsumi 1977). The Bryde's whale appears to have a preference for water temperatures between approximately 15° and 20°C (Yoshida and Kato 1999).

Distribution—The Bryde's whale is found in tropical and subtropical waters, generally not moving poleward of 40° in either hemisphere (Jefferson et al. 1993). Long migrations are not typical of Bryde's whales, though limited shifts in distribution toward and away from the equator, in winter and summer, respectively, have been observed (Cummings 1985). The Bryde's whales' large wintering grounds may extend from the western North Pacific to the central North Pacific, with 20°N perhaps being the northernmost boundary (Ohizumi et al. 2002). During the winter, Bryde's whales are distributed in the western North Pacific around the Mariana, Ogasawara, Kazan, and Phillippine Islands, as well as near New Guinea (Ohizumi et al. 2002). Tagging data suggests that Bryde's whales undertake considerable east-west migrations, and that the stock in the western and central North Pacific does the same (Kishiro 1996). In summer, the distribution of Bryde's whales in the western North Pacific extends as far north as 40°N, but many individuals remain in lower latitudes, as far south as about 5°N. Data also suggest that winter and summer grounds partially overlap in the central North Pacific (Kishiro 1996; Ohizumi et al. 2002). Bryde's whales are also distributed in the central North Pacific in summer; the southernmost summer distribution of Bryde's whales inhabiting the central North Pacific is about 20°N (Kishiro 1996). By November, Bryde's whales are usually absent from their central North Pacific summering area (Miyashita et al. 1995); in the western North Pacific, they migrate as far south as the equator in winter (Kishiro 1996; Miyashita et al. 1996). In March, Bryde's whales are found at high densities in several areas of the central Pacific, from approximately 175°E to 150°W and 15°N to 5°S (Miyashita et al. 1995). Some whales remain in higher latitudes (around 25°N) in both winter and summer (Kishiro 1996).

- Information Specific to the Marianas MRA Study Area—Bryde's whales are seen year-round throughout tropical and subtropical waters (Kato 2002). They have been reported to occur in both deep and shallow waters globally. The Bryde's whale is expected to occur from the 50 m isobath to seaward of the Marianas study area and vicinity (**Figure B-9**). There is also a low or unknown occurrence from the coastline, including lagoons, to the 50 m isobath. Bryde's whales are sometimes seen very close to shore and even inside enclosed bays (Best et al. 1984). There was one sighting in July 1999, approximately 9.3 to 18.5 km west of FDM. Additionally, there was a sighting 195 km southeast of Guam made during December 1996, which was reported to the NOAA Fisheries for their Platforms of Opportunity Program (**Figure B-9**). There is one reported stranding for this area that occurred in August 1978 (Eldredge 1991, 2003). Occurrence patterns are expected to be the same throughout the year.

Behavior and Life History—This species is generally seen alone or in pairs (Tershy 1992), although they can be seen in groups of up to 10 individuals (Miyazaki and Wada 1978). The Bryde's whale does not have a well-defined breeding season in most areas. There is a 2-year reproductive cycle composed of 11 to 12 months gestation, 6 months of lactation, and 6 months resting (Kato 2002). Bryde's whales are lunge-feeders, feeding on fish and krill (Nemoto and Kawamura 1977). Cummings (1985) reported that Bryde's whales may dive as long as 20 min.

Acoustics and Hearing—Bryde's whales produce low frequency tonal and swept calls similar to those of other rorquals (Oleson et al. 2003). Calls vary regionally, yet all but one of the call types have a fundamental frequency below 60 Hz; they last from one-quarter of a second to several seconds; and they are produced in extended sequences (Oleson et al. 2003). While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

- Pygmy and Dwarf Sperm Whales (*Kogia breviceps* and *Kogia sima,* respectively)

Description—Pygmy sperm whales have a shark-like head with a narrow underslung lower jaw (Jefferson et al. 1993). The flippers are set high on the sides near the head. The small falcate dorsal fin of the pygmy sperm whale is usually set well behind the midpoint of the back (Jefferson et al.

1993). The dwarf sperm whale is similar in appearance to the pygmy sperm whale, but it has a larger dorsal fin, generally set nearer the middle of the back (Jefferson et al. 1993). The dwarf sperm whale also has a shark-like profile but with a more pointed snout than the pygmy sperm whale. Pygmy and dwarf sperm whales reach body lengths of around 3 and 2.5 m, respectively (Plön and Bernard 1999).

Dwarf and pygmy sperm whales are difficult for the inexperienced observer to distinguish from one another at sea, and sightings of either species are often categorized as *Kogia* spp. The difficulty in identifying pygmy and dwarf sperm whales is exacerbated by their avoidance reaction towards ships and change in behavior towards approaching survey aircraft (Würsig et al. 1998). Based on the cryptic behavior of these species and their small group sizes (much like that of beaked whales), as well as similarity in appearance, it is difficult to identify these species in sightings at sea.

Status—*Kogia* spp. are designated as least concern on the IUCN Red List (Reeves et al. 2003). There are no abundance estimates available for *Kogia* spp. in this area.

Habitat Preferences—Both species of *Kogia* generally occur in waters along the continental shelf break and over the continental slope (e.g., Baumgartner et al. 2001; McAlpine 2002; Baird 2005). Data from the Gulf of Mexico suggest that *Kogia* may associate with frontal regions along the shelf break and upper continental slope, areas with high epipelagic zooplankton biomass (Baumgartner et al. 2001). The zooplankton is likely part of the diet of one or more of the common prey species of *Kogia* (and not of the whales themselves).

There appear to be some habitat preference differences between the two species of the genus *Kogia*. Several studies have suggested that pygmy sperm whales live mostly beyond the continental shelf edge, while dwarf sperm whales tend to occur closer to shore, often over the outer continental shelf (Rice 1998; Wang et al. 2002; MacLeod et al. 2004). In particular, work on strandings and feeding habits in South Africa has indicated this (Ross 1979; Plön et al. 1998). However, after first suggesting this, Ross (1984) later indicated that the difference may be more in terms of a difference between juveniles and adults, with juveniles being more coastal, perhaps in both species. Unfortunately, most such studies are based on stranding records, which do not provide the best evidence on habitat selection, and they often appear to ignore Ross' (1984) later reinterpretation of his own earlier conclusion.

More reliable is a conclusion that the pygmy sperm whale is more temperate, and the dwarf sperm whale more tropical, since it is based at least partially on live sightings at sea from a large database from the eastern tropical Pacific (Wade and Gerrodette 1993). There, the pygmy sperm whale was not seen in truly tropical waters south of the southern tip of Baja California, but the dwarf sperm whale was common in those waters. This idea is also supported by the distribution of strandings in South American waters (Muñioz-Hincapié et al. 1998). Also, in the western tropical Indian Ocean, the dwarf sperm whale was much more common than the pygmy sperm whale, which is consistent with this hypothesis (Ballance and Pitman 1998).

In conclusion, although the dwarf sperm whale does appear to prefer more tropical waters, the exact habitat preferences of the two species are not well-known. Distribution at sea in relation to the shelf edge requires further study. Both species have been seen in both continental shelf and more oceanic waters. It may be that earlier conclusions were misleading, due to biases caused by the inadequacy of stranding data, lack of incorporation of age class effects, and possibly even by local adaptation of each species to the conditions of specific areas.

Distribution—Both *Kogia* species have a worldwide distribution in tropical and temperate waters (Jefferson et al. 1993).

- Information Specific to the Marianas MRA Study Area—There are only stranding records available for these two species in the Marinas study area and vicinity—3 for the dwarf sperm whale and 1 for the pygmy sperm whale (Kami and Lujan 1976; Reeves et al. 1999; Eldredge

1991, 2003). As noted earlier, identification to species for this genus is difficult, particularly at sea. Based on the known preference of these two species for deep waters, *Kogia* are expected to occur from the vicinity of the shelf break to seaward of the Marianas study area and vicinity (**Figure B-10**). For example, in the Hawaiian Islands, *Kogia* were found in waters with a mean bottom depth of 2,004 m (Baird et al. 2003a). There is a low or unknown occurrence for these two species between the 50 m isobath and the shelf break in this area (**Figure B-10**). At the Society Islands, a dwarf sperm whale was sighted in relatively shallow waters (bottom depth of 120 m) (Gannier 2000) and MacLeod et al. (2004) reported sighting *Kogia* most often in waters with a bottom shallower than 200 m in the northern Bahamas. Occurrence patterns are expected to be the same throughout the year.

Behavior and Life History—*Kogia* species have small group sizes (mean group size is usually two individuals) (Willis and Baird 1998a). A recent study of *Kogia* in South Africa has determined that these two species have a much earlier attainment of sexual maturity and shorter life span than other similarly sized toothed whales (Plön and Bernard 1999). Sexual maturity is attained at around 4 years in both sexes of both species. *Kogia* feed on cephalopods and, less often, on deep-sea fishes and shrimps (Caldwell and Caldwell 1989; Baird et al. 1996; Willis and Baird 1998a; Wang et al. 2002). A typical observation of this species is animals logging at the water surface for periods of up to a few minutes then slowly sinking or slow rolling out of sight and not being resighted (e.g., Baird 2005). Willis and Baird (1998a) reported that *Kogia* make dives of up to 25 min. A satellite-tagged pygmy sperm whale released off Florida was found to make long nighttime dives, presumably indicating foraging on squid in the deep scattering layer (Scott et al. 2001).

Acoustics and Hearing—Pygmy sperm whale clicks range from 60 to 200 kHz, with a dominant frequency of 120 kHz (Thomson and Richardson 1995). There is no information available on dwarf sperm whale vocalizations or hearing capabilities. An auditory brainstem response study indicates that pygmy sperm whales have their best hearing between 90 and 150 kHz (Ridgway and Carder 2001).

♦ Cuvier's Beaked Whale (*Ziphius cavirostris*)

Description—Cuvier's beaked whales are relatively robust compared to other beaked whale species. Male and female Cuvier's beaked whales may reach 7.5 and 7.0 m in length, respectively (Jefferson et al. 1993). This species has a relatively short beak, which along with the curved jaw, resembles a goose beak. The body is spindle-shaped, and the dorsal fin and flippers are small, as is typical for beaked whales. A useful diagnostic feature is a concavity on the top of the head, which becomes more prominent in older individuals. Cuvier's beaked whales are dark gray to light rusty brown in color, often with lighter color around the head. In adult males the head and much of the back can be light gray to white in color, and they also often have many light scratches and circular marks on the body (Jefferson et al. 1993).

Status—There are no abundance estimates for the Cuvier's beaked whale in this area. The Cuvier's beaked whale is designated as data deficient on the IUCN Red List (Reeves et al. 2003).

Habitat Preferences—Beaked whales normally inhabit deep ocean waters (>2,000 m) or continental slopes (200 to 2,000 m) and only rarely stray over the continental shelf (Pitman 2002). Cuvier's beaked whales are generally sighted in waters with a bottom depth greater than 200 m and are frequently recorded at depths of 1,000 m or more (Gannier 2000; MacLeod et al. 2004). They are commonly sighted around seamounts, escarpments, and canyons. MacLeod et al. (2004) reported that Cuvier's beaked whales occur in deeper waters than Blainville's beaked whales in the Bahamas.

Distribution—The Cuvier's beaked whale is the most widely distributed of all beaked whale species, occurring in all three major oceans and most seas (Heyning 1989). This species occupies almost all temperate, subtropical, and tropical waters, as well as subpolar and even polar waters in some areas (MacLeod et al. in press). In the western Pacific, records range from Japan to southern New Zealand (MacLeod et al. in press).

- Information Specific to the Marianas MRA Study Area—Beaked whales may be expected to occur in the area mostly seaward of the shelf break (**Figure B-11**). There is a low or unknown occurrence of beaked whales on the shelf between the 50 m isobath and the shelf break, which takes into account that deep waters come very close to the shore in this area. In some locales, beaked whales can be found in waters over the shelf, so it is possible that beaked whales have similar habitat preferences here. Occurrence patterns are expected to be the same throughout the year.

Behavior and Life History—Life history data on beaked whale species are extremely limited for the Cuvier's beaked whale. All species of beaked whales probably feed at or close to the bottom in deep oceanic waters, taking whatever suitable prey they encounter or feeding on whatever species are locally abundant (MacLeod et al. 2003). Analyses of stomach contents from captured and stranded individuals suggest that beaked whales are deep-diving animals, feeding by suction (Heyning 1989; Heyning and Mead 1996; Santos et al. 2001; MacLeod et al. 2003). Stomach contents of Cuvier's beaked whales primarily contain cephalopods, and rarely, fish (MacLeod et al. 2003). Dives exceeding 45 min and longer have been documented for Cuvier's beaked whales (Jefferson et al. 1993); Baird et al. (2004) documented a dive up to 87 min in duration for a tagged individual. Johnson et al. (2004) recorded dives as deep as 1,267 m.

Acoustics and Hearing—Very little information is available on characteristics of sound produced by beaked whales. MacLeod (1999) suggested that beaked whales use frequencies of between 300 Hz and 129 kHz for echolocation, and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication. Click pulses of Cuvier's beaked whales recorded by Frantzis et al. (2002) had a peak frequency between 13 and 17 kHz.

There is no direct information available on the hearing abilities of beaked whales (MacLeod 1999). Beaked whale ears are predominantly adapted to hear ultrasonic frequencies (MacLeod 1999). Based on the anatomy of the ears of beaked whales, these species may be more sensitive than other cetaceans to low frequency sounds; however, as noted earlier, there is no direct evidence to support this idea (MacLeod 1999).

- Blainville's Beaked Whale (*Mesoplodon densirostris*)

Description—Blainville's beaked whales appear to reach a maximum of around 4.7 m in length and weights up to 1,033 kg (Jefferson et al. 1993). Adults are blue-gray on their dorsal side and white below (Jefferson et al. 1993). All *Mesplodon* species have a relatively small head, large thorax and abdomen, and short tail. *Mesoplodon* species all have a pair of throat grooves on the ventral side of the head on the lower jaw. Beaked whales in the genus *Mesoplodon* are characterized by the presence of a single pair of sexually dimorphic tusks, which erupt only in adult males. The lower jaw of the Blainville's beaked whale is highly arched and massive flattened tusks extend above the upper jaw in adult males (Jefferson et al. 1993).

Status—There are no abundance estimates for the Blainville's beaked whale in this area. The Blainville's beaked whale is designated as data deficient on the IUCN Red List (Reeves et al. 2003).

Habitat Preferences—Beaked whales normally inhabit deep ocean waters (>2,000 m) or continental slopes (200 to 2,000 m), and only rarely stray over the continental shelf (Pitman 2002). Most of the ecological information regarding this species comes from the northern Bahamas (MacLeod et al. 2004; MacLeod and Zuur 2005). The Blainville's beaked whale in the northern Bahamas was most often sighted in waters with a bottom depth of 200 to 1,000 m (MacLeod and Zuur 2005); the majority of its time was spent along the canyon wall, where water depth is less than 800 m (Claridge 2003; MacLeod et al. 2004; MacLeod and Zuur 2005). In the Society Islands, Blainville's beaked whales were observed in waters with a bottom depth of 300 to 1,400 m (Gannier 2000). Ritter and Brederlau (1999) reported sightings of this species in waters with a bottom depth less than 500 m, and as shallow as 100 m, off the island of La Gomera in the Canary Islands. Both Baird et al. (2004) and

MacLeod et al. (2004) reported that Blainville's beaked whales are found in shallower waters than Cuvier's beaked whales in the Hawaiian Islands and the Bahamas, respectively.

Distribution—The Blainville's beaked whale occurs in temperate and tropical waters of all oceans (Jefferson et al. 1993). The distribution of *Mesoplodon* species in the western North Atlantic may relate to water temperature (Mead 1989; MacLeod 2000), with Blainville's beaked whale generally occurring in warmer southern waters (MacLeod 2000). In the eastern Pacific, where there are about a half-dozen *Mesoplodon* species known, the Blainville's beaked whale is second only to the pygmy beaked whale (*Mesoplodon peruvianus*) in abundance in tropical waters (Wade and Gerrodette 1993). In waters of the western Pacific, where the pygmy beaked whale is not considered to be present, the Blainville's beaked whale is probably the most common and abundance tropical species of *Mesoplodon* (Jefferson personal communication).

- Information Specific to the Marianas MRA Study Area—There are no occurrence records for this species in the Marianas study area and vicinity, but this area is within the known distribution range for this species. Beaked whales may be expected to occur in the area including and seaward of the shelf break (**Figure B-11**). There is a low or unknown occurrence of beaked whales on the shelf between the 50 m isobath and the shelf break, which takes into account that deep waters come very close to the shore in this area. In some locales, beaked whales can be found in waters over the shelf, so it is possible that beaked whales have similar habitat preferences here. Occurrence patterns are expected to be the same throughout the year.

Behavior and Life History—Observed group sizes for the Blainville's beaked whale are generally small, with single individuals or pairs being the most common (Jefferson et al. 1993). In the northern Bahamas, groups of one to seven individuals have been reported; groups in this area contain a number of adult female and juveniles, and it is rare for more than one adult male to be present (MacLeod et al. 2004). Most sightings are brief; these whales are often difficult to approach and they actively avoid aircraft and vessels (Würsig et al. 1998). Life history data for the Blainville's beaked whale are extremely limited. All species of beaked whales probably feed at or close to the bottom in deep oceanic waters, taking whatever suitable prey they encounter or feeding on whatever species are locally abundant (MacLeod et al. 2003). Analysis of stomach contents from captured and stranded individuals suggests that beaked whales are deep-diving animals, feeding by suction predominantly on mesopelagic fish and squid or deepwater benthic invertebrates (Mead 1989; Heyning and Mead 1996; Santos et al. 2001; MacLeod et al. 2003). *Mesoplodon* species feed on small cephalopods (Mead 1989; MacLeod et al. 2003). Dives exceeding 45 min and longer have been documented for Blainville's beaked whales (Jefferson et al. 1993). Tagged Blainville's beaked whales have been recorded to dive to depths as great as 975 m (Baird et al. 2004; Johnson et al. 2004).

Acoustics and Hearing—MacLeod (1999) suggested that beaked whales use frequencies of between 300 Hz and 129 kHz for echolocation, and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication. Recently, an acoustic recording tag was attached to two Blainville's beaked whales in the Ligurian Sea (Johnson et al. 2004). This species was found to be highly vocal, producing high-frequency echolocation clicks with no significant energy below 20 kHz (Johnson et al. 2004). The source level of these clicks ranged from 200 to 220 dB re 1 µPa-m (Johnson et al. 2004). Madsen et al. (2005) reported interclick intervals of 300 to 400 ms.

There is no direct information available on the actual hearing abilities of beaked whales (MacLeod 1999). Beaked whale ears are predominantly adapted to hear ultrasonic frequencies (MacLeod 1999). Based on the anatomy of the ears of beaked whales, these species may be more sensitive than other cetaceans to low frequency sounds; however, as noted earlier, there is no direct evidence to support this idea (MacLeod 1999).

- Ginkgo-toothed Whale (*Mesoplodon ginkgodens*)

Description—The maximum known sizes for ginkgo-toothed whales are 4.9 m for females and 4.8 m for males (Jefferson et al. 1993). All *Mesoplodon* species have a relatively small head, large thorax and abdomen, and short tail. *Mesoplodon* species all have a pair of throat grooves on the ventral side of the head on the lower jaw. Adult male ginkgo-toothed whales appear to be dark gray over the entire body with a faint light patch on the anterior half of the rostrum and lower jaw, while females are apparently lighter in color (Mead 1989). They are not as heavily scarred as are other *Mesoplodon* spp. Beaked whales in the genus *Mesoplodon* are characterized by the presence of a single pair of sexually dimorphic tusks, which erupt only in adult males. In the ginkgo-toothed beaked whale, the tusks of males are wide and flattened with a small denticle at their apex (Mead 1989).

Status—There are no abundance estimates for the ginkgo-toothed beaked whale in this area. The ginkgo-toothed beaked whale is designated as data deficient on the IUCN Red List (Reeves et al. 2003).

Habitat Preferences—Beaked whales normally inhabit deep ocean waters (>2,000 m) or continental slopes (200 to 2,000 m), and only rarely stray over the continental shelf (Pitman 2002). Palacios (1996) suggested based on stranding records in the eastern Pacific Ocean, that this species may select relatively cool, upwelling-modified habitats, such as those found in the California and Perú Currents and along the equatorial front.

Distribution—The ginkgo-toothed whale is known only from strandings (there are no confirmed sightings) in temperate and tropical waters of the Pacific and Indian Oceans (Mead 1989; Palacios 1996).

- Information Specific to the Marianas MRA Study Area—There are no occurrence records for this species in the Marianas study area and vicinity, but this area is within the known distribution range for this species. Beaked whales may be expected to occur in the area including and seaward of the shelf break (**Figure B-11**). There is a low or unknown occurrence of beaked whales on the shelf between the 50 m isobath and the shelf break, which takes into account that deep waters come very close to the shore in this area. In some locales, beaked whales can be found in waters over the shelf, so it is possible that beaked whales have similar habitat preferences here. Occurrence patterns are expected to be the same throughout the year. Very little is known about the distribution of this species. What is known of its range suggests any records in the Marianas MRA study area and vicinity would be rare (Jefferson personal communication).

Behavior and Life History—Little life history data is available for the ginkgo-toothed whale. Durations of long dives for *Mesoplodon* species are over 20 min (Barlow 1999; Baird et al. 2004). All species of beaked whales probably feed at or close to the bottom in deep oceanic waters, taking whatever suitable prey they encounter or feeding on whatever species are locally abundant (MacLeod et al. 2003). Analysis of stomach contents from captured and stranded individuals suggests that beaked whales are deep-diving animals, feeding by suction predominantly on mesopelagic fish and squid or deepwater benthic invertebrates (Mead 1989; Heyning and Mead 1996; Santos et al. 2001; MacLeod et al. 2003).

Acoustics and Hearing—MacLeod (1999) suggested that beaked whales use frequencies of between 300 Hz and 129 kHz for echolocation, and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication. There is no information available for ginkgo-toothed whale vocalizations.

There is no direct information available on the actual hearing abilities of beaked whales (MacLeod 1999). Beaked whale ears are predominantly adapted to hear ultrasonic frequencies (MacLeod 1999). Based on the anatomy of the ears of beaked whales, these species may be more sensitive than other cetaceans to low frequency sounds; however, as noted earlier, there is no empirical evidence to support this idea (MacLeod 1999).

♦ <u>Hubbs' Beaked Whale</u> (*Mesoplodon carlhubbsi*)

Description—The body and head shape of the Hubbs' beaked whale is typical of other *Mesoplodon* species. All *Mesoplodon* species have a relatively small head, large thorax and abdomen, and short tail. The Hubbs' beaked whale is medium-sized, reaching a maximum length of about 5.3 m and a weight of approximately 1,500 kg (Mead et al. 1982). The body coloration is medium to dark gray, with the underside of the flukes lighter than the dorsal side (Mead et al. 1982). The most prominent external feature of this species is the pigmentation of the head, particularly in the adult male, which has a white rostrum and a white "skull cap" or "beanie" in the melon in front of and around the blowhole (Mead et al. 1982). *Mesoplodon* species all have a pair of throat grooves on the ventral side of the head on the lower jaw. Beaked whales in the genus *Mesoplodon* are characterized by the presence of a single pair of sexually dimorphic tusks, which erupt only in adult males. The male Hubbs' beaked whale has a massive flattened tusk in the middle of each side of the lower jaw, which protrudes above the level of the upper jaw (Heyning 1984).

Status—There are no abundance estimates available for the Hubbs' beaked whale in this area. The Hubbs' beaked whale is designated as data deficient on the IUCN Red List (Reeves et al. 2003).

Habitat Preferences—Beaked whales normally inhabit deep ocean waters (>2,000 m) or continental slopes (200 to 2,000 m), and only rarely stray over the continental shelf (Pitman 2002). Along the Pacific Coast of the North America, the distribution of this species corresponds with the dilute and upwelling domains on the surface and with the confluence of the subarctic current and the California Current systems at depth (Mead et al. 1982).

Distribution—The Hubbs' beaked whale appears to be restricted to the North Pacific Ocean (Mead et al. 1982; Houston 1990; MacLeod et al. in press). Nearly all records to date have been strandings along the west coast of North America and in Japan. However, there have also been several sightings in relatively nearshore waters of the Pacific Northwest, and MacLeod et al. (in press) speculated that the distribution might actually be continuous across the North Pacific between about 30° and 45°N. This, however, remains to be confirmed.

- <u>Information Specific to the Marianas MRA Study Area</u>—There are no occurrence records for this species in the Marianas study area and vicinity, but this area is within the known distribution range for this species. Beaked whales may be expected to occur in the area including and seaward of the shelf break (**Figure B-11**). There is a low or unknown occurrence of beaked whales on the shelf between the 50 m isobath and the shelf break, which takes into account that deep waters come very close to the shore in this area. In some locales, beaked whales can be found in waters over the shelf, so it is possible that beaked whales have similar habitat preferences here. Occurrence patterns are expected to be the same throughout the year. The range of the Hubbs' beaked whale is not well-known. While it is possible that this species could occur in the Marianas MRA study area and vicinity, its apparent preference for colder waters suggests that any occurrence would be extralimital.

Behavior and Life History—Life history data for the Hubbs' beaked whale are extremely limited. Calving in this species most probably takes place in summer (Mead et al. 1982; Willis and Baird 1998b).

Durations of long dives for *Mesoplodon* species are over 20 min (Barlow 1999; Baird et al. 2004). All species of beaked whales probably feed at or close to the bottom in deep oceanic waters, taking whatever suitable prey they encounter or feeding on whatever species are locally abundant (MacLeod et al. 2003). Analysis of stomach contents from captured and stranded individuals suggests that beaked whales are deep-diving animals, feeding by suction predominantly on mesopelagic fish and squid or deepwater benthic invertebrates (Mead 1989; Heyning and Mead 1996; Santos et al. 2001; MacLeod et al. 2003). Stomach contents of a stranded Hubbs' beaked whale consisted of squid beaks, fish otoliths, and fish bones (Mead et al. 1982).

Acoustics and Hearing—MacLeod (1999) suggested that beaked whales use frequencies of between 300 Hz and 129 kHz for echolocation, and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication. Vocalizations recorded from two juvenile Hubbs' beaked whales consisted of low and high frequency click trains ranging in frequency from 300 Hz to 80 kHz and whistles with a frequency range of 2.6 to 10.7 kHz and duration of 156 to 450 msec (Lynn and Reiss 1992; Marten 2000).

There is no direct information available on the exact hearing abilities of beaked whales (MacLeod 1999). Beaked whale ears are predominantly adapted to hear ultrasonic frequencies (MacLeod 1999). Based on the anatomy of the ears of beaked whales, these species may be more sensitive than other cetaceans to low frequency sounds; however, as noted earlier, there is no empirical evidence to support this idea (MacLeod 1999). There are no hearing data available for the Hubbs' beaked whale.

♦ Longman's Beaked Whale (*Indopacetus pacificus*)

Description—This species was often referred to as the "tropical bottlenose whale" in the past. This was due to the fact that whales now known to be of this species had been sighted in various locations in the tropical/subtropical Indo-Pacific but not identified to species (Pitman et al. 1999). At the time, this species was known only from a handful of skulls, and the external appearance of the species was undescribed. Until several stranded specimens were identified as Longman's beaked whales based on skull morphology and genetics (Dalebout et al. 2003), the sighted whales were thought to be members of the *Hyperoodon* genus (either far-ranging southern bottlenose whales or possibly an undescribed tropical species). We now know these animals to be Longman's beaked whales. The Longman's beaked whale looks very much like the southern bottlenose whale (*Hyperoodon planifrons*) in general shape and coloration, though is more slender (Pitman et al. 1999; Dalebout et al. 2003). The estimated adult length is 7 to 8 m (Pitman et al. 1999). The tall, falcate dorsal fin is set far back on the body (Pitman et al. 1999; Dalebout et al. 2003). The head has a well-rounded melon in profile and the beak length is variable, suggesting developmental changes in beak size (Pitman et al. 1999; Dalebout et al. 2003). This species has a single pair of teeth that are set close to the tip of the lower jaw; it is suspected that, like most other beaked whales species, only adult males will have erupted teeth (Dalebout et al. 2003). The body color has been described as variable but is dominated by tan to grayish-brown tones (Pitman et al. 1999). Young animals are distinctively patterned; they are darker gray-brown above with a conspicuous pale melon and white sides (Pitman et al. 1999). The light area on the head extends only as far back as the blowhole.

Status—Longman's beaked whale is considered to be a relatively rare beaked whale species (Pitman et al. 1999; Dalebout et al. 2003). There is no designation for this species on the IUCN Red List. There are no abundance estimates for this species in this area.

Habitat Preferences—Beaked whale abundance off the eastern U.S. may be highest in association with the Gulf Stream and associated warm-core rings (Waring et al. 1992). In summer, beaked whales use the shelf edge region off the northeast U.S. as primary habitat (Waring et al. 2001). Ferguson et al. (2001) noted that offshore waters beyond the continental slope are not often identified as beaked whale habitat, yet this may be a function of lack of survey effort rather than a reflection of the animals' true habitat. Longman's beaked whale appears to have a preference for warm tropical water, with most sightings occurring in waters with a SST warmer than 26ºC (Pitman et al. 1999).

Distribution—Beaked whales normally inhabit deep ocean waters (>2,000 m) or continental slopes (200 to 2,000 m), and only rarely stray over the continental shelf (Pitman 2002). Longman's beaked whale is known from tropical waters of the Pacific and Indian Oceans (Pitman et al. 1999; Dalebout et al. 2003). Ferguson and Barlow (2001) reported that all Longman's beaked whale sightings were south of 25ºN.

➢ Information Specific to the Marianas MRA Study Area—There are no occurrence records for this species in the Marianas study area and vicinity, but this area is within the known distribution range for this species. Beaked whales may be expected to occur in the area including around seaward of the shelf break (**Figure B-11**). There is a low or unknown occurrence of beaked whales on the shelf between the 50 m isobath and the shelf break, which takes into account that deep waters come very close to the shore in this area. In some locales, beaked whales can be found in waters over the shelf, so it is possible that beaked whales have similar habitat preferences here. Occurrence patterns are expected to be the same throughout the year. Longman's beaked whale is not as rare as previously thought. However, the frequency with which it has been sighted in the eastern and western tropical Pacific oceans (MacLeod et al. in press) suggests that it is probably not as common as the Cuvier's and *Mesoplodon* beaked whales (Ferguson et al. 2001).

Behavior and Life History—Groups are relatively large and range in size from one to 100 individuals; mean group size for this species is 18.5 individuals (Pitman et al. 1999). There is no available information on life history for Longman's beaked whale (Dalebout et al. 2003).

All species of beaked whales probably feed at or close to the bottom in deep oceanic waters, taking whatever suitable prey they encounter or feeding on whatever species are locally abundant (MacLeod et al. 2003). There is no information available regarding feeding behavior and preferred prey of the Longman's beaked whale. Analysis of stomach contents from captured and stranded individuals suggests that beaked whales are deep-diving animals, feeding by suction predominantly on mesopelagic fish and squid or deepwater benthic invertebrates (Mead 1989; Heyning and Mead 1996; Santos et al. 2001; MacLeod et al. 2003). Individual dive times of 18 and 25 min have been reported for this species (Gallo-Reynoso and Figueroa-Carranza 1995).

Acoustics and Hearing—MacLeod (1999) suggested that beaked whales use frequencies of between 300 Hz and 129 kHz for echolocation, and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication. There is no information available for Longman's beaked whale vocalizations.

There is no direct information available on the exact hearing abilities of beaked whales (MacLeod 1999). Beaked whale ears are predominantly adapted to hear ultrasonic frequencies (MacLeod 1999). Based on the anatomy of the ears of beaked whales, these species may be more sensitive than other cetaceans to low frequency sounds; however, as noted earlier, there is no direct evidence to support this idea (MacLeod 1999).

♦ Rough-toothed Dolphin (*Steno bredanensis*)

Description—This is a relatively robust dolphin with a cone-shaped head and the only one with no demarcation between the melon and beak (Jefferson et al. 1993). The "fore-head" slopes smoothly from the blowhole onto the long narrow neck (Reeves et al. 2002). The rough-toothed dolphin has large flippers that are set far back on the sides and a prominent falcate dorsal fin (Jefferson et al. 1993). The body is dark gray, with a prominent narrow dorsal cape that dips slightly down onto the side below the dorsal fin. The lips and much of the lower jaw are white, and many individuals have white scars. The rough-toothed dolphin reaches 2.8 m in length (Jefferson et al. 1993).

Status—The rough-toothed dolphin is designated as data deficient on the IUCN Red List (Reeves et al. 2003). There are no abundance estimates for this species in this area. Rough-toothed dolphins are common in tropical areas, but not nearly as abundant as some other dolphin species (Reeves et al. 2002). Nothing is known about stock structure for the rough-toothed dolphin in the North Pacific (Carretta et al. 2004).

Habitat Preferences—The rough-toothed dolphin is regarded as an offshore species that prefers deep waters; however, it can occur in waters with variable bottom depths (e.g., Gannier and West 2005). It rarely occurs close to land, except around islands with steep drop-offs nearshore (Reeves et al. 2002; Gannier and West 2005). In the Gulf of Mexico, the rough-toothed dolphin occurs primarily over the deeper waters off the continental shelf (bottom depths of 950 to 1,100 m) (Davis et al. 1998), though off the Florida panhandle, they can be found over the continental shelf (Fulling et al. 2003). In some regions, this species may regularly frequent coastal waters and areas with shallow bottom depths. For example, there are reports of rough-toothed dolphins over the continental shelf in shallow waters around La Gomera, Canary Islands (Ritter 2002), Puerto Rico and the Virgin Islands (Mignucci-Giannoni 1998), and in coastal waters off Brazil, including even in a lagoon system (Flores and Ximenez 1997; Lodi and Hetzel 1999). At the Society Islands, rough-toothed dolphins were sighted in waters with a bottom depth less than 100 m to over 3,000 m, although apparently favoring the 500 to 1,500 m range (Gannier 2000).

Distribution—Rough-toothed dolphins are found in tropical to warm-temperate waters globally, rarely ranging north of 40ºN or south of 35ºS (Miyazaki and Perrin 1994).

- Information Specific to the Marianas MRA Study Area—As an oceanic species, the rough-tooth dolphin is expected to occur from the shelf break to seaward of the Marianas study area (**Figure B-12**). There is also a low or unknown occurrence of rough-toothed dolphins from the coastline (including harbors and lagoons) to the shelf break (**Figure B-12**), which takes into consideration the possibility of encountering this species in more shallow waters, based on distribution patterns for this species in other tropical locales. Occurrence patterns are expected to be the same throughout the year.

Behavior and Life History—Small groups of 10 to 20 rough-toothed dolphins are most common, with herds up to 50 animals reported (Miyazaki and Perrin 1994; Reeves et al. 1999). Rough-toothed dolphins often associate with other cetacean species (Miyazaki and Perrin 1994; Nekoba-Dutertre et al. 1999; Ritter 2002; Wedekin et al. 2004). In the Society and Marquesas Islands, rough-toothed dolphins are sometimes sighted in association with large schools of melon-headed whales and Fraser's dolphins, short-finned pilot whales, as well as with humpback whales (Gannier 2000, 2002; Gannier and West 2005). Rough-toothed dolphins tend to associate with floating objects in the eastern tropical Pacific and Gulf of Mexico (Pitman and Stinchcomb 2002; Fulling et al. 2003). Cephalopods and fish, including large fish such as dorado, are prey (Miyazaki and Perrin 1994; Reeves et al. 1999; Pitman and Stinchcomb 2002). Reef fish are also preyed upon; Perkins and Miller (1983) noted that parts of reef fish had been found in the stomachs of stranded rough-toothed dolphins in Hawai'i. Gannier and West (2005) observed rough-toothed dolphins feeding during the daytime on epipelagic fishes, including flying fishes. Rough-toothed dolphins are known to interact with fisheries in tropical areas, for example, pulling fish from longlines (Nitta and Henderson 1993; Nekoba-Dutertre et al. 1999; Poole personal communication). Female rough-toothed dolphins reach sexual maturity between 4 and 6 years of age; males attain sexual maturity between 5 and 10 years (Mead et al. 2001). Rough-toothed dolphins may stay submerged for up to 15 min and are known to dive as deep as 70 m, but can probably dive much deeper (Miyazaki and Perrin 1994).

Acoustics and Hearing—The vocal repertoire of the rough-toothed dolphin includes broad-band clicks, barks, and whistles (Yu et al. 2003). Echolocation clicks of rough-toothed dolphins are in the frequency range of 0.1 to 200 kHz, with a peak of about 25 kHz (Miyazaki and Perrin 1994; Yu et al. 2003). Whistles show a wide frequency range: 0.3 to >24 kHz (Yu et al. 2003). There is no published information on hearing ability of this species.

- Common and Indo-Pacific Bottlenose Dolphins (*Tursiops truncatus* and *Tursiops aduncus*, respectively)

Description—Bottlenose dolphins (genus *Tursiops*) are medium-sized, relatively robust dolphins that vary in color from light gray to charcoal. *Tursiops* is named for its short, stocky snout that is distinctively set off from the melon by a crease (Jefferson et al. 1993). There is striking regional variation in body size; adult body length ranges from 1.9 to 3.8 m (Jefferson et al. 1993).

The taxonomy of *Tursiops* continues to be in flux; two species are currently recognized, the common bottlenose dolphin (*Tursiops truncatus*) and the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) (Rice 1998; IWC 2004), with additional species likely to be recognized with more genetic analyses

(Natoli et al. 2004). Indo-Pacific bottlenose dolphins can be distinguished from the common bottlenose dolphin using genetic, osteological, and external morphology data (Wang et al. 1999, 2000a, 2000b). Both species occur as two morphotypes (or forms): a nearshore (coastal) and an offshore form (Hersh and Duffield 1990; Hoelzel et al. 1998). There is a clear distinction between the nearshore and offshore form of the bottlenose dolphin in the western North Atlantic and western North Pacific suggesting that the two forms may be eventually considered two different species (Curry and Smith 1997; Hoelzel et al. 1998; Kingston and Rosel 2004).

Status—Bottlenose dolphins are designated as data deficient on the IUCN Red List (Reeves et al. 2003). Nothing is known of stock structure around the Marianas. The only estimate of abundance of bottlenose dolphins for the region around the study area is an estimate of 31,700 animals for the area north of the Marianas (Miyashita 1993), which may possibly coincide with the stock of offshore bottlenose dolphins that occurs around the Marianas.

Habitat Preferences—*Tursiops* live in coastal areas of all continents (except Antarctica), around many oceanic islands and atolls, and over shallow offshore banks and shoals. In the eastern tropical Pacific and elsewhere there are pelagic populations that range far from land (Scott and Chivers 1990; Reeves et al. 2002). The common bottlenose dolphin has a wider range than the Indo-Pacific bottlenose dolphin; it ranges beyond the tropics and subtropics into temperate waters (Reeves et al. 2002). One satellite-tagged common bottlenose dolphin in the western North Atlantic moved into waters with a bottom depth greater than 5,000 m (Wells et al. 1999). The Indo-Pacific bottlenose dolphin is common in shallow water within 1 km of shore; individuals are seen regularly just seaward of the surf zone and in clear water just outside turbid estuarine plumes (Reeves et al. 2002).

Risk of predation and food availability influence bottlenose dolphin habitat use (Shane et al. 1986; Wells et al. 1987; Allen et al. 2001; Heithaus and Dill 2002). Predation risk is determined by the number of predators in an area, the ability of predators and prey to detect each other, and the probability of capture after detection; predation risk can be influenced by a suite of habitat attributes, such as water clarity and depth (Heithaus 2001).

Distribution—The overall range of *Tursiops* is worldwide in tropical to temperate waters. *Tursiops* generally do not range poleward of 45º, except around the United Kingdom and northern Europe (Jefferson et al. 1993). The common bottlenose dolphin has been recorded in tropical to temperate regions throughout the world. The Indo-Pacific bottlenose dolphin is reported throughout much of the warm temperate and tropical Indian Ocean and western Pacific Ocean. In the western North Pacific, this species occurs from southern Japan southward (including the Taiwan Strait), in the subtropical western South Pacific, in much of the Indonesian archipelago, along the north coast of Australia between New South Wales and Western Australia, and along the entire rim of the Indian Ocean to South Africa, including the Persian Gulf and Red Sea (Reeves et al. 2002). Both the common bottlenose dolphin and the Indo-Pacific bottlenose dolphin occur in the Indo-Pacific region.

Bottlenose dolphins found in nearshore waters around the main Hawaiian Islands are island-associated, with all sightings occurring in relatively nearshore and shallow waters (<200 m), and no apparent movement between the islands (Baird et al. 2002, 2003a). Baird et al. (2003a) noted the possibility of a second population of bottlenose dolphins in the Hawaiian Islands, based on sighting data, with a preference for deeper (bottom depth of 400 to 900 m) waters.

Climate changes can contribute to range extensions. For example, 600 km northward range extension to Monterey Bay (for some bottlenose dolphins known from the San Diego, California, area) was linked to the 1982/1983 El Niño event (Wells et al. 1990). Some dolphins remain to this day in the northern waters following return to normal water temperatures, suggesting that the dolphins might have responded more to secondary effects of the warm-water incursion, such as changes in prey distribution, than to the temperature changes themselves (Wells and Scott 1999).

- Information Specific to the Marianas MRA Study Area—There are no occurrence records for this species in the Marianas study area and vicinity, but this area is within the known distribution range for this species. Identification to species for *Tursiops* can be difficult for the inexperienced observer. However, any occurrence of bottlenose dolphins in the Marianas study area would likely be of the common bottlenose dolphin (Jefferson personal communication; Perrin personal communication). Miyashita (1993) reported that all his sightings of bottlenose dolphins in the western Pacific were of a larger, unspotted type (presumably the common bottlenose dolphin, as opposed to the Indo-Pacific bottlenose dolphin). The Indo-Pacific bottlenose dolphin is considered to be a species associated with continental margins, as it does not appear to occur around offshore islands great distances from a continent, such as the Marianas (Jefferson personal communication). However, since the Indo-Pacific bottlenose dolphin occurs directly west and to the south of the Marianas study area, there is the possibility of extralimital occurrences of this species.

Bottlenose dolphins are expected to occur from the coastline to the 2,000 m isobath (**Figure B-13**), which takes into consideration the known habitat preferences of *Tursiops* globally. Individuals are expected to occur in both harbors and lagoons based on observations worldwide in similar habitats. There is a low or unknown occurrence of the bottlenose dolphin seaward of the 2,000 m isobath (**Figure B-13**). This pattern takes into account possible movement by bottlenose dolphins between the CNMI chain, as well as sightings globally in deep waters. Occurrence patterns are expected to be the same throughout the year.

Interestingly, there are no stranding records available for this species in the Marianas study area and vicinity, and only a mention by Trianni and Kessler (2002) that bottlenose dolphins are seen in coastal waters of Guam. It is possible that bottlenose dolphins do not occur in great numbers in this island chain. Gannier (2002) attributed the fact that large densities of bottlenose dolphins do not occur at the Marquesas Islands to the fact that the area does not have a significant shelf component. A similar situation could be occurring in the Marianas MRA study area and vicinity.

Behavior and Life History—*Tursiops* are very gregarious; they are typically found in groups of 2 to 15 individuals, although groups of up to 100 or more have been reported in some areas (Shane et al. 1986). Based on photo-identification techniques using dorsal fin shapes and markings (Würsig and Würsig 1977; Würsig and Jefferson 1990), it is well known that *Tursiops* has a fluid social organization (Connor et al. 2000). Habitat structure, in terms of complexity and water depth, is generally a major force that shapes *Tursiops* groupings (Shane et al. 1986). Shallow-water areas typically have smaller group sizes than open or oceanic areas (Wells et al. 1980). Open coastlines, however, differ in habitat structure and prey distribution from more protected areas. Protected areas have been found to foster relatively small school sizes, some degree of regional site fidelity, and limited movement patterns (Wells et al. 1987). In contrast, semi-open habitats often sustain larger school sizes, diminished levels of site fidelity, and more expansive home ranges (Defran and Weller 1999). In waters of the eastern tropical Pacific, group size estimates range into the thousands, and herds of over 100 are not uncommon (Scott and Chivers 1990). In the tropical Pacific, bottlenose dolphin groups around offshore islands and near coastlines average between 72 and 94 individuals, and groups in more offshore locations average around 40 to 44 dolphins (Scott and Chivers 1990).

Along the Atlantic coast of the U.S., where the majority of detailed work on bottlenose dolphins has been conducted, male and female bottlenose dolphins reach physical maturity at 13 years, with females reaching sexual maturity as early as 7 years (Mead and Potter 1990). Bottlenose dolphins are flexible in their timing of reproduction. Seasons of birth for bottlenose dolphin populations are likely responses to seasonal patterns of availability of local resources (Urian et al. 1996). For the same central U.S. Atlantic coast areas, Hohn (1980) reported one (spring) and possibly two calving seasons (spring and fall), whereas Mead and Potter (1990) reported a prolonged calving season with a spring peak. There is a gestation period of one year (Caldwell and Caldwell 1972). Calves of bottlenose dolphins typically remain with their mothers for 3 to 6 years (Wells et al. 1987). In the Pacific, there is clearly much geographical variation among various coastal and offshore populations (Walker 1981; Kasuya et al. 1997). In Japanese waters, calves are born at a length of around 128 cm, with a calving peak in June (Kasuya et al. 1997). Sexual maturity appears to be reached at similar ages as in the Atlantic (5 to 13 years for females and 9 to 11+ for males; Kasuya et al. 1997).

Tursiops are opportunistic feeders, taking a wide variety of fishes, cephalopods, and shrimp (Wells and Scott 1999) using a wide variety of feeding strategies (Shane 1990). In addition to use of active echolocation to find food, bottlenose dolphins likely detect and orient to fish prey by listening for the sounds they produce – so-called passive listening (Barros and Myrberg 1987; Gannon et al. 2005). Nearshore bottlenose dolphins prey predominately on coastal fish and cephalopods, while offshore individuals prey on pelagic cephalopods and a large variety of epi- and mesopelagic fish species (Walker 1981; Van Waerebeek et al. 1990; Mead and Potter 1995).

Navy bottlenose dolphins have been trained to reach maximum diving depths of about 300 m (Ridgway et al. 1969). Reeves et al. (2002) noted that the presence of deep-sea fish in the stomachs of some offshore individual bottlenose dolphins suggests that they dive to depths of more than 500 m. Dive durations up to 15 min have been recorded for trained individuals (Ridgway et al. 1969). Typical dives, however, are more shallow and of a much shorter duration.

Acoustics and Hearing—Sounds emitted by bottlenose dolphins have been classified into two broad categories: pulsed sounds (including clicks and burst-pulses) and narrow-band continuous sounds (whistles), which usually are frequency-modulated. Clicks and whistles have a dominant frequency range of 110 to 130 kHz and a source level of 218 to 228 dB re 1 µPa-m (Au 1993) and 3.5 to 14.5 kHz and 125 to 173 dB re 1 µPa-m, respectively (Ketten 1998). Generally, whistles range in frequency from 0.8 to 24 kHz (Thomson and Richardson 1995).

The bottlenose dolphin has a functional high-frequency hearing limit of 160 kHz (Au 1993) and can hear sounds at frequencies as low as 40 to 125 Hz (Turl 1993). Inner ear anatomy of this species has been described (Ketten 1992). Electrophysiological experiments suggest that the bottlenose dolphin brain has a dual analysis system: one specialized for ultrasonic clicks and the other for lower-frequency sounds, such as whistles (Ridgway 2000). The audiogram of the bottlenose dolphin shows that the lowest thresholds occurred near 50 kHz at a level around 45 dB re 1 µPa-m (Nachtigall et al. 2000). Below the maximum sensitivity, thresholds increased continuously up to a level of 137 dB at 75 Hz. Above 50 kHz, thresholds increased slowly up to a level of 55 dB at 100 kHz, then increased rapidly above this to about 135 dB at 150 kHz. Scientists have reported a range of best sensitivity between 25 and 70 kHz, with peaks in sensitivity occurring at 25 and 50 kHz at levels of 47 and 46 dB re 1 µPa-m (Nachtigall et al. 2000). Richardson (1995) noted that the differences between the reported audiograms for these two studies might be attributable in part due to conducting the experiments in tanks. A neurophysiological method was used to determine the high-frequency audiograms (5 to 200 kHz) of five bottlenose dolphins (Richardson 1995). Temporary threshold shifts (TTS) in hearing have been experimentally induced in captive bottlenose dolphins (Ridgway et al. 1997; Schlundt et al. 2000; Nachtigall et al. 2003). Ridgway et al. (1997) observed changes in behavior at the following minimum levels for 1 sec tones: 186 dB at 3 kHz, 181 dB at 20 kHz, and 178 dB at 75 kHz (all re 1 µPa-m). TTS levels were 194 to 201 dB at 3 kHz, 193 to 196 dB at 20 kHz, and 192 to 194 dB at 75 kHz (all re 1 µPa-m). Schlundt et al. (2000) exposed bottlenose dolphins to intense tones (0.4, 3, 10, 20, and 75 kHz); the animals demonstrated altered behavior at source levels of 178 to 193 dB re 1 µPa-m, with TTS after exposures generally between 192 and 201 dB re 1 µPa-m (though one dolphin exhibited TTS after exposure at 182 dB re 1 µPa-m). Nachtigall et al. (2003) determined threshold for a 7.5 kHz pure tone stimulus. No shifts were observed at 165 or 171 dB re 1 µPa-m, but when the noise level reached 179 dB re 1 µPa-m, the animal showed the first sign of TTS. Recovery apparently occurred rapidly, with full recovery apparently within 45 min following noise exposure. TTS measured between 8 and 16 kHz (negligible or absent at higher frequencies) after 30 minutes of noise exposure (4 to 11 kHz) at 160 dB re 1 µPa-m (Nachtigall et al. 2004).

- Pantropical Spotted Dolphin (*Stenella attenuata*)

Description—The pantropical spotted dolphin is a generally slender dolphin. This species has a dark dorsal cape, while the lower sides and belly of adults are gray. The beak is long and thin; the lips and beak tend to be bright white. A dark gray band encircles each eye and continues forward to the apex of the melon; there also is a dark gape-to-flipper stripe (Jefferson et al. 1993). Pantropical spotted dolphins are born spotless and develop spots as they age, although the degree of spotting varies geographically (Perrin and Hohn 1994). Adults may reach 2.6 m in length (Jefferson et al. 1993).

Status—Pantropical spotted dolphins may have several stocks in the western Pacific (Miyashita 1993), although this is not confirmed at present. There are estimated to be about 127,800 spotted dolphins in the waters surrounding the Mariana Islands (Miyashita 1993). This species is designated as lower risk on the IUCN Red List (Reeves et al. 2003). Three subspecies are recognized in the Pacific Ocean. One inhabits nearshore waters around the Hawaiian Islands, another occurs in offshore waters of the eastern tropical Pacific, and a third occurs in coastal waters between Baja California and the northwestern coast of South America (Reeves et al. 2002).

Habitat Preferences—In the eastern Pacific, the pantropical spotted dolphin is an inhabitant of the tropical, equatorial and southern subtropical water masses, characterized by a sharp thermocline at less than 50 m depth, surface temperatures greater than 25ºC and salinities less than 34 ppt (Au and Perryman 1985). Most sightings of this species in the Gulf of Mexico and Caribbean occur over the lower continental slope (Davis et al. 1998; Mignucci-Giannoni et al. 2003). Pantropical spotted dolphins may also be sighted in shallow waters near the edge of the continental shelf (Peddemors 1999; Gannier 2002).

Distribution—The pantropical spotted dolphin is distributed in tropical and subtropical waters worldwide (Perrin and Hohn 1994). Range in the central Pacific is from the Hawaiian Islands in the north to at least the Marquesas in the south (Perrin and Hohn 1994).

- <u>Information Specific to the Marianas MRA Study Area</u>—The pantropical spotted dolphin is primarily an oceanic species (Jefferson et al. 1993). Based on the known habitat preferences of the pantropical spotted dolphin, this species is expected to occur seaward of the shelf break (200 m isobath) (**Figure B-14**). Low or unknown occurrence of the pantropical spotted dolphin from the coastline (except in harbors and lagoons) to the shelf break (**Figure B-14**) is based on sightings of pantropical spotted dolphins being reported in coastal waters of Guam by Trianni and Kessler (2002) and coastal populations of pantropical spotted dolphins in tropical locations, such as off Central America and Hawai'i. Occurrence patterns are assumed to be the same throughout the year.

Behavior and Life History—Group size for the pantropical spotted dolphin may range from just a few dolphins to several thousand (Jefferson et al. 1993). Observations of dolphin groups caught in tuna purse seines in the eastern tropical Pacific show that there are subgroups containing mother/calf pairs, adult males, or juveniles (Pryor and Shallenberger 1991). Pantropical spotted dolphins in the eastern tropical Pacific Ocean and Indian Ocean are often found in mixed species aggregations that include spinner dolphins, tunas, and various oceanic bird species. In the eastern tropical Pacific, where this species has been best studied, there are two calving peaks–one in spring and one in fall (Perrin and Hohn 1994). Pantropical spotted dolphins prey on epipelagic fish, squid, and crustaceans, with mesopelagic species dominating stomach contents (Perrin and Hohn 1994; Robertson and Chivers 1997; Wang et al. 2003). Results from various tracking and food habit studies suggest that pantropical spotted dolphins in the eastern tropical Pacific and off Hawai'i feed primarily at night on epipelagic species and on mesopelagic species which rise towards the water's surface after dark (Robertson and Chivers 1997; Scott and Cattanach 1998; Baird et al. 2001). Dives during the day are generally shorter and more shallow than dives at night; rates of descent and ascent are higher at night than during the day (Baird et al. 2001). Similar mean dive durations and depths have been obtained for tagged pantropical spotted dolphins in the eastern tropical Pacific and off Hawai'i (Baird et al. 2001).

Acoustics and Hearing—Pantropical spotted dolphin whistles have a dominant frequency range of 6.7 to 17.8 kHz (Ketten 1998). Click source levels between 197 and 220 dB have been recorded for pantropical spotted dolphins (Schotten et al. 2004). There are no published hearing data for pantropical spotted dolphins (Ketten 1998). Anatomy of the ear of the pantropical spotted dolphin has been studied (Ketten 1992, 1997).

♦ Spinner Dolphin (*Stenella longirostris*)

Description—This is a slender dolphin that has a very long, slender beak (Jefferson et al. 1993). The dorsal fin ranges from slightly falcate to triangular or even canted forward. The spinner dolphin generally has a dark eye-to-flipper stripe and dark lips and beak tip (Jefferson et al. 1993). This species typically has a three-part color pattern (dark gray cape, light gray sides, and white belly). Adults can reach 2.4 m in length (Jefferson et al. 1993). There are four known subspecies of spinner dolphins, and probably other undescribed ones (Perrin 1998; Perrin et al. 1999). These include a globally-distributed nominal subspecies, which is probably the one that occurs in the Marianas (*S. l. longirostris*), as well as several forms with restricted distributions that almost certainly do not occur there (*S. l. orientalis*, *S. l. centroamerica*, and *S. l. roseiventris*).

Status—There are no estimates of abundance for the spinner dolphin in this area. The spinner is the most common species in the Marianas study area. This species is designated as lower risk on the IUCN Red List (Reeves et al. 2003).

Habitat Preferences—Spinner dolphins occur in both oceanic and coastal environments. Most sightings of this species have been associated with inshore waters, islands, or banks (Perrin and Gilpatrick 1994). Oceanic populations, such as those in the eastern tropical Pacific, often are found in waters with a shallow thermocline (Au and Perryman 1985; Reilly 1990). The thermocline concentrates pelagic organisms in and above it, upon which the dolphins feed. Spinner dolphins are associated with tropical surface water typified by extensive stable thermocline ridging and relatively little annual variation in surface temperature (Reeves et al. 1999). Coastal populations usually are found in island archipelagos, where they are tied to trophic and habitat resources associated with the coast (Norris and Dohl 1980; Poole 1995). Norris et al. (1994) suggested that the availability of prey and resting habitats are the primary limiting factors influencing the occurrence of spinner dolphins in Hawai'i. As noted by Lammers (2004), presumably these are the same constraints faced by populations at other islands.

Spinner dolphins at islands and atolls rest during daytime hours in shallow, wind-sheltered nearshore waters and forage over deep waters at night (Norris et al. 1994; Östman 1994; Poole 1995; Gannier 2000, 2002; Lammers 2004; Östman-Lind et al. 2004). Suitable habitat for resting includes bay complexes around islands (Poole 1995), or shallow waters near the coast (Lammers 2004); Lammers (2004) noted a preference for the 10 fathom isobath. It should be noted, however, that while certain bays or shoal areas are repeatedly occupied, others are only infrequently visited, or not occupied at all (Norris et al. 1985; Poole 1995). Spinner dolphins often rest in lagoons (Gannier 2000; Trianni and Kessler 2002). Preferred resting habitat is usually more sheltered from prevailing tradewinds than adjacent areas and the bottom substrate is generally dominated by large stretches of white sand bottom rather than the prevailing reef and rock bottom along most other parts of the coast (Norris et al. 1994; Lammers 2004). These clear, calm waters and light bottom substrates provide a less cryptic backdrop for predators like tiger sharks (Norris et al. 1994; Lammers 2004).

Distribution—The spinner dolphin is found in tropical and subtropical waters worldwide. Limits are near 40ºN and 40ºS (Jefferson et al. 1993). These dolphins occur near islands such as Hawai'i, the Mariana Islands, the South Pacific, the Caribbean, and Fernando de Noronha Island off Brazil. Spinner dolphins have been documented to travel distances of 40 km between islands in the main Hawaiian Islands (Maldini 2003). Long-term studies of island-associated spinner dolphins in the Pacific have been conducted since the 1970s along the Kona coast of Hawai'i (Norris et al. 1994; Östman 1994; Östman-Lind et al. 2004) and since the 1980s at Mo'orea, French Polynesia (Poole 1995). In Hawai'i, spinner dolphins occur along the leeward coasts of all the major islands and around several of the atolls northwest of the main island chain. Long-term site fidelity has been noted for spinner dolphins along the Kona coast of the island of Hawai'i, along O'ahu, and off the island of Moorea in the Society Islands (Norris et al. 1994; Östman 1994; Poole 1995; Marten and Psarakos 1999), with some individuals being sighted for up to 12 years at Moorea (Poole 1995).

- Information Specific to the Marianas MRA Study Area—The spinner dolphin is expected to occur throughout the entire Marianas study area and vicinity, except within Apra Harbor, where there is a low or unknown occurrence for this species (**Figure B-15**). Spinner dolphins are behaviorally sensitive and avoid areas with much anthropogenic usage, which is why it is unknown whether this species would occur in Apra Harbor. Lagoons are high-usage habitat for resting by spinner dolphins; spinner dolphin occurrence in at least Saipan and Cocos Lagoons would be concentrated (**Figure B-15**), with animals congregating during the day to rest (as they do in other locales, such as Hawai'i and French Polynesia). In the Mariana Islands, dolphins are reported in Saipan Lagoon at Saipan nearly every year (Trianni and Kessler 2002). Typically, these sightings are from the northern part of the lagoon, referred to as Tanapag Lagoon (Trianni and Kessler 2002). Spinner dolphins travel among the CNMI island chain (Trianni and Kessler 2002). Spinner dolphins are seen at FDM (DoN 2001; Trianni and Kessler 2002), Guam (Trianni and Kessler 2002), and at Rota (Michael personal communication). High-use areas at Guam include Bile Bay, Tumon Bay, Double Reef, north Agat Bay, and off Merizo (Cocos Lagoon area) (Eldredge 1991; Amesbury et al. 2001; Odell personal communication). With further research efforts, including boat and aerial surveys, it is likely that other areas of the Marianas study area and vicinity would be determined to be high-usage habitat. Occurrence patterns are assumed to be the same throughout the year.

Behavior and Life History—Group sizes range from less than 50 up to several thousand individuals (Jefferson et al. 1993). Reported group sizes in the Mariana Islands range from 1 to 120 individuals, with most groups consisting of less than 30 individuals (Trianni and Kessler 2002; Michael personal communication).

Social groupings in this species are typically very fluid in Hawaiian waters; large groups form, break up, and re-form with different subgroups throughout the day (Norris et al. 1994). In the offshore eastern tropical Pacific, there is some segregation by age and sex among dolphin groups (Perrin and Gilpatrick 1994). In contrast, Karczmarski et al. (2001) observed that at the isolated Midway Atoll, there were actually long-term bonds between individuals and the society was closed. Karczmarski et al. (2001) suggested that the difference in the overall society structure of spinner dolphins is caused by the variable influence of available resting places; at Midway Atoll, a lagoon is the only major resting site available.

In the eastern tropical Pacific and Indian Ocean, spinner dolphins are often seen with pantropical spotted dolphins and tuna (Perrin and Gilpatrick 1994; Ballance and Pitman 1998). Island-associated spinner dolphins, such as those at Hawai'i and Mo'orea, do not have tuna associated with them, at least not while the dolphins are in their daytime rest areas (Poole 1995). Island-associated spinner dolphins have been observed associating with bottlenose dolphins and pantropical spotted dolphins (Psarakos et al. 2003; Lammers 2004; Östman-Lind et al. 2004).

The studies of spinner dolphins along the island of Hawai'i provide the current framework for our understanding of spinner dolphin behavior and social organization; this was detailed first by Norris and Dohl (1980) and later by Norris et al. (1994), Östman (1994), and Lammers (2004). Spinner dolphins at different islands and atolls carry out their daily cycle in the same general behavior pattern in the sense that groups come into shallow waters to rest and socialize, and then move further offshore in the late afternoon or early evening to forage. There are typically groups of 20 to 100+ individual dolphins that enter the shallow waters in the morning and gradually descend into a state of lowered activity level for several hours (Norris and Dohl 1980; Norris et al. 1994; Östman 1994; Lammers 2004). Periods of rest are characterized by very cohesive group formations and an almost total absence of acoustic activity. In the late afternoon/early evening, following a period of renewed social activity, groups move offshore again towards their evening foraging grounds. The cycle is repeated almost daily, with the only seasonal changes being adjustments in the timing of events, which reflects shifts in day length. Similar patterns of spinner dolphin foraging and resting cycles also have observed at other island habitats such as Moorea in French Polynesia (Poole 1995), Midway atoll (Karczmarski et al. 2001), and off Brazil (Silva-Jr et al. 2004).

Spinner dolphins feed primarily on small mesopelagic fishes, squids, and sergestid shrimps, diving to at least 200 to 300 m (Perrin and Gilpatrick 1994). Foraging takes place primarily at night when the mesopelagic community migrates vertically towards the surface and also horizontally towards the shore at night (Benoit-Bird et al. 2001; Benoit-Bird and Au 2004). Rather than foraging offshore for the entire night, spinner dolphins track the horizontal migration of their prey (Benoit-Bird and Au 2003). This tracking of the prey allows spinner dolphins to maximize their foraging time while foraging on the prey at its highest densities (Benoit-Bird and Au 2003; Benoit-Bird 2004). Spinner dolphins begin foraging at a protruding bank, most likely because the prey layer enters shallow waters here before anywhere else along the coast (Lammers 2004). Spinner dolphins dive to meet the rising layer of prey organisms and forage cooperatively (Benoit-Bird and Au 2003). Life history of the spinner dolphin has been well-described for the eastern tropical Pacific Ocean, where the species is killed in large numbers in tuna purse seine nets (reviewed in Perrin 1998). Gestation lasts about 10 months, length of lactation is about 1 to 2 years, and sexual maturity occurs at lengths and ages of 1.65 to 1.70 m and 4 to 7 years (females) and 1.60 to 1.80 m and 7 to 10 years (males). There is some geographic variation, but other spinner dolphin populations probably have life history characteristics similar to those listed.

Sazima et al. (2003) and Silva Jr. et al. (2004) reported that spinner dolphins off northeast Brazil vomit after a meal rich in squid, and that reef fishes were observed feeding on this vomit. Würsig et al. (1994) did not report similar vomiting behavior for Hawaiian spinner dolphins, possibly due to their feeding primarily on fishes. Trianni and Kessler (2002) reported on a stranded individual in Saipan whose stomach was engorged with seagrass.

Spinner dolphins are well known for their propensity to leap high into the air and spin before landing in the water; the purpose of this behavior is unknown. Calving peaks in different spinner dolphin populations range from late spring to fall (Jefferson et al. 1993).

Acoustics and Hearing—Pulses, whistles, and clicks have been recorded from this species. Pulses and whistles have dominant frequency ranges of 5 to 60 kHz and 8 to 12 kHz, respectively (Ketten 1998). Spinner dolphins consistently produce whistles with frequencies as high as 16.9 to 17.9 kHz, with a maximum frequency for the fundamental component at 24.9 kHz (Bazúa-Durán and Au 2002; Lammers et al. 2003). Clicks have a dominant frequency of 60 kHz (Ketten 1998). The burst pulses are predominantly ultrasonic, often with little or no energy below 20 kHz (Lammers et al. 2003). Source levels between 195 and 222 dB have been recorded for spinner dolphin clicks (Schotten et al. 2004).

- Striped Dolphin (*Stenella coeruleoalba*)

Description—The striped dolphin is uniquely marked with black lateral stripes from eye to flipper and eye to anus. There is also a white V-shaped “spinal blaze” originating above and behind the eye and narrowing to a point below and behind the dorsal fin (Leatherwood and Reeves 1983). There is a dark cape and white belly. This is a relatively robust dolphin with a long, slender beak and prominent dorsal fin reaching 2.6 m in length.

Status—This species is designated as lower risk on the IUCN Red List (Reeves et al. 2003). The stock structure of striped dolphins in the western Pacific is poorly known, although there is evidence for more than one stock (Miyashita 1993). A putative population south of 30°N in the western Pacific was estimated to number about 52,600 dolphins, and this is probably the group from which any striped dolphins around the Marianas would come.

Habitat Preferences—Striped dolphins are usually found beyond the continental shelf, typically over the continental slope out to oceanic waters, often associated with convergence zones and waters influenced by upwelling (Au and Perryman 1985). In the eastern Pacific, striped dolphins inhabit areas with large seasonal changes in surface temperature and thermocline depth, as well as seasonal upwelling (Au and Perryman 1985; Reilly 1990). This species appears to avoid waters with sea temperatures of less than 20ºC (Van Waerebeek et al. 1998). Off the coast of Japan, striped dolphins congregate at the periphery of the Kuroshio Current where warm water meets up with cold water (Miyazaki et al. 1974). Gannier (1999) noted diel variations in distribution in the northwestern Mediterranean Sea consistent with nocturnal feeding by dolphins close to the shelf break with a diurnal offshore-inshore movement.

Distribution—The striped dolphin has a worldwide distribution in cool-temperate to tropical waters. This species is well documented in both the western and eastern Pacific off the coasts of Japan and North America (Perrin et al. 1994a); the northern limits are the Sea of Japan, Hokkaido, Washington state, and along roughly 40ºN across the western and central Pacific (Reeves et al. 2002). Scattered records exist from the South Pacific as well (Perrin et al. 1994a).

- Information Specific to the Marianas MRA Study Area—Striped dolphins are not common in most truly tropical areas (Jefferson personal communication). There is only one record of striped dolphin occurrence in the Marianas study area and vicinity—a stranding that occurred in July 1985 (Wilson et al. 1987; Eldredge 1991, 2003). Eldredge (1991) erroneously reported that additional records, aside from the stranding he documented, appeared in Wilson et al. (1987); it is actually the same record. There is a low or unknown occurrence of the striped dolphin in this area seaward of the 100 m isobath (**Figure B-16**), since this is an oceanic species. Occurrence patterns are assumed to be the same throughout the year.

Behavior and Life History—Striped dolphins are found in groups numbering between 100 and 500 individuals, though sometimes they gather in the thousands. Striped dolphins have been found in association with seabirds and other species of marine mammals (Baird et al. 1993).

Life history information is based mostly on western North Pacific specimens (Archer and Perrin 1999). Males reach sexual maturity between 7 and 15 years of age, at an average body length of 2.2 m. Females become sexually mature between 5 and 13 years of age (Archer and Perrin 1999). Off Japan, where their biology has been best studied, there are two calving peaks: one in summer, another in winter (Perrin et al. 1994a).

Striped dolphins often feed in pelagic or benthopelagic zones along the continental slope or just beyond oceanic waters. A majority of the prey possess luminescent organs, suggesting that striped dolphins may be feeding at great depths, possibly diving to 200 to 700 m to reach potential prey (Archer and Perrin 1999). Striped dolphins may feed at night, in order to take advantage of the deep-scattering layer's diurnal vertical movements. Small, mid-water fishes (in particular, myctophids or lanternfish) and squids are the dominant prey (Perrin et al. 1994a).

Acoustics and Hearing—Striped dolphin whistles range from 6 to 24+ kHz, with dominant frequencies ranging from 8 to 12.5 kHz (Thomson and Richardson 1995). The striped dolphin's range of most sensitive hearing (defined as the frequency range with sensitivities within 10 dB of maximum sensitivity) was determined to be 29 to 123 kHz using standard psycho-acoustic techniques; maximum sensitivity occurred at 64 kHz (Kastelein et al. 2003). Hearing ability became less sensitive below 32 kHz and above 120 kHz (Kastelein et al. 2003).

- Short-beaked Common Dolphin (*Delphinus delphis*)

Description—There are two species in the genus *Delphinus*: the long-beaked common dolphin (*Delphinus capensis*) and the short-beaked common dolphin (*Delphinus delphis*) (Heyning and Perrin 1994). The short-beaked common dolphin is the species most likely to occur in the Marianas MRA study area (Jefferson personal communication).

Short-beaked common dolphins are moderately slender animals with a relatively long beak and a tall, slightly falcate dorsal fin. Common dolphins are distinctively marked; they have a V-shaped dark saddle that produces an hourglass pattern on the side of the body (Jefferson et al. 1993). The back is a dark, brownish gray; the belly is white; and the anterior flank patch is tan to cream in color. The lips are dark and there is a stripe running from the apex of the melon to encircle the eye. There is also a black to dark gray chin-to-flipper stripe. Adults can reach lengths of up to 2.6 m (Jefferson et al. 1993).

Status—There are no abundance estimates for the short-beaked common dolphin in this area. This species is designated as least concern on the IUCN Red List (Reeves et al. 2003).

Habitat Preferences—Common dolphins occupy a wide range of habitats, including waters over the continental shelf, along the continental shelf break, and over prominent underwater topography (e.g., seamounts) (Hui 1979; Evans 1994). The long-beaked common dolphin appears to be restricted to waters relatively close to shore (Jefferson and Van Waerebeek 2002); there is no known occurrence for this species around archipelagos great distance from a continent (Jefferson personal communication). Common dolphins in some populations appear to preferentially travel along bottom topographic features such as escarpments and seamounts (Evans 1994). In tropical regions, where common dolphins are routinely sighted, they are found in upwelling-modified waters (Au and Perryman 1985; Ballance and Pitman 1998; Reilly 1990). Common dolphins prefer areas with large seasonal changes in surface temperature and thermocline depth (Au and Perryman 1985).

Distribution—*Delphinus* is a widely distributed genus of cetacean. It is found worldwide in temperate, tropical, and subtropical seas. The range of the short-beaked common dolphin may extend entirely across the tropical and temperate North Pacific (Heyning and Perrin 1994). All animals observed at sea and collected as specimens from the offshore eastern tropical Pacific, ranging as far south as northern Peru, have been of the short-beaked form (Heyning and Perrin 1994). In the eastern North Pacific, all sightings of long-beaked common dolphins have been within about 100 NM of shore (Heyning and Perrin 1994).

- Information Specific to the Marianas MRA Study Area—There are no occurrence records for this species in the Marianas study area and vicinity, but this area is within the known distribution range for this species. There is a low or unknown occurrence of the short-beaked common dolphin from the shelf break to seaward of the Marianas study area and vicinity (**Figure B-17**). Short-beaked common dolphins are thought to be more common in cool temperate waters of the North Pacific, although there are populations in cooler, upwelling modified waters of the eastern tropical Pacific (Au and Perryman 1985). The absence of known areas of major upwelling in the western tropical Pacific suggests that common dolphins will not be found there, although there have been some reports of sightings of this species (Masaki and Kato 1979). However, the species identification of these records is not confirmed, and therefore is in doubt. Occurrence patterns are assumed to be the same throughout the year.

Behavior and Life History—Group size ranges from several dozen to over 10,000 (Jefferson et al. 1993). Common dolphins are fast-moving swimmers, active bowriders, and often jump in the air. Calving peaks differ from stock to stock. Calving peaks in spring and autumn, or spring and summer, have been reported for various populations (Jefferson et al. 1993).

Delphinus feed on a wide variety of epipelagic and mesopelagic schooling fishes and squids associated with the deep scattering layer (Ohizumi et al. 1998). Common dolphins feed opportunistically on those species most abundant locally and change their diet according to fluctuations in the abundance and availability of prey (Young and Cockcroft 1994). Based on a small sample size from the eastern North Pacific, the short-beaked common dolphin may feed more extensively on squid than the long-beaked form (Heyning and Perrin 1994). Diel fluctuations in vocal activity of this species (more vocal activity during late evening and early morning) appear to be linked to feeding on the deep scattering layer as it rises during the same time (Goold 2000).

Acoustics and Hearing—Recorded *Delphinus* vocalizations include whistles, chirps, barks, and clicks (Ketten 1998). Clicks and whistles have dominant frequency ranges of 23 to 67 kHz and 0.5 to 18 kHz, respectively (Ketten 1998). Popov and Klishin (1998) recorded auditory brainstem responses from a common dolphin. The audiogram was U-shaped with a steeper high-frequency branch. The audiogram bandwidth was up to 128 kHz at a level of 100 dB above the minimum threshold. The minimum thresholds were observed at frequencies of 60 to 70 kHz.

- Risso's Dolphin (*Grampus griseus*)

Description—Risso's dolphins are moderately large, robust dolphins reaching at least 3.8 m in length (Jefferson et al. 1993). The head is blunt, without a distinct beak, and there is a vertical crease on the front of the melon. The dorsal fin is tall and falcate and the flippers are sickle-shaped. Young Risso's dolphins range from light gray to dark brownish gray and are relatively unmarked (Jefferson et al. 1993). Adults range from dark gray to nearly white and are covered with white scratches and splotches.

Status—This species is designated as data deficient on the IUCN Red List (Reeves et al. 2003). Essentially nothing is known of stock structure of Risso's dolphins in the western Pacific. Assuming that several stocks may occur there, Miyashita (1993) used Japanese survey data to estimate that about 7,000 Risso's dolphins occur in the area to the north of the Mariana Islands.

Habitat Preferences—A number of studies have noted that Risso's dolphins are most commonly found along the continental slope (CETAP 1982; Baumgartner 1997; Davis et al. 1998; Mignucci-Giannoni 1998; Kruse et al. 1999). Baumgartner (1997) hypothesized that the strong correlation between Risso's dolphin distribution and the steeper portions of the upper continental slope in the Gulf of Mexico is most likely the result of cephalopod distribution in the same area.

Distribution—The Risso's dolphin is distributed worldwide in tropical to warm-temperate waters, roughly between 60ºN and 60ºS, where surface water temperature is usually greater than 10ºC (Kruse et al. 1999). Water temperature appears to be a factor that affects the distribution of Risso's dolphins in the Pacific (Kruse et al. 1999). Changes in local distribution and abundance along the California coast are probably in response to protracted or unseasonal warm-water events, such as El Niño events (Shane 1994). Changes in both abundance and shoreward shifts of Risso's dolphin distribution have been reported during such periods.

- Information Specific to the Marianas MRA Study Area—Risso's dolphins are expected to occur in the Marianas study area from the shelf break to seaward of the Marianas study area and vicinity (**Figure B-18**). While there is a predominance of Risso's dolphin sightings worldwide in areas with steep bottom topography, this species is also found in deeper waters. The largest numbers for this species will likely be in the vicinity of the shelf break and upper continental slope (Jefferson personal communication). There is an area of low or unknown occurrence from the 50 m isobath to the shelf break (**Figure B-18**). This takes into consideration also the possibility that this species, with a preference for waters with steep bottom topography, might swim into areas where deep water is close to shore. Leatherwood et al. (1979) and Shane (1994) reported on sightings of Risso's dolphins in shallow waters in the northeastern Pacific, including near oceanic islands. These sites are in areas where the continental shelf is narrow and deep water is closer to the shore (Leatherwood et al. 1979; Gannier 2000, 2002). Occurrence patterns are assumed to be the same throughout the year.

Behavior and Life History—Little is known about the life history of this species. Risso's dolphins are quite social; groups usually average about 30 individuals, but can range up to over several hundred (Kruse et al. 1999), or even several thousand (Jefferson personal communication). Risso's dolphins occur in stable, age- and sex-segregated groups, which interact fluidly with a larger population. This species commonly associates with other cetacean species (Kruse et al. 1999). They may remain submerged on dives for up to 30 min; typical swimming speed is 1.67 to 1.94 m/sec (Kruse et al. 1999). Cephalopods are the primary prey (Clarke 1996).

Acoustics and Hearing—Risso's dolphin vocalizations include broadband clicks, barks, buzzes, grunts, chirps, whistles, and simultaneous whistle and burst-pulse sounds (Corkeron and van Parijs 2001). The combined whistle and burst pulse sound appears to be unique to Risso's dolphin

(Corkeron and van Parijs 2001). Corkeron and van Parijs (2001) recorded five different whistle types, ranging in frequency from 4 to 22 kHz. Broadband clicks had a frequency range of 6 to greater than 22 kHz. Low-frequency narrowband grunt vocalizations had a frequency range of 0.4 to 0.8 kHz. A recent study established empirically that Risso's dolphins echolocate; estimated source levels were up to 216 dB re 1 µPa-m (Philips et al. 2003).

Nachtigall et al. (1995) conducted baseline audiometric work. Because of the natural background noise (the study was conducted in a natural setting), it was not possible to precisely determine peak (or best) hearing sensitivity in the species. Maximum sensitivity occurred between 8 and 64 kHz. Reported thresholds were 124 dB at 1.6 kHz, 71.7 dB at 4 kHz, 63.7 dB at 8 kHz, 63.3 dB at 16 kHz, 66.5 dB at 32 kHz, 67.3 dB at 64 kHz, 74.3 dB at 80 kHz, 124.2 dB at 100 kHz, and 122.9 dB at 110 kHz.

- Melon-headed Whale (*Peponocephala electra*)

Description—Melon-headed whales at sea closely resemble pygmy killer whales; both species have a blunt head with little or no beak. Melon-headed whales have pointed (versus rounded) flippers and a more triangular head shape than pygmy killer whales (Jefferson et al. 1993). The body is charcoal gray to black, with unpigmented lips (which often appear light gray, pink or white) and a white urogenital patch (Perryman et al. 1994). This species also has a triangular face "mask" and indistinct cape (which dips much lower below the dorsal fin than that of pygmy killer whales). Melon-headed whales reach a maximum length of 2.75 m (Jefferson et al. 1993).

Status—There are no abundance estimates available for the melon-headed whale in this area. This species is designated as least concern on the IUCN Red List (Reeves et al. 2003).

Habitat Preferences—Melon-headed whales are most often found in offshore, deep waters. For example, most melon-headed whale sightings in the Gulf of Mexico have been in deep waters, well beyond the edge of the continental shelf (Mullin et al. 1994; Davis and Fargion 1996) and in waters over the abyssal plain (Jefferson personal communication). Nearshore sightings are generally from areas where deep, oceanic waters are found near the coast (Perryman 2002). Melon-headed whales are found close to shore (within a few kilometers) around the Society and Marquesas Islands of French Polynesia (Gannier 2000, 2002), and Lembata Island of the Indonesian archipelago (Rudolph et al. 1997), as well as in some waters of the Philippines (Leatherwood et al. 1992). In the eastern tropical Pacific, this species is primarily found in upwelling modified and equatorial waters (Au and Perryman 1985; Perryman et al. 1994).

Distribution—Melon-headed whales are found worldwide in tropical and subtropical waters. They have occasionally been reported from higher latitudes, but these sightings are often associated with incursions of warm water currents (Perryman et al. 1994). Donaldson (1983) suggested that the presence of melon-headed whales in the waters of Guam, Palau, and Japan suggests a possible link between equatorial Pacific and northern Pacific populations of this species, via the Mariana Islands.

- Information Specific to the Marianas MRA Study Area—The melon-headed whale is an oceanic species. There are records of its occurrence for the Marianas study area and vicinity. There was a live stranding on the beach at Inarajan Bay, Guam in April 1980 (Kami and Hosmer 1982; Donaldson 1983), and there have been some sightings at Rota and Guam (Michael personal communication; Odell personal communication). Melon-headed whales are expected to occur from the shelf break (200 m isobath) to seaward of the Marianas study area and vicinity (**Figure B-19**). There is also a low or unknown occurrence from the coastline to the shelf break which would take into account any sightings that could occur closer to shore since deep water is very close to shore at these islands. For example, during July 2004, there was a sighting of an estimated 500 melon-headed whales and an undetermined smaller number of rough-toothed dolphins at Rota in waters with a bottom depth of 76 m (Michael personal communication). Occurrence patterns are assumed to be the same throughout the year.

Behavior and Life History—Melon-headed whales are typically found in large groups, ranging between 150 and 1,500 individuals (Perryman et al. 1994; Gannier 2002), though Watkins et al. (1997) described smaller groupings of 10 to 14 individuals. These animals often log at the water's surface in large schools composed of noticeable subgroups. Melon-headed whales are often found in mixed-species aggregations, commonly with Fraser's dolphins (Miyazaki and Wada 1978; Perryman et al. 1994; Jefferson and Barros 1997; Reeves et al. 1999; Gannier 2000), as well as on occasion, spinner, bottlenose, and rough-toothed dolphins (Reeves et al. 1999; Gannier 2000; Perryman 2002).

Very few data are available on life history. It is unclear whether there is significant seasonality in calving (Jefferson and Barros 1997). Females reach sexual maturity at about 11.5 years and males at 16.5 years (Jefferson and Barros 1997). These life history parameters are estimated from work on a single school of melon-headed whales that mass-stranded at Aoshima, southern Japan (Miyazaki et al. 1998), and therefore must be taken as highly preliminary. Melon-headed whales prey on squid, pelagic fishes, and occasionally crustaceans. Most of the fish and squid families eaten by this species consist of mesopelagic forms found in waters up to 1,500 m deep, suggesting that feeding takes place deep in the water column (Jefferson and Barros 1997). There is no information on specific diving depths for melon-headed whales.

Acoustics and Hearing—The only published acoustic information for melon-headed whales is from the southeastern Caribbean (Watkins et al. 1997). Sounds recorded included whistles and click sequences. Whistles had dominant frequencies around 8 to 12 kHz; higher-level whistles were estimated at no more than 155 dB re 1 μPa-m (Watkins et al. 1997). Clicks had dominant frequencies of 20 to 40 kHz; higher-level click bursts were judged to be about 165 dB re 1 μPa-m (Watkins et al. 1997). No data on hearing ability for this species are available.

♦ Fraser's Dolphin (*Lagenodelphis hosei*)

Description—The Fraser's dolphin reaches a maximum length of 2.7 m and is generally more robust than other small delphinids (Jefferson et al. 1993). This species has a short, stubby beak, small flippers, and a subtriangular dorsal fin. The most conspicuous feature of the Fraser's dolphin coloration is the dark band running from the face to the anus, although it is not present in younger animals (Jefferson et al. 1997). The stripe is set off from the surrounding areas by thin, pale, cream-colored borders. There is also a dark chin-to-flipper stripe.

Status—This species is designated as data deficient on the IUCN Red List (Reeves et al. 2003). There are no abundance estimates available for the Fraser's dolphin in this area.

Habitat Preferences—This is an oceanic species, except in places where deep water approaches the coast (Dolar 2002). Fraser's dolphins are found close to shore in some regions, such as around the Society Islands of French Polynesia (Gannier 2000), around several islands of the Indo-Malay archipelago in the Indo-Pacific area (Rudolph et al. 1997), and in some waters of the Philippines (Leatherwood et al. 1992). In the offshore eastern tropical Pacific, this species is distributed mainly in upwelling-modified waters (Au and Perryman 1985).

Distribution—The Fraser's dolphin is found in tropical and subtropical waters around the world, typically between 30ºN and 30ºS (Jefferson et al. 1993). Strandings in temperate areas are considered extralimital and usually are associated with anomalously warm-water temperatures (Perrin et al. 1994b). As noted by Reeves et al. (1999), the documented distribution of this species is skewed towards the eastern Pacific, which may reflect the intensity of research associated with the tuna fishery rather than an actual higher density of occurrence there than in other tropical regions.

- Information Specific to the Marianas MRA Study Area—There are no occurrence records for this species in the Marianas study area and vicinity, but this area is within the known distribution range for this species. The Fraser's dolphin is an oceanic species. In the Gulf of Mexico, this species has been seen in waters over the abyssal plain (Leatherwood et al. 1993). Therefore, the Fraser's dolphin is expected to occur from the shelf break to seaward of the Marianas study area and vicinity (**Figure B-20**). In some locales, as noted earlier, Fraser's dolphins do approach closer to shore, particularly in locations where the shelf is narrow and deep waters are nearby, so there is also a low or unknown occurrence from the 100 m isobath to the shelf break. Occurrence patterns are assumed to be the same throughout the year.

Behavior and Life History—Fraser's dolphins are usually seen in large, fast-moving groups. Most sightings have been of groups ranging between 100 and 1,000 individuals. Fraser's dolphins have been seen in mixed-species aggregations with melon-headed whales in the eastern tropical Pacific, South Pacific, and Gulf of Mexico (Jefferson and Leatherwood 1994; Reeves et al. 1999; Gannier 2000). Very little is known of the natural history of this species, including reproduction. Available data do not show strong evidence of calving seasonality. Sexual maturity for both sexes occurs at about 7 years of age (Jefferson and Leatherwood 1994). Fraser's dolphins feed on mid-water fishes, squids, and shrimps (Jefferson and Leatherwood 1994; Perrin et al. 1994b). There is no information available on depths to which Fraser's dolphins dive, but they are thought to be capable of deep dives.

Acoustics and Hearing—Very little is known of the acoustic abilities of the Fraser's dolphin. Fraser's dolphin whistles have a frequency range of 7.6 to 13.4 kHz (Leatherwood et al. 1993). There are no hearing data for this species.

- Pygmy Killer Whale (*Feresa attenuata*)

Description—The pygmy killer whale is often confused with the melon-headed whale and the false killer whale. Flipper shape is the best distinguishing characteristic—pygmy killer whales have rounded flipper tips (Jefferson et al. 1993). The body of the pygmy killer whale is somewhat slender (especially posterior to the dorsal fin), with a rounded head that has little or no beak (Jefferson et al. 1993). The color of this species is dark gray to black, with a prominent narrow cape that dips only slightly below the dorsal fin and a white to light gray ventral band that widens around the genitals. The lips and snout tip are sometimes white. Pygmy killer whales reach lengths of up to 2.6 m (Jefferson et al. 1993).

Status—There are no abundance estimates for the pygmy killer whale in this area. This species is designated as data deficient on the IUCN Red List (Reeves et al. 2003).

Habitat Preferences—The pygmy killer whale is considered to be an oceanic species. In the northern Gulf of Mexico, this species is found primarily in deeper waters off the continental shelf (Davis and Fargion 1996; Davis et al. 2000; Würsig et al. 2000) and waters out over the abyssal plain (Jefferson personal communication). In some areas, pygmy killer whales are found within a few kilometers of shore over the shelf, such as around the Marquesas Islands of French Polynesia (Gannier 2002), off Lembata Island of the Indonesian archipelago (Rudolph et al. 1997), as well as in some waters off the Philippines (Leatherwood et al. 1992).

Distribution—This species has a worldwide distribution in deep tropical and subtropical oceans. Pygmy killer whales generally do not range north of 40ºN or south of 35ºS (Jefferson et al. 1993). Reported sightings suggest that this species primarily occurs in equatorial waters, at least in the eastern tropical Pacific (Perryman et al. 1994). Most of the records outside the tropics are associated with strong, warm western boundary currents that effectively extend tropical conditions into higher latitudes (Ross and Leatherwood 1994).

- Information Specific to the Marianas MRA Study Area—There are no occurrence records for this species in the Marianas study area and vicinity, but this area is within the known distribution range for this species. Pygmy killer whales are easily confused with false killer whales and melon-headed whales, which are two species that also have expected occurrence in the Marianas study area. The pygmy killer whale is expected to occur from the shelf break (200 m isobath) to seaward of the Marianas study area and vicinity (**Figure B-21**). There is also a low or unknown occurrence from the 100 m isobath to the shelf break, which would take into account any sightings that could occur just inshore of the shelf break, since deep water is very close to shore at these islands. Occurrence patterns are assumed to be the same throughout the year.

Behavior and Life History—Almost nothing is known about the reproductive biology and social organization of this species. This species usually forms relatively small groups (Ross and Leatherwood 1994). Pygmy killer whales eat mostly fish and squid, and sometimes attack other dolphins (Perryman and Foster 1980; Ross and Leatherwood 1994). They occur in small to moderate herds of most often less than 50 to 60 individuals. There is no information available on diving behavior of this species.

Acoustics and Hearing—The pygmy killer whale emits short duration, broadband signals similar to a large number of other delphinid species (Madsen et al. 2004). Clicks produced by pygmy killer whales have centroid frequencies between 70 and 85 kHz; there are bimodal peak frequencies between 45 and 117 kHz; the estimated source levels are between 197 and 223 dB re 1 μPa-m (Madsen et al. 2004). These clicks possess characteristics of echolocation clicks (Madsen et al. 2004). There are no hearing data available for this species.

- False Killer Whale (*Pseudorca crassidens*)

Description—The false killer whale is a large, dark gray to black dolphin with a faint gray patch on the chest, and sometimes light gray areas on the head (Jefferson et al. 1993). The false killer whale has a long slender body, a rounded overhanging forehead, and little or no beak (Jefferson et al. 1993). The dorsal fin is falcate and slender. The flippers have a characteristic hump on the leading edge—this is perhaps the best characteristic for distinguishing this species from the other "blackfish" (pygmy killer, melon-headed, and pilot whales) (Jefferson et al. 1993). Individuals reach maximum lengths of 6.1 m (Jefferson et al. 1993).

Status—This species is designated as least concern on the IUCN Red List (Reeves et al. 2003). Nothing is known of the stock structure of false killer whales in the North Pacific Ocean. There are estimated to be about 6,000 false killer whales in the area surrounding (mostly north of) the Mariana Islands (Miyashita 1993).

Habitat Preferences—This species is found primarily in oceanic and offshore areas, though they do approach close to shore at oceanic islands (Baird 2002). False killer whales have been known to approach very close to shore in such areas as the inshore waters of Washington and British Columbia (Baird et al. 1989), the coast and estuaries of China (Zhou et al. 1982), the Marquesas Islands of French Polynesia (Gannier 2002), and Lembata Island of the Indonesian archipelago (Rudolph et al. 1997). Inshore movements are occasionally associated with movements of prey and shoreward flooding of warm ocean currents (Stacey et al. 1994).

Distribution—False killer whales are found in tropical and temperate waters, generally between 50ºS and 50ºN latitude with a few records north of 50ºN in the Pacific and the Atlantic (Odell and McClune 1999). Seasonal movements in the western North Pacific may be related to prey distribution (Odell and McClune 1999). Baird et al. (2005a) noted considerable inter-island movements of individuals in the Hawaiian Islands.

- Information Specific to the Marianas MRA Study Area—There are two unpublished sightings and no reported strandings of the false killer whale in the Marianas study area and vicinity. The false killer whale is an oceanic species, occurring in deep waters, and is known to occur close to shore near oceanic islands (Baird 2002, Jefferson personal communication). The false killer whale in the Marianas study area and vicinity is expected to occur seaward of the 50 m isobath (**Figure B-22**). There is also a low or unknown occurrence from the coastline to the 50 m isobath which would take into account any sightings that could occur closer to shore since deep water is very close to shore at these islands. Occurrence patterns are assumed to be the same throughout the year.

Behavior and Life History—This species may occur in large groups (group sizes as large as 300 have been reported) (Brown et al. 1966). The known maximum dive depth is about 500 m (Odell and McClune 1999). No seasonality in reproduction is known for the false killer whale (Jefferson et al. 1993). False killer whales primarily eat deep-sea cephalopods and fish (Odell and McClune 1999), but they have been known to attack other cetaceans, including dolphins (Perryman and Foster 1980; Stacey and Baird 1991), sperm whales (Palacios and Mate 1996), and baleen whales (Jefferson personal communication). False killer whales in many different regions are known to take tuna from longlines (Mitchell 1975; Nitta and Henderson 1993).

Acoustics and Hearing—The dominant frequencies of false killer whale whistles are 4 to 9.5 kHz; those of their clicks are 25 to 30 kHz and 95 to 130 kHz (Thomas et al. 1990b; Thomson and Richardson 1995). The source level is 220 to 228 dB re 1 μPa-m (Ketten 1998). Best hearing sensitivity measured for a false killer whale was around 16 to 64 kHz (Thomas et al. 1988, 1990b).

- Killer Whale (*Orcinus orca*)

Description—This is probably the most instantly-recognizable of all the cetaceans. The black-and-white color pattern of the killer whale is striking, as is the tall, erect dorsal fin of the adult male 1.0 to 1.8 m in height). The white oval eye patch and variably-shaped saddle patch, in conjunction with the shape and notches in the dorsal fin, help in identifying individuals. The killer whale has a blunt head with a stubby, poorly-defined beak, and large, oval flippers. Females may reach 7.7 m in length and males 9.0 m (Dahlheim and Heyning 1999). The killer whale is the largest member of the dolphin family.

Status—This species is designated as lower risk on the IUCN Red List (Reeves et al. 2003). There are no abundance estimates available for the killer whale in this area. Little is known of stock structure of killer whales in the North Pacific, with the exception of the northeastern Pacific where resident, transient, and offshore stocks have been described for coastal waters of Alaska, British Columbia, and Washington to California (Carretta et al. 2004).

Habitat Preferences—Killer whales can be found in the open sea, as well as in coastal areas (Dahlheim and Heyning 1999). Offshore concentrations of killer whales in the eastern tropical Pacific occur within the divergence zones of the NEC and the Equatorial Counter Current (Dahlheim et al. 1982). Killer whales have the most ubiquitous distribution of any species of cetacean, and they have been observed in virtually every marine habitat, from the tropics to the poles, and from shallow, inshore waters (and even rivers) to deep, oceanic regions (Dahlheim and Heyning 1999). Although they are not common in most of these habitat types, there is a possibility of seeing killer whales just about anywhere in the marine environment.

Distribution—This is a cosmopolitan species found throughout all oceans and contiguous seas, from equatorial regions to the polar pack-ice zones. This species has sporadic occurrence in most regions (Ford 2002), including the Micronesia region (Reeves et al. 1999). Though found in tropical waters and the open ocean, killer whales as a species are most numerous in coastal waters and at higher latitudes (Mitchell 1975; Miyazaki and Wada 1978; Dahlheim et al. 1982).

Sightings in most tropical waters, although not common, are widespread (Visser and Bonoccorso 2003). Japanese tuna longline fishermen and Japanese whaling or whale sighting vessels reported killer whale presence in Pacific equatorial waters (Iwashita et al. 1963; Miyashita et al. 1995), though Reeves et al. (1999) noted that records from fishermen have reliability issues, since they are often not sufficiently well-documented. Observations from Japanese whaling or whale sighting vessels are more credible (Miyashita et al. 1995) and indicate concentrations of killer whales north of the Northern Mariana Islands.

- Information Specific to the Marianas MRA Study Area—Killer whales in general are uncommon in most tropical areas (Jefferson personal communication). The distinctiveness of this species would lead it to be reported more than any other member of the dolphin family, if it occurs in a certain locale. Rock (1993) reported that killer whales have been reported in the tropical waters around Guam, Yap, and Palau "for years." There is, however; a paucity of sighting documentation to substantiate this claim (Reeves et al. 1999; Visser and Bonoccorso 2003). There are a few sightings (most are unconfirmed) of killer whales off Guam (Eldredge 1991). Gerry Davis (personal communication) has observed killer whales off Cocos Island, Guam on more than one occasion and off Galvez Bank, Guam. There was also a confirmed sighting of these animals by the USCG in the late 1980s off Santa Rosa Bank, Guam (Davis personal communication). One sighting of a killer whale was made 27 km west of Tinian during January 1997 and reported to the NOAA Fisheries Platforms of Opportunity Program. There was also a badly decomposed killer whale found stranded on Guam in August 1981 (Kami and Hosmer 1982). Killer whales are infrequently sighted and found stranded around the Hawaiian Islands (Shallenberger 1981; Tomich 1986; Mobley et al. 2001; Baird et al. 2003a), though with increasing numbers of boaters, sightings each year could be expected (Baird personal communication). Since this species has a sporadic occurrence in tropical waters and can be found in both coastal areas and the open ocean, there is a low or unknown occurrence of the killer whale from the coastline (except in the industrial Apra Harbor) to seaward of the Marianas study area and vicinity (**Figure B-23**). Occurrence patterns are assumed to be the same throughout the year.

Behavior and Life History—Killer whales have the most stable social system known among all cetaceans. In all areas where longitudinal studies have been carried out, there appear to be long-term associations between individuals and limited dispersal from maternal groups called pods (Baird 2000).

Killer whales have a diverse diet, feeding on bony fishes, elasmobranchs, cephalopods, seabirds, sea turtles, and other marine mammals (Jefferson et al. 1991; Fertl et al. 1996). Diet is specific to the type of killer whale. Transients are primarily mammal-eaters, residents are mostly fish-eaters, and offshores appear to eat mostly fish as well. Killer whales in the tropics have been observed feeding on fishes, elasmobranchs, and sea turtles (e.g., Fertl et al. 1996; Gannier 2002; Visser and Bonoccorso 2003; Pitman and Dutton 2004). Killer whale interference with fisheries in the tropics is well known; for example, they remove fish from longlines (Iwashita et al. 1963; Visser and Bonoccorso 2003). Killer whales use passive listening as a primary means of locating prey and use different echolocation patterns for different hunting strategies (Barrett-Lennard et al. 1996). For example, they mask their clicks and encode their signals in background noise when hunting other cetaceans, prey that can hear their high-frequency clicks. In contrast, killer whales do not mask their high-frequency signals when hunting fish that are not capable of hearing in this frequency range.

The maximum depth recorded for free-ranging killer whales diving off British Columbia is 264 m (Baird et al. 2005b). On average, however, for seven tagged individuals, less than 1% of all dives examined were to depths greater than 30 m (Baird et al. 2003a). A trained killer whale dove to a maximum of 260 m (Dahlheim and Heyning 1999). The longest duration of a recorded dive from a radio-tagged killer whale was 17 min (Dahlheim and Heyning 1999).

Acoustics and Hearing—The killer whale produces a wide variety of clicks and whistles, but most of its sounds are pulsed and at 1 to 6 kHz (Thomson and Richardson 1995). Source levels of echolocation signals range between 195 and 224 dB re 1 μPa-m (Au et al. 2004). Acoustic studies of resident killer whales in British Columbia have found that there are dialects, in their highly stereotyped, repetitive discrete calls, which are group-specific and shared by all group members (Ford 2002). These dialects likely are used to maintain group identity and cohesion, and may serve as indicators of relatedness that help in the avoidance of inbreeding between closely related whales (Ford 2002). Dialects also have been documented in killer whales occurring in northern Norway, and likely occur in other locales as well (Ford 2002).

The killer whale has the lowest frequency of maximum sensitivity and one of the lowest high-frequency hearing limits known among toothed whales (Szymanski et al. 1999). The upper limit of hearing is 100 kHz for this species. The most sensitive frequency, in both behavioral and in auditory brainstem response audiograms, has been determined to be 20 kHz (Szymanski et al. 1999).

♦ <u>Short-finned Pilot Whale</u> (*Globicephala macrorhynchus*)

Description—There are two species of pilot whales worldwide; only the short-finned pilot whale is expected to occur in the Marianas study area. Pilot whales are among the largest members of the family Delphinidae. In general, the short-finned pilot whale is smaller than the long-finned pilot whale, reaching lengths of 5.5 m (females) and 6.1 m (males) (Jefferson et al. 1993).

Pilot whales have bulbous heads, with a forehead that sometimes overhangs the rostrum; there is little or no beak (Jefferson et al. 1993). The dorsal fin is distinctive, being generally broader-based than it is tall. It is falcate and usually rounded at the tip, and is set well forward of the middle of the back. The flippers of the short-finned pilot whale are long and sickle-shaped and range from 16% to 22% of the total body length (Jefferson et al. 1993). Both pilot whale species are black on the back and sides; in many individuals, there is a light gray saddle patch located behind the dorsal fin. Pilot whales also have a white to light gray anchor-shaped patch on the chest (Jefferson et al. 1993).

Status—This species is designated as lower risk on the IUCN Red List (Reeves et al. 2003). There are no abundance estimates for the short-finned pilot whale in this area. Stock structure of short-finned pilot whales has not been adequately studied in the North Pacific, except in Japanese waters, where two stocks have been identified based on pigmentation patterns and head shape differences of adult males (Kasuya et al. 1988). The southern stock of short-finned pilot whales (Kasuya et al. 1988), which is probably the one associated with the Marianas Islands area, has been estimated to number about 18,700 whales in the area south of 30°N latitude (Miyashita 1993). This is the closest population estimate for the Marianas area.

Habitat Preferences—Pilot whales are found over the continental shelf break, in slope waters, and in areas of high topographic relief (Olson and Reilly 2002). While pilot whales are typically distributed along the continental shelf break, movements over the continental shelf are commonly observed in the northeastern U.S. (Payne and Heinemann 1993) and close to shore at oceanic islands, where the shelf is narrow and deeper waters are nearby (Mignucci-Giannoni 1998; Gannier 2000). A number of studies in different regions suggest that the distribution and seasonal inshore/offshore movements of pilot whales coincide closely with the abundance of squid, their preferred prey (Hui 1985; Waring et al. 1990; Payne and Heinemann 1993; Waring and Finn 1995; Bernard and Reilly 1999). Short-finned pilot whale occurrence in the Caribbean seems to coincide with the inshore movement of spawning octopus (Mignucci-Giannoni 1998). Short-finned pilot whale distribution off southern California changed dramatically after the El Niño event in 1982 through 1983, when squid did not spawn as usual in the area, and pilot whales virtually disappeared from the area for nine years (Shane 1994).

Distribution—The short-finned pilot whale is found worldwide in tropical to warm-temperate seas, generally in deep offshore areas. The short-finned pilot whale usually does not range north of 50ºN or south of 40ºS (Jefferson et al. 1993). The long-finned pilot whale (*Globicephala melas*) is not known to presently occur in the North Pacific (Kasuya 1975); the range of the short-finned pilot whale appears to be expanding to fill the former range of the long-finned pilot whale (Bernard and Reilly 1999). Pilot whales are sighted throughout the Micronesia region (Reeves et al. 1999).

- <u>Information Specific to the Marianas MRA Study Area</u>—There are a very small number of occurrence records for the short-finned pilot whale in the Marianas study area and vicinity. Miyashita et al. (1996) reported sightings in the vicinity of the Northern Mariana Islands during February through March 1994, but did not provide the actual sighting coordinates. A group of more than 30 individuals was sighted in late April 1977 near Uruno Point, off the northwest coast of Guam (Birkeland 1977). A stranding occurred on Guam in July 1980 (Kami and Hosmer 1982; Donaldson 1983; Schulz 1980).

  Expected occurrence of the short-finned pilot whale in the Marianas study area and vicinity is seaward of the 100 m isobath (**Figure B-24**). The known preference of this species globally for steep bottom topography, which is most probably related to distribution of squid, was considered. With a narrow shelf and deep waters in close proximity to the shore, there is also a low or unknown occurrence of pilot whales in waters over the shelf from the coastline to the 100 m isobath, not including any lagoons. Occurrence patterns are assumed to be the same throughout the year.

Behavior and Life History—Pilot whales are very social and may be seen in groups of several individuals to upwards of several hundreds. They appear to live in relatively stable female-based groups (Jefferson et al. 1993). Pilot whales are often sighted associated with other cetaceans (e.g., Bernard and Reilly 1999; Gannier 2000). These are the most frequently reported mass-stranded marine mammals globally (Nelson and Lien 1996; Mazzuca et al. 1999).

Average age at sexual maturity for short-finned pilot whales is 9 years for females, and 17 years for males (Bernard and Reilly 1999). The gestation period for short-finned pilot whales is 15 to 16 months, with a mean calving interval of 4.6 to 5.7 years (Bernard and Reilly 1999). Calving peaks in the northern hemisphere vary by stock (Jefferson et al. 1993).

Pilot whales are deep divers. They can stay submerged for over 10 min; the maximum dive depth measured is 610 m (Bernard and Reilly 1999). The deepest dives recorded by Baird et al. (2003b) for tagged short-finned pilot whales were typically 600 to 800 m for 27 min. Pilot whales feed primarily on squid, but also take fish (Bernard and Reilly 1999). Pilot whales are not generally known to prey on other marine mammals; however, records from the eastern tropical Pacific suggest that the short-finned pilot whale does occasionally chase, attack, and may eat dolphins during fishery operations (Perryman and Foster 1980), and they have been observed harassing sperm whales in the Gulf of Mexico (Weller et al. 1996).

Acoustics and Hearing—Short-finned pilot whale whistles and clicks have a dominant frequency range of 2 to 14 kHz and a source level of 180 dB re 1 µPa-m (Ketten 1998). There are no published hearing data available for this species.

♦ Northern Elephant Seal (*Mirounga angustirostris*)

Description—The northern elephant seal is the largest pinniped in the Northern Hemisphere (the second-largest in the world, after the southern elephant seal *Mirounga leonina*). It is one of the most sexually dimorphic mammals, with adult males much larger than adult females (Deutsch et al. 1994). The northern elephant seal reaches a standard length of up to 2.8 to 3.0 m and weights of 600 to 800 kg (females) and 3.8 to 4.1 m and 300 kg (males) (Stewart and Huber 1993). As males reach adulthood, they also develop other secondary sexual characteristics. These include the nose being enlarged into an overhanging proboscis (thus the name, elephant seal) and the development of a highly cornified and wrinkled chest shield, which often becomes heavily scarred (and therefore, reddish or pinkish) from fighting with other males of high status. Females and young males lack these exaggerated characters; their appearance is more similar to that of the related monk seals. The coloration of the northern elephant seal is simple countershading, with a dark brown back and slightly lighter belly.

Status—The northern elephant seal population has recovered dramatically after being reduced to several dozen to perhaps no more than a few animals in the 1890s (Bartholomew and Hubbs 1960; Stewart et al. 1994). Although movement and genetic exchange continues between rookeries, most elephant seals return to their natal rookeries when they start breeding (Huber et al. 1991). The California and Mexican breeding groups may be demographically isolated and are currently considered two separate stocks (Carretta et al. 2004).

The population size has to be estimated, since all age classes are not ashore at any one time of the year (Carretta et al. 2004). There is a conservative minimum population estimate of 60,547 elephant seals in the California stock (Carretta et al. 2004). Based on trends in pup counts, abundance in California is increasing by around 6% annually, but the Mexican stock is evidently decreasing slowly (Stewart et al. 1994; Carretta et al. 2004).

Habitat Preferences—Breeding and molting habitat for northern elephant seals is characterized by sandy beaches, mostly on offshore islands, but also in some locations along the mainland coast of the U.S. (Stewart et al. 1994). When on shore, seals will also use small coves and sand dunes behind and adjacent to breeding beaches (Stewart personal communication). They rarely enter the water during the breeding season, but some seals will spend short periods in tide pools and alongshore; these are most commonly weaned pups that are learning to swim (Le Boeuf et al. 1972).

Feeding habitat is mostly in deep, offshore waters of warm temperate to subpolar zones (Stewart and DeLong 1995; Stewart 1997; Le Bouef et al. 2000). Some seals will move into subtropical or tropical waters while foraging (Stewart and DeLong 1995).

The effects of El Niño events on some pinniped species in the North Pacific can be severe. Stewart and Yochem (1991) studied the effects of the strong 1982/1983 ENSO on northern elephant seals breeding in the southern California Channel Islands. They found that females arrived 5 to 8 days later, gave birth earlier, and spent less overall time ashore nursing their pups during that winter season. Females appeared to be in poorer physical condition and to be less productive over the next year. However, these effects were not particularly severe and were of short duration. Stewart and Yochem (1991) speculated that the deep-diving habits of elephant seals make them less vulnerable to the negative effects of El Niño events than other, more shallow-water, pinnipeds.

Distribution—The northern elephant seal is endemic to the North Pacific Ocean, occurring almost exclusively in the eastern and central North Pacific. Vagrant individuals do sometimes range to the western North Pacific, however. Northern elephant seals occur in Hawaiian waters only rarely, as extralimital vagrants. The most far-ranging individual appeared on Nijima Island, off the Pacific coast of Japan in 1989 (Kiyota et al. 1992). This demonstrates the great distances that these animals are capable of covering.

Northern elephant seals breed on island and mainland rookeries from central Baja California, Mexico, to northern California (Stewart and Huber 1993). Breeding occurs primarily on offshore islands (Stewart et al. 1994). The major rookeries in Mexico are Isla Cedros, Isla Benito del Este, and Isla Guadalupe, while in California, they are the Southern California Channel Islands, Piedras Blancas, Cape San Martin, Año Nuevo Island and peninsula, the Farallon Islands, and Point Reyes (Stewart et al. 1994; Carretta et al. 2004).

The foraging range extends thousands of kilometers offshore from the breeding range into the central North Pacific. Adult males and females segregate while foraging and migrating (Stewart and DeLong 1995; Stewart 1997). Adult females mostly range west to about 173°W between the latitudes of 40° and 45°N, whereas adult males range further north into the Gulf of Alaska and along the Aleutian Islands to between 47° and 58°N (Stewart and Huber 1993; Stewart and DeLong 1995; Le Bouef et al. 2000). Adults stay offshore during migration, while juveniles and subadults are often seen along the coasts of Oregon, Washington, and British Columbia (Stewart and Huber 1993). Females may cover over 5,500 km and males over 11,000 km during these post-breeding migrations (Stewart and DeLong 1994).

- <u>Information Specific to the Marianas MRA Study Area</u>—There are no confirmed records of the northern elephant seal in the Micronesia region; however, Reeves et al. (1999) and Eldredge (2001, 2003) have noted occurrence records for seals (unidentified species) in the nearby Marshall and Gilbert islands. The elephant seal is known to make long-distance movements, including as far west as the Hawaiian Islands and Japan (NWAFC 1978; Antonelis and Fiscus 1980; Tomich 1986; Kiyota et al. 1992; Fujimori 2002), so extralimital occurrences in the Marianas study area are possible.

Behavior and Life History—Elephant seals are gregarious during the breeding season, but appear to be relatively solitary at sea. Adult elephant seals spend from 8 to 10 months at sea and undertake two annual migrations between haulout and feeding areas (Stewart and DeLong 1995). They haul out on land to give birth and breed, and after spending time at sea to feed (post-breeding migration), they generally return to the same areas to molt (Stewart and Yochem 1984; Stewart and DeLong 1995). The different age and sex classes have somewhat differing annual cycles and migration patterns (Stewart 1997). After weaning their pups in late winter, adult females forage at sea for about 70 days before returning to land to molt their pelage. Following one month ashore, the females return to sea for eight months (coincident with gestation), before returning to the rookery to give birth. Elephant seals do not necessarily return to the same beaches for breeding and molting. For example, Huber et al. (1991) found that female northern elephant seals often molt on one island and breed on another. Adult males spend approximately four months at sea following the breeding season, returning to shore in summer to molt. After one month ashore, they return to sea for four months before returning to the rookery for the breeding season.

In December, male elephant seals haul out for the breeding season; many individuals remain there continuously until March. In January, after many males have been on land for several weeks, the adult females come ashore, give birth, suckle their young for about 27 days, breed, and depart (Le Boeuf and Peterson 1969; Stewart and Huber 1993). Gestation is about 11 months, but there is a two to three month period of delayed implantation. During the breeding season, elephant seals congregate in large numbers on their breeding rookeries. Animals of all ages and both sexes are present on these beaches, although yearlings generally do not return during the breeding season, and are rare at rookeries. Large rookeries, such as those on Año Nuevo Island and peninsula and the Channel Islands, may contain thousands of seals, which mostly arrange themselves in harems consisting of up to several dozen breeding females, a single dominant (alpha) male, and the newborn pups. Other animals, especially other bulls seeking to challenge the alpha male or sneak copulations, often surround the harems.

Males reach sexual maturity at about 6 or 7 years, but do not reach “social maturity” until 9 or 10 years. Most adult males do not have high enough social status to do much breeding – a few high ranking males called “alpha males” actually do the vast majority of the fertilization of the females (Le Boeuf 1974). Both males and females lose a large proportion of their body mass while fasting during the breeding season, and they must feed intensively after returning to sea to regain weight.

During the molting period, which is at different times of the year for different age classes, seals lose their fur in large patches with the underlying epidermis. This is called a “catastrophic molt” and molting seals look very ragged (Stewart and Huber 1993). Adults return to land between March and August to molt, with males returning later than females (Carretta et al. 2004).

Elephant seals are probably the deepest and longest diving pinnipeds; few marine mammals can match their abilities. Adults dive continuously, day and night, during their feeding migrations (DeLong and Stewart 1991; Le Boeuf et al. 1986, 1989). Elephant seals may spend as much as 90% of their time submerged (DeLong and Stewart 1991); this year-round pattern of continuous, long, deep dives explains why northern elephant seals are rarely seen at sea and why their oceanic whereabouts and migrations have long been unknown (Stewart and DeLong 1995). The average diving cycle consists of a 23 min dive, followed by a 2 to 4 min surface interval (Le Boeuf et al. 1986, 1989; DeLong and Stewart 1991). The longest known dive is 77 min (Stewart and Huber 1993). Dives average between 350 and 550 m in depth, with dives as deep as 1,561 m (females) and 1,585 m (males) (Stewart and Huber 1993). Males and females pursue different foraging strategies. Females range widely over deep water, apparently foraging on patchily distributed, vertically migrating, pelagic prey, whereas males forage along the continental margin at the distal end of their migration, and they may at times feed on benthic prey (Le Boeuf et al. 2000).

Northern elephant seals feed primarily on cephalopods, hake, and other epipelagic, mesopelagic, and bathypelagic fishes and crustaceans, such as pelagic red crabs (Condit and Le Boeuf 1984; DeLong and Stewart 1991; Stewart and Huber 1993; Antonelis et al. 1994). Most significant prey species make vertical migrations and are part of the deep scattering layer (Antonelis et al. 1994).

Acoustics and Hearing—The northern elephant seal produces loud, low-frequency in-air vocalizations (Bartholomew and Collias 1962). The mean fundamental frequencies are in the range of

147 to 334 Hz for adult males (Le Bouef and Petrinovich 1974). The mean source level of the male-produced vocalizations during the breeding season is 110 dB (Sanvito and Galimberti 2003). In-air calls made by aggressive males include: (1) snoring, which is a low-intensity threat; (2) a snort (0.2 to 0.6 kHz) made by a dominant male when approached by a subdominant male; and (3) a clap threat (<2.5 kHz) which may contain signature information at the individual level (Thomson and Richardson 1995). Seismic (low frequency) vibrations accompany these in-air vocalization; they are produced as the males move about and vocalize on sand beaches (Shipley et al. 1992). These sounds appear to be important social cues (Shipley et al. 1992). The mean fundamental frequency of airborne calls for adult females is 500 to 1,000 Hz (Bartholomew and Collias 1962). In-air sounds produced by females include a <0.7 kHz belch roar used in aggressive situations and a 0.5 to 1 kHz bark used to attract the pup (Bartholomew and Collias 1962). Pups use a <1.4 kHz call to maintain contact with the mother (Bartholomew and Collias 1962). As noted by Kastak and Schusterman (1999), evidence for underwater sound production by this species is scant. Except for one unsubstantiated report (Poulter 1968), none have been definitively identified (Fletcher et al. 1996; Burgess et al. 1998). Burgess et al. (1998) detected possible vocalizations, in the form of click trains that resembled those used by males for communication in air.

The audiogram of the northern elephant seal indicates that this species is well-adapted for underwater hearing; sensitivity is best between 3.2 and 45 kHz, with greatest sensitivity at 6.4 kHz and an upper frequency cutoff of approximately 55 kHz (Kastak and Schusterman 1999). Elephant seals exhibit the greatest sensitivity to low frequency (<1 kHz) sound of seals whose hearing has been tested (Kastak and Schusterman 1998). In-air hearing is generally poor, but is best for frequencies between 3.2 and 15 kHz, with greatest sensitivity at 6.3 kHz (Kastak and Schusterman 1999). The upper frequency limit in air is approximately 20 kHz (Kastak and Schusterman 1999). Elephant seals are relatively good at detecting tonal signals over masking noise (Southall et al. 2000).

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3.2 SEA TURTLES

3.2.1 Introduction

Sea turtles are long-lived reptiles that can be found throughout the world's tropical, subtropical, and temperate seas (CCC and STSL 2003). There are seven living species of sea turtles from two distinct families, the Cheloniidae (hard-shelled sea turtles; six species) and the Dermochelyidae (leatherback sea turtle; one species). These two families can be distinguished from one another on the basis of their carapace (upper shell) and other morphological features. Sea turtles are an important marine resource in that they provide nutritional, economic, and existence (non-use) value to humans (Witherington and Frazer 2003). Over the last few centuries, sea turtle populations have declined dramatically due to anthropogenic activities such as coastal development, oil exploration, commercial fishing, marine-based recreation, pollution, and over-harvesting (NRC 1990; Eckert 1995). As a result, all six species of sea turtles found in U.S. waters are currently listed as either threatened or endangered under the ESA.

Sea turtles are highly adapted for life in the marine environment. Unlike terrestrial and freshwater turtles, sea turtles possess powerful, modified forelimbs (or flippers) that enable them to swim continuously for extended periods of time (Wyneken 1997). They also have compact and streamlined bodies that help to reduce drag. Additionally, sea turtles are among the longest and deepest diving of the air-breathing vertebrates, spending as little as 3 to 6% of their time at the water's surface (Lutcavage and Lutz 1997). These physiological traits and behavioral patterns allow for highly efficient foraging and traveling. Sea turtles often travel thousands of kilometers between their nesting beaches and feeding grounds, which makes the aforementioned suite of adaptations very important (Ernst et al. 1994; Meylan 1995). Sea turtle traits and behaviors also help protect them from predation. Sea turtles have a tough outer shell and grow to a large size as adults; mature leatherback turtles can weigh up to 916 kg (Eckert and Luginbuhl 1988). Sea turtles cannot withdraw their head or limbs into their shell, so growing to a large size as adults is important. As juveniles, some species of sea turtles evade predation by residing in habitats that are either structurally complex or moderately shallow. This prohibits marine predators such as sharks, marine crocodiles, and large fishes from easy access (Musick and Limpus 1997).

Although they are specialized for life at sea, sea turtles begin their lives on land. Aside from this brief terrestrial period, which lasts approximately three months as eggs and an additional few minutes to a few hours as hatchlings scrambling to the surf, sea turtles are rarely encountered out of the water. Sea turtles return to land primarily to nest, although some species in Hawai'i, Australia, the Galapagos Islands, and the Mexican Pacific also bask on land (Carr 1995; Spotila et al. 1997). Sea turtles observed on land are almost always females since males are not involved in the nesting process and likely gain fewer benefits from basking on land. Females bask to thermoregulate, elude predators, avoid harmful mating encounters with male sea turtles, and possibly to accelerate the development of their eggs (Spotila et al. 1997). On occasion, sea turtles can unintentionally strand on land if they are dead, injured, or cold-stunned.

Female sea turtles nest in tropical, subtropical, and warm-temperate latitudes, often in the same region where they were born (Miller 1997). Upon selecting a suitable nesting beach, sea turtles tend to re-nest in close proximity during subsequent nesting attempts. Some individuals fail to nest when emerging from the ocean. These non-nesting emergences, or false crawls, occur when sea turtles are either obstructed from laying their eggs by debris, rocks, or roots or are distracted by conditions on the nesting beach (e.g., noise, lighting, or human presence). Individuals that are successful at nesting usually lay several clutches of eggs during a nesting season with each clutch containing between 50 and 200 eggs depending upon the species (Witzell 1983; Dodd 1988; Hirth 1997). Most female sea turtles, with the possible exception of Kemp's ridleys, do not nest in consecutive years; instead, they will often skip two or three years before returning to the nesting grounds (Márquez-M. 1994; Ehrhart 1995). Nesting success is vital to the long-term existence of sea turtles since only one out of every one thousand hatchlings survives long enough to reproduce (Frazer 1986).

During the nesting season, daytime temperatures can be lethal on tropical, subtropical, and warm-temperate beaches. As a result, adult sea turtles most often nest and hatchlings most often emerge from their nest at night (Miller 1997). After emerging from the nest, sea turtle hatchlings use visual cues (e.g., light intensity or wavelengths) to orient themselves towards the sea (Lohmann et al. 1997). Hatchlings have a strong tendency to crawl in the direction of the brightest light, which on most beaches is towards the ocean/sky horizon (Ernst et al. 1994). However, some hatchlings never make it into the water. On the beach, sea turtle hatchlings are easy prey for seabirds during the day, and scavenging crabs and mammals at night (Ehrhart 1995; Miller 1997). Hatchlings can also be disoriented if artificial beachfront lighting appears brighter than the seaward horizon (Lutcavage et al. 1997).

Hatchlings that make it into the water will end up spending the first few years of their lives in offshore waters, drifting in convergence zones or amidst floating vegetation, where they find food (mostly pelagic invertebrates) and refuge in flotsam that accumulates in surface circulation features (Carr 1987). Originally labeled the "lost year," this stage in a sea turtle's life history is now known to be much longer in duration, possibly lasting a decade or more (Chaloupka and Musick 1997; Bjorndal et al. 2000). Sea turtles will spend several years growing in the "early juvenile nursery habitat," which is usually pelagic and oceanic, before migrating to distant feeding grounds that comprise the "later juvenile developmental habitat," which is usually demersal and neritic (Musick and Limpus 1997; Frazier 2001). Hard-shelled sea turtles most often utilize shallow nearshore and inshore waters as later juvenile developmental habitats, whereas leatherback turtles, depending on the season, can utilize either coastal feeding areas in temperate waters or offshore feeding areas in tropical waters (Frazier 2001).

Once in the later juvenile developmental habitat, most sea turtles change from surface to benthic feeding and begin to feed upon larger items such as crustaceans, mollusks, sponges, coelenterates, fishes, and seagrasses (Bjorndal 1997). An exception is the leatherback turtle, which will feed on pelagic soft-bodied invertebrates at both the surface and at depth (S. Eckert et al. 1989). Sea turtles do not have teeth, but their jaws have modified "beaks" suited to their particular diet (Mortimer 1995). A sea turtle's diet exhibited varies according to its feeding habitat and its preferred prey. Upon moving from the later juvenile developmental habitat to the adult foraging habitat, sea turtles may demonstrate further changes in prey preference, dietary composition, and feeding behavior (Bjorndal 1997; Musick and Limpus 1997). Sea turtles undergo complex seasonal movements, which are influenced by changes in ocean currents, turbidity, salinity, and food availability. As a result, they need to possess a specialized digestive system so that a diverse array of food items can be consumed (Mortimer 1995; Musick and Limpus 1997).

In addition to the above factors, the distribution of many sea turtle species is dependent upon and often restricted by water temperature (Epperly et al. 1995; Davenport 1997; Coles and Musick 2000). Most sea turtles become lethargic at temperatures below 10°C and above 40°C (Spotila et al. 1997). Coles and Musick (2000) observed that loggerhead turtles off North Carolina only inhabited waters between 13.3° and 28°C. This suggests that sea turtles are not randomly distributed in ocean waters but choose to stay within certain temperature ranges. The preferred temperature range varies among age classes, species, and seasons. As a species, the leatherback turtle has a much wider range of preferred water temperatures than other species because its thermoregulatory capabilities allow it to maintain a warm body temperature in temperate waters and avoid overheating in tropical waters (Spotila et al. 1997).

Although sea turtles are nearsighted out of water, their vision underwater is very good. Their sense of smell is also very keen and sea turtles are believed to use olfaction in conjunction with sight during foraging (Ernst et al. 1994). Sea turtle hearing sensitivity is not well studied. Reception of sound through bone conduction, with the skull and shell acting as receiving structures, is hypothesized to occur in some sea turtle species (Lenhardt et al. 1983). A few preliminary investigations using adult green, loggerhead, and Kemp's ridley turtles suggest that these sea turtles are most sensitive to low-frequency sounds (Ridgway et al. 1969; Lenhardt et al. 1983; Moein Bartol et al. 1999).

The range of maximum sensitivity for sea turtles is 100 to 800 Hz, with an upper limit of about 2,000 Hz (Lenhardt 1994). Hearing below 80 Hz is less sensitive but still potentially usable to the animal (Lenhardt 1994). Green turtles are most sensitive to sounds between 200 and 700 Hz, with peak sensitivity at 300 to 400 Hz. They possess an overall hearing range of approximately 100 to 1,000 Hz (Ridgway et al. 1969). Moein Bartol et al. (1999) reported that juvenile loggerhead turtles hear sounds between 250 and 1,000 Hz, while O'Hara and Wilcox (1990) found that they would often avoid sources of low-frequency sound. Finally, sensitivity even within the optimal hearing range is apparently low—threshold detection levels in water are relatively high at 160 to 200 dB with a reference pressure of one dB re 1 μPa-m (Lenhardt 1994). Not only are sea turtles receptive to sounds, they also emit sounds. Nesting leatherback turtles produce sounds in the 300 to 500 Hz range (Mrosovsky 1972).

For more information on the biology, life history, and conservation of sea turtles, the following websites can be consulted: seaturtle.org (http://www.seaturtle.org), the Caribbean Conservation Corporation (http://www.cccturtle.org), and the Archie Carr Center for Sea Turtle Research (http://accstr.ufl.edu/index.html). Other important resources include NOAA Fisheries and USFWS authored sea turtle recovery plans (http://www.nmfs.noaa.gov/prot_res/ PR3/recovery.html), NOAA Fisheries compiled Proceedings of the Annual Symposia on Sea Turtle Biology and Conservation (http://www.nmfs.noaa.gov/prot_res/PR3/Turtles/symp osia.html), Bjorndal (1995), Lutz and Musick (1997), and Lutz et al. (2003).

3.2.2 Sea Turtles of the Marianas MRA Study Area

Four of the world's seven living species of sea turtles have been reported in the waters around Guam and the CNMI (Pritchard 1995; NMFS and USFWS 1998a, 1998b, 1998c, 1998d; Kolinski 2001). These include the green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), leatherback (*Dermochelys coriacea*), and olive ridley (*Lepidochelys olivacea*) turtles. The loggerhead turtle (*Caretta caretta*) is also known to occur in the North Pacific Ocean but has never been sighted in the Marianas region (NMFS and USFWS 1998e). However, due to this species' wide-ranging nature, there is a slight possibility that it could occur in this region. As a result, a total of five sea turtle species are known to occur, or have the potential to occur, in the Marianas MRA study area (**Table 3-2**).

Table 3-2. Sea turtle species known to occur or potentially occurring in the Marianas MRA study area. Taxonomy follows Pritchard (1997). [[1] A species' occurrence in the study area can be described as one of the following: Regular—occurs as a regular or normal part of the fauna in the study area, regardless of how abundant or common it is; Rare—occurs in the study area sporadically; or Extralimital—does not normally occur in the study area and occurrences there are considered beyond the species' normal range; [2] As a species, the green turtle is listed as threatened. However, the Eastern Pacific nesting stock is listed as endangered. Since the nesting areas for green turtles encountered at sea often cannot be determined, a conservative approach to management requires the assumption that at least some of the greens found in the study area could be endangered].

	Scientific Name	ESA Status	Occurrence[1]
Order Testudines (turtles)			
Suborder Cryptodira (hidden-necked turtles)			
Family Cheloniidae (hard-shelled sea turtles)			
Green turtle	*Chelonia mydas*	Threatened[2]	Regular
Hawksbill turtle	*Eretmochelys imbricata*	Endangered	Regular
Loggerhead turtle	*Caretta caretta*	Threatened	Rare
Olive ridley turtle	*Lepidochelys olivacea*	Threatened	Rare
Family Dermochelyidae (leatherback sea turtle)			
Leatherback turtle	*Dermochelys coriacea*	Endangered	Rare

The threatened green turtle is the only sea turtle species that is routinely observed during surveys around Guam and the CNMI (Wiles et al. 1995; Kolinski et al. 1999; Pultz et al. 1999; Kolinski 2001). As a result, some scientists have concluded that it is the only sea turtle species that is common to the area (Kolinski et al. 1999; Pultz et al. 1999; Kolinski 2001). Kolinski (2001) notes that the other resident sea turtle of the Marianas archipelago, the endangered hawksbill turtle, should be classified as extremely rare. However, others believe that hawksbill turtles are not rare inhabitants of the study area and vicinity, even though they are far less abundant than green turtles (Wiles et al. 1995).

Most scientists agree that the endangered leatherback and threatened olive ridley turtles are infrequent visitors to the region. Leatherback encounters in the waters of the study area are presumed to involve individuals that are in transit to distant foraging or nesting areas in the Pacific Ocean, while olive ridley encounters likely involve individuals that are blown off course (also known as waifs) (Pritchard 1995; Kolinski 2001). It is also possible that loggerhead turtles could occur in the Marianas MRA study area, with nesting populations located in Japan and eastern Australia, a life cycle that carries individuals throughout the North Pacific Ocean, and recent sighting records from the Philippines (Sagun et al. 2005).

The distribution of all available sea turtle occurrence records by season (dry=December through June; rainy=July through November) is presented in **Figure C-1**. Occurrence records include sightings from aerial (helicopter), marine tow, SCUBA, snorkel, and shoreline surveys as well as opportunistic sightings during recreational SCUBA diving trips. It should be noted that the number of sea turtle records in a given season or portion of the study area is often a function of the source or type of data, level of effort, and sighting conditions.

Unidentified sea turtles (individuals that could not be identified to species) often account for a good number of sighting and nesting records. Hard-shelled sea turtles (which include the green, hawksbill, loggerhead, and olive ridley turtles) are often difficult to distinguish to species, particularly when they are young (i.e., small size classes) and especially during aerial and boat surveys. Sea turtles may respond to aircraft overflights and vessel approaches by making a quick dive, even before being sighted by observers, which makes both sighting and identifying a sea turtle difficult. Species identification is less reliable when individuals from the general public (e.g., recreational divers, beachgoers) sight sea turtles. The reliability of species recognition may also be in question when sea turtles strand or nest, especially if qualified individuals are not present to make an accurate identification (Lund 1985).

Occurrence data from surveys at four of the five islands in the southern Marianas arc between 1999 and 2001 reveal that the small uninhabited islands of FDM and Aguijan likely sustain on the order of tens of sea turtles while the larger inhabited islands of Saipan and Tinian probably support on the order of hundreds of sea turtles. It is estimated that the CNMI portion of the southern Marianas arc, which also includes Rota, likely supports between 1,000 and 2,000 resident sea turtles. Turtle densities and abundances in the CNMI appear to be highest at Tinian, despite its smaller size relative to Saipan and its apparent lack of seagrass forage. Juvenile sea turtles are the most abundant life stage found in the study area and vicinity; they accounted for between 60% and 82% of all sea turtle sightings at Saipan in 1999 and between 67% and 85% of all sightings at Tinian and Aguijan in 2001 (Kolinski et al. 1999; Pultz et al. 1999; Kolinski 2001).

There are no recent estimates of the number of sea turtles inhabiting the nearshore waters around Guam, although survey data from the 1970s and 1980s suggested that sea turtle numbers had been reduced over that time period (Davis n.d.; Wiles et al. 1995). During the 1990s, however, aerial survey sightings of sea turtles gradually increased from year to year (Cummings 2002). Historically, sea turtles were known to be highly abundant at several locations including off the northern and eastern coasts. Groups of 40 to 50 individuals were often observed between Ritidian Point and Pati Point during aerial surveys. From 1975 to 1979, approximately 70% of all sea turtles observed during aerial surveys around Guam were seen along the island's eastern coast (from Inarajan Bay to Ritidian Point). According to Pritchard (1995), greater numbers of sea turtles likely occurred there due to lower levels of development and fishing pressure. From 1989 to 1991, 58% of all aerial survey sightings of sea turtles occurred in northern Guam between Tanguisson Beach and Pago Bay (Wiles et al. 1995). Sea turtles have also been commonly observed inside Apra Harbor (DoN 2003a; Gutierrez 2004).

Although the resident juvenile foraging population in the study area and vicinity is large, the adult nesting population is small (Wiles et al. 1989; Pultz et al. 1999; Kolinski et al. 2001). Rota is thought to support few nesting turtles (Wiles et al. 1990), while the beaches on FDM and other islands of the northern Marianas arc are likely unsuitable for sea turtle nesting (DoN 2004). Regular nesting activity in this region is only prevalent on Guam, Tinian, and Saipan (**Figure 3-3**). However, nesting activity at these three islands is infrequent when compared to other areas in the Pacific Ocean such as Mexico, Costa Rica, Japan, Australia, and the Northwestern Hawaiian Islands (Kolinski et al. 1999; Kolinski 2001).

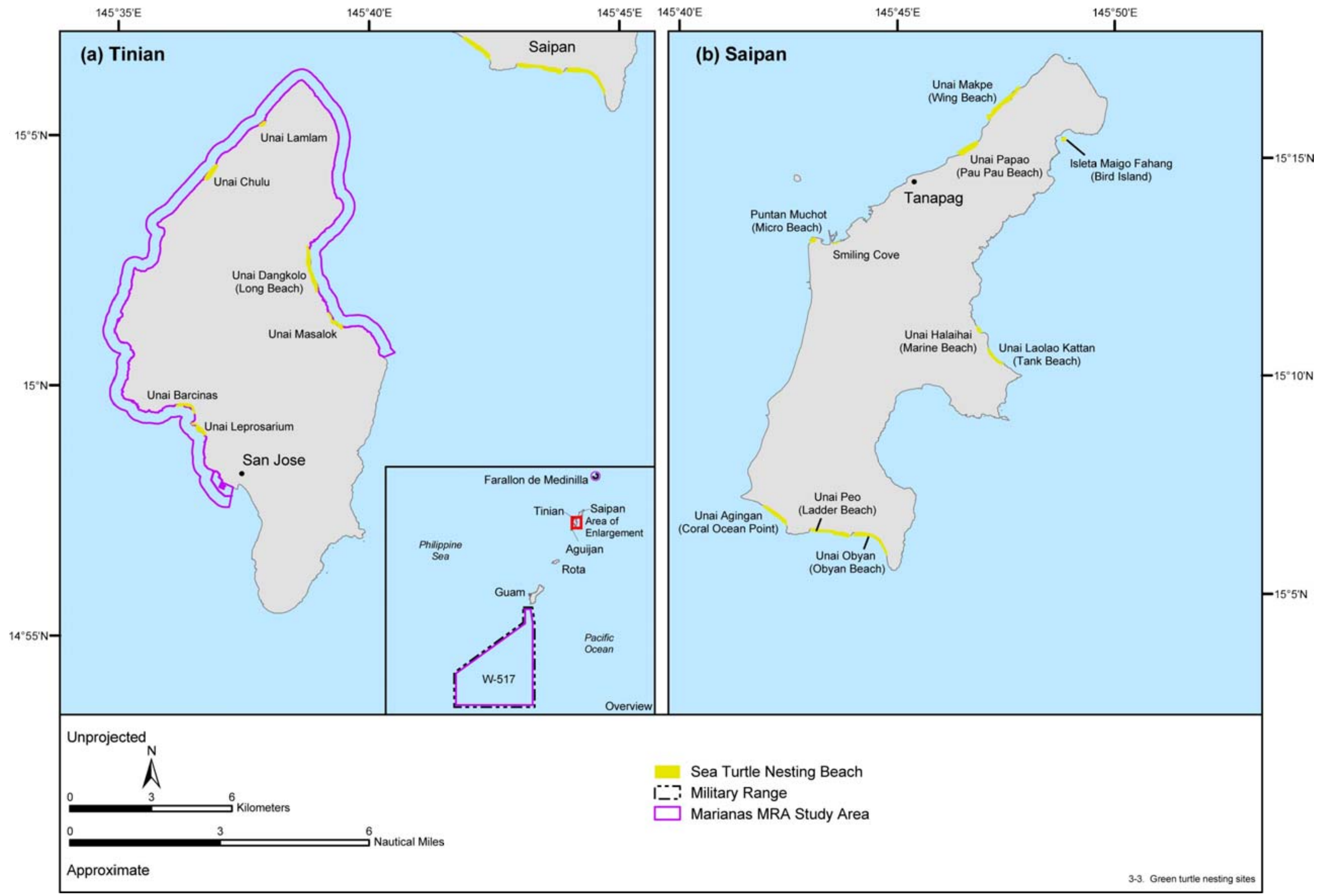

Figure 3-3. Beaches with known sea turtle nesting activity on (a) Tinian and (b) Saipan. Source information: Kolinski et al. (1999), Pultz et al. (1999), CNMI DFW (2005), and DoN (2005a).

The prevalence of certain species and life stages within the region suggests that the southern portion of the Marianas arc (including Guam) can be classified as a major foraging habitat for juvenile green turtles and a minor nesting habitat for adult green turtles. This classification does not diminish the importance of the nesting habitats on Guam and the CNMI or their potential to support other sea turtle species, as additional research needs to be conducted in those areas (Kolinski 2001).

Based upon the available occurrence data as well as information from the scientific literature, sea turtles are expected to occur year round in all waters of the Marianas MRA study area and vicinity located inside the shelf break, with the highest concentrations of sea turtles occurring in waters less than 50 m deep around Guam, Tinian, Saipan, and Rota (**Figure C-1**). Beyond the shelf break, sea turtle occurrence is low/unknown due to a lack of survey effort in deeper waters and the knowledge that small numbers of transient individuals travel to, from, or through the study area during developmental or reproductive migrations (Eckert 1993; Musick and Limpus 1997; Frazier 2001; Gutierrez 2004).

The five sea turtle species known to occur or potentially occurring in the Marianas MRA study area are listed below in taxonomic order as presented in **Table 3-2**. Summarized below are the description, status, habitat preferences, distribution (including location and seasonal occurrence in the Marianas MRA study area), behavior, and life history for each species.

♦ <u>Green Turtle</u> (*Chelonia mydas*)

Description—The green turtle (*Chelonia mydas*) is the largest hard-shelled sea turtle, with adults commonly exceeding 100 cm in carapace length and 100 kg in weight. As hatchlings, they are only about 50 mm long and weigh approximately 25 g. Adult carapaces range in color from solid black to gray, yellow, green, and brown in muted to conspicuous patterns; the plastron is a much lighter yellow to white. Hatchlings are distinctively black on the dorsal surface and white on the ventral (NMFS and USFWS 1998a).

The genus *Chelonia* includes a single species, *Chelonia mydas*, with two distinct subspecies, the East Pacific green or black turtle (*Chelonia mydas agassizii*) and the green turtle (*Chelonia mydas mydas*). The East Pacific green turtle is conspicuously smaller, lighter in color, and has a narrower, more strongly vaulted carapace than the green turtle (NMFS and USFWS 1998a, 1998f). According to genetic analyses, *C. m. agassizii* is not a unique lineage relative to other green turtle populations throughout the world (Bowen and Karl 1997). As a result, the genus *Chelonia* is considered monotypic in this report and any mention of “green turtle” will be in reference to the species, *Chelonia mydas*, rather than to the two proposed subspecies.

Status—Green turtles are classified as threatened under the ESA throughout their Pacific range, except for the population that nests on the Pacific coast of Mexico (identified by the NMFS and USFWS [1998f] as *C. m. agassizii*), which is classified as endangered. East Pacific green turtles are recognized as a distinct population segment by the NOAA Fisheries and USFWS and are managed under a separate recovery plan. With the exception of Hawai’i, green turtle populations are in serious decline throughout the Pacific Ocean. The primary threats to green turtles at Guam and the CNMI include direct harvesting of turtles and eggs as well as habitat loss due to rapidly expanding tourism, including increased coastal development on nesting beaches. There are no estimates of the current population size of green turtles in the Pacific Ocean (NMFS and USFWS 1998a, 1998f).

Habitat Preferences—In the Pacific Ocean, the early juvenile developmental habitat of the green turtle is unknown. After hatchlings leave the nesting beach, they apparently move into convergence zones in the open ocean where they spend an undetermined amount of time in the pelagic environment (Balazs 2004). Once green turtles reach a carapace length of 35 cm, they migrate to shallow nearshore areas where they spend the majority of their lives as late juveniles and adults (Balazs 1980; NMFS and USFWS 1998a).

The optimal habitats for benthic-stage juveniles and adults are warm, quiet, and shallow (3 to 10 m) waters that possess an abundance of submerged aquatic vegetation (seagrasses and/or algae) and are located in close proximity to nearshore reefs or rocky areas used for resting (Balazs 1980; Ernst et al. 1994). Green turtles can feed as deep as their primary food source will grow. In Hawai'i, green turtles are known to forage and rest in waters as deep as 20 to 50 m (Brill et al. 1995). In the Mariana Islands, resting areas usually occur just outside of the fringing reef in caves and depressions associated with the reef face. Resting areas can also be found in channels and other structures associated with hard substrate. These areas tend to be located at water depths between 10 and 40 m (NMFS 1998).

Distribution—Green turtles are distributed worldwide in tropical and subtropical waters with temperatures above 20°C. The most important nesting and feeding grounds lie within the tropics (Pritchard 1997). In U.S. Pacific waters, green turtles are regularly found off the coasts of southern California, the Hawaiian Islands, American Samoa, Guam, the CNMI, and several of the unincorporated U.S. territories such as Wake Island and Palmyra Atoll (NMFS and USFWS 1998a). During warm spells, adult and juvenile green turtles have been sighted in waters as far north as Alaska, where 15 occurrences have been documented since 1960 (Eckert 1993; Wing and Hodge 2002). This species occurs throughout the year in tropical waters such as those off of Guam and the CNMI.

As they grow, juvenile green turtles are known to move through a series of developmental feeding habitats, which are often separated by thousands of kilometers (Hirth 1997). Mixed-stock analyses on juvenile foraging populations have revealed that developmental feeding habitats likely contain green turtles from multiple stocks. Green turtles captured on foraging grounds off Baja California and in San Diego Bay have shown physical and genetic characteristics of both the Mexican Pacific and Hawaiian breeding populations (Dutton and McDonald 1990; Nichols et al. 2000a). However, little is known regarding the stock compositions of juvenile foraging populations in the insular Pacific Ocean.

Adult green turtles are known to undertake extensive migrations, the longest of which are between their foraging habitats and nesting beaches. Long-distance reproductive migrations have been noted for green turtles nesting at a number of locations in the Pacific Ocean including the Northwestern Hawaiian Islands, Taiwan, Hong Kong, American Samoa, and Guam (Balazs 1976, 1980, 1983; Cheng 2000; Chan 2003; Craig et al. 2004; Gutierrez 2004). From June through November 2000, biologists from the Guam Division of Aquatic and Wildlife Resources (DAWR) satellite-tracked an adult green turtle's post-nesting movements from its nesting beach at Hagåtña, Guam to its feeding grounds in the southern Philippines, a trip of nearly 3,500 km (**Figure 3-4**).

Green turtles nest throughout the Pacific Ocean, with active nesting colonies in the eastern, central, and western regions. Major nesting colonies in the eastern Pacific are located in Mexico and the Galapagos Islands, while high-density nesting sites in the western Pacific are found primarily in eastern Australia (along the Great Barrier Reef). Green turtle nesting populations in the insular Pacific Ocean are relatively small. The largest nesting colony in the insular Pacific occurs at French Frigate Shoals in the Northwestern Hawaiian Islands, where about 200 to 700 females nest each year. Elsewhere in the U.S. Pacific, low-level nesting (less than ten individuals per year) occurs at scattered locations in the CNMI, Guam, and American Samoa (NMFS and USFWS 1998a). At least 24 green turtle nests were documented during comprehensive beach surveys on Tinian in 1995 and six green turtle nests were documented during similar surveys on Saipan in 1999 (Kolinski et al. 1999; Pultz et al. 1999).

- Information Specific to Marianas MRA Study Area—Green turtles are by far the most abundant sea turtle found throughout the Marianas archipelago. Aerial surveys conducted by the Guam Division of Aquatic and Wildlife Resources (DAWR) indicate the presence of a year-round resident population in Guam's nearshore waters (NMFS 1998). From 1989 to 1991, green turtles accounted for at least 65.8% of all aerial survey sightings around the island (Davis n.d.). Aggregations of foraging and resting green 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

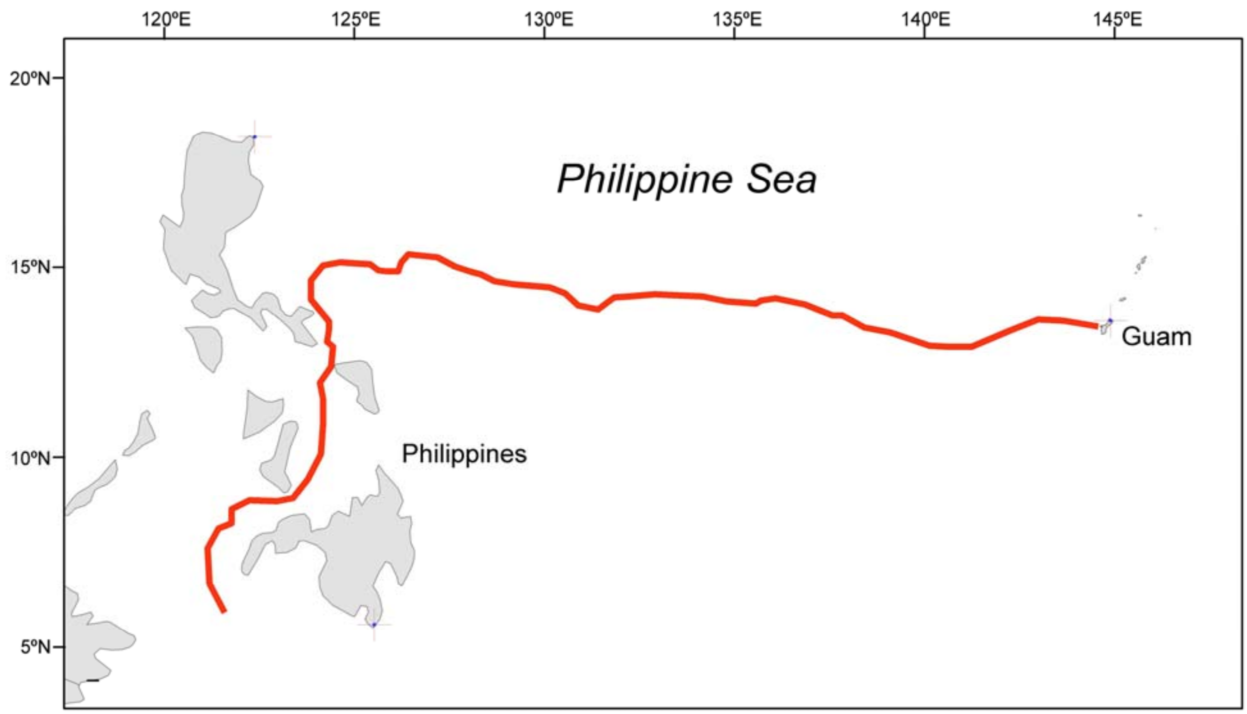

Figure 3-4. The post-nesting migration of a female green turtle satellite-tagged near Hagåtña, Guam in June 2000. The sea turtle's movements were monitored via the ARGOS satellite system under the funding of the Commander, U.S. Naval Forces Marianas (COMNAVMARIANAS). The last recorded location occurred in November 2000 in the Panguataran Islands, Philippines. Map adapted from: Gutierrez (2004).

locations throughout the island's shelf (Davis n.d.; Wiles et al. 1995; DoN 2003a; Abraham et al. 2004). Recreational SCUBA divers regularly see green turtles at the following sites off Guam: Boulder Alley, Ane Caverns, Napoleon Cut, Gab Gab I, and the Wall (Franko's Maps 2005). Green turtle nesting on Guam is most prevalent at the northern and southern ends of the island. At present, the Guam DAWR regularly surveys eight separate stretches of beach for green turtle nesting activity (Gutierrez 2004). The most utilized nesting beaches at Guam are Tarague Beach, Falcona Beach, Ritidian Beach, Asiga Beach, Urunao Point, and the beaches along Cocos Island and Sella Bay (Davis n.d.; Pritchard 1995; Wiles et al. 1995; Gutierrez 2004). However, beaches that are not currently being surveyed could be equally as important.

At Tinian, green turtle abundance and density are highest along the island's relatively uninhabited east coast. The most recent estimate of the number of green turtles inhabiting the nearshore waters around Tinian was 832 turtles in 2001 (Kolinski et al. 2004). Green turtle numbers are projected to be higher at Tinian than at Saipan, even though Saipan is a larger island with more extensive seagrass habitats. The presence of seagrasses around Tinian is limited, so green turtles occurring there likely feed on algae. At least 24 known forage species of algae were found at Tinian during recent habitat surveys (Kolinski 2001). Since only juvenile age classes feed primarily on algae, it is likely that Tinian does not serve as a resident foraging ground for adult green turtles (Pultz et al. 1999). However, nesting surveys have indicated that adult green turtles utilize most, if not all, beaches on Tinian for nesting (NMFS 1998). The beaches that are most often utilized are Unai Dangkolo (Long Beach), Unai Barcinas, Unai Leprosarium, and Unai Lamlam (Pultz et al. 1999; DoN 2005a; **Figure 3-3**). In 1995, an adult green turtle nesting at Tinian was later recovered in the Philippines. This event provided evidence that adult green turtles nesting in the Marianas archipelago have geographically distinct foraging grounds that are often located thousands of kilometers away. In June 2002, a team of personnel from the Navy, CNMI Division of Fish and Wildlife (DFW), Guam DAWR, and USFWS satellite-tagged three adult female green turtles on their nesting beaches at Tinian. This project was implemented to further study the movements and migrations of green sea turtles from waters and beaches that are owned and leased by the Navy on and around Tinian (Kessler and Vogt 2002).

At FDM, four green turtles were observed at the northern end of the island during Navy-sponsored marine tow and SCUBA surveys in 2003 (DoN 2004). At least 9 green turtles were observed during underwater surveys in both 1999 and 2000, while at least 12 green turtles were observed during surveys in 2001. Most green turtles at FDM have been found either swimming over the reef platform or resting in holes or caves (DoN 2001). Green turtles are not as abundant at FDM as they are at some of the larger islands of the Marianas chain. Due to strong current and tidal conditions, the beaches at FDM are highly unsuitable for nesting (DoN 2004). Also, seagrasses and benthic algae are relatively sparse around the island and can probably support no more than a few green turtles at a time (NMFS 1998).

Based on the above information, green turtles are expected to occur year round in all shelf waters of the study area and vicinity from FDM to Guam (**Figure C-2**). Around the larger islands of Tinian, Saipan, Rota, and Guam, green turtle occurrence is concentrated in waters less than 50 m deep. It is at these water depths where green turtle foraging and resting habitats (e.g., fringing reefs, reef flats, and seagrass beds) are usually found. Beyond the shelf break, green turtle occurrence is low/unknown. Nesting females and early juveniles are known to move through oceanic waters of the Marianas chain during their reproductive and developmental migrations (Gutierrez 2004; Kolinski et al. 2004), but likely do not do so in large enough numbers every year to warrant those waters being designated as additional areas of expected occurrence.

Behavior and Life History—Late juvenile and adult green turtles feed primarily on seagrasses (e.g., turtle grass, manatee grass, shoal grass, and eelgrass), macroalgae, and reef-associated organisms (Burke et al. 1992; Ernst et al. 1994; Bjorndal 1997). Early juveniles are omnivorous; they feed on a variety of algae, invertebrates, and small fishes (Ernst et al. 1994). Observations of foraging adult green turtles in Hawai'i suggest that when benthic age classes feed, they generally lie down on the sea bottom and, when food is no longer within easy reach, they crawl or swim to a nearby site (Hochscheid et al. 1999).

Green turtles take between 27 and 50 years to reach sexual maturity, the longest age to maturity for any sea turtle species (Frazer and Ehrhart 1985). In the insular Pacific Ocean, mature females nest from one to seven times in a season (one to two is typical) at approximately 10 to 15 day intervals and reproduce every 2 to 3 years (Balazs 1980). In contrast, over half of all adult male green turtles return to the breeding grounds every year. During the breeding season, green turtle courtship and copulation occur in waters proximal to the nesting beach (Owens 1980; NMFS and USFWS 1998a). The nesting season for green turtles at Guam and the CNMI likely commences in late January and concludes in August, although recent surveys of nesting beaches on Guam have revealed that green turtle nesting can occur throughout the year (Kolinski et al. 1999; Pultz et al. 1999; Gutierrez 2004). At Tinian, green turtle clutch sizes during the 1995 nesting season ranged from 73 to 110 eggs with an average of 91 eggs per nest (Pultz et al. 1999).

Green turtles typically make dives shallower than 30 m (Hochscheid et al. 1999; Hays et al. 2000); however, a maximum dive depth of 110 m has been recorded in the Pacific Ocean (Berkson 1967). The maximum dive time recorded for a juvenile green turtle in Hawai'i is 66 min, with routine dives ranging from 9 to 23 min (Brill et al. 1995). In Guam's Agana Boat Basin, a female green turtle stayed underwater for a record 79 min in order to elude capture by local fishermen (Anonymous 1976).

- Hawksbill Turtle (*Eretmochelys imbricata*)

Description—The hawksbill turtle is a small to medium-sized sea turtle. Adults range between 65 and 90 cm in carapace length and typically weigh around 80 kg (Witzell 1983). Hawksbills are distinguished from other sea turtles by their hawk-like beaks, posteriorly overlapping carapace scutes, and two pairs of claws on their flippers. The carapace of this species is often brown or amber with irregularly radiating streaks of yellow, orange, black, and reddish-brown (NMFS and USFWS 1998b).

Status—Hawksbill turtles are classified as endangered under the ESA and are second only to the Kemp's ridley turtle in terms of endangerment (Bass 1994; NMFS and USFWS 1998b). In U.S. waters, hawksbill populations are noted as neither declining nor showing indications of recovery (Plotkin 1995). Only five regional populations worldwide remain with more than 1,000 females nesting annually (Seychelles, the Mexican Atlantic, Indonesia, and two in Australia) (Meylan and Donnelly 1999). A lack of regular quantitative surveys for hawksbill turtles in the Pacific Ocean and the discrete nature of this species' nesting have made it extremely difficult for scientists to assess the distribution and population status of hawksbills in the region (NMFS and USFWS 1998b; Seminoff et al. 2003). The status of the hawksbill is clearly of a higher concern for the Pacific due to the serious depletion of the species caused by international harvest and habitat destruction (NMFS and USWFS 1998b).

Habitat Preferences—In the Atlantic Ocean and Caribbean Sea, early juveniles are known to inhabit oceanic waters, where they are sometimes associated with drift lines and floating patches of *Sargassum* (Parker 1995). In the Pacific Ocean, the oceanic whereabouts of this early life stage is unknown (NMFS and USFWS 1998b). However, it is likely that they would occur in similar areas of advection where flotsam accumulates (HDLNR 2002).

It is believed that hawksbill turtles migrate to benthic foraging grounds when they reach 20 to 25 cm in length (Meylan 1988). Late juvenile and adult hawksbill turtles forage around coral reefs, mangroves, and other hard-bottom habitats in open bays and coastal zones throughout the tropical Pacific Ocean, with adults occupying somewhat deeper waters (to 24 m) than late juveniles (to 12 m) due to their ability to make deeper dives (Eckert 1993).

Distribution—Hawksbill turtles are circumtropical in distribution, generally occurring from 30°N to 30°S latitude within the Atlantic, Pacific, and Indian Ocean basins (NMFS and USFWS 1998b). Although they exhibit similar habitat and water temperature preferences, hawksbills are generally less common than green turtles around insular habitats of the North Pacific Ocean, with the exception of the waters surrounding Palau (NMFS 1998).

Hawksbills were originally thought to be a non-migratory species because of the close proximity of their nesting beaches to their coral reef feeding habitats and the high rates of local recapture. Hawksbills are now known to travel long distances over the course of their lives (Meylan 1999). Tag return, genetic, and telemetry studies have indicated that hawksbill turtles utilize multiple developmental habitats as they age. However, within a given life stage, such as the late juvenile stage, some hawksbills may remain at a specific developmental habitat for a long period of time (Meylan 1999). Foraging hawksbills at Guam and the CNMI likely come from natal beaches located a good distance away from the Marianas archipelago, such as those in Palau, the Philippines, and possibly southern Japan (NMFS 1998; NMFS and USFWS 1998b).

Hawksbill nesting in the North Pacific Ocean is widespread and occurs at scattered locations in very small numbers (Eckert 1993). The NMFS and USFWS (1998b) note that the nesting picture for hawksbills throughout Micronesia appears grim. The nesting population of hawksbills at Palau is the largest of all Micronesian islands located north of the equator (Eckert 1993). Pritchard (1995) indicates that hawksbills nest sporadically in Guam and rarely, if ever, in the CNMI. If Palau represents the highest hawksbill nesting activity known in the region, with conceivably as few as 20 nesting females per year, then all of Micronesia, with its thousands of islands and atolls, may not support collectively more than a few hundred nesting females per year (NMFS and USFWS 1998b).

- <u>Information Specific to Marianas MRA Study Area</u>—Although there are only a few recent hawksbill occurrence records in the study area and vicinity (DoN 2004; Michael 2004), historical records indicate a likely presence of this species in the coastal waters surrounding the islands of the southern Marianas arc (i.e., from FDM south to Guam) (Wiles et al. 1989, 1990, 1995; Kolinski 2001; Gutierrez 2004). As a result, hawksbill turtles are expected to occur in all study area waters located inside the shelf break, including within Guam's Apra Harbor. However, since the species is highly endangered and does not occur in large numbers anywhere within the region, there are no areas of concentrated occurrence around Guam and the CNMI. In deeper waters beyond the shelf break (e.g., throughout W-517 and in a large portion of the study area around FDM), the occurrence of the hawksbill turtle is low/unknown. In these waters, the preferred habitat of the hawksbill is scarce and survey effort is minimal. This occurrence pattern is due to the species' great reliance on shallow coastal areas, where coral reefs and live/hardbottom habitats primarily occur, and the possibility that small numbers of individuals may be making long-distance migrations through the oceanic waters of the study area on their way to and from areas of the North Pacific Ocean where they are more abundant, such as Palau.

During aerial surveys between 1989 and 1991, hawksbills represented 13.2% of all sea turtles sighted around Guam (Davis n.d.). Wiles et al. (1995) indicate that hawksbills are typically found near river mouths as well as inside Apra Harbor. These are areas where sponges, their preferred food, are common. Sasa Bay, which is located in the backwaters of Apra Harbor, appears to be an area where hawksbills are most often encountered (Gutierrez 2004). Randall et al. (1975) note that hawksbills have also been sighted in the protected waters of Cocos Lagoon. Hawksbill turtles are also regular inhabitants of Tinian, albeit in much fewer numbers than green turtles. Even though past surveys at Tinian (1984/1985, 1994/1995, and 2001) have failed to produce a single sighting record, time and area constraints may have led to foraging hawksbills being missed (Wiles et al. 1989; Pultz et al. 1999; Kolinski 2001). The only occurrence records that exist for FDM are two in-water sightings at the southwestern corner of the island in 2001 and one at the northwest corner of the island in 2004 (DoN 2005b). Each of these observations was recorded during Navy-sponsored marine tow and SCUBA dive surveys around the island. Both of the hawksbills sighted in 2001 were immature individuals less than 50 cm in carapace length, while the individual observed in 2004 was somewhat larger at 70 cm in carapace length (DoN 2005b).

There are only a few documented records of hawksbills nesting in the Marianas region although only a subset of the region's beaches are adequately surveyed for sea turtle nesting activity. One hawksbill nest was recorded between Urunao Point and Tarague Beach (northern Guam) in 1984 and single nesting events were recorded on a small beach at Sumay Cove, Apra Harbor in 1991 and 1992 (Davis n.d.; NMFS 1998). Hawksbill turtles have not been observed to nest on Tinian although nesting attempts could be made at times and locations where surveys are not being conducted. Since hawksbills prefer to nest in areas with sufficient vegetative cover, it's possible that some nests are never found on surveyed beaches. Lund (1985) notes that hawksbill nests are often very difficult to identify when qualified observers are not present. Hawksbills are unlikely to be encountered on the beaches of FDM, which are unsuitable for nesting (DoN 2003b).

Behavior and Life History—Early juveniles are believed to utilize pelagic *Sargassum* or other flotsam as a developmental habitat, but little is known about their diets during this stage. Upon recruiting to benthic feeding habitats, hawksbills are known to become omnivorous and will feed on encrusting organisms such as sponges, tunicates, bryozoans, algae, mollusks, and a variety of other items such as crustaceans and jellyfish (Bjorndal 1997). Older juveniles and adults are more specialized and feed primarily on sponges. Sponges comprise as much as 95% of their diet in some locations (Witzell 1983; Meylan 1988).

Hawksbill turtles often nest in multiple, small, scattered colonies. Nesting is often seasonal, but can extend throughout the year with one or two peaks. In Palau, for example, hawksbill nesting is known to occur year round with peaks from June to August and December to January. Since very few data are available for hawksbills that nest in Micronesia, much of the information presented below is taken from studies of other rookeries in the Caribbean, Indian Ocean, and western Pacific regions. Mating is believed to take place in the shallow waters adjacent to the nesting beach. Nesting occurs on both low- and high-energy beaches in tropical latitudes. It is often a nocturnal activity that occurs on beaches with sufficient vegetative cover. Females will often nest between two and five times per season with inter-nesting intervals of about 14 to 16 days. The typical remigration interval is two to three years. Clutch sizes in the central and western Pacific Ocean are relatively large at 110 to 150 eggs, and incubation time is 50 to 61 days (Eckert 1993; NMFS and USFWS 1998b).

Hawksbills may have one of the longest routine dive times of all the sea turtles. Starbird et al. (1999) reported that inter-nesting females at Buck Island averaged 56.1 min dives with a maximum dive time of 73.5 min. Mean surface time was about 2 min. Average dives during the day ranged from 34 to 65 min, while those at night were between 42 and 74 min. The movements of all the turtles studied were confined to an area less than 1.5 km^2. Data from time-depth recorders have indicated that foraging dives of immature hawksbills in Puerto Rico range from 8.6 to 14 min and have a mean depth of 4.7 m (van Dam and Diez 1996). These individuals were found to be most active during the day.

- Loggerhead Turtle (*Caretta caretta*)

Description—Loggerheads are large, hard-shelled sea turtles. The average carapace length of an adult female loggerhead is between 90 and 95 cm and the average weight is 100 to 150 kg (Dodd 1988; NMFS and USFWS 1998e). The size of a loggerhead turtle's head compared to the rest of its body (i.e., aspect ratio) is substantially larger than that of other sea turtles. Adults are mainly reddish-brown in color on top and yellowish underneath.

Status—Loggerhead turtles are classified as threatened under the ESA. There are no historical data to determine with certainty the past or present abundance of loggerhead turtles in the Pacific Ocean. A few thousand to hundreds of thousands of loggerheads likely comprise the juvenile foraging population found off Baja California Sur, Mexico while as many as two to three thousand loggerheads may nest annually on beaches throughout Japan. The rate of growth or decline in loggerhead turtle populations throughout the Pacific Ocean is unknown (NMFS and USFWS 1998e).

Incidental bycatch in commercial fisheries is a tremendous source of loggerhead mortality. Lewison et al. (2004) noted that an estimated 30,000 to 75,000 loggerhead turtles were taken as pelagic longline bycatch in the Pacific Ocean in 2000. Rapid declines in nesting females at all major Pacific rookeries suggest that longline bycatch is leading to increased levels of loggerhead mortality in the Pacific Ocean (Kamezaki et al. 2003; Limpus and Limpus 2003). In 2004, the NOAA Fisheries concluded that the pelagic longline fishery is likely to jeopardize the continued existence of loggerhead turtles in the Pacific Ocean. As a protective measure, the NOAA Fisheries is now prohibiting U.S. vessels from fishing with shallow longline sets throughout the Pacific Ocean (NMFS 2004).

Habitat Preferences—The loggerhead turtle occurs worldwide in habitats ranging from coastal estuaries, bays, and lagoons to waters far beyond the continental shelf (Dodd 1988). Early juvenile loggerheads are primarily oceanic, occurring in pelagic convergence zones where they are transported throughout the ocean by dominant currents (Carr 1987). Late juvenile and adult loggerheads are generally found around reefs and other hard bottom habitats although a large population of juveniles is found in pelagic waters of the eastern Pacific Ocean off Baja California Sur. Mexican shrimpers often see juvenile loggerheads floating on the surface in waters 20 to 60 m deep (Cliffton et al. 1995).

Satellite-tracking studies on loggerheads captured in pelagic longline fishing gear indicate that individuals traveling west in the North Pacific Ocean move north and south on a seasonal basis. These individuals move primarily through the region bounded by 28°N and 40°N latitude and occupy sea surface temperatures between 15° and 25°C. The Transition Zone Chlorophyll Front and the Kuroshio Extension Current appear to be important foraging and migration habitats for loggerhead turtles in this region (Polovina et al. 2004). Polovina et al. (2000) noticed that juvenile loggerheads often follow the 17° and 20°C isotherms north of Hawai'i.

Distribution—The loggerhead turtle is a circumglobal species inhabiting the temperate, subtropical, and tropical waters of the Atlantic, Pacific, and Indian Oceans (Ernst et al. 1994). Polovina et al. (2000) have inferred that the distribution of loggerheads is continuous across the Pacific Ocean, although Eckert (1993) and the NMFS and USFWS (1998e) identified loggerheads as being rare in the central Pacific. In the eastern Pacific Ocean, loggerheads have been documented to occur as far north as Alaska and as far south as Chile (Bane 1992). A large juvenile foraging population is found off the west coast of Baja California Sur, in a band starting about 30 km offshore and extending out at least another 30 km (NMFS and USFWS 1998e; Nichols et al. 2000b).

Genetic analyses indicate that nearly all of the loggerheads found in the North Pacific Ocean are born on nesting beaches in Japan (Bowen et al. 1995; Resendiz et al. 1998). Pacific loggerheads appear to utilize the entire North Pacific Ocean during the course of development, much like Atlantic loggerheads use the North Atlantic Ocean. There is substantial evidence that both stocks make two separate transoceanic crossings. The first crossing (west to east) is made immediately after hatching from the nesting beach, while the second (east to west) is made upon reaching either the late juvenile or adult life stage. In the North Atlantic Ocean, hatchlings born on beaches in the western Atlantic swim with the North Atlantic Gyre system in order to reach developmental habitats in the eastern Atlantic (around the Azores and Madeira) (Bolten et al. 1998). In the North Pacific Ocean, hatchlings born on beaches in the western Pacific swim with the NPSG system in order to reach developmental habitats in the eastern Pacific (off southern California and Mexico) (Polovina et al. 2000). Unlike the case in the eastern Atlantic, where nesting grounds actually do exist (e.g., in the Mediterranean Sea along the coast of Greece), all juvenile loggerheads found in the eastern Pacific must eventually return to the western Pacific in order to reproduce. Nichols et al. (2000b) have concluded that loggerhead turtles are highly capable of transpacific migration and that the band of water between 25°N and 30°N, also known as the Subtropical Frontal Zone, may be an important migratory corridor for loggerheads returning to the western Pacific.

Major nesting grounds are located in warm, temperate and subtropical regions, with some scattered nesting in the tropics. The world's largest loggerhead nesting colonies are found at Masirah Island, Oman (bordering the Arabian Sea) and along the Atlantic coast of Florida. Nesting in the Pacific basin is restricted to the western region (primarily Japan and Australia). There is no loggerhead nesting on Pacific beaches under U.S. jurisdiction (NMFS and USFWS 1998e).

- Information Specific to Marianas MRA Study Area—There are no sighting, stranding, or nesting records for loggerhead turtles around Guam and the CNMI. The nearest occurrences of this species are from the waters off Palau and the Philippines (NMFS and USFWS 1998d; Sagun et al. 2005). This species is more apt to be found in temperate waters of the North Pacific Ocean (i.e., north of 25°N) off of countries such as Japan, China, Taiwan, northwestern Mexico, and the southwestern U.S. including Hawai'i (NMFS and USFWS 1998e; Polovina et al. 2001, 2004). However, Guam and the CNMI are identified as being within the species' overall range (USFWS 2005). Also, the westward flowing current of the NPSG system, which late juvenile stage loggerheads use when returning to the western Pacific, passes through the Marianas region (Pickard and Emery 1982; Polovina et al. 2000). As a result, the occurrence of the loggerhead turtle is low/unknown throughout the year in all oceanic waters of the study area and vicinity located beyond the shelf break. Since loggerhead occurrences in the waters off Guam and the CNMI would most likely involve transient individuals, occurrence is not expected in coastal (i.e, shelf) waters around any of the islands in the study area and vicinity (**Figure C-4**).

Behavior and Life History—The diet of a loggerhead turtle changes with age and size. The gut contents of early juveniles found in masses of *Sargassum* contained parts of *Sargassum,* zooplankton, jellyfish, larval shrimp and crabs, insects, and gastropods (Carr and Meylan 1980; Richardson and McGillivary 1991; Witherington 1994). Late juvenile loggerhead turtles are omnivorous, foraging on pelagic crabs, mollusks, jellyfish, and vegetation captured at or near the surface (Dodd 1988). Off Baja California Sur, the distribution of juvenile loggerheads coincides with that of a large population of pelagic red crabs (*Pleuroncodes planipes*) (NMFS and USFWS 1998e). This indicates that juvenile loggerheads in the eastern Pacific Ocean are probably feeding on dense concentrations of this highly abundant crustacean. Adult loggerheads are generally carnivorous, foraging on benthic invertebrates in nearshore waters. However, fish and plants are also taken on occasion (Dodd 1988).

Loggerhead nesting in the North Pacific Ocean occurs between April and August, when nearshore water temperatures reach 20°C and above (NMFS and USFWS 1998e). Females from the Japanese nesting stock nest at least three times per season, at about two-week intervals (Eckert 1993). Loggerhead clutches contain between 60 and 150 eggs and often take about 60 days to incubate. Dodd (1988) estimated that the global average hatching success for loggerheads is nearly 75%. Adult females nest at multiple year intervals, with the majority nesting every two years (Frazer 1995).

On average, loggerhead turtles spend over 90% of their time underwater (Byles 1988; Renaud and Carpenter 1994). Dive-depth distributions compiled by Polovina et al. (2003) in the North Pacific Ocean indicate that loggerheads tend to remain at depths shallower than 100 m. Routine dive depths are typically shallower than 30 m, although dives of up to 233 m were recorded for a post-nesting female loggerhead off Japan (Sakamoto et al. 1990). Routine dives can last from 4 to 172 min (Byles 1988; Sakamoto et al. 1990; Renaud and Carpenter 1994).

- Olive Ridley Turtle (*Lepidochelys olivacea*)

Description—The olive ridley is a small, hard-shelled sea turtle named for its olive green colored shell. Adults often measure between 60 and 70 cm in carapace length and rarely weigh over 50 kg. The carapace of an olive ridley turtle is wide and almost circular in shape. The olive ridley differs from the Kemp's ridley, the other member of the genus *Lepidochelys*, in that it possesses a smaller head, a narrower carapace, and several more lateral carapace scutes (NMFS and USFWS 1998d).

Status—Olive ridleys are classified as threatened under the ESA, although the Mexican Pacific coast nesting population is labeled as endangered. There has been a general decline in the abundance of this species since its listing in 1978. Until the advent of commercial exploitation, the olive ridley was highly abundant in the eastern tropical Pacific, probably outnumbering all other sea turtle species combined in the area (NMFS and USFWS 1998d). Cliffton et al. (1995) estimated that a minimum of 10 million olive ridleys were present in ocean waters off the Pacific coast of Mexico prior to 1950. Even though there are no current estimates of worldwide abundance, the olive ridley is still considered the most abundant of the world's sea turtles. However, the number of olive ridley turtles occurring in U.S. territorial waters is believed to be small (NMFS and USFWS 1998d).

Habitat Preferences—Olive ridley turtles typically inhabit offshore waters, foraging either at the surface or at depth (usually up to 150 m). The habitat preferences of the olive ridley more closely parallel those of the leatherback rather than those of its relative, the Kemp's ridley. Olive ridleys and leatherbacks both occupy oceanic habitats and nest primarily on the Pacific shores of the American tropics and in the Guianas. Both species also nest in moderate numbers in southern Asia and in very small numbers elsewhere (e.g., in Australia and on small oceanic islands in the Pacific Ocean) (NMFS and USFWS 1998d). Polovina et al. (2004) discovered that olive ridleys in the North Pacific Ocean are found primarily between 8° and 31°N latitude in waters between 23° and 28°C.

Distribution—The olive ridley turtle is a pantropical species, occurring worldwide in tropical and warm temperate waters. It is by far the most common and widespread sea turtle in the North Pacific Ocean; individuals regularly occur in waters as far north as California and as far south as Ecuador (Pitman 1990; NMFS and USFWS 1998d). Further offshore from North and South America, olive ridley turtles become increasingly uncommon, both at sea and around oceanic islands (Balazs 1995). Olive ridleys are rare visitors to the insular Pacific Ocean, although they have been recorded in increasing numbers in Hawai'i over the past few decades (Eckert 1993). Available information suggests that olive ridleys traverse the oceanic waters surrounding the Hawaiian Islands during foraging and developmental migrations (Nitta and Henderson 1993).

The second largest nesting population of olive ridleys occurs in the eastern Pacific Ocean, along the west coasts of Mexico and Central America (NMFS and USFWS 1998d). The largest rookeries in this region can be found in southern Mexico and northern Costa Rica. Nesting also takes place in the western Pacific Ocean along the shores of Malaysia and Thailand (Eckert 1993). Female olive ridleys rarely nest in the insular Pacific Ocean due to their preference for beaches located along continental margins. In Hawai'i, a single nesting was recorded in September 1985 on the island of Maui, but there was no successful hatching associated with this event (Balazs and Hau 1986). Since there are no other known nesting records for the insular Pacific Ocean, this nesting attempt can be considered an anomaly (NMFS and USFWS 1998d).

Genetic analysis of olive ridleys taken in the Hawai'i-based longline fishery has shown that individuals from both eastern and western Pacific nesting populations forage in the insular North Pacific Ocean (Dutton et al. 2000). However, olive ridleys born on eastern Pacific beaches appear to utilize different oceanic habitats in the region from those used by individuals born on western Pacific beaches. Olive ridleys of western Pacific origin have been observed in association with major ocean currents of the central North Pacific, specifically the southern edge of the Kuroshio Extension Current, the NEC, and the Equatorial Counter Current. These habitats, which are also frequented by Pacific loggerhead turtles, are probably not used as frequently by olive ridleys of eastern Pacific origin. Instead, olive ridleys from eastern Pacific nesting populations seem to inhabit waters in the center of the Subtropical Gyre system. These waters are characterized by warmer temperatures, weaker currents, greater vertical stratification, and a deeper thermocline (Polovina et al. 2003, 2004). It is unknown whether olive ridley occurrences in more tropical areas of the insular Pacific Ocean, such as Micronesia, would include individuals of eastern or western Pacific origin.

- Information Specific to Marianas MRA Study Area—Only one olive ridley record exists for Guam and the CNMI, an alleged capture in the waters near Saipan (Pritchard 1977). The exact location of this capture, however, is unknown since the turtle was offered for sale in a local souvenir shop. The nearest in-water sightings of this species have occurred within the Yap and Palau Districts (Eckert 1993; Pritchard 1995). It is possible that future occurrences could occur in the study area and vicinity, since olive ridleys are a tropical species, they are the most abundant sea turtles in the Pacific Ocean, and they have been satellite-tracked through North Pacific waters as far south as 8°N during developmental migrations (NMFS and USFWS 1998d; Polovina et al. 2004). The occurrence of the olive ridley turtle is low/unknown throughout the year in all waters surrounding Guam and the CNMI that are seaward of the shelf break because they are primarily an oceanic species. In portions of the study area located inside the shelf break (e.g., Apra Harbor, Agat Bay, nearshore waters around northern Tinian), olive ridleys are not expected to occur (**Figure C-5**).

Behavior and Life History—The olive ridley turtle is considered omnivorous, eating a variety of benthic and pelagic prey items including fish, crabs, shrimp, snails, oysters, sea urchins, jellyfish, salps, fish eggs, and vegetation (NMFS and USFWS 1998d). However, crustaceans and fish serve as their primary food source. Analyses of stomach contents from olive ridleys caught in the Hawai'i-based longline fishery indicate that individuals in the central Pacific Ocean feed predominantly on tunicates (salps and pyrosomas), which are found well below the water surface (Polovina et al. 2004). At sea, olive ridleys readily associate with floating objects such as logs, plastic debris, and even dead whales (Arenas and Hall 1992; Pitman 1992). Scientists believe that olive ridleys associate with flotsam since it provides them with shelter from predation and an abundance of prey items (NMFS and USFWS 1998d). Olive ridleys in the eastern Pacific are also known to bask at the surface, where they are often accompanied by seabirds that will roost upon their exposed carapaces and feed on fish that aggregate beneath them (Pitman 1993).

Unlike all other species of sea turtle except the Kemp's ridley, the olive ridley is known for nesting en masse. This type of nesting activity is known as an arribada (Spanish for "arrival"). During an arribada, hundreds to tens of thousands of breeding olive ridleys congregate in the waters in front of the nesting beach and then, signaled by some unknown cue, emerge from the sea in unison. There is currently no estimate of the age at which females begin to reproduce; however, the average length of nesting adults at Playa Nancite, Costa Rica was 63.3 cm. Nesting occurs throughout the year, peaking from August to December in the eastern Pacific, from February to July in Malaysia, and from October to February in Thailand. Females usually nest every one to two years. A typical female produces two clutches per nesting season, with each clutch averaging 105 eggs. Lone individuals nest at 15- to 17-day intervals while mass nesters arrive to the nesting beach at 28-day intervals.

Incubation time from deposition to emergence is approximately 55 days (Eckert 1993; NMFS and USFWS 1998d).

Relatively few studies have investigated the diving behavior of olive ridley turtles. In the eastern tropical Pacific, olive ridleys have been shown to make more frequent submergences and spend more time at the surface during the day than at night (Beavers and Cassano 1996). As a result, nighttime dives are longer in duration (reaching a maximum of 95.5 min). Olive ridleys have been observed diving to depths of 300 m, although only about 10% of their time is spent at depths greater than 100 m (Eckert et al. 1986; Polovina et al. 2003).

- Leatherback Turtle (*Dermochelys coriacea*)

Description—The leatherback turtle is the largest living sea turtle. These turtles are placed in the family Dermochelyidae, a separate family from all other sea turtles, in part because of their unique carapace structure. A leatherback turtle's carapace lacks the outer layer of horny scutes possessed by all other sea turtles; instead, it is composed of a flexible layer of dermal bones underlying tough, oily connective tissue and smooth skin. The body of a leatherback is barrel-shaped and tapered to the rear, with seven longitudinal dorsal ridges, and is almost completely black with variable spotting. All adults possess a unique spot on the dorsal surface of their head, a marking that can be used by scientists to identify specific individuals (McDonald and Dutton 1996). Adult carapace lengths range from 119 to 176 cm with an average around 145 cm (NMFS and USFWS 1998c). Adult leatherbacks weigh between 200 and 700 kg. Surveys of nesting leatherbacks in the Atlantic and Pacific Oceans indicate gene flow between rookeries within ocean basins and also that western Atlantic and eastern Pacific leatherbacks shared a common ancestor in recent evolutionary history (Dutton et al. 1994).

Status—Leatherback turtles in the Pacific Ocean are highly endangered and may become extinct in the next several decades if current trends in mortality persist. Lewison et al. (2004) estimated that more than 50,000 leatherbacks were taken as pelagic longline bycatch in 2000 and that thousands of these turtles die each year from longline gear interactions in the Pacific Ocean alone. Leatherbacks are seriously declining at most Pacific Ocean rookeries, including Indonesia, Malaysia, and Mexico (NMFS and USFWS 1998c). No attempts have been made to assess the status of foraging populations. The most recent estimate of the worldwide leatherback population was 34,500 nesting females, with a lower and upper limit of 26,200 and 42,900 nesting females (Spotila et al. 1996).

Habitat Preferences—There is limited information available regarding the habitats utilized by early juvenile leatherbacks because this age class is entirely oceanic (NMFS and USFWS 1998c). However, it is known that early juveniles are generally restricted to waters greater than 26°C and that they likely do not associate with *Sargassum* or other flotsam, as is the case for the other five sea turtle species found in U.S. waters (NMFS and USFWS 1998c; Eckert 2002).

Late juvenile and adult leatherback turtles are known to range from mid-ocean to the continental shelf and nearshore waters (Schroeder and Thompson 1987; Shoop and Kenney 1992; Grant and Ferrell 1993). Juvenile and adult foraging habitats include both coastal feeding areas in temperate waters and offshore feeding areas in tropical waters (Frazier 2001). The movements of adult leatherbacks appear to be linked to the seasonal availability of their prey and the requirements of their reproductive cycle (Collard 1990; Davenport and Balazs 1991). During their oceanic migrations, leatherbacks prefer convergence zones and upwelling areas in the open ocean, along continental margins, or near large archipelagos (HDLNR 2002).

Distribution—The leatherback turtle is distributed circumglobally in tropical and warm-temperate waters throughout the year and into cooler temperate waters during warmer months (Ernst et al. 1994). Leatherbacks in the North Pacific Ocean are broadly distributed from the eastern tropical Pacific region to as far north as Alaska, where 19 occurrences have been documented since 1960 (Eckert 1993; Wing and Hodge 2002). This species migrates further and moves into cold waters more than any other sea turtle species (Bleakney 1965; Lazell 1980; Shoop and Kenney 1992). This species is also the most oceanic and most wide-ranging of sea turtles, undertaking extensive migrations following depth contours for hundreds, even thousands, of kilometers (Morreale et al. 1996; Hughes et al. 1998). Using satellite telemetry, Morreale et al. (1996) determined that post-nesting female leatherbacks in the Pacific Ocean share identical migrational pathways. However, the timing and routing of their reproductive migrations in the Pacific Ocean are still unknown. It is believed that migratory corridors exist along the west coasts of the U.S. and Mexico and in the pelagic zone surrounding the Hawaiian Islands (Nitta and Henderson 1993; NMFS and USFWS 1998c).

There are few quantitative data available concerning the seasonality, abundance, or distribution of leatherbacks in the central North Pacific Ocean. The leatherback is not typically associated with insular habitats, such as those characterized by coral reefs, yet individuals are occasionally encountered in deep ocean waters near prominent archipelagos such as the Hawaiian Islands (Eckert 1993). Leatherbacks are regularly sighted by fishermen in Hawai'i's offshore waters, generally beyond the 183 m contour, and especially at the southeastern end of the island chain and off the north coast of Oahu (Nitta and Henderson 1993; Balazs 1995, 1998). Leatherbacks encountered in these waters, including those caught incidental to fishing operations, may represent individuals in transit from one part of the Pacific Ocean to another (NMFS and USFWS 1998c). Leatherbacks apparently have a wide geographic distribution throughout the region where the Hawai'i-based longline fishery operates, with sightings and reported interactions commonly occurring around seamount habitats located above the Northwestern Hawaiian Islands (from 35° to 45°N and 175° to 180°W) (Skillman and Balazs 1992; Skillman and Kleiber 1998).

Some of the world's largest nesting populations of leatherback turtles are found in the Pacific Ocean; however, nesting is not likely to occur on Pacific beaches under U.S. jurisdiction (NMFS and USFWS 1998c). The Pacific coast of Mexico is generally regarded as the most important leatherback breeding ground in the world. Roughly one-half of the world's leatherback population nests there (Pritchard 1982). Other principal nesting sites in the Pacific basin include beaches in Malaysia, Indonesia, Papua New Guinea, and Costa Rica (Spotila et al. 1996). Leatherbacks generally do not nest in the insular Pacific and are not known to nest at Guam and the CNMI (Eckert 1993). It is not known whether leatherbacks encountered in the insular Pacific Ocean come from eastern or western Pacific nesting beaches. However, a genetic analysis of 14 individuals captured in the Hawai'i-based longline fishery revealed that a majority (12) came from the western Pacific nesting population (HDLNR 2002).

- Information Specific to Marianas MRA Study Area—Of the three sea turtle species that have been sighted around Guam and the CNMI during marine surveys, the leatherback turtle is the least common (NMFS and USFWS 1998c). This species is occasionally encountered in the deep, pelagic waters of the Marianas archipelago, although only a few occurrence records exist (Eckert 1993; Wiles et al. 1995). In 1978, a 113-kg leatherback was rescued from waters southeast of Cocos Island, Guam (Eldredge 2003). From 1987 to 1989, divers reported seeing leatherbacks in the waters off Harnom Point, Rota; however, none have been seen in the area in recent times (Michael 2004). Leatherbacks do not nest at any of the islands in Micronesia.

  As a result, leatherback turtles are not expected to occur in coastal (i.e., shelf) waters around any of the islands of the Marianas chain. In oceanic waters beyond the shelf break, leatherback occurrence is low/unknown due to a lack of survey effort over those waters, the weak association between leatherbacks and insular regions of the North Pacific Ocean, and the belief that any leatherbacks encountered in the area would be transient individuals (Eckert 1993; Kolinski 2001). These occurrence patterns hold for all seasons (**Figure C-6**).

Behavior and Life History—The wide range of leatherbacks is a result of their highly evolved thermoregulatory capabilities. Leatherbacks can maintain body core temperatures well above the ambient water temperature. For example, a leatherback caught off Nova Scotia, Canada had a body temperature of 25.5°C in water that was 7.5°C (Frair et al. 1972). A variety of studies have shown that leatherbacks have a range of anatomical and physiological adaptations that enable them to regulate internal body temperatures (Mrosovsky and Pritchard 1971; Greer et al. 1973; Neill and Stevens 1974; Paladino et al. 1990).

Leatherback turtles predominantly feed upon gelatinous zooplankton such as cnidarians (jellyfish and siphonophores) and tunicates (salps and pyrosomas); however, a wide variety of other prey items are known (Bjorndal 1997; NMFS and USFWS 1998c). In offshore waters of the North Pacific Ocean, leatherbacks appear to feed primarily on pyrosomas, although they have also been known to ingest longline hooks baited with sama (tuna bait) and squid (swordfish bait) (Davenport and Balazs 1991; Skillman and Balazs 1992; Grant 1994; Work and Balazs 2002). Leatherbacks feed throughout the water column from the surface to depths of 1,200 m (Eisenberg and Frazier 1983; Davenport 1988). Studies of leatherback turtle diving patterns off St. Croix, USVI suggested that they forage at night on the deep-scattering layer (DSL), a strata of vertically migrating zooplankton that concentrates below 600 m during the day and moves to the surface at night (S. Eckert et al. 1989). Siphonophores, salps, and jellyfish are primary constituents of the DSL.

Mating is thought to occur prior to or during the migration from temperate to tropical waters (Eckert and Eckert 1988). Typical clutches range in size from 50 to over 150 eggs, with clutch sizes in the western Pacific being generally larger than in the eastern Pacific. The incubation period lasts from 55 to 75 days. Females nesting on the Pacific coast of Mexico lay 1 to 11 clutches in a single season at 9- to 10-day intervals (NMFS and USFWS 1998c). Females remain in the general vicinity of the nesting habitat during inter-nesting intervals, with total residence in the nesting/inter-nesting habitats lasting up to four months (K. Eckert et al. 1989; Keinath and Musick 1993). Most adult females return to nest on their natal beach every two to three years; however, remigration intervals (the number of years between successive nesting seasons) between one and five years have been recorded (Boulon et al. 1996). In the Mexican Pacific, the nesting season of the leatherback extends from November to February, with some females arriving as early as August (Fritts et al. 1982; NMFS and USFWS 1998c). In the western Pacific, nesting peaks in May and June in China, June and July in Malaysia, and December and January in Queensland, Australia (NMFS and USFWS 1998c).

The leatherback is the deepest diving sea turtle. The depth to which a leatherback dives is influenced by the age of the turtle, the reason for the dive, and the proximity to shore. In general, older leatherbacks and those found in the open ocean make deeper dives than younger individuals and those that inhabit shallower waters (Ernst et al. 1994; Salmon et al. 2004). Leatherbacks in open ocean environments frequently exhibit V-shaped dive patterns (in which they descend to a certain depth and then immediately ascend to the surface), whereas leatherbacks in shallow water environments more often exhibit U-shaped dive patterns (in which they swim down to the ocean floor, remain on the bottom for several minutes, and then return directly to the surface) (Eckert et al. 1996). Average dive depths for post-nesting leatherbacks off the continental shelf of St. Croix ranged from 35 to 122 m, with estimated maximum depths of over 1,000 m (S. Eckert et al. 1989; Eckert et al. 1996). Typical dive durations averaged 6.9 to 14.5 min per dive, with a maximum of 42 min (Eckert et al. 1996). On average, day dives tend to be deeper, longer, and less frequent than those at night (S. Eckert et al. 1989).

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4.0 FISH AND FISHERIES

4.1 FISH/INVERTEBRATES

Distribution and abundance of fishery species depends greatly on the physical and biological factors associated with the ecosystem, as well as the individual species. Physical parameters include habitat quality variables such as salinity, temperature, dissolved oxygen, and large-scale environmental perturbations (e.g., ENSO). 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. 1999). Rarely is one factor responsible for the distribution of fishery species, but is a combination of factors. For example, pelagic species optimize their growth, reproduction and survival by tracking gradients of temperature, oxygen, or salinity (Helfman et al. 1999). Additionally, the spatial distribution of food resources is variable and changes with prevailing physical habitat parameters. Another major component in understanding species distribution is the location of highly productive regions such as frontal zones. These areas concentrate higher trophic-level predators such as tuna and provide visual clues for the location of target species for commercial fisheries (NMFS-PIR 2001).

Environmental variations, such as ENSO events, change the normal characteristics of water temperature, thereby changing the patterns of water flow. The NEC (westward) and the Subtropical Countercurrent (eastward) are major influences on distribution of fishes and invertebrates in the Marianas MRA study area and vicinity (study area; Eldredge 1983). ENSO events alter normal current patterns, alter productivity, and have dramatic effects on distribution, habitat range and movement of pelagic species (NMFS 2003a).

In the northern hemisphere, El Niño 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 (NOAA 2002). El Niño events have caused fisheries such as the skipjack tuna fishery to shift over 1,000 km (NMFS-PIR 2001).

Coral reef communities surrounding the study area have a reputation for year-round uniformity and stability (Amesbury et al. 1986). While this is true for most species in the area, there are exceptions. Seasonal variations in pelagic species distributions in the area are understood. Several of the reef fish species (juvenile rabbitfish, juvenile jacks, juvenile goatfish, and bigeye scad, *Selar crumenophthalmus*) targeted in the study area show strong seasonal fluctuation, usually related to juvenile recruitment (Amesbury et al. 1986).

Fish species composition within the study area is typical of what you find in most Indo-Pacific insular, coral reef-bordered coastal areas. Seventy-three percent of the total number of species found belongs to 20 families (Myers and Donaldson 2003). The geographic location of the study area suggests a more diverse ichthyofauna than areas such as the Hawaiian Islands. Recorded species diversity in the Guam/Marianas island chain is lower than that of the Hawaiian archipelago. Actual diversity may be higher and the recorded diversity may be an artifact of insufficient sampling (Paulay 2003a). However, many other factors, such as larval recruitment and frequent natural disturbances, have dramatic impacts on species diversity (Randall 1995). Myers and Donaldson (2003) noted the occurrence of 1,019 fish species (epipelagic and demersal species found to 200 m) within the study area. Inshore species are composed primarily of widespread Indo-Pacific species (58%) with the remainder consisting of circumtropical species (3.6%) and nearly equal numbers of species with widespread distributions primarily to the west, south, and east of the islands (Myers and Donaldson 2003). Ten species of inshore and epipelagic fishes are currently considered endemic to the Marianas. However, this number is probably too high due to the observations of transient species in the area (Myers and Donaldson 2003). Additionally, Myers and Donaldson (2003) identified 1,106 species of fish known from the Mariana Islands and adjacent territorial waters. Extensive studies have been done on the biogeography of inshore and epipelagic fauna found in the Marianas from 0 to 100 m. Currently, occurrence and distribution of benthic and mesopelagic species from 100 m to greater than 200 m are incomplete and poorly understood

(Myers and Donaldson 2003). Lack of adequate data has made it difficult to identify and interpret other sources of variation in the distribution and/or decline of the fisheries resources of these islands. Declining fisheries resources is a major problem facing Guam; however, CNMI has adopted some of the strictest fishing regulations in the Pacific banning gears such as SCUBA/hookah spear fishing, gill nets, drag nets, and surround nets.

According to the Guam DAWR, fish populations have declined 70% over the past 15 years. Finfish harvest dropped from 151,700 kg in 1985 to 62,689 kg in 1999 (Richmond and Davis 2002). Catch-per-unit-effort has dropped over 50% since 1985, and landings of large reef fish are rare (Richmond and Davis 2002). Seasonal harvest of juvenile rabbitfish has also declined in recent years. Currently, there is little data assessing the health of fish resources in the study area but it is believed that populations increase as you travel north due to decreased fishing pressure (Starmer et al. 2002). Regulations such as the ban of spearfishing with SCUBA and gill netting have been proposed to aid in the relief of fishing pressure in the area (Richmond and Davis 2002).

4.1.1 Essential Fish Habitat: Distribution and Species

The WPRFMC manages major fisheries within the EEZ around Hawai'i and the territories and possessions of the U.S. in the Pacific Ocean (WPRFMC 1998, 2001). The WPRFMC (3 to 200 NM), in conjunction with the Guam Division of Aquatic and Wildlife Resources (0 to 3 NM) and the CNMI Division of Fish and Wildlife manages the fishery resources in the study area. The WPRFMC has also proposed to defer fisheries management from 0 to 3 NM to the CNMI DFW (WPRFMC 2001). The WPRFMC focuses on the major fisheries in the study area that require regional management. The WPRFMC currently oversees five major FMPs and their associated amendments for bottomfish, pelagics, crustaceans, precious corals, and coral reef ecosystems.

The MSFCMA, as amended by the SFA, contains provisions for the identification and protection of habitat essential to production of federally managed species. The act requires NOAA Fisheries to assist regional fishery management councils in including EFH in their respective FMP.

EFH provisions impose procedural requirements on both councils and federal agencies. Councils must identify adverse impacts on EFH resulting from both fish and non-fishing activities, and describe measures to minimize or mitigate these impacts. Councils can also provide comments and make recommendations to federal or state agencies that propose actions that may affect habitat, including EFH, of a managed species. Agencies must then decide how they intend to minimize or mitigate the identified adverse impacts. Fishing activities that may adversely impact EFH include but are not limited to the following: anchor damage from vessels attempting to maintain position over productive fishing habitat, heavy weights and line entanglement occurring during normal hook-and-line fishing operations, lost gear from lobster fishing operations, and remotely operated vehicle tether damage to precious coral during harvesting operations. Seven non-fishing activities have been identified that directly or indirectly affect habitat used by management unit species and are as follows: infaunal and bottom-dwelling organisms, turbidity plumes, biological availability of toxic substances, damage to sensitive habitat, current patterns/water circulation modification, loss of habitat function, contaminant runoff, sediment runoff, and shoreline stabilization projects (WPRFMC 2001).

The FMPs developed for federally managed species under the jurisdiction of these fishery management councils should include identification and description of the EFH, description of non-fishing and fishing threats, and suggested measures to conserve and enhance the EFH. Each of these councils is also required in the FMPs to identify the EFH-HAPC where one or more of the following criteria are demonstrated: (a) ecological function, (b) sensitivity to human-induced environmental degradation, (c) development activities stressing habitat type, or (d) rarity of habitat. In addition to the EFH status, some of these species are assigned status categories in conjunction with the ESA and various federal or international agencies. These status categories will be discussed in the "status" section of the EFH descriptions.

EFH species, as designated by the WPRFMC (2004a), are discussed in the following subsections and are listed in **Table 4-1**. These species have been divided into management units according to their ecological relationships and preferred habitats. Management units include bottomfish management unit species (BMUS), pelagic management unit species (PMUS), crustacean management unit species (CMUS), and coral reef ecosystem management unit species (CRE MUS). For each management unit, the status, distribution (including range), habitat preference (depth, bottom substrate), life history (migration, spawning), and EFH/HAPC designations are provided in the following sections.

Table 4-1. The fish and invertebrate species with essential fish habitat (EFH) designated in the Marianas MRA study area. [[1]Species not listed under the Currently Harvested Coral Reef Taxa; [2]Species not managed under Bottomfish FMP or included in proposed Bottomfish Amendment 8 (35 additional species); [3]Species not listed under Currently Harvested Coral Reef Taxa, managed under Bottomfish FMP, or included in proposed Bottomfish Amendment 8; [4]Excluding hogo (*Pontinus macrocephela*) which is included in proposed Bottomfish Amendment 8 (emperors/snappers); [5]Species not managed under Crustacean FMP; *****Includes all other coral reef ecosystem management unit species that are marine plants, invertebrates, and fishes that are not listed under the Currently Harvested Coral Reef Taxa or are not bottomfish management unit species, crustacean management unit species, Pacific pelagic management unit species, precious coral or seamount groundfish]

BOTTOMFISH MANAGEMENT UNIT SPECIES

Shallow-water Species Complex (0-100 m):
Gray jobfish (*Aprion virescens*)
Lunartail grouper (*Variola louti*)
Blacktip grouper (*Epinephelus fasciatus*)
Ambon emperor (Lethrinus amboinensis)
Redgill emperor (*Lethrinus rubrioperculatus*)
Giant trevally (*Caranx ignobilis*)
Black jack (*Caranx lugubris*)
Amberjack (*Seriola dumerili*)
Blue stripe snapper (*Lutjanus kasmira*)

Deep-water Species Complex (100-400 m):
Squirrelfish snapper (*Etelis carbunculus*)
Longtail snapper (*Etelis coruscans*)
Pink snapper (*Pristipomoides filamentosus*)
Yellowtail snapper (*Pristipomoides auricilla*)
Yelloweye snapper (*Pristipomoides flavipinnis*)
Pink snapper (*Pristipomoides sieboldii*)
Yellow-barred snapper (*Pristipomoides zonatus*)
Silver jaw jobfish (*Aphareus rutilans*)

PELAGIC MANAGEMENT UNIT SPECIES

Marketable Species Complex:

Temperate Species
Striped marlin (*Tetrapturus audax*)
Broadbill swordfish (*Xiphias gladius*)
Northern bluefin tuna (*Thunnus thynnus*)
Albacore tuna (*Thunnus alalunga*)
Bigeye tuna (*Thunnus obesus*)
Mackerel (*Scomber* spp.)
Pomfret (Bramidae)
  Sickle pomfret (*Taractichthys steindachneri*)
  Lustrous pomfret (*Eumegistus illustris*)

Tropical Species
Yellowfin tuna (*Thunnus albacares*)
Kawakawa (*Euthynnus affinis*)
Skipjack tuna (*Katsuwonus pelamis*)

Tropical Species (*continued*)
Frigate and bullet tunas (*Auxis thazard, Auxis rochei*)
Slender tunas (*Allothunnus fallai*)
Indo-Pacific blue marlin (*Makaira nigricans*)
Black marlin (*Makaira indica*)
Shortbill spearfish (*Tetrapturus angustirostris*)
Sailfish (*Istiophorus platypterus*)
Dolphinfishes (Coryphaenidae)
  Dolphinfish (*Coryphaena hippurus*)
  Pompano dolphinfish (*Coryphaena equiselas*)
Wahoo (*Acanthocybium solandri*)
Moonfish (*Lampris guttatus*)

Non-marketable Species Complex:
Snake mackerels or oilfish (Gempylidae)
  Escolar (*Lepidocybium flavobrunneum*)
  Oilfish (*Ruvettus pretiosus*)

Sharks
Common thresher shark (*Alopias vulpinus*)
Pelagic thresher shark (*Alopias pelagicus*)
Bigeye thresher shark (*Alopias superciliousus*)
Shortfin mako shark (*Isurus oxyrinchus*)
Longfin mako shark (*Isurus paucus*)
Salmon shark (*Lamna ditropis*)
Silky shark (*Carcharhinus falciformis*)
Oceanic whitetip shark (*Carcharhinus longimanus*)
Blue shark (*Prionace glauca*)

CRUSTACEAN MANAGEMENT UNIT SPECIES

Spiny and Slipper Lobster Complex
Spiny lobster (*Panulirus penicillatus, Panulirus* spp.)
Chinese slipper lobster (*Parribacus antarcticus*)

Coral Reef Ecosystem *

Currently Harvested Coral Reef Taxa (CHCRT):
Surgeonfishes (Acanthuridae)
  Orange-spot surgeonfish (*Acanthurus olivaceus*)
  Yellowfin surgeonfish (*Acanthurus xanthopterus*)

Table 4-1. Continued

Surgeonfishes (Acanthuridae) (continued)
- Convict tang (*Acanhturus triostegus*)
- Eye-striped surgeonfish (*Acanthurus dussumieri*)
- Blue-lined surgeonfish (*Acanthurus nigroris*)
- Blue-banded surgeonfish (*Acanthurus lineatus*)
- Blackstreak surgeonfish (*Acanthurus nigricauda*)
- White-spotted surgeonfish (*Acanthurus guttatus*)
- Ringtail surgeonfish (*Acanthurus blochii*)
- Brown surgeonfish (*Acanthurus nigrofuscus*)
- Elongate surgeonfish (*Acanthurus mata*)
- Mimic surgeonfish (*Acanthurus pyroferus*)
- Striped bristletooth (*Ctenochaetus striatus*)
- Twospot bristletooth (*Ctenochaetus binotatus*)
- Bluespine unicornfish (*Naso unicornus*)
- Orangespine unicornfish (*Naso lituratus*)
- Humpnose unicornfish (*Naso tuberosus*)
- Blacktongue unicornfish (*Naso hexacanthus*)
- Bignose unicornfish (*Naso vlamingii*)
- Whitemargin unicornfish (*Naso annulatus*)
- Spotted unicornfish (*Naso brevirostris*)
- Humpback unicornfish (*Naso brachycentron*)
- Barred unicornfish (*Naso thynnoides*)
- Gray unicornfish (*Naso caesius*)

Triggerfishes (Balistidae)
- Titan triggerfish (*Balistoides viridescens*)
- Clown triggerfish (*Balistoides conspicillum*)
- Orangestripped triggerfish (*Balistapus undulatus*)
- Pinktail triggerfish (*Melichtys vidua*)
- Black triggerfish (*Melichtys niger*)
- Blue triggerfish (*Pseudobalistes fucus*)
- Picassofish (*Rhinecanthus aculeatus*)
- Wedged picassofish (*Rhinecanthus rectangulus*)
- Briddles triggerfish (*Sufflamen fraenatus*)

Jacks (Carangidae)
- Bigeye scad (*Selar crumenophthalmus*)
- Mackerel scad (*Decapterus macarellus*)

Requiem Sharks (Carcharhinidae)
- Grey reef shark (*Carcharhinus amblyrhynchos*)
- Silvertip shark (*Carcharhinus albimarginatus*)
- Galapagos shark (*Carcharhinus galapagenis*)
- Blacktip reef shark (*Carcharhinus melanopterus*)
- Whitetip reef shark (*Triaenodon obesus*)

Soldierfishes/Squirrelfishes (Holocentridae)
- Bigscale soldierfish (*Myripistris berndti*)
- Bronze soldierfish (*Myripristis adusta*)
- Blotcheye soldierfish (*Myripristis murdjan*)
- Brick soldierfish (*Myripristis amaena*)
- Scarlet soldierfish (*Myripristis pralinia*)
- Violet soldierfish (*Myripristis violacea*)
- Whitetip soldierfish (*Myripristis vittata*)
- Yellowfin soldierfish (*Myripristis chryseres*)
- Pearly soldierfish (*Myripristis kuntee*)
- Tailspot squirrelfish (*Sargocentron caudimaculatum*)

Soldierfishes/Squirrelfishes (Holocentridae) (continued)
- File-lined squirrelfish (*Sargocentron microstoma*)
- Pink squirrelfish (*Sargocentron tieroides*)
- Crown squirrelfish (*Sargocentron diadema*)
- Peppered squirrelfish (*Sargocentron punctatissimum*)
- Blue-lined squirrelfish (*Sargocentron tiere*)
- Long jaw squirrelfish (*Sargocentron spiniferum*)
- Spotfin squirrelfish (*Neoniphon* spp.)

Flagtails (Kuhliidae)
- Barred flagtail (*Kuhlia mugil*)

Rudderfishes (Kyphosidae)
- Gray rudderfish (*Kyphosus bigibbus*)
- Highfin rudderfish (*Kyphosus cinerascens*)
- Lowfin rudderfish (*Kyphosus vaigensis*)

Wrasses (Labridae)
- Napoleon wrasse (*Cheilinus undulatus*)
- Triple-tail wrasse (*Cheilinus trilobatus*)
- Floral wrasse (*Cheilinus chlorourus*)
- Harlequin tuskfish (*Cheilinus fasciatus*)
- Ring-tailed wrasse (*Oxycheilinus unifasciatus*)
- Bandcheek wrasse (*Oxycheilinus digrammus*)
- Arenatus wrasse (*Oxycheilinus arenatus*)
- Razor wrasse (*Xyrichtys pavo*)
- Whitepatch wrasse (*Xyrichtys aneitensis*)
- Cigar wrasse (*Cheilio inermis*)
- Blackeye thicklip (*Hemigymnus melapterus*)
- Barred thicklip (*Hemigymnus fasciatus*)
- Three-spot wrasse (*Halichoeres trimaculatus*)
- Checkerboard wrasse (*Halichoeres hortulanus*)
- Weedy surge wrasse (*Halichoeres margaritaceus*)
- Surge wrasse (*Thalassoma purpureum*)
- Redribbon wrasse (*Thalassoma quinquevittatum*)
- Sunset wrasse (*Thalassoma lutescens*)
- Longface wrasse (*Hologynmosus doliatus*)
- Rockmover wrasse (*Novaculichthys taeniourus*)

Goatfishes (Mullidae)
- Yellow goatfish (*Mulloidichthys* spp.)
- Yellowfin goatfish (*Mulloidichthys vanicolensis*)
- Yellowstripe goatfish (*Mulloidichthys flaviolineatus*)
- Banded goatfish (*Parupeneus* spp.)
- Dash-dot goatfish (*Parupeneus barberinus*)
- Redspot goatfish (*Parupeneus heptacanthus*)
- White-lined goatfish (*Parupeneus ciliatus*)
- Yellowsaddle goatfish (*Parupeneus cyclo*stoma)
- Side-spot goatfish (*Parupeneus pleurostigma*)
- Multi-barred goatfish (*Parupeneus multifaciatus*)
- Bantail goatfish (*Upeneus arge*)

Mullets (Mugilidae)
- Engel's mullet (*Valamugil engeli*)
- False mullet (*Neomyxus leuciscus*)
- Fringelip mullet (*Crenimugil crenilabis*)
- Yellowmargin moray (*Gymnothorax flavimarginatus*)

Table 4-1. Continued

Moray Eels (Muraenidae)
 Giant moray (*Gymnothorax javanicus*)
 Undulated moray (*Gymnothorax undulatus*)

Octopuses (Octopodidae)
 Day octopus (*Octopus cyanea*)
 Night octopus (*Octopus ornatus*)

Threadfins (Polynemidae)
 Sixfeeler threadfin (*Polydactylus sexfilis*)

Bigeyes (Pricanthidae)
 Glasseye (*Heteropriacanthus cruentatus*)
 Bigeye (*Priacanthus hamrur*)

Mackerels (Scombridae)
 Dogtooth tuna (*Gymnosarda unicolor*)

Parrotfishes (Scaridae)
 Bumphead parrotfish (*Bolbometopon muricatum*)
 Parrotfish (*Scarus* spp.)
 Pacifc longnose parrotfish (*Hipposcarus longiceps*)
 Stareye parrotfish (*Catolomus carolinus*)

Rabbitfishes (Siganidae)
 Forktail rabbitfish (*Siganus aregentus*)
 Randall's rabbitfish (*Siganus randalli*)
 Scribbled rabbitfish (*Siganus spinus*)
 Vermiculate rabbitfish (*Siganus verimiculatus*)

Barracudas (Sphyraenidae)
 Heller's barracuda (*Sphyraena helleri*)
 Great barracuda (*Sphyraena barracuda*)

Turban shells/Green snails (Turbinidae)
 Green snails (*Turbo* spp.)

AQUARIUM TAXA/SPECIES
Surgeonfishes (Acanhturidae)
 Yelow tang (*Zebrasoma flavescens*)
 Yellow-eyed surgeon fish (*Ctenochaetus strigosus*)
 Achilles tang (*Acanthurus achilles*)

Moorish Idols (Zanclidae)
 Moorish idol (*Zanclus cornutus*)

Angelfishes (Pomacanthidae)
 Shepard's angelfish (*Centropyge shepardi*)
 Lemonpeel angelfish (*Centropyge flavissimus*)

Hawkfishes (Cirrhitidae)
 Flame hawkfish (*Neocirrhitus* armatus)
 Longnose hawkfish (*Oxycirrhites typus*)

Butterflyfishes (Chaetodontidae)
 Threadfin butterflyfish (*Chaetodon auriga*)
 Raccoon butterflyfish (*Chaetodon lunula*)

AQUARIUM TAXA/SPECIES (CONTINUED)
Butterflyfishes (Chaetodontidae) (continued)
 Black-backed butterflyfish (*Chaetodon melannotus*)
 Saddled butterflyfish (*Chaetodon ephippium*)

Damselfishes (Pomacentridae)
 Blue-green chromis (*Chromis viridis*)
 Humbug dascyllus (*Dascyllus aruanus*)
 Three-spot dascyllus (*Dascyllus trimaculatus*)

Scorpionfishes (Scorpaenidae)

Feather-duster worms (Sabellidae)

Potentially Harvested Coral Reef Taxa (PHCRT):
FISH MANAGEMENT UNIT SPECIES
Other wrasses (Labridae spp.)[1]
Requiem Sharks (Carcharhinidae spp.)[1]
Hammerhead Sharks (Sphyrnidae spp.)[1]
Whiptail Stingrays (Dasyatididae)
Eagle Rays (Myliobatidae)
Manta rays (Mobulidae)
Other groupers (Serranidae spp.)[2]
Jacks/Trevallies (Carangidae)[3]
Other soldierfishes/squirrelfishes (Holocentridae spp.)[1]
Other goatfishes (Mullidae)[1]
Other surgeonfishes (Acanthuridae spp.)[1]
Other emperor fishes (Lethrinidae)[4]
False morays (Chlopsidae)[1]
Conger and garden eels (Congridae)[1]
Spaghetti eels (Moringuidae)[1]
Snake eels (Ophichthidae)[1]
Other morays (Muraenidae)[1]
Cardinalfishes (Apogonidae)
Bigeyes (Pricanhtidae)[1]
Other butterflyfishes (Chaetodontidae spp.)[1]
Other angelfishes (Pomacanthidae spp.)[1]
Other damselfishes (Pomacentridae)[1]
Turkeyfishes (Scorpaenidae)[3]
Blennies (Blenniidae)
Other barracudas (Sphyraenidae spp.)[1]
Sandperches (Pinguipedidae)
Left-eye Flounders (Bothidae)
Right-eye Flounders (Pleurnectidae)
Soles (Soleidae)
Trunkfishes (Ostraciidae)
Puffers (Teradontidae)
Porcupinefishes (Diodontidae)
Spadefishes/Batfishes (Ephippidae)
Monofishes (Monodactylidae)
Grunts (Haemulidae)
Remoras (Echineididae)
Tilefishes (Malacanthidae)
Dottybacks (Pseudochromidae)
Prettyfins (Plesiopidae)
Coral crouchers (Caracanthidae)
Soapfishes (Grammistidae)

Table 4-1. Continued

FISH MANAGEMENT UNIT SPECIES (CONTINUED)
Trumpetfishes (Autostomidae)
  Chinese trumpetfish (*Aulostomus chinensis*)
Cornetfishes (Fistularidae)
  Reef cornetfish (*Fistularia commersoni*)
Flashlightfishes (Anomalopidae)
Herrings/Sprats/Sardines (Clupeidae)
Anchovies (Engraulidae)
Gobies (Gobiidae)
Other snappers (Lutjanidae) [2]
Other triggerfishes (Balistidae spp.) [1]
Filefishes (Monocanthidae spp.)
Other rabbitfishes (Siganidae) [1]
Rudderfishes (Kyphosidae) [1]
Fusiliers (Caesionidae)
Hawkfishes (Cirrhitidae) [1]
Frogfishes (Antennariidae)
Pipefishes/Seahorses (Syngnathidae)

INVERTEBRATE MANAGEMENT UNIT SPECIES
Mollusks (Mollusca) [1]
  Sea snails and sea slugs (Gastropods)
    Trochus (*Trochus* spp.)
  Bivalves (Oysters and clams)
    Black-lipped pearl oyster (*Pinctada margaritifera*)
    Giant clams (Tridacnidae)
    Other clams
  Nautiluses, cuttlefishes, squids, and octopuses
Mollusks (Mollusca) [1] (continued)
  (Cephalopods)
Sea squirts or tunicates (Ascidians)
Moss animals (Bryozoans)
Mantis shrimps, lobsters, crabs, and shrimps (Crustaceans) [5]
Sea cucumbers and sea urchins (Echinoderms)
Segmented worms (Annelids)

SESSILE BENTHOS MANAGEMENT UNIT SPECIES
Algae (Seaweeds)
Sponges (Porifera)
Corals (Cnidaria)
  Hydrozoans
    Stinging or fire corals (Millepora)
    Lace corals (Stylasteridae)
    Hydroid fans (Solanderidae)
  Scleractinian Anthozoans
    Stony corals (Scleractinia)
    Ahermatypic corals (Azooxanthellate)
  Non-Scleractinian Anthozoans
    Anemones (Actinaria)
    Colonial anemones or soft zoanthid corals (Zoanthidae)
    Soft corals and gorgonians (Alcyonaria)
    Blue coral (*Heliopora coerulea*)
    Organ-pipe corals or star polyps (*Tubipora musica*)
Live Rock

4.2 MANAGEMENT UNITS

4.2.1 Bottomfish Management Unit Species

Status—Seventeen species are currently managed as BMUS by the WPRFMC through the *Bottomfish and Seamount Groundfish Fishery Management Plan* (WPRFMC 1986a) and subsequent amendments (**Table 4-1**; WPRFMC 1998, 2004a). In the Northern Marianas, Guam, and American Samoa, the BMUS are divided into a shallow-water complex and a deep-water complex based on depth and species composition. Under Draft Amendment 8, 30 bottomfish species from both the shallow-water and deep-water complexes have been proposed by WPRFMC for incorporation into the existing BMUS (NMFS 2003b). All 17 species have viable recreational, subsistence, and commercial fisheries (WPRFMC 2004b) with none of the BMUS approaching an overfished condition (NMFS 2004a). The BMUS found in the study area are not listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—The shallow-water (0 to 100 m) and the deep-water (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).

Habitat Preferences—Bottomfish comprising the shallow-water and deep-water complexes concentrate around the 183 m contour (index of bottomfish habitat) that surrounds Guam and the Northern Marianas Islands (WPRFMC 1998). Juvenile and adult bottomfish are usually found in habitats characterized by a mosaic of sandy bottoms and rocky areas of high structural complexity (WPRFMC 1998). Habitats encompassing the shallow-water complex consist of shelf and slope areas (Spalding et al. 2001). The shelf area includes various habitats such as mangrove swamps, seagrass beds, shallow lagoons, hard, flat 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 (Heemstra and Randall 1993; Allen 1985; Myers 1999; Amesbury and Myers 2001; Allen and Adrim 2003). The deep-water complex inhabits areas of high relief with hard rocky bottoms such as steep slopes, pinnacles, headlands, rocky outcrops, and coral reefs (Allen 1985; Parrish 1987; Haight et al. 1993).

Life History—Very little is known about the ecology (life history, habitat, feeding, and spawning) of the bottomfish species managed in the area (WPRFMC 1998). However, limited information is available for various larval, juvenile, and adult bottomfish genera of the shallow-water and deep-water complexes.

Within the shallow-water complex, snappers form large aggregations and groupers/jacks occur in pairs within large aggregations near areas of prominent relief. Spawning coincides with lunar periodicity corresponding with new/full moon events (Grimes 1987; Myers 1999; Amesbury and Myers 2001). Groupers have been shown to undergo small, localized migrations of several kilometers to spawn (Heemstra and Randall 1993). 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°C (Miller et al. 1979).

Within the deep-water complex, snappers aggregate near areas of bottom relief as individuals or in small groups (Allen 1985). Snappers may be batch or serial spawners, spawning multiple times over the course of the spawning season (spring and summer peaking in November and December), exhibit a shorter, more well-defined spawning period (July to September), or have a protracted spawning period (June through December peaking in August) (Allen 1985; Parrish 1987; Moffitt 1993). Some snappers display a crepuscular periodicity and migrate diurnally from areas of high relief during the day at depths of 100 to 200 m to shallow (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—(WPRFMC 1998; **Figures D-1**, **D-2**, and **D-3**; **Table 4-2**)

- Eggs and Larvae—EFH for these life stages is the water column extending from the shoreline to the outer limit of the EEZ down to a depth of 400 m and encompasses both the shallow-water and deep-water complexes.
- 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 and includes the shallow-water and deep-water complexes.

HAPC Designations—(WPRFMC 1998; **Figures D-1**, **D-2**, and **D-3**). Based on the known distribution and habitat requirements, all life stages of the BMUS have HAPC designated in the study area that includes all slopes and escarpments between 40 and 280 m.

4.2.2 Pelagic Management Unit Species

Status—Thirty-three species are currently managed as PMUS by the WPRFMC through the *Fishery Management Plan for the Pelagic Fisheries of the Western Pacific Region* (WPRFMC 1986b) and subsequent amendments (WPRFMC 1998). PMUS are divided into the following species complex designations: marketable species, non-marketable species, and sharks (**Table 4-1**). The designation of these complexes is based on the ecological relationships among the species and their preferred habitat (WPRFMC 1998). The marketable species complex has been further divided into temperate and tropical assemblages. The temperate species complex includes those PMUS that are 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*). Additionally, a potential squid PMUS consisting of three flying squid species has been proposed by the WPRFMC for incorporation into the existing PMUS (NMFS-PIR 2004).

Table 4-2. Bottomfish management unit species EFH designations. Source data: WPRFMC (1998, 2001). [Habitat: 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)]

Management Unit Species/Taxa	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	Comments
BOTTOMFISH											
Shallow-water Species (0 to 100 m)											
Gray jobfish (*Aprion virescens*)		A		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	ND
Redgill emperor (*Lethrinus rubrioperculatus*)									A	E,L	Adult depth of 0-160 m
Giant trevally (*Caranx ignoblis*)										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 (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, Adult depth of 100-200 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

Currently, no data are available to determine if the PMUS are approaching an overfished condition (NMFS 2004a) except for the bigeye tuna. NMFS (2004b) determined that overfishing was occurring Pacific wide on this species. In addition, the shark species are afforded protection under the Shark Finning Prohibition Act (NMFS 2002).

The broadbill swordfish, albacore tuna, common thresher shark (*Alopias vulpinus*), and salmon shark (*Lamna ditropis*) have been listed as data deficient on the IUCN Red List of threatened species (Safina 1996; Uozumi 1996a; Goldman and Human 2000; Goldman et al. 2001). The shortfin mako shark (*Isurus oxyrinchus*), oceanic whitetip shark (*Caracharhinus longimanus*), and the blue shark (*Prionace glauca*) have been listed as near threatened (Smale 2000a; Stevens 2000a, 2000b). The bigeye tuna is listed as vulnerable (Uozumi 1996b).

Distribution—PMUS occur in tropical and temperate waters of the western Pacific Ocean. Geographical distribution among the PMUS is governed by 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 (WPRFMC 1998).

Habitat Preferences—PMUS are typically found in epipelagic to pelagic waters, however, shark species can be found in inshore benthic, neritic to epipelagic, and mesopelagic waters. Factors such as gradients in temperature, oxygen, or salinity can affect the suitability of a habitat for pelagic fishes. 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, such as broadbill swordfish and bigeye tuna are known to aggregate near the surface at night. However, during the day broadbill swordfish can be found at depths of 800 m and bigeye tuna around 275 to 550 m. Juvenile albacore tuna generally concentrate above 90 m with adults found in deeper waters (90 to 275 m) (WPRFMC 1998).

Life History—Migration and life history patterns of most PMUS are poorly understood in the Pacific Ocean. Additionally, very little is known about the distribution and habitat requirements of the juvenile lifestages of tuna and billfish prior to recruitment into fisheries. Seasonal movements of cooler-water tunas such as the northern bluefin 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 that are not targeted by fisheries in the Pacific such as gempylids, sharks, and pomfrets (WPRFMC 1998).

EFH Designations—(WPRFMC 1998; **Figures D-4**, **D-5**, and **D-6**; **Table 4-3**)

- Eggs and Larvae—The (epipelagic zone) water column down to a depth of 200 m from the shoreline to the outer limit of the EEZ.
- Juveniles and Adults—The water column down to a depth of 1,000 m from the shoreline to the outer limit of the EEZ.

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 EEZ.

4.2.3 Crustacean Management Unit Species

Status—Five species are currently managed as CMUS by the WPRFMC through the *Fishery Management Plan of the Spiny Lobster Fisheries of the Western Pacific Region* and the *Final Combined Fishery Management Plan, Environmental Impact Statement, Regulatory Analysis, and Draft Regulations*

Table 4-3. Pelagic management unit species EFH designations. Source data: WPRFMC (1998, 2001). [Habitat: 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)]

Management Unit Species/Taxa	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	Comments
PELAGIC											
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 m
Northern bluefin tuna (*Thunnus thynnus*)										A,J,L,E	ND
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	ND
Promfet (Bramidae)											
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	ND
Bullet tuna (*Auxis rochei*)										A,J,L,E	ND
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
Dolphinfishes (Coryphaenidae)											

Table 4-3. Continued

Management Unit Species/Taxa	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	Comments
Tropical Species (continued)											
Dolphinfish (*Coryphaena hippurus*)			A,J							A,J,L,E	ND
Pompano dolphinfish (*Coryphaena equiselas*)										A,J,L,E	ND
Wahoo (*Acanthocybium solandri*)										A,J,L,E	Adult depth <200 m
Moonfish (*Lampris guttatus*)										A,J	Depth distribution: surface to 500 m
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
Sharks											
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	ND
Salmon shark (*Lamna ditropis*)										A,J	Depth distribution: surface to 152 m
Silky shark (*Carcharhinus falciformis*)									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

for the Spiny Lobster Fisheries of the Western Pacific Region (WPRFMC 1981, 1982) and subsequent amendments (WPRFMC 1998). CMUS is divided into the spiny and slipper lobster complex and the Kona crab (*Ranina ranina*) (WPRFMC 1998). Four species are managed as the spiny and slipper lobster complex by the CMUS and the PHCRT (WPRFMC 1998, 2001): spiny lobster (*Panulirus penicillatus* and *Panulirus* spp.), ridgeback spiny lobster (*Scyllarides haani*), and Chinese slipper lobster (*Parribacus antarcticus*). The Kona crab is managed as a single species under the CMUS and PHCRT (WPRFMC

1998; 2001). Currently, no data are available to determine if these lobster species or the Kona crab of the CMUS are approaching an overfished condition (NMFS 2004a). The spiny lobster is a main component of the inshore lobster catch (Hensley and Sherwood 1993) and it is overfished on Guam (Paulay personal communication). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004). The ridgeback slipper lobster and the Kona crab have not been recorded in the Marianas (Paulay personal communication).

Distribution—Members of CMUS occur in the Indo-Pacific region (Holthuis 1991; WPRFMC 1998). There are 839 species of crustaceans in the Marianas (Paulay et al. 2003a). There are 13 species of spiny lobster that occur in the tropical and subtropical Pacific between 35°N and 35°S (Holthuis 1991; WPRFMC 1998). There are five species of *Panulirus* in the Marianas and *P. penicillatus* is the most common species (WPRFMC 2001; Paulay et al. 2003a).

Habitat Preferences—In general, adults of the CMUS favor sheltered areas with rocky substrates and/or sandy bottoms. There is a lack of published data pertaining to the preferred depth distribution of decapod larvae and juveniles in this region (WPRFMC 2001). The spiny lobster is mainly found in windward surf zones of oceanic reefs but some are also found on sheltered reefs (Pitcher 1993; Paulay personal communication). 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 10 m while others are found to depths of around 110 m (Holthuis 1991; Pitcher 1993; WPRFMC 2001; Paulay personal communication). Small juvenile spiny lobsters are found only in the same habitat as larger individuals (Pitcher 1993). The ridgeback spiny lobster likely occurs on rocky bottoms; it is known from depths between 10 and 135 m (Holthuis 1991). The depth distribution of the Chinese slipper lobster is 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 in depths of 24 to 115 m (Smith 1993; Poupin 1996; WPRFMC 1998).

Life History—Decapods exhibit a wide range of feeding behaviors, but most combine nocturnal predation with scavenging; large invertebrates are the typical prey items (WPRFMC 2001). Both lobsters and crabs are ovigerous—the females carry fertilized eggs on the outside of their body. The relationships between egg production, larval settlement, and stock recruitments are poorly understood (WPRFMC 1998, 2001). Spiny lobsters produce eggs in summer and fall. The larvae have a pelagic distribution of about one year and can be transported up to 3,704 km by prevailing ocean currents (WPRFMC 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; there are insufficient data to define the exact spawning season in the study area (WPRFMC 1998). This species remains buried in the substratum during the day, emerging only at night to search for food (Bellwood 2002).

EFH Designations—(WPRFMC 1998; **Figures D-7**, **D-8**, and **D-9**; **Table 4-4**)

- Larvae—EFH for this lifestage is the water column from the shoreline to the outer limit of the EEZ down to a depth of 150 m.
- Juveniles and Adults—All bottom habitat from the shoreline to a depth of 100 m is designated as EFH.

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

4.2.4 Coral Reef Ecosystem Management Unit Species

4.2.4.1 Introduction to Coral Reef Ecosystem Management Unit Species

The Coral Reef Ecosystem Fishery Management Plan (CRE FMP) manages coral reef ecosystems surrounding the following U.S. Pacific Island areas: the State of Hawai'i, the Territories of American

Table 4-4. Crustaceans management unit species EFH designations. Source data: WPRFMC (1998, 2001). [Habitat: 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)]

Management Unit Species/Taxa	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	Comments
CRUSTACEANS											
Spiny and Slipper Lobster Complex											
Spiny lobster (*Panulirus penicillatus, Panulirus* spp.)		All			A,J	All	All		All	L	Depth distribution: 9 - 183 m
Chinese slipper lobster (*Parribacus antarcticus*)						A					Depth distribution: 0-20 m

Samoa and Guam, the CNMI, and the Pacific remote island areas of Johnston Atoll, Kingman Reef, Palmyra and Midway Atolls, and Jarvis, Howland, Baker and Wake Islands (WPRFMC 2001). For the purpose of this fishery management plan, these areas make up the Western Pacific Region and CHCRT and Potentially Harvested Coral Reef Taxa (PHCRT) will only be delineated by specific U.S. Pacific Island areas when information is available. While this MRA focuses on the CNMI and Guam study area, all family information provided corresponds to the entire Western Pacific Region unless otherwise noted.

In addition to EFH, WPRFMC also identified HAPC which are specific areas within EFH that are essential to the life cycle of important coral reef species.

HAPC for all life stages of the CRE MUS includes all hardbottom substrate between 0 and 100 m depth in the study area. Five individual HAPC sites have been identified for the island of Guam, one of which, Jade Shoals, occurs within Apra Harbor. Orote Point Ecological Reserve Area lies immediately outside of Apra Harbor. The remaining three occur in the northern (Ritidian Point), northwest (Haputo Ecological Preserve), and southern (Cocos Lagoon) areas of the island (Research Planning Inc. 1994; WPRFMC 2001; **Figure D-22**).

4.2.4.2 Currently Harvested Coral Taxa

The CHCRT are managed under the CRE FMP by the WPRFMC (2001). CHCRT are species that have been identified which: (1) are currently being 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 (WPRFMC 2001). A complete list of managed species occurring in the study area and their respective fishery management units are found in **Table 4-1**.

4.2.4.2.1 Fish families

- **Acanthuridae** (Surgeonfishes)

  Status—Twenty-four of the 25 species of surgeonfish managed in Micronesia as part of the CHCRT by the WPRFMC (2001) occur in CNMI and Guam (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). In addition, another 14 species of surgeonfishes are found in the study and have EFH designated under the PHCRT (WPRFMC 2001). Currently, no data are available to determine if surgeonfishes of the CHCRT are approaching an overfished situation (NMFS 2004a). Surgeonfish 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). They are also valuable in the aquarium trade. Aquarium species are discussed further as part of a separate management unit species assemblage (WPRFMC 2001). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Surgeonfish 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. As juveniles, surgeonfish are found in reef areas until mature. Adults are found throughout coral reef habitats and are typically associated with subsurge reef habitats. They are found at depths from 0 to 150 m, but are commonly found between 0 and 30 m deep (WPRFMC 2001).

Life History—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 (WPRFMC 2001). 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). Surgeonfish 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).

EFH Designations—(WPRFMC 2001; **Figures D-10**, **D-14**, and **D-18**; **Table 4-5**)

- Eggs and Larvae—The water column from the shoreline to the outer boundary of the EEZ to a depth of 100 m.
- Adult and Juveniles—All bottom habitat and the adjacent water column from 0 to 100 m.

- **Blastulae** (Triggerfish's)

Status—Nine species of triggerfish are managed in Micronesia as part of the CHCRT by the WPRFMC (2001) and occur in CNMI and Guam (Amesbury and Myers 2001; Myers and Donaldson 2003). All have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Eight additional species of triggerfish are found in the study area and have EFH designated under the PHCRT (WPRFMC 2001). Currently, no data are available to determine if triggerfish's of the CHCRT are approaching an overfished situation (NMFS 2004a). Triggerfish 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 study area are listed on the IUCN Red List of threatened species (IUCN 2004).

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

Habitat Preferences—Habitat preferences for triggerfish's includes 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 a lot of caves and crevices. Depth preferences depending on species range from shallow sub tidal zones to waters as deeper than 100 m (Myers 1999).

Life History—There is little information on the spawning and migrational patterns of triggerfish in the western Pacific. Triggerfish are generally solitary, but do form pairs during spawning. Balastid spawning events show some correlation to lunar cycles and eggs are typically deposited in shallow

Table 4-5. Coral reef ecosystem management unit species EFH designations. Source data: Colin and Anderson (1995); Sorokin (1995); Myers (1999); WPRFMC (2001). [Habitat: 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)]

Management Unit Species/Taxa	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	Comments
CORAL REEF ECOSYSTEM											
Currently Harvested Coral Reef Taxa											
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 m
Unicornfishes (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)											
Bodianus, *Xyrichtys*, and *Xyrichtys* 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 spp.		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
Octopuses (Octopodidae)	A,J, S	All	A,J, S	All	All	All	All		All	L	Adult depth of 0-50 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

Table 4-5. Continued

Management Unit Species/Taxa	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	Comments
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
Bumphead parrotfish (*Bolbometopon muricatum*)	J	J		J		A,J,S	A,J,S			E,L	Adult depth of 1-30 m
Mackerels (Scombridae)											
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 1-50 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
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
Aquarium Taxa/Species											
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 m
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
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
Potentially Harvested Coral Reef Taxa											
FISH MANAGEMENT UNIT SPECIES											
Hammerhead sharks (Sphyrnidae)	A,J	A,J	A,J		A,J	A,J	A,J		A,J	A,J	Adult depth of 1-275 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
Emperors (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 morays, conger and garden eels, spaghetti eels, and snake eels (Chlopsidae, Congridae, Moringuidae, 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

Table 4-5. Continued

Management Unit Species/Taxa	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	Comments
Flounders and soles (Bothidae, Soleidae, and Pleuronectidae)		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
Batfishes (Ephippidae)	J	A,J,S	J		A,S	A,J,S	A,J,S		A,S	All	Adult depth of 20-30 m
Monos (Monodactylidae)	A,J,S	A,J,S	A,J,S			A,J,S	A,J,S			E,L	Adult depth of 0-10 m
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 (Echineididae)						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 (Plesiopodae)	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
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
INVERTEBRATE MANAGEMENT UNIT SPECIES											
Molluscs (Mollusca)											
Sea snails (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
Trochus (*Trochus* spp.)		A,J,S				A,J,S	A,J,S			E,L	Adult depth of 7-25 m
Sea slugs (Opistobranchs)	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

Table 4-5. Continued

Management Unit Species/Taxa	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	Comments
Oysters and clams (Bivalves)											
Black-lipped pearl oyster (*Pinctada margaritifera*)	A,J	A,J, S				A,J,S	A,J,S		A,J,S	E,L	Depth distribution: littoral/sub-littoral 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
Nautiluses, cuttlefishes, and squids (Cephalopods)		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
Tunicates (Ascidians)	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 0-120 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/slipper		All			A,J	All	All		All	L	Adult depth of 20-55 m
Shrimp/Mantis shrimps		All	A,J	A,J	A,J	All	All		All	L	Adult depth of 3-70 m
Crabs (true/hermit)	A,J	All	A,J	A,J	A,J	All	All		All	L	Adult depth of 0-115 m
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
SESSILE BENTHOS MANAGEMENT UNIT SPECIES											
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

Table 4-5. Continued

Management Unit Species/Taxa	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	Comments
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		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
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 rock		A,J	A,J			A,J	A,J		A,J	E,L	

pits excavated by the parents. Larvae are pelagic with prejuveniles often being associated with floating algae (WPRFMC 2001).

EFH Designations—(WPRFMC 2001; Figures D-10, D-14, and D-18; **Table 4-5**)

- <u>Eggs and Larvae</u>—The water column from the shoreline to the outer boundary of the EEZ to a depth of 100 m.
- <u>Adult and Juveniles</u>—All bottom habitat and the adjacent water column from 0 to 100 m.

- **Carangidae** (Jacks)

Status—Two species of carangids, the big eye 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 (Amesbury and Myers 2001; Myers and Donaldson 2003). Both species have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004b). In addition, the remaining 26 species of jacks found in the study area are designated as EFH under the PHCRT (WPRFMC 2001). Currently, no data are available to determine if the bigeye and mackerel scads of the CHCRT are approaching an overfished situation (NMFS 2004a). Both of these fishes are economically important food fish on many of the U.S. Pacific Islands and there is a small seasonal fishery for bigeye scad in the Mariana archipelago (Uchida 1983; WPRFMC 2001). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—The Carangids are a large family represented in all tropical and temperate seas with the majority being 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 Micronesia (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). This species can be found off the coast of Guam year round but is scarce in July and August, which may be due to spawning (Uchida 1983).

Habitat Preferences—Carangid eggs are planktonic and larvae are common in nearshore waters. 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 (WPRFMC 2001). Adult Carangids can range from reef habitats to deep slope habitats at depths of 0 to 350 m (WPRFMC 2001).

Mackerel scad are a schooling species that are 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 2004).

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 Marianas 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 (WPRFMC 2001).

Decapterus spp. and *Selar* spp. tend to spawn in pelagic environments. Eggs are also found in pelagic waters and 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 miles (mi) offshore. Larval and juvenile fish remain in offshore pelagic waters for the first several months of their life, after which they migrate to the nearshore adult habitat. Spawning occurs from March to August, peaking from May to July (WPRFMC 2001).

EFH Designations—(WPRFMC 2001; **Figures D-10**, **D-14**, and **D-18**; **Table 4-5**)

- Eggs and Larvae—The water column from the shoreline to the outer boundary of the EEZ to a depth of 100 m.
- Adult and Juveniles—All bottom habitat and the adjacent water column from 0 to 100 m.

♦ **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 (Amesbury and Myers 2001; Myers and Donaldson 2003). All have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). In addition, the four other species of requiem sharks found in the study area have EFH designated under the PHCRT (WPRFMC 2001). Currently, no data are available to determine if requiem sharks of the CHCRT are approaching an overfished situation (NMFS 2004a). Of the nine sharks managed under CHCRT/PHCRT in the study area, five are listed on the IUCN Red List of threatened species.

The grey reef shark (*C. amblyrhynchos*), blacktip reef shark (*C. melanopterus*), whitetip reef shark (*Triaenodon obesus*), and Galapagos shark (*Carcharinus galapagensis*) are categorized by the IUCN as a lower risk but near threatened species; whereas the tiger shark (*Galeocerdo cuvier*) is near threatened (Heupel 2000; Simpfendorfer 2000; Smale 2000a, 2000b; Bennett et al. 2003). All of the requiem sharks are afforded protection under the Shark Finning Protection Act (NMFS 2002).

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 (WPRFMC 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 Marianas 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).

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) (WPRFMC 2001). 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 (WPRFMC 2001).

EFH Designations—(WPRFMC 2001; **Figures D-11**, **D-15**, and **D-19**; **Table 4-5**)

- Eggs and Larvae—N/A
- Adult and Juveniles—All bottom habitat and the adjacent water column from 0 to 100 m to the outer extent of the EEZ.

♦ **Holocentridae** (Soldierfishes/Squirrelfishes)

Status—Seventeen of the 19 holocentrid species (nine soldierfish and eight squirrelsfish) that are managed in Micronesia as part of the CHCRT by the WPRFMC (2001) and are reported as occurring in CNMI and Guam (Amesbury and Myers 2001; Myers and Donaldson 2003), and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining 16 holocentrid species found in the study area have designated EFH under the PHCRT (WPRFMC 2001). Currently, no data are available to determine if soldierfishes/squirrelfishes of the CHCRT are approaching an overfished situation (NMFS 2004a). These fish are commonly sold in fish markets and are popular aquarium fish (Allen and Steene 1987). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

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).

Habitat Preferences—Soldierfish and squirrelfish occupy relatively shallow-water over coral reefs or rocky bottoms (Randall and Greenfield 1999). 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. Holocentrid fishes are found from shallow-water down to approximately 40 m, with some species occurring as deep as 235 m (WPRFMC 2001). Adults are usually demersal and larvae are planktonic for several weeks (Froese and Pauly 2004).

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 (WPRFMC 2001).

EFH Designations—(WPRFMC 2001; **Figures D-10**, **D-14**, and **D-18**; **Table 4-5**)

- Eggs and Larvae—The water column from the shoreline to the outer boundary of the EEZ to a depth of 100 m.
- Adult and Juveniles—All rocky and coral areas and the adjacent water column from 0 to 100 m.

♦ **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 (Amesbury and Myers 2001; Myers and Donaldson 2003) and has EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining two flagtail species found in the study area have designated EFH under the PHCRT (WPRFMC 2001). Currently, no data are available to determine if the barred flagtail of the CHCRT are approaching an overfished situation (NMFS 2004a). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Flagtails are distributed throughout the Indo-Pacific region (WPRFMC 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 2001a).

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 (WPRFMC 2001; Froese and Pauly 2004). At night the schools break up and the fish forage in the water column above the reef (Froese and Pauly 2004). Juveniles are found individually or in small aggregations in tidal pools or along shallow shoreline areas (Froese and Pauly 2004). Flagtails can tolerate a wide range of salinities and can be found in freshwater, brackish water, or salt water (WPRFMC 2001). The barred flagtail is found in tropical waters from 32°N to 32°S at depths from 3 to 18 m (Froese and Pauly 2004).

Life History—Information is lacking on the life history of this family (WPRFMC 2001).

EFH Designations—(WPRFMC 2001; **Figures D-12**, **D-16**, and **D-20**; **Table 4-5**)

- Eggs and Larvae—The water column from the shoreline to the outer limits of the EEZ to a depth of 100 m.
- Adult and Juveniles—All bottom habitat and the adjacent water column from 0 to 46 m.

♦ **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 (Amesbury and Myers 2001; Myers and Donaldson 2003) and Micronesia (2005). All three species have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). In addition, the one remaining rudderfish species found in the study area has designated EFH under the PHCRT (WPRFMC 2001). Currently, no data are available to determine if rudderfishes of the CHCRT are approaching an overfished situation (NMFS 2004a). 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 study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Rudderfish are found in the Atlantic, Indian, and Pacific oceans (Froese and Pauly 2004). In the Indo-Pacific, this family is found throughout tropical and subtropical waters from Easter Island westward to the Red Sea (WPRFMC 2001).

Habitat Preferences—Rudderfish are found near shore over rocky bottoms or associated with coral reefs along exposed coasts (Froese and Pauly 2004; WPRFMC 2001). Adults are usually found swimming several meters above the bottom. The blue sea chub (*Kyphosus. cenerascens*) occurs at depths of at least 24 m (WPRFMC 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; WPRFMC 2001).

The grey rudderfish, *K. bigibbus*, is found in tropical waters from 35°N to 28°S typically associated with reefs (Froese and Pauly 2004).

The highfin rudderfish, *K. cinerascens*, is found in tropical waters from 35°N to 30°S at depths from 1 to 24 m (Froeses and Pauly 2004).

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 2004).

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 (WPRFMC 2001). Adults spawn in large numbers in pelagic waters (Froese and Pauly 2004).

EFH Designations—(WPRFMC 2001; **Figures D-13**, **D-17**, and **D-21**; **Table 4-5**)

- Eggs, Larvae, and Juvenile—The water column from the shoreline to the outer boundary of the EEZ to a depth of 100 m.
- Adult—All rocky and coral bottom habitat and the adjacent water column from 0 to 27 m.

♦ **Labridae** (Wrasses)

Status—Twenty of the 22 species of the family Labridae that are managed in Micronesia as part of the CHCRT by the WPRFMC (2001) and occur in CNMI and Guam (Amesbury and Myers 2001; Myers and Donaldson 2003). All 20 species have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining 65 wrasse species found in the study area have designated EFH under the PHCRT (WPRFMC 2001). Currently, no data are available to determine if wrasses of the CHCRT are approaching an overfished situation (NMFS 2004a). Very little information exists on the commercial harvest of labrids in Guam or the Northern Marianas. However, wrasses make up a small percentage of the commercial fish trade in numbers, value, and weight for both areas (WPRFMC 2001).

One species of wrasse found in the study area, *Cheilinus undulatus* (humphead wrasse), is listed by the IUCN Red List as "Endangered" (IUCN 2004). The humphead wrasse was also listed as a "Species of Concern" by the NOAA Fisheries Office of Protected Resources in 2004 (NMFS 2004d). According to IUCN, a taxon is "Endangered" when the best available evidence indicates: (1) an observed, estimated, inferred, or suspected population size reduction of ≥50% over the last 10 years or three generations, whichever is longer, where the reduction or its causes may not have ceased, may not be understood, or may not be reversible; and (2) a population size reduction of ≥50%, projected or suspected to be met within the next 10 years or three generations, whichever is longer (up to a maximum of 100 years), based on the index of abundance appropriate to the taxon and actual or potential levels of exploitation (Cornish et al. 2004). 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 (WPRFMC 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 SCUBA gear, (3) lack of coordinated, consistent national and regional management, (4) illegal, unregulated, or unreported fisheries, and (5) loss of habitat (NMFS 2004d).

Distribution—Wrasses are found in shallow tropical and temperate seas of the Atlantic, Indian, and Pacific Oceans (Froese and Pauly 2004). This species is distributed throughout the shallow areas of the western Pacific (WPRFMC 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 Ryukyus in the north, including China and Chinese Taipei, east to Wake Island, south to New Caledonia, and throughout Micronesia (Myers 1999).

Habitat Preferences—Labrids prefer shallow-waters closely associated with coral reefs (WPRFMC 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; WPRFMC 2001). Most wrasses are found in relatively calm waters between about 3 and 20 m, however, some species occur at depths greater than 200 m (Allen and Steene 1987; WPRFMC 2001). Adults roam the coral reefs during the day keeping close to coral or rocky cover (Froese and Pauly 2004). At night, they may rest in caves or under coral ledges, bury themselves in the sand, or lie motionless on the bottom (WPRFMC 2001; Froese and Pauly 2004). Labrid eggs and larvae are pelagic and are routinely found in the open ocean (WPRFMC 2001). Juveniles, like adults, inhabit a wide range of habitats from shallow lagoons to deep reef slopes (WPRFMC 2001).

Humphead wrasses occur along steep outer reef slopes, channel slopes, and occasionally on lagoon reefs, at depths from 1 to 60 m (WPRFMC 2001; Froese and Pauly 2004). 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 2004). Juveniles are associated with coral-rich areas of lagoon reefs, usually among thickets of *Acropora* corals (Froese and Pauly 2004). The eggs and larvae of this species are pelagic (Sadovy et al. 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 (WPRFMC 2001).

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 et al. 2003). Humpheads may spawn during several or all months of the year associated with a range of different reef habitats (Sadovy et al. 2003).

EFH Designations—(WPRFMC 2001; **Figures D-10**, **D-14**, and **D-18**; **Table 4-5**)

- Eggs, Larvae, Juvenile, and Adult—The water column and all bottom habitats extending from the shoreline to the outer boundary of the EEZ to a depth of 100 m.

♦ **Mullidae** (Goatfishes)

Status—Eleven of the 13 species of the family Mullidae that are managed in Micronesia as part of the CHCRT by the WPRFMC (2001) and occur in CNMI and Guam (Amesbury and Myers 2001; Myers and Donaldson 2003). All 11 have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining three species of goatfishes found in the study area have designated EFH under the PHCRT (WPRFMC 2001). Currently, no data are available to determine if goatfishes of the CHCRT are approaching an overfished situation (NMFS 2004a). A number of goatfish are commercially important in the western Pacific and most of the catch is marketed fresh (Randall 2001b). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Goatfish are found in tropical and subtropical regions of the Atlantic, Indian, and Pacific Oceans (Froese and Pauly 2004). The majority of species in this family can be found in the Indo-West Pacific region (Allen and Steene 1987).

Habitat Preferences—Generally, goatfish are found over sandy areas in shallow-waters adjacent to reefs at depths at about 10 m (Allen and Steene 1987; WPRFMC 2001). However, some species have been reported as deep as 140 m (WPRFMC 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 (WPRFMC 2001).

Life History—Goatfish are commonly found schooling and may spawn either in groups or pairs (WPRFMC 2001). Goatfish are pelagic spawners and aggregations of 300 to 400 individuals are common for certain species (Allen and Steene 1987).

EFH Designations—(WPRFMC 2001; **Figures D-10**, **D-14**, and **D-18**; **Table 4-5**)

- Eggs and Larvae—The water column extending from the shoreline to the outer boundary of the EEZ to a depth of 100 m.
- Juvenile and Adult—All rocky/coral and sand-bottom habitat and the adjacent water column from 0 to 100 m.

- **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 (Amesbury and Myers 2001; Myers and Donaldson 2003). All three have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining two species of mugulids found in the study area have designated EFH under the PHCRT (WPRFMC 2001). Currently, no data are available to determine if mullets of the CHCRT are approaching an overfished situation (NMFS 2004a). Several species of mullets are of moderate to major importance to fisheries in the western Pacific and small-scale, subsistence fisheries are probably also relatively prominent (Harrison and Senou 1999). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—The family Mugilidae can be found in all tropical and temperate seas but are most speciose in the Indo-West Pacific region (Harrison and Senou 1999; Foese and Pauly 2004).

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 2004).

The acute-jawed mullet, *Neomyxus leuciscus*, is found in the Pacific Ocean around southern Japan and the Mariana, and Bonin Islands east to the Hawaiian, Line, and Ducie Islands. In Micronesia this species is found around the Ifaluk, Mariana, and Marshal Islands (Froese and Pauly, 2004).

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; WPRFMC 2001).

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 2004).

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 2004).

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 2004).

Life History—Very little information concerning the spawning and migration of these species is available. It is presumed that 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 2004).

EFH Designations—(WPRFMC 2001; **Figures D-12**, **D-16**, and **D-20**; **Table 4-5**)

- Eggs/Larvae—The water column from the shoreline to the outer limits of the EEZ to a depth of 100 m.
- Juvenile/Adult—All sand and mud bottoms and the adjacent water column from 0 to 46 m.

♦ **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 (Amesbury and Myers 2001; Myers and Donaldson 2003). All three species have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining 43 species of moray eels found in the study area have designated EFH under the PHCRT (WPRFMC 2001). Currently, no data are available to determine if moray eels of the CHCRT are approaching an overfished situation (NMFS 2004a). There is no commercial fishery for morays and most are taken as incidental catch but they are sold in fish markets and readily eaten in the western Pacific (Bohlke et al. 1999). These species are also targets of the aquarium trade. None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Morays are found worldwide in tropical and subtropical waters (Froese and Pauly 2004).

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 2004).

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 2004).

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 2004).

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 (Bohlke et al. 1999). Juvenile and adult morays lurk in holes and crevices during the day and emerge at night to search the reef for food (Waikiki Aquarium 1999a). Moray eggs pelagic and the leptocephalic larvae are epipelagic (WPRFMC 2001; Forese and Pauly 2004).

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 shorelines to seaward reefs (Froese and Pauly 2004).

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 2004).

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 2004).

Life History—Information is lacking on the life history of this family (WPRFMC 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).

EFH Designations—(WPRFMC 2001; **Figures D-10**, **D-14**, and **D-18**; **Table 4-5**)

- Eggs and Larvae—The water column from the shoreline to the outer boundary of the EEZ to a depth of 100 m.
- Juvenile and Adult—All rocky coral areas and the adjacent water column and the adjacent water column from 0 to 100 m.

♦ **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 study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining 22 species of octopus found in the study area have designated EFH under the PHCRT (WPRFMC 2001). Currently, no data are available to determine if octopuses of the CHCRT are approaching an overfished situation (NMFS 2004a). 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 study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Members of the family Octopodidae occur in all the oceans of the world from the equator to polar latitudes (Norman 1998, Waikiki Aquarium 1998a). 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 (WPRFMC 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 (WPRFMC 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 1998a).

Life History—Life history information is lacking for these species of octopus (WPRFMC 2001). 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 Aquarium1998a).

EFH Designations—(WPRFMC 2001; **Figures D-10**, **D-14**, and **D-18**; **Table 4-5**)

➢ Eggs, Juvenile, and Adult—EFH for the adult, juvenile phase and demersal eggs are defined as all coral, rocky, and sand-bottom areas from 0 to 100 m.

♦ **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) and has been reported as occurring in CNMI and Guam (Amesbury and Myers 2001; Myers and Donaldson 2003). EFH has been designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c) for this species. Currently, no data are available to determine if the sixfeeler threadfin of the CHCRT is approaching an overfished situation (NMFS 2004a). This species is highly valued as food-fish (WPRFMC 2001). This species is not listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—The sixfeeler threadfin is found throughout the tropical waters of the Atlantic and Indo-Pacific Oceans from 30°N to 0°N (WPRFMC 2001; Froese and Pauly 2004). 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 inhabits turbid waters along sandy shorelines and over sandy lagoon bottoms usually associated with high-energy surf zones (Myers 1999; Feltes 2001; WPRFMC 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 (WPRFMC 2001). Juvenile sixgill threadfin are found from the shoreline breaker to 100 m depth (WPRFMC 2001).

Life History—Spawning occurs close to shore for three to six days per month and is associated with the lunar cycle (Myers 1999; WPRFMC 2001). In Hawai'i, the sixfeeler threadfin spawns from June to September, with a peak in July and August (WPRFMC 2001). Spawning may occur year round in tropical locations (WPRFMC 2001). Both eggs and larvae are subject to advection by ocean currents (WPRFMC 2001).

EFH Designations—(WPRFMC 2001; **Figures D-10**, **D-14**, and **D-18**; **Table 4-5**)

- Eggs and Larvae—The water column extending from the shoreline to the outer boundary of the EEZ to a depth of 100 m.
- Juvenile and Adult—All rocky/coral and sand-bottom habitat and the adjacent water column from 0 to 100 m.

♦ **Priacanthidae** (Bigeyes)

Status—Two species of the family Priacanthidae (Bigeyes) are managed in Micronesia as part of the CHCRT by the WPRFMC (2001) and are reported as occurring in CNMI and Guam (Amesbury and Myers 2001; Myers and Donaldson 2003). Both species have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining 4 species of bigeyes found in the study area have designated EFH under the PHCRT (WPRFMC 2001). Currently, no data are available to determine if bigeyes of the CHCRT are approaching an overfished situation (NMFS 2004a). These species are excellent food-fish but are not important in most fishery areas (Starnes 1999; Amesbury and Myers 2001). These two species are not listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Priacanthids can be found in the tropical and subtropical waters of the Atlantic, Indian, and Pacific Oceans (Froese and Pauly 2004).

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 2004).

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 (WPRFMC 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 2004).

The glasseye is a subtropical species that ranges from 33°N to 32°S at depths from 3 to 300 m (Froese and Pauly 2004). This species is commonly associated with lagoons or seaward reefs below the surge zone, generally around islands (Froese and Pauly 2004; 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 2004).

The moontail bullseye is a tropical species ranging from 32°N to 24°S at depths from 8 to 250 m (Froese and Pauly 2004). 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 (Starnes 1999; Froese and Pauly 2004).

Life History—Spawning for this species has not been observed (WPRFMC 2001). Daily migrations usually occur above and away from the reef in search of food (Myers 1999).

EFH Designations—(WPRFMC 2001; **Figures D-10**, **D-14**, and **D-18**; **Table 4-5**)

- Eggs and Larvae—The water column extending from the shoreline to the outer boundary of the EEZ to a depth of 100 m.
- Juvenile and Adult—All rocky/coral and sand-bottom habitat and the adjacent water column from 0 to -9100 m.

♦ **Scombridae** (Mackerels)

Status—One mackerel species, the dogtooth tuna (*Gymnosarda unicolor*), is managed in Micronesia as part of the CHCRT by the WPRFMC (2001) and has been reported as occurring in CNMI and Guam (Amesbury and Myers 2001; Myers and Donaldson 2003). EFH has been designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c) for this species. Currently, no data are available to determine if the dogtooth tuna of the CHCRT is approaching an overfished situation (NMFS 2004a). The dogtooth tuna is not listed on the IUCN Red List of threatened species (IUCN 2004).

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, form the surface to depths of approximately 100 m (Collette and Nauen 1983). Dogtooth tuna prefer water temperatures ranging from 20° to 28°C (WPRFMC 2001). Dogtooth tuna larvae are found in surface and subsurface tows, generally concentrated at depths from 20 to 30 m (WPRFMC 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 (WPRFMC 2001). Diurnal migrations have been observed in older larvae, making their way to the surface at night (WPRFMC 2001). Spawning is believed to occur year round in tropical locations (WPRFMC 2001). Dogtooth tuna are generally solitary species but may occur is small schools of six or less (Froese and Pauly 2004).

EFH Designations—(WPRFMC 2001; **Figures D-10**, **D-14**, and **D-18**; **Table 4-5**)

- Eggs, Larvae, Juvenile, and Adult—The water column from the shoreline to the outer boundary of the EEZ to a depth of 100 m.

♦ **Scaridae** (Parrotfishes)

Status—Four species of the family Scaridae are managed in Micronesia as part of the CHCRT by the WPRFMC (2001) and are reported as occurring in CNMI and Guam (Amesbury and Myers 2001; Myers and Donaldson 2003). Each species has EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining 21 species of parrotfishes found in the study area have designated EFH under the PHCRT (WPRFMC 2001). Currently, no data are available to determine if parrotfishes of the CHCRT are approaching an overfished situation (NMFS 2004a). Parrotfish are not a major commercial catch but they are an important food-fish and are frequently found in fish markets (Westneat 2001; Froese and Pauly 2004). There are no species of parrotfish listed on the IUCN Red List of threatened species but the bumphead parrotfish, *Bolbometopon muricatum*, was listed as a "Species of Concern" by the NOAA Fisheries Office of Protected Resources in 2004 (IUCN 2004; NMFS 2004d).

The bumphead parrotfish is one of the most desirable and most vulnerable nearshore reef fish in the U.S. Western Pacific Islands. Bumphead parrotfish are an important species in the live reef fish trade as well as the aquarium trade. This species has all but disappeared from Guam's reefs and has shown significant declines throughout its range. Reasons attributing to the decline of this species include 1) overexploitation and destructive fishing techniques; 2) degradation and loss of coral reef habitats; and 3) a vulnerable life history (NMFS 2004d).

Distribution—Parrotfish are mainly a tropical species occurring in the Atlantic, Indian, and Pacific Oceans (Froese and Pauly 2004). The majority of these species are found inhabiting the coral reefs of the Indian and western Pacific Oceans.

The bumphead parrotfish, *Bolbometopon muricatum*, can be found throughout the Indo-Pacific from the Red Sea and East Africa in the east to the Line Islands and Samoa in the west, north to Yaeyama, south to the Great Barrier Reef and New Caledonia. In Micronesia, this species can be found from Palau to the Caroline, Mariana, and Wake Islands (Froese and Pauly 2004).

Habitat Preferences—Parrotfish are commonly found around coral reefs, and are usually most abundant in shallow-waters to a depth of 30 m (Westneat 2001). This species occupies 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). Parrotfish sleep under ledges or wedged against coral or rock at night (Myers 1999).

The bumphead parrotfish can be found in tropical waters from 30° N to 24° S from 1 to 30 m deep (Froese and Pauly 2004). Adults are found in small groups in clear outer lagoons and around seaward reefs and are often located on reef crests or fronts (WPRFMC 2001; Froese and Pauly 2004). Adults may utilize a wide range of coral and shallow-water habitat types, but juveniles are usually found in lagoons (WPRFMC 2001).

Life History—Parrotfish 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. Parrotfish may migrate into lagoons or to the outer reef slope in order to spawn. Some parrotfish 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 (WPRFMC 2001).

At this time, no reliable data are available on the spawning and migration of the bumphead parrotfish (Myers 1999; WPRFMC 2001; Froese and Pauly 2004).

EFH Designations—(WPRFMC 2001; **Figures D-10**, **D-14**, and **D-18**; **Table 4-5**)

- Eggs and Larvae—The water column from the shoreline to the outer limit of the EEZ to a depth of 100 m.
- Juvenile and Adult—All bottom habitat and the adjacent water column from 0 to 100 m.

♦ **Siganidae** (Rabbitfish)

Status—Four of the 6 species of the family Siganidae are managed in Micronesia as part of the CHCRT by the WPRFMC (2001). All 6 occur in CNMI and Guam (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). The remaining 2 species of rabbitfish found in the study area have designated EFH under the PHCRT (WPRFMC 2001). Currently, no data are available to determine if rabbitfishes of the CHCRT are approaching an overfished situation (NMFS 2004a). Rabbitfish are a highly esteemed food-fish and may make up a large portion of marketable reef fish is 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 2004). There are no species of rabbitfish listed on the IUCN Red List of threatened species located within the study area (IUCN 2004).

Distribution—Rabbitfish are found throughout the Indo-Pacific and eastern Mediterranean (Froese and Pauly 2004).

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 (WPRFMC 2001). Eggs are usually adhesive and demersal but at least one species the schooling rabbitfish (*S. aregenteus*), is known to have pelagic eggs (WPRFMC 2001). Rabbitfish can be divided into schooling species and pairing species. Schooling species of rabbitfish tend to occupy a wide range of habitats, whereas, pairing species tend to remain in one area usually among branches of hard corals (WPRFMC 2001).

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 the 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 (WPRFMC 2001).

EFH Designations—(WPRFMC 2001; **Figures D-10**, **D-14**, and **D-18**; **Table 4-5**)

- <u>Eggs and Larvae</u>—The water column from the shoreline to the outer boundary of the EEZ to a depth of 100 m.
- <u>Juvenile and Adult</u>—All bottom habitat and the adjacent water column from 0 to 100 m.

♦ **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 (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining 4 species of barracudas found in the study area have designated EFH under the PHCRT (WPRFMC 2001). Currently, no data are available to determine if barracudas of the CHCRT are approaching an overfished situation (NMFS 2004a). In the western Pacific, barracudas are marketed fresh, frozen, dried, salted, or smoked (Senou 2001). There are no species of barracuda listed on the IUCN Red List of threatened species located within the study area (IUCN 2004).

Distribution—Barracudas can be found in tropical and subtropical waters in the Atlantic, Indian, and Pacific Oceans (Froese and Pauly 2004).

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 (Forese and Pauly 2004).

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 2004).

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)

Heller's barracuda is a subtropical species found from 30°N to 25°S at depths from 15 to 60 m (Froese and Pauly 2004). 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 2004). Juveniles occur among mangroves and in shallow sheltered inner reefs (WPRFMC 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 (WPRFMC 2001). Heller's barracuda can be found in large school during the day, whereas, the great barracuda is diurnal and solitary (Froese and Pauly 2004).

EFH Designations—(WPRFMC 2001; **Figures D-10**, **D-14**, and **D-18**; **Table 4-5**)

- Eggs, Larvae, Juvenile, and Adult—The water column from the shoreline to the outer boundary of the EEZ to a depth of 100 m.

♦ **Turbinidae** (Turban shells)

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 subfamily have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). The main species of turban shells harvested are the green snail (*Turbo marmoratus*), the rough turban (*T. setosus*), and the silver-mouth turban (*T. Argyrostomus*). Only the latter two species are found in the study area (Smith 2003). Currently, no data are available to determine if turban shells of the CHCRT are approaching an overfished situation (NMFS 2004a). There are no species of turban shells listed on the IUCN Red List of threatened species located within the study area (IUCN 2004).

Distribution—Turban shells are distributed throughout the Indo-Pacific region extending into the South Pacific (WPRFMC 2001).

Habitat Preferences—Turban shells are found in shallow-waters of warm temperate and tropical seas (Poutiers 1998a). These species prefer healthy coral reef habitats, which receive a constant flow of oceanic water. Juveniles can be found on shallow reef crests while adults prefer deeper habitats (WPRFMC 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 (WPRFMC 2001).

EFH Designations—(WPRFMC 2001; **Figures D-10**, **D-14**, and **D-18**; **Table 4-5**)

- Eggs and Larvae—The water column from the shoreline to the outer boundary of the EEZ to a depth of 100 m.
- Juvenile and Adult—All bottom habitat and the adjacent water column from 0 of 100 m.

4.2.4.2.2 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 (Amesbury and Myers 2001; Myers and Donaldson 2003). All taxa within this management unit have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). 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 study area due to the prohibition of the commercial export of live aquarium fishes in the Marianas. Guam allows the export of aquarium species but only has one commercial operation at this time (WPRFMC 2001). The EFH designations for all aquarium species managed as CHCRT are described in the following paragraphs.

EFH Designations—(WPRFMC 2001; Figures D-10, D-14, and D-18; **Table 4-5**)

- Eggs and Larvae—All waters from 0 to 100 m from the shoreline to the limits of the EEZ.
- Juvenile and Adult—All coral, rubble, or other hard-bottom features and the adjacent water column from 0 to 100 m.

- **Acanthuridae** (Surgeonfishes)

A complete summary of the family Acanthuridae including EFH and HAPC designations is provided earlier in the CHCRT section. The following three surgeonfishes will be 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 (Amesbury and Myers 2001; Myers and Donaldson 2003), and has EFH designation within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if the yellow tang is approaching an overfished situation (NMFS 2004a). This species is not listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—The yellow tang can be found in the Pacific Ocean associated with Ryukyu, Mariana, Marshall, Marcus, Wake, and Hawaiian Islands (Froese and Pauly 2004).

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 in water temperatures ranging from 24° to 28°C at depths between 2 and 46 m (Froese and Pauly 2004).

Life History—At this time, information on the life stages of the yellow tang is limited. The yellow tang may spawn in groups or pairs (Myers 1999).

- 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 (Amesbury and Myers 2001; Myers and Donaldson 2003), and has EFH designation within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if the yellow-eyed surgeonfish of the CHCRT is approaching an overfished situation (NMFS 2004a). This species is not listed on the IUCN Red List of threatened species (IUCN 2004).

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 in water temperatures ranging from 21° to 27°C at depths between 1 and 113 m (Froese and Pauly 2004).

Life History—Very little information exists 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 (Amesbury and Myers 2001; Myers and Donaldson 2003), and has EFH designation within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if the Achilles tang of the CHCRT is approaching an overfished situation (NMFS 2004a). This species is not listed on the IUCN Red List of threatened species (IUCN 2004).

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 in water temperatures ranging from 26° to 28°C at depths between 0 and 10 m (Froese and Pauly 2004).

Life History—There is very little information available on the life history of the Achilles tang at this time (WPRFMC 2001).

♦ **Zanclidae** (Moorish Idol)

Status—The Moorish idol (*Zanclus cornutus*), a sole member of this monotypic family, is an aquarium taxa that is managed in Micronesia as part of the CHCRT by the WPRFMC (2001), has been reported as occurring in CNMI and Guam (Amesbury and Myers 2001; Myers and Donaldson 2003), and has EFH designation within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if the Moorish idol of the CHCRT is approaching an overfished situation (NMFS 2004a). This species is not listed on the IUCN Red List of threatened species (IUCN 2004).

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 Hawai'ian Islands and south to Lord Howe, the Kermadecs, Rapa, and Ducie Islands. The Moorish idol tang 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 in water temperatures ranging from 24° to 28°C at depths between 3 and 182 m (Froese and Pauly 2004).

Life History—The Moorish idol is usually found in small groups but may occur in schools numbering over 100 individuals (Myers 1999).

♦ **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 (Amesbury and Myers 2001; Myers and Donaldson 2003). Both species have EFH designation within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining 15 species of angelfishes found in the study area have designated EFH under the PHCRT (WPRFMC 2001). Currently, no data are available to determine if angelfishes of the CHCRT are approaching an overfished situation (NMFS 2004a). 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 2001a). These species are not listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—The angelfish can be found throughout the tropical waters of the Atlantic, Indian, and Pacific Oceans (Froese and Pauly 2004).

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 Ryukyus and south to New Caledonia and Rapa. The lemonpeel angelfish is found throughout Micronesia (Froese and Pauly 2004).

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 2004). 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 2004). In the Marianas, 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 2004). In the Marianas, 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 2004).

- **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 (Amesbury and Myers 2001; Myers and Donaldson 2003). Both species have EFH designation within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining seven species of hawkfishes found in the study area have designated EFH under the PHCRT (WPRFMC 2001). Currently, no data are available to determine if hawkfishes of the CHCRT are approaching an overfished situation (NMFS 2004a). 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 (IUCN 2004).

Distribution—Hawkfishes can be found from the tropical western and eastern Atlantic, Indian, and Pacific Oceans (Froese and Pauly 2004).

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 Ryukyus 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 2001c).

The longnose hawkfish prefers steep outer reef slopes exposed to strong currents. This species if 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*, *Pocillopora elegans*, *P. eydouxi*, or *P. verrucosa* (Myers 1999).

Life History—Spawning occurs throughout the year in tropical waters and only during warmer months in temperate areas. These species usually spawns at dusk or during early nighttime (Myers 1999).

- **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 (Amesbury and Myers 2001; Myers and Donaldson 2003). Each species has EFH designation within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining 27 species of butterflyfishes found in the study area have designated EFH under the PHCRT (WPRFMC 2001). Currently, no data are available to determine if butterflyfishes of the CHCRT are approaching an overfished situation (NMFS 2004a). Although harvested as food-fish, the primary value of the butterflyfish 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 2001b). None of the four aquarium species are listed on the IUCN Red List of threatened species (IUCN 2004). The yellow-crowned butterflyfish, *Chaetodon flavocoronatus*, is listed as vulnerable on the IUCN Red List of threatened species in the study area (Roberts 1996).

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 2004).

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 2004).

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 2004).

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 2004).

Habitat Preferences—Butterflyfish are diurnal species that are generally found near coral reefs (Froese and Pauly 2004). Juveniles tend to occupy shallower, more sheltered habitats than adults. Butterfly fish eggs are planktonic (WPRFMC 2001).

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 2004).

The raccoon butterflyfish inhabits shallow reef flats of lagoons and seaward reefs to depths of over 30 m (Froese and Pauly 2004). 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 2004). Juveniles prefer rocks of inner reef flats and tide pools (Froese and Pauly 2004). 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 2004).

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 2004).

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 2004). Very little information is known about the spawning and migration of the other three butterflyfishes (Myers 1999; WPRFMC 2001; Froese and Pauly 2004).

- **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 (Amesbury and Myers 2001; Myers and Donaldson 2003). All three species have EFH designation within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining 46 species of damselfishes found in the study area have designated EFH under the PHCRT (WPRFMC 2001). Currently, no data are available to determine if damselfishes of the CHCRT are approaching an overfished situation (NMFS 2004a). Their most important commercial use is as aquarium fishes, especially the anemone fish (Allen 2001). None of these aquarium species are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Damselfish can be found in all tropical seas but are most abundant in the Indo-West Pacific region (Froese and Pauly 2004).

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 Ryukyu Islands and south to New Caledonia (Froese and Pauly 2004).

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 2004).

The threespot dascyllus (*D. trimaculatus*) can be found distributed throughout the tropical Indo-West 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 2004).

Habitat Preferences—Damselfish typically occur in shallow-water or coral or rock substrata associated with shelter (Myers 1999).

The blue-green chromis is 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 2004).

The humbug dascyllus inhabits shallow lagoons and subtidal reef flats. This species can be found in large aggregations above staghorn, *Acropora*, thickets and in smaller groups above isolated coral heads (Froese and Pauly 2004). 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 2004).

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). The threespot dascyllus is found in tropical waters from 30°N to 30°S at depths from 1 and 55 m. Juveniles are associated with sea anemones, sea urchins, or small coral heads (Froese and Pauly 2004).

Life History—The blue-green chromis is non-migratory and spawning occurs on sand and rubble (Froese and Pauly 2004). Very little information is known about the spawning and migration of the humbug and threespot dascyllus (Myers 1999; WPRFMC 2001; Froese and Pauly 2004).

- **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 (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designation within the boundaries of the study area (WPRFMC 2001: NMFS 2004c). Currently, no data are available to determine if scorpionfishes of CHCRT are approaching an overfished situation (NMFS 2004a). Most species in the Western Central Pacific are small and dangerous to handle and do not form the basis of large fisheries (Poss 1999a). These species are not listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Scorpaenids can be found in all tropical and temperate sea (Froese and Pauly 2004).

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 (WPRFMC 2001). The eggs are pelagic and larvae of this species are planktonic (Froese and Pauly 2004).

Life History—Most scorpionfishes are ovoviparous, producing between a few hundred and a few thousand eggs, although, some are viviparous (Poss 1999a).

- **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 study area (WPRFMC 2001; NMFS 2004c). These species are not listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Feather-duster worms are common throughout the world in shallow-water (Waikiki Aquarium 1998b).

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 1995; Hoover 1998; Waikiki Aquarium 1998b). 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; WPRFMC 2001).

Life History—Feather-duster worms are dioecious (separate sexes) and fertilization of eggs is external (Hawaii Biological Survey 2001a). Fertilized eggs develop into trochophore larvae (type of larva with several bands of cilia) that are plantonic for a short time before settling on the reef substrate to mature (primarily a complex reef habitat; Bailey-Brock 2003). Feather-duster worms can also propagate by fragmentation. They can also regenerate body parts (Hawaii Biological Survey 2001a).

4.2.4.3 Potentially Harvested Coral Reef Taxa

The PHCRT are managed under the FMP for the CRE 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 MUS (WPRFMC 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 (WPRFMC 2001). Since 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 EEZ to a depth of 100 m (**Figure D-22**, **D-23**, and **D-24**; **Table 4-5**; WPRFMC 2001).

A complete list of the PHCRT occurring in the study area is found in **Table 4-1**. All of the family, subfamily, or species that are listed in the CHCRT also occur on the PHCRT list. Descriptions of these taxa will be presented only in the CHCRT section. Descriptions of the individual families, subfamilies, or species comprising the fish, invertebrate, and sessile benthos MUS are described in the following paragraphs.

4.2.4.3.1 Fish management unit species

- **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 study area (WPRFMC 2001; NMFS 2004c). Currently, there is no data available to determine if the scalloped hammerhead of the PHCRT is approaching an overfished situation (NMFS 2004a). Hammerhead sharks are generally caught in low numbers as part of longline fishery (NMFS-PIR 2001) and are readily available to inshore primitive and small commercial fisheries (Compagno 1998). This species is listed on the IUCN Red List of threatened species as near threatened (Kotas 2000).

  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, 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, ranging from the surface, surfline, and intertidal region down at least 275 m depth (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 (WPRFMC 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 (WPRFMC 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).

- **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 (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if rays of the PHCRT are approaching an overfished situation (NMFS 2004a). 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). Eagle rays and devil rays are attractive and desirable as captives in large aquaria and oceanaria (Compagno and Last 1999a, 1999b). Both of the above species are listed on the IUCN Red List of threatened species as data deficient (Ishihara 2000; Ishihara et al. 2002). In addition, the porcupine stingray (*Urogymnus asperrimus*) is listed as vulnerable on the IUCN Red List (Compagno 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 (Myers 1999; Hennemann 2001).

  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 (WPRFMC 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 1999a; Last and Compagno 1999).

  Life History—Stingrays are viviparous (Last and Compagno 1999), whereas eagle rays and manta rays are ovoviviparous (WPRFMC 2001). Stingrays produce a litter with two to six young with a 12-month gestation period (Last and Compagno 1999). The spotted eagle ray produces an average of four pups per liter after a gestation period of about 12 months (Bester 2004), while the manta ray may give birth to one pup during a breeding season (Passarelli and Piercy 2004). During the winter, manta rays migrate to warmer areas, deeper waters or disperse offshore (Passarelli and Piercy 2004). Some species of eagle rays breed in shallow bays and lagoons (Compagno and Last 1999a).

- **Serranidae** (Groupers)

  Status—More than 40 species of groupers are managed in Micronesia as part of BMUS and PHCRT by the WPRFMC (1998, 2001). All 40 species occur in the CNMI and Guam (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if groupers of the PHCRT are approaching an overfished situation (NMFS 2004a). Groupers are most highly priced food fishes and are actively caught by commercial and sport fishermen (Heemstra and Randall 1999). The following groupers within the study area have been listed on the IUCN Red List of threatened species: giant grouper (*Epinephelus lanceolatus*) as vulnerable (Sadovy 1996); brown-marbled grouper (*E. fuscoguttatus*) as near threatened (Cabanban 2004); and humpback grouper (*Cromileptes atlivelis*) as data deficient (Samoilys and Pollard 2000).

  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 be due to 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 et al. 2004). Juveniles are found in shallow-water reef areas (seagrass beds and tide pools) and estuarine habitats (WPRFMC 2001). Adults utilize shallow coastal coral reef areas to deep slope rocky habitats from 0 to 400 m (Heemstra and Randall 1993). Regardless of size, groupers are typically ambush predators, hiding in crevices and among coral and rocks (WPRFMC 2001). Most species of groupers are solitary fishes with a limited home range (Heemstra and Randall 1993).

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 1993). 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 et al. 2004).

- **Lethrinidae** (Emperors)

Status—Lethrinids are managed in Micronesia as part of BMUS and PHCRT by the WPRFMC (1998, 2001). Numerous species have been reported from the CNMI and Guam (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). 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 (WPRFMC 1998). Currently, no data are available to determine if emperor fishes of the PHCRT are approaching an overfished situation (NMFS 2004a). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—The emperor fish is widely distributed over the Indo-Pacific in tropical and sub-tropical waters with a few species ranging into warm-temperate waters (Debelius 2002).

Habitat Preferences—Little is known about the biology of the emperor fish (WPRFMC 2001). Emperors are known to occur in the deeper waters of coral reefs and adjacent sandy areas from 0 to 350 m (WPRFMC 2001). Some lethrinid species are found inhabiting coastal waters, including coral and rocky reefs, sand flats, seagrass beds, and mangrove swamps (Debelius 2002). Most species occur either singly or in schools to feed primarily at night on or near reefs (Myers 1999).

Life History—Spawning behavior of lethrinids is poorly documented (WPRFMC 1998). Based on available data, spawning occurs throughout the year and is preceded by localized migrations during crepuscular periods (Carpenter 2001b). Peak spawning events occur on or near the new moon. Spawning occurs near the surface as well as near the bottom of reef slopes (WPRFMC 2001).

- **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 (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if eels of the PHCRT are approaching an overfished situation (NMFS 2004a). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Eels are distributed worldwide in tropical and temperate seas (Allen and Steene 1987).

Habitat Preferences—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 between 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 (Myers 1999; Smith 1999; Debelius 2002; Allen et al. 2003).

Life History—Most eel species are known to migrate for spawning (WPRFMC 2001). Individual spawning characteristics varies 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 (WPRFMC 2001).

♦ **Apogonidae** (Cardinalfishes)

Status—Fifty-eight cardinalfish species are managed in Micronesia as part of PHCRT by the WPRFMC (2001). These managed species occur in the CNMI and Guam (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if cardinalfish of the PHCRT are approaching an overfished situation (NMFS 2004a). Generally, this species is not important economically, but a few species are seen in the aquarium trade or as tuna bait (Allen 2001). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Apogonids are a very large family of small reef fishes that are distributed in shallow coastal waters of the Atlantic, Pacific, and Indian Oceans (Debelius 2002).

Habitat Preferences—Cardinalfishes are found in 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, then emerging at night to feed on the reef (Allen 2001; Amesbury and Myers 2001; Debelius 2002). Although typically solitary, in pairs or loose clusters, a few species (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 (WPRFMC 2001).

Life History—Apogonid species display a variety of different spawning patterns including year-round, spring and fall peaks and phases of the moon (WPRFMC 2001). Courtship and spawning in cardinalfishes are always paired rather than group activities (Debelius 2002). Cardinalfish 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).

♦ **Blenniidae** (Blennies)

Status—Fifty-three species of blennies are managed in Micronesia as part of PHCRT by the WPRFMC (2001). At least 80% of these managed species occur in the CNMI and Guam (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if blennies of the PHCRT are approaching an overfished situation (NMFS 2004a). They have very little commercial importance because of their small size (Springer 2001). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Blennies have a worldwide distribution occurring in tropical and temperate seas. The Indo-Pacific population consists of two subfamilies: sabretooth (Salariinae) and combtooth (Blenniinae) blennies based on dentition and diet (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 (Springer 2001; Debelius 2002). This group exhibits complex color patterns that enable them to be well camouflaged to the surrounding habitat

(WPRFMC 2001). Most of the combtooth blennies are sedentary inhabitants of rocky shorelines, reef flats or shallow seaward reefs from 1 to 30 m depths (Myers 1999). Some combtooth blennies (e.g., *Alticus*, *Istiblennius*, and *Entomacrodus*), called rockskippers, inhabit tidal zones where they are able to leap between tide pools, while others in the genus *Escenius*, generally occupy coral-rich areas, which are atypical due to their limited distribution (Allen et al. 2003). Sabretooth blennies utilize empty worm tubes or shells when they are 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 et al. 2003).

Life History—The reproductive biology of blennies has been studied extensively, although there are many variations, most are demersal territorial fishes that deposit adhesive eggs in or near a shelter hole that are guarded by the male (Amesbury and Myers 2001). Spawning occurs throughout the year with a peak from January to April (WPRFMC 2001).

- **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 (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if sandperches of the PHCRT are approaching an overfished situation (NMFS 2004a). A few species are large enough to be of commercial importance as food, but only of limited value (Randall 2001d). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Only the genus, *Parapercis,* occurs in the Indo-Pacific region (Myers 1999).

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 (WPRFMC 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). There is no evidence of spawning migrations (WPRFMC 2001).

- **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 (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Although flatfishes are among the world's important food fishes, there is currently no data available to determine if flatfishes of the PHCRT are approaching an overfished situation (NMFS 2004a). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Flatfishes are distributed on tropical and temperate continental shelves worldwide. Some species are associated with coral reefs in the Indo-Pacific (Myers 1999).

Habitat Preferences—Habitat for most flatfish consist of softbottoms such as sand, mud, silt, or gravel that is often associated with coral reefs (Myers 1999). Some species occur directly on the reef or with the reef framework (WPRFMC 2001). Juveniles and adults are often found in lagoons, caves, flats, and reefs (WPRFMC 2001). Flatfishes exhibit adaptive camouflage to closely match the surrounding bottom habitat (Allen et al. 2003). Some flatfishes are found in water deeper than 100 m (e.g., panther flounder, *Bothus pantheinus*), with some species being common in shallower habitats (1 to 73 m) (Myers 1999). Larvae are often found in the upper 100 m of the water column (WPRFMC 2001).

Life History—Eggs of the flounder and sole are pelagic. As larvae metamorphose into juveniles and adults they become demersal. Information on the reproductive process and the extent of spawning aggregations in the Indo-Pacific species are lacking (WPRFMC 2001).

- **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 (Amesbury and Myers 2001; Myers and Donaldson 2003), and all have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if trunkfishes of the PHCRT are approaching an overfished situation (NMFS 2004a). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Trunkfish or boxfish are distributed in both the Indo-Pacific and Indo-pan-Pacific regions of Micronesia (Myers 1999; Amesbury and Myers 2001).

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 (Myers 1999; Matsuura 2001a). These fish have been reported at depths from 1 to100 m (Amesbury and Myers 2001). Postlarvae and juveniles are commonly collected in grassbeds and other shallow areas (WPRFMC 2001).

Life History—Trunkfish are sexually dimorphic. The species of trunkfish studied so far are haremic with males defending a large territory with non-territorial females and subordinate males. Trunkfish spawning occurs in pairs at dusk, usually above a structure (WPRFMC 2001).

- **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 (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if pufferfishes or porcupinefishes of the PHCRT are approaching an overfished situation (NMFS 2004a). Some porcupine fishes are inflated, dried, and sold as curios (Leis 2001). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Pufferfish and porcupinefish are distributed worldwide throughout tropical and temperate waters including brackish and some freshwater habitats (Waikiki Aquarium 1999b; Matsuura 2001b).

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: WPRFMC 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 1999b). Most puffers are solitary but a few form small aggregations (WPRFMC 2001). Larval forms are pelagic occurring from 0 to 100 m (WPRFMC 2001).

Life History—Most information on pufferfish reproduction has been collected in temperate locations; however, some assumptions can be made about tropical species (WPRFMC 2001). All species lay demersal adhesive eggs, although the courtship often occurs near the surface (Myers 1999). At least one species, the blacksaddled goby (*Canthigaster valentini*), is haremic with males spawning at mid-morning 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 as pairs or groups of males with a single female. In Hawai'i, porcupinefish have a peak spawning in late spring with some spawning also occurring from January to September (WPRFMC 2001).

- **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 (Amesbury and Myers 2001; Myers and Donaldson 2003). All species have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if the batfishes of the PHCRT are approaching an overfished situation (NMFS 2004a). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Batfishes occur in tropical temperate sea 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 which occur over muddy, silty, and/or sandy bottoms and coral reefs (WPRFMC 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 (Myers 1999; Debelius 2001). Juvenile *Platax* species often mimic floating leaves or crinoids, whereas adult species of *Platax* travel through open water tightly-knit schools (Kuiter and Debelius 2001).

Life History—Little information is known about the spawning or egg characteristics of Indo-Pacific ephippids (Leis and Trnski 1989). However, observations on the Atlantic spadefish *Chaetodipterus faber* suggest that members of this family may migrate offshore to spawn and could explain the formation of large schools (Kuiter and Debelius 2001).

- **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 (Amesbury and Myers 2001; Myers and Donaldson 2003) and has EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if the diamondfish of the PHCRT is approaching an overfished situation (NMFS 2004a). 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 (IUCN 2004).

Distribution—The diamondfish ranges from the Red Sea to Samoa, north to the Yaeyamas, south to New Caledonia, and Palau to the east Carolines and Marianas in Micronesia (Allen et al. 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 (Myers 1999; Allen et al. 2003). Juveniles and adults of this species can be found over silt, mud, sand, or coral bottoms WPRFMC 2001). This species feeds in open water during the day and night (Debelius 2001).

Life History—Diamondfish eggs are demersal and adhesive in freshwater and probably pelagic in seawater (WPRFMC 2001).

- **Haemulidae** (Grunts)

Status—Eleven grunt species are managed in Micronesia as part of PHCRT by the WPRFMC (2001). Six of these species occur in the CNMI and Guam (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001;

NMFS 2004c). Currently, no data are available to determine if grunts of the PHCRT are approaching an overfished situation (NMFS 2004a). Grunts have become scarce in the heavily fished waters of Guam (Myers 1999). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Grunts are distributed in tropical and temperate seas and in marine and brackish waters worldwide. All eleven species have been recorded from Micronesian waters (WPRFMC 2001).

Habitat Preferences—Grunts are mostly reef dwellers which 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 (WPRFMC 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).

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 (WPFMC 2001).

- **Echineididae** (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 (Amesbury and Myers 2001; Myers and Donaldson 2003), and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if remoras of the PHCRT are approaching an overfished situation (NMFS 2004a). Remoras are not considered to be of any commercial importance (Collette 1999). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Remoras are circumglobal in their distribution and are found throughout Micronesia (WPRFMC 2001).

Habitat Preferences—Remoras occur in coastal and pelagic waters and utilize a wide variety of hosts including fishes, marine mammals, and ships/boats (Myers 1999; Debelius 2001). Species associated with coral reef dwellers are found near reefs to 50 m (Allen et al. 2003).

Life History—Information is lacking on the spawning techniques and/or locations of remoras (WPFMC 2001). Eggs of the sharksucker (*Echeneis naucrates*) and remora (*Remora remora*) are pelagic and spherical (Leis and Trnski 1989).

- **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 (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if tilefishes of the PHCRT are approaching an overfished situation (NMFS 2004a). Tilefishes are very high quality food fishes with several species being commercially important (Dooley 1999). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—This family is distributed worldwide in tropical and temperate seas and is represented by three genera in the Indo-Pacific region (WPRFMC 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, rubble or talus areas of barren seaward slopes (WPRFMC 2001). Tilefish frequently build mounds under rocks in the sand or excavate burrows when facing a potential threat (Debelius 2002).

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 and Trnski 1989).

- **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 (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if dottybacks of the PHCRT are approaching an overfished situation (NMFS 2004a). Some species are of commercial importance in the aquarium fish trade (Gill 1999). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Dottybacks are distributed in the tropical Indo-Pacific being represented by two genera in Micronesian waters (Nelson 1994).

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, and 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—The 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 (WPRFMC 2001; Allen et al. 2003). Hatching typically occurs at night, shortly after sunset (WPRFMC 2001).

- **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 (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if prettyfins of the PHCRT are approaching an overfished situation (NMFS 2004a). Some species are popular in the aquarium trade (Mooi 1999). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Prettyfins are distributed in the tropical Indo-Pacific (Nelson 1994).

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 (WPRFMC 2001). Most species are secretive by day but venture out at night to feed (Myers 1999). Prettyfins school in caves or overhangs, are found in loose aggregations or schools around coral heads, or occur solitary (Mooi 1999).

Life History—Prettyfin reproduction is similar to the closely related dottybacks (WPRFMC 2001). They produce demersal eggs with hair-like filaments that either entangle with one another to form a mass or adhere eggs to a hard surface (Mooi 1999). Eggs are guarded by the male in a crevice or cave and males are known to mouthbrood the eggs (Mooi 1999; Myers 1999).

- **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 (Amesbury and Myers 2001; Myers and

Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if coral crouchers of the PHCRT are approaching an overfished situation (NMFS 2004a). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Coral crouchers are distributed in the Indian and Pacific Oceans (Nelson 1994).

Habitat Preferences—Coral crouchers inhabit branches of certain *Stylophora*, *Pocillopora*, and *Acropora* corals at depths from 0 to 10 m where they tightly wedge themselves into the coral branched when disturbed (Myers 1999). Other than their close association with corals, little is known of their biology (Poss 1999b).

Life History—The spawning mode and development at hatching of coral crouchers is not known (WPRFMC 2001).

♦ **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 (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if soapfishes of the PHCRT are approaching an overfished situation (NMFS 2004a). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Soapfishes are distributed in the Atlantic, Pacific, and Indian Ocean represented by five genera in Micronesia of the Indo-Pacific region (Myers 1999; WPRFMC 2001).

Habitat Preferences—Soapfishes are small, grouper-like, secretive fishes that occur on reef flats, shallow lagoon, outer reef slopes, and wave-washed seaward reefs (WPRFMC 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. *Liopropoma* has pelagic eggs, whereas *Pseudogramma* has large demersal eggs (WPRFMC 2001).

♦ **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 (Amesbury and Myers 2001; Myers and Donaldson 2003) and has EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if the trumpetfish of the PHCRT is approaching an overfished situation (NMFS 2004a). 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 (IUCN 2004).

Distribution—The trumpetfish is distributed in the tropical Atlantic and Indo-Pacific region occurring in Hawai’i, Micronesia, and American Somoa (Nelson 1994; WPRFMC 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 which 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 1999c).

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 (WPRFMC 2001).

♦ **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 (Amesbury and Myers 2001; Myers and Donaldson 2003) and has EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if the cornetfish of the PHCRT is approaching an overfished situation (NMFS 2004a). 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 (IUCN 2004).

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 1994; WPRFMC 2001).

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 (Myers 1999; Allen et al. 2003). They are usually seen in relatively open sandy areas within schools of similarly sized individuals (WPRFMC 2001) and occasionally occur in mid-water, above steep dropoffs (Myers 1999).

Life History—Cornetfish eggs are large, pelagic, and subject to advection by ocean currents (WPRFMC 2001).

♦ **Anomalopidae** (Flashlightfishes)

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 (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if flashlightfishes of the PHCRT are approaching an overfished situation (NMFS 2004a). Flashlightfishes are popular species in public aquariums and a target as bait for local fisherman (Paxton and Johnson 1999). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Flashlightfishes are scattered in warm-water localities, primarily the Indo-Pacific region (Nelson 1994).

Habitat Preferences—Flashlighfishes 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). Flashlightfishes are nocturnal, remaining hidden during the day and venturing out into the water column at night to feed (WPRFMC 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 (Waikiki Aquarium 1999d; Allen et al. 2003).

Life History—The eggs of flashlightfishes are pelagic, positively buoyant, and subject to advection by ocean currents (WPRFMC 2001).

♦ **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 (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if sprat of the PHCRT are approaching an overfished situation (NMFS 2004a). In the Marianas, 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 study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Clupeids are distributed worldwide in freshwater and marine systems and are represented by four genera in Micronesia and the Indo-Pacific region (Nelson 1994; Myers 1999).

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 (WPRFMC 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 and Trnski 1989).

- **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 (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if anchovies of the PHCRT are approaching an overfished situation (NMFS 2004a). Anchovies are commercially important being utilized as live bait for pole and line tuna fisheries (Myers 1999; Wongratana et al. 1999). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Anchovies are distributed in the Atlantic, Indian, and Pacific Oceans represented by three genera in Micronesia of the Indo-Pacific region (Nelson 1994; Myers 1999).

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 (WPRFMC 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 (WPRFMC 2001).

Life History—Anchovy eggs are pelagic and subject to advection by ocean currents (WPRFMC 2001). In the genera *Thryssa*, eggs are spherical and small to moderate in size, whereas the genera *Encrasicholina* and *Stolephorus*, eggs are ovate to elliptical and vary from small to large (Leis and Trnski 1989).

- **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 (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if gobies of the PHCRT are approaching an overfished situation (NMFS 2004a). 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 study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Gobies are distributed worldwide in temperate and tropical seas represented by 212 genera in the Indo-Pacific region (WPRFMC 2001; Allen et al. 2003).

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*) (WPRFMC 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 et al. 2003). The gobies, either singly or in pairs, act as sentinels for the snapping shrimp (*Alpheus* spp.) which maintains the burrow (WPRFMC 2001).

Life History—Gobies appear to spawn promiscuously with many individuals loosely organized into a social hierarchy or with individuals maintaining small contiguous territories (WPRFMC 2001). Pairing and apparent monogamy is also documented for a number of gobies (Debelius 2002). 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 (WPRFMC 2001).

- **Lutjanidae** (Snappers)

Status—Snapper species are managed in Micronesia as part of BMUS and PHCRT by the WPRFMC (1998, 2001). Twenty-three lutjanid species occur in the CNMI and Guam (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if snappers of the PHCRT are approaching an overfished situation (NMFS 2004a). 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 study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Snappers occur in the subtropical and tropical waters of the Atlantic, Indian, and Pacific Oceans and are represented by eight genera in Micronesia of the Indo-Pacific region (Nelson 1994; 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 (Amesbury and Myers 2001; Allen et al. 2003). 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 undergo 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 (WPRFMC 2001). 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).

Life History—Snappers are batch or serial spawners, spawning multiple times over the course of the spawning season, exhibit a shorter, more well-defined spawning period, or have a protracted spawning period (Allen 1985; Parrish 1987; Moffitt 1993). They form large aggregations near areas of prominent relief and spawn with lunar periodicity coinciding with new/full moon events (Grimes 1987).

- **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 (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if filefishes of the PHCRT are approaching an overfished situation (NMFS 2004a). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Filefishes occur in tropical and temperate waters of the Atlantic, Indian, and Pacific Oceans (Nelson 1994).

Habitat Preferences—Filefishes are found in lagoons, shallow coral and rocky reefs, seaward reefs with steeply sloping areas, and seagrass beds in depths ranging from 10 m to over 220 m (Myers 1999; Hutchins 2001). Adults are solitary or occur in pairs, while some juvenile species form schools (Debelius 2001).

Life History—Little is known of the reproduction of most filefish species (Debelius 2002). Some species are sexually dimorphic (WPRFMC 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).

- **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 (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if fusiliers of the PHCRT are approaching an overfished situation (NMFS 2004a). Fusiliers are important in coral-reef fisheries where they are utilized as bait fish for tuna fisheries (Carpenter 2001c). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Fusiliers occur in the tropical waters of the Indo-Pacific region (Allen et al. 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 et al. 2003). At night, fusiliers shelter in crevices and under coral heads (WPRFMC 2001).

Life History—Fusiliers have a prolonged spawning season with recruitment peaks occurring once or twice a year (WPRFMC 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 they stay near the surface and subgroups within the mass swirl rapidly in circles and release gametes (Carpenter 1988).

- **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 (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if frogfishes of the PHCRT are approaching an overfished situation (NMFS 2004a). Aside from their value in the aquarium trade, frogfishes have no significant economic interest in the western central Pacific (Pietsch 1999). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Frogfishes occur in all subtropical and tropical waters of the Indo-Pacific region and occasionally temperate waters (Nelson 1994).

Habitat Preferences—Frogfishes are found in estuaries and turbid coastal waters, but occur in low number and are rare on most coral reefs areas (WPRFMC 2001). Habitats include seagrass beds, algae, sponge, seaward reefs, and rock or corals within tidepools and lagoon (Waikiki Aquarium 1999e).

Life History—Spawning female frogfishes lay thousands of tiny eggs within large, (raft)-shaped gelatinous masses at 3 to 4 day intervals (Myers 1999).

- **Syngnathidae** (Pipefishes and Seahorses)

  Status—In Micronesia, 37 pipefish and seahorse species are managed in Micronesia as part of PHCRT by the WPRFMC (2001). Twenty pipefish species and the thorny seahorse (*Hippocampus histrix*) occur in the CNMI and Guam (Amesbury and Myers 2001; Myers and Donaldson 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if pipefishes or seahorses of the PHCRT are approaching an overfished situation (NMFS 2004a). 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 study area (Vincent 1996a, 1996b; Lourie et al. 2004).

  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 1994).

  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 (WPRFMC 2001). Habitats include seagrasses, floating weeds, algae, corals, mud bottoms, and sand, rubble, or mixed reef substrate from tidepools to lagoon and seaward reefs (Myers 1999). Demersal syngnathid populations occur in singly or in pairs at depths ranging from a few centimeters to more than 400 m, although they are generally limited to water shallower than 50 m (Allen et al. 2003). Juveniles are occasionally found in the open sea in association with floating debris (WPRFMC 2001).

  Life History—Spawning by pipefishes and seahorses involves the female depositing her eggs into a ventral pouch on the male, who carries the egg until hatching at intervals of 3 to 4 days (WPRFMC 2001). Breeding populations occur throughout the salinity range from fresh to hypersaline waters (Dawson 1985).

4.2.4.3.2 Invertebrate management unit species

- **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 study area (WPRFMC 2001; NMFS 2004c). None of Guam's prosobranchs are known to be endemic; however, several are endemic to the Marianas. The majority of the 895 prosobranchs Smith (2003) reported for Guam are marine species. The actual diversity of marine prosobranchs of Guam and the CNMI is probably much greater than currently known considering that the majority of prosobranchs less than 3.5 mm in size have yet to be described (Smith 2003). The topshell gastropod (*Trochus niloticus*) was introduced after World War II (WWII) in an effort to establish a commercial fishery (Smith 2003). Currently, it is regulated with size restrictions and strictly monitored (Hensley and Sherwood 1993). During a cursory survey of Apra Harbor, Paulay et al. (1997) found 218 gastropod species. The species diversity in Apra Harbor is expected to be greater (Paulay personal communication).

  Distribution—Gastropods are found worldwide in tropical, subtropical, and temperate waters of marine and freshwater ecosystems (Kay 1995).

  Habitat Preferences—Gastropods inhabit all bottom econiches of coral reef ecosystems ranging from the surfaces of sediments and rocks, dead coral heads, living corals to seaweed thalloms (Sorokin 1995). The prosobranchs are the most numerous of the gastropods occupying a variety of reef habitats including soft sediments, rocky and stony littoral/sublittoral areas, reef flat rocks and outer slope rocks, lagoons of barrier reefs, trenches of rocks at the reef-flat edge and beach rocks, reef flats, and patch reefs (Sorokin 1995). The prosobranch (*Trochus niloticus*) occupies a well-defined habitat from the intertidal and shallow subtidal zones on the seaward margin of coral reefs at depths ranging from 0 to 24 m (Nash 1993; Paulay personal communication). Nudibranchs or sea slugs are predatory opisthobranchs inhabiting a variety of substrates including the surface of soft corals (alcyonaceans and gorgonaceans) and sponges (Colin and Arneson 1995; Paulay personal communication). Sea slugs prey on diverse taxa including soft corals and sponges (Colin and Arneson 1995; Paulay personal communication).

Life History—Sea snails generally have separate sexes, whereas sea slugs are unisexual. Fertilization may be external or internal in sea snails. Sea snail species that undergo internal fertilization produce eggs that may be enclosed in protective layers of gelatinous mucus or corneous capsules. The majority of sea slugs deposit eggs in ribbon-like clusters. In sea snail species, embryos hatch as free-swimming planktonic larvae or as crawling young (Poutiers 1998a).

- **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 2003b) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Both the commercially harvested black-lipped pearl oyster (*Pinctada margaritifera*) and giant clams (Tridacnidae) occur on Guam (Paulay 2003a). 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 2003b).

Distribution—Oysters and clams are found in all tropical and temperate seas of the world except for the giant clams, which are confined to the Indo-West Pacific region (Briggs 1974). The overall biodiversity of the malacological fauna is probably the greatest in the western central Pacific (Poutiers 1998b).

Habitat Preferences—Bivalves comprise 10% to 30% of the coral reef malacofauna utilizing rocky hard substrates for sessile and boring species and soft-bottom areas for vagile species (Sorokin 1995). Sessile bivalves inhabit reef areas such as rocky surfaces of reef-flats, dead coral heads, patch reefs, walls of trenches and channels, and on coarse sands and rubble substrates on flat and littoral areas (Sorokin 1995). Boring bivalves are extremely widespread in areas of the rocky flat and in areas of profuse coral growth hidden in coral colonies (Sorokin 1995). The sandy bottom of channels crossing the reef-flat and its outer slopes as well as on silty coral sands in the lagoons of barrier reefs are inhabited mainly by vagile bivalves (Sorokin 1995). The black-lipped pearl oyster occurs in lagoons, bays, and sheltered reef areas to around 40 m depth, but is most abundant just below the low-water (Sims 1993). Giant clams use various habitats including high- or low-islands, sandy atoll lagoon floors, fringing reefs, or exposed intertidal areas to depths less than 40 m (Munro 1993).

Life History—In the majority of bivalves, sexes are separate. Fertilization is external, giving rise to free-swimming larvae followed by a metamorphosis leading to a benthonic mode of life (Poutiers 1998b). Some species may be unisexual. If planktonic, the larval stage is reduced or totally absent, young hatch directly as benthic organisms (Poutiers 1998b).

- **Cephalopods** (Nautiluses, Cuttlefishes, Squids, and Octopuses)

Status—Cephalopods are managed in Micronesia as part of PHCRT by the WPRFMC (2001). Twenty-four species including one cuttlefish, one squid, and 22 octopuses have been reported from the CNMI and Guam (Ward 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if cephalopods of the PHCRT are approaching an overfished situation (NMFS 2004a). Cephalopods are of considerable ecological and commercial fisheries importance in the Western Central Pacific where the squid, cuttlefish, and octopus are harvested for food items in the subsistence fishery (WPRFMC 2001) and shells of nautiloids are used for ornamental purposes in the shell curio trade (Dunning et el. 1998). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Cephalopods are found in all tropical and temperate seas of the world except for the nautiloids whose distribution are restricted to Indo-West Pacific region (Roper et al. 1984).

Habitat Preferences—Cephalopods occur over a wide variety of habitats, including deep coral reefs (nautiloids), hole and crevices in rocky or coral areas and burrows in the sand (octopuses), and seagrass beds and nearby reef areas over sandy, muddy, and rocky bottoms (cuttlefishes and squids) (Dunning 1998a, 1998b; Norman 1998; Reid 1998). Their range of depth extends from the surface to over 5,000 m (Roper et al. 1984). Some species (e.g., nautiloids, squids) exhibit diurnal vertical migration, moving upward to feed during the night and dispersing into the deeper water during the day (Dunning 1998a, 1998b).

Life History—Cephalopods have separate sexes and reproduction occurs through copulation (Colin and Arneson 1995). Eggs are encapsulated in a gelatinous finger-like strings (squids), grape-like clusters (cuttlefishes), attached to each other (octopuses), or in a capsule (nautiloids) adhering to various substrates (e.g., rocks, shells, seagrass) (Dunning 1998a, 1998b; Norman 1998; Reid 1998). Spawning varies between the various groups of cephalopods. Nautiloids have a single annual egg laying season in shallow-water (80 to 100 m), peaking around October (Dunning 1998a; WPRFMC 2001), whereas squids and cuttlefish migrate in aggregations seasonally to spawn in response to temperature changes twice a year (Dunning 1998b; Reid 1998). Octopuses lay eggs which are tended by the female until hatching (Norman 1998).

- **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 study area (WPRFMC 2001; NMFS 2004c). Ascidians are of economic importance for bio-prospecting and problematic as marine fouling organisms by clogging cooling water intakes and interfering with boat operations (WPRFMC 2001).

Distribution—Ascidians are common worldwide and inhabit shallow-waters of the tropical Pacific (Colin and Arneson 1995; WPRFMC 2001).

Habitat Preferences—Solitary and colonial tunicates are important components of the reef cryptofauna ranging from high-light and high-energy environments to protected deeper water areas (Sorokin 1995; WPRFMC 2001). Ascidians attach to inert surfaces such as dead corals, stones, shells, pilings, ship bottoms and less durable surfaces of seaweeds, mangrove roots, sand, and mud, or grow epizoically on other sessile organisms (e.g., soft corals, sponges, other tunicates) (Colin and Arneson 1995). Solitary and colonial forms colonize new surfaces in disturbed areas, and are also found on outer reef slopes (WPRFMC 2001). Larval and adult sea squirts occur from intertidal areas to 120 m depth or greater (WPRFMC 2001).

Life History—Both sexual and asexual reproduction occurs in ascidians and is highly variable, both by family and genera. Solitary forms release both eggs and sperm into the water, whereas the colonial forms in ovoviviparous, releasing only larvae (Colin and Arneson 1995). The release of certain chemicals by tunicates may trigger various processes, such as spawning, larval attraction, etc. (WPRFMC 2001). Solitary and colonial ascidians are unisexual but reproduce asexually by budding (WPRFMC 2001).

♦ **Bryozoans** (Moss Animals)

Status—Bryozoans are managed in Micronesia as part of PHCRT and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). While bryozoans are probably very diverse in the study area (e.g., Tilbrook 2001), only one species (*Penetrantia clinoidales*) is described on Guam (Paulay 2003c). Bryozoans are economically important for bio-prospecting and as marine fouling organisms that interfere with boat operations and clog industrial water intakes and conduits (WPRFMC 2001).

Distribution—Bryozoans are inhabitants of tropical Pacific reefs ranging from Hawai'i to the Indian Ocean (Colin and Arneson 1995).

Habitat Preferences—Though widespread on tropical reefs, bryozoans are often not recognized due to the fact that they occur in mixed associations with algae, hydroids, sponges, and tunicates on older portions of coral reefs (WPRFMC 2001). These benthic sessile organisms occur from the intertidal zone to abyssal depths (WPRFMC 2001). Forming encrusting, erect branching or foliose colonies, bryozoans attach to rocks, corals, shells, other animals, mangrove roots, and algae or grow on shaded surfaces on the undersides of coral heads, rock ledges, rubble, and fill cavities within the reef structure (Sorokin 1995). Encrusting forms are found everywhere, whereas the erect and delicate branching or foliose forms are typical of more protected areas (Sorokin 1995; WPRFMC 2001; Paulay personal communication).

Life History—Bryozoans are colonial animals that develop from a sexually-produced zooid (Hawaii Biological Survey 2001b). The asexual budding of the primary zooid develops a group of daughter cells which will undergo a succession of budding and production of daughter cells (i.e., bryozoans are colonies of zooids). Most marine bryozoans are hermaphroditic (produce both eggs and sperm). Bryozoans release sperm into the water column and retain fertilized eggs in a cavity where they are brooded before larvae are released into the water column (WPRFMC 2001). Bryozoans exhibit a positive phototropic reaction, but become negatively phototrophic before metamorphosis, settling in dark places on the reef. This may be dependent upon day length and temperature (WPRFMC 2001). Most bryozoans settle on hard substrates, some settle on sand (Hawaii Biological Survey 2001b).

♦ **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). Over 839 crustacean species (36 stomatopods and 672 decapods) have been reported from the CNMI and Guam (WPRFMC 2001; Paulay et al. 2003a) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if all crustaceans of the PHCRT are approaching an overfished situation; lobsters are probably overfished (NMFS 2004a; Paulay personal communication). 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 (WPRFMC 2001). None of the species found in the study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Crustaceans are amongst the most abundant and diverse marine organisms in waters of the Pacific tropical and subtropical islands. Crustaceans are found in all tropical and temperate seas of the world (Eldredge 1995).

Habitat Preferences—Reef crustaceans are one of the most diverse and abundant groups of the coral reef vagile and sedentary benthos (Sorokin 1995). Crustaceans occur over a wide variety of coral reef habitat and associated environs including cavities of coral and rock or smooth-walled burrows on sandy bottoms (mantis shrimps), pockets of corals, among rubble, or buried in sand on reef flats and in seagrass beds (penaeid, caridean, and stenopodid shrimps), subtidal holes or crevices of rocky and coralline bottoms (spiny, slipper, and coral lobsters), and mud or sandy bottoms in high littoral sands, crevices or burrows among subtidal rocks and coral heads, or on the surfaces of marine plants and other invertebrates (true and hermit crabs) (Chan 1998a, 1998b; Manning 1999; Ng 1998). The depth distribution of these different reef crustaceans (mantis shrimp, coral associated shrimps, lobsters, and crabs) varies from 0 to more than 100 m (WPRFMC 2001). Some crustaceans also provide symbiotic or commensal associations with other marine organisms (e.g., cleaner shrimps, crabs: camouflage, protection, etc.) (Colin and Arneson 1995).

Life History—Stomatopods lay as many as 50,000 eggs which are joined together by an adhesive secretion and held by the female in a small subchelate appendage where the eggs are constantly turned and cleaned. Besides peneids which shed their eggs directly into the water, all other decapods carry their eggs on their pleiopods (WPRFMC 2001).

- **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 (WPRFMC 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 2003d; Starmer 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). At least 196 of these species are known from Guam (Paulay 2003d). 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 and Birkeland 1997).

Distribution—The phylum Echinodermata is exclusively marine and distributed throughout all oceans, at all latitudes, and depths from the intertidal zone down to the deep sea (Colin and Arneson 1995). Echinoderm fauna are widely distributed across several localities of the Indo-Pacific region with few taxa being endemic (Pawson 1995).

Habitat Preferences—A small proportion of echinoderms form dense monospecific populations in shallow reef zones and play important roles in trophodynamics and nutrient regeneration. The coral reef habitat and associated environments inhabited by echinoderms include sandy bottoms of lagoons, coral sand, and reef-flat rocks (sea urchins); hardbottom biotopes of reef flats, sublittoral and patch reefs, outer reef slope, and cryptofaunal habitats (sea stars); under stones in trenches on reef flats or on seagrasses (brittle stars); weak current areas in reef-flats and outer slope trenches and caves (feathered stars); and coral slopes (passages), inner/outer lagoons, inner/outer reef-flats covered with sand and rubble (sea cucumbers) (Sorokin 1995; Conand 1999; Miskelly 1968). Most echinoderms (e.g., brittle and feathered stars) are nocturnal, hiding in the daytime and feeding at nighttime (Sorokin 1995). They also have formed commensal relationships with small reef organism (e.g., shrimps and fishes) (Colin and Arneson 1995).

Life History—The majority of echinoderms have separate sexes, but unisexual forms occur among the sea stars, sea cucumbers, and brittle stars. Many species have external fertilization, which produce planktonic larvae, but some brood their eggs, never releasing free-swimming larvae (Colin and Arneson 1995).

- **Annelids** (Segmented Worms)

Status—Segmented worms or polychaetes are managed in Micronesia as part of PHCRT (WPRFMC 2001). At least 76 genera and over 100 species of polychaetes have been reported from Guam (Bailey-Brock 2003) and have EFH designated within the boundaries of the study area (WPRFMC

2001; NMFS 2004c). Polychaetes are important food resources of reef fishes and invertebrates with some species being indicators of environmental perturbation and reef condition (Bailey-Brock 2003).

Distribution—Polychaetes are primarily marine worms that are extremely abundant and widespread in tropical and temperate oceans. There are very few brackish and freshwater forms living in streams and estuaries of tropical regions (Colin and Arneson 1995). Islands in the tropical central and western Pacific region have species-rich polychaete communities that are mostly cryptic, endolithic, or infanual (Bailey-Brock 1995).

Habitat Preferences—Benthic coral reef polychaetes are associated with hard or softbottom materials or live among marine vegetation (Bailey-Brock 1995). The polychaetes occupying all these econiches in the coral reef biotopes and are classified into two groups: free-living (free-swimming) errant and sedentary (tube-dwelling) segmented worms (Sorokin 1995). Specific types of coral reef habitats frequently colonized by these polychaetes include rocky intertidal areas (e.g., tide pools and shallow sand-filled depressions associated with lava rocks, basalt, and limestone benches), mud and sand at the sediment-water interface, reef flats, sandy tops of patch reefs, sandy cays, seagrasses, mangroves, and fleshy or thalloid algae (Bailey-Brock 1995; Sorokin 1995). In addition to coral reefs, polychaetes also colonize vessel hulls, docks, and harbor walls as well as floating slippers, glass floats, and debris (Bailey-Brock 1995). Polychaetes stabilize sand on reef flats by their tube-building activities, bore into coral rock contributing to the erosion of reef materials, or are commensals of sponges, mollusks, holothurians, and hydroids (Sorokin 1995).

Life History—Most polychaetes have separate sexes, although some are unisexual and a few change sex. Fertilization of eggs takes place in the water column for species, which release their gametes into the water. Other species mate and female retain the fertilized eggs within their body cavities (Colin and Arneson 1995). Some species swarm in water during their breeding season, others spawn during the first lunar cycle, and some undergo asexual breeding by simple division of the body into several pieces (Sorokin 1995)

4.2.4.3.3 Sessile benthos management unit species

- **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; WPRFMC 2001) and Guam (237 species; Lobban and Tsuda 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Algae are classified as EFH because they are direct contributors to the well-being and protection of fish species, both as a source of food and protection to larvae and small fish species (WPRFMC 2001). Currently, there is no fishery for algal species in the American Flag Pacific Islands (WPRFMC 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 study area are listed on the IUCN Red List of threatened species (IUCN 2004).

Distribution—Algae are found worldwide along most shorelines and shallow-water environments. In the Indo-Pacific they have a discontinuous distribution and a low level of endemicity (South 1993).

Habitat Preferences—Seaweeds are prominent organisms in the shallow-water photic zone ranging from the spray zone well above the high tide level to depths as great as 268 m (South 1993). From the intertidal to shallow subtidal zones, they occur on soft and/or hard substrata within a variety of marine benthic habitats such as flat reefs, sheltered bays and coves, and rocky wave-exposed areas along the shore or on the edge of the reef (Truno 1998). Algae occupy a wide range of habitats including but not limited to: sandy bottoms of lagoons; shallow, calm fringing reefs; barrier reef coral bommies; outer reef flats; and the outer reef slope (WPRFMC 2001). Coralline algae are of primary importance in constructing algal ridges that are characteristic of exposed Indo-Pacific reefs preventing oceanic waves from eroding coastal areas (WPRFMC 2001).

Life History—Both sexual and asexual reproduction occurs in the algae with predominance of one or the other being linked to type of algae and the predominant geographical and environmental conditions affecting the algal populations (WPRFMC 2001). Most unicellular and multicellular algae have asexual and sexual life cycles of varying complexity (South 1993).

- **Porifera** (Sponges)

Status—Sponges are managed in Micronesia as part of the PHCRT by the WPRFMC (2001). Over 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 study area (WPRFMC 2001; NMFS 2004c). Sponges are found throughout the study area (Kelly et al. 2003).

Distribution—Poriferans represent a significant component of all tropical, temperate, and polar marine benthic communities (Kelley-Borges and Valentine 1995). Sponges found in the Indo-West Pacific region are the most diverse in the world (Briggs 1974). Within the Marianas, there is considerable variation in the distribution and composition of poriferan species among neighboring reefs and islands. This was evident by the spongal faunal distribution observed on Guam (Kelly et al. 2003).

Habitat Preferences—Sponge diversity, regardless of depth, is greatest on coral reefs, in caves and vertical areas not colonized by hard corals (WPRFMC 2001). They are also abundant in seagrass beds, mangroves, and other environments (Colin and Arneson 1995). On the reef-flat and on upper zones of the reef slope, the spongal fauna consists mostly of phototropic and boring species. The more abundant and varied spongal communities inhabit the middle depths of the outer slope especially the buttress zone and the upper part of the fore-reef (Sorokin 1995). Sponges also provide homes for a huge variety of animals including shrimp, crabs, barnacles, worms, brittlestars, holothurians, and other sponges (Colin and Arneson 1995).

Life History—Reproduction among sponges is highly variable and is sexual (viviparous and oviparous) or asexual (budding, fragmentation, and gemmules) (Colin and Arneson 1995). Mass spawning and release of sperm is triggered by lunar and diurnal periodicity (WPRFMC 2001).

- **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; Randall 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Within the 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).

Distribution—Hydrozoan corals of the order Milleporina are found on reefs of the Indo-Pacific, the tropical eastern Pacific, the western Atlantic (Caribbean), and along the coastline of Brazil (Veron 2000). Among the Stylasterina hydrozoans, *Stylaster* occurs in the Indo-Pacific and Atlantic Oceans whereas *Distichopora* occurs all over the Indo-west Pacific and the Galapagos Islands (Veron 2000). Hydroids found in the study area are also found in tropical, subtropical, and temperate areas of the western and eastern Atlantic Ocean, the western and eastern Pacific Ocean, and the Indian Ocean.

Habitat Preferences—Hydrozoans are colonial, polyp-like animals that occur in cryptic habitats or have calcareous skeletons resembling scleractinian corals (e.g., *Millepora* and *Stylaster* spp.) (Colin and Arneson 1995). *Millepora* spp. are colonial and hermatypic forms that utilize the projecting parts of the reef where strong to powerful turbulent currents occur at depths from 0 to10 m, and may occur in deepwater habitats (Veron 2000; Paulay personal communication) and are abundant on upper reef slopes and lagoons (WPRFMC 2001). Lace corals, *Stylaster* and *Distichopora* spp., are abundant under overhangs or on the roof of caves within the reef under low light from 10 to 20 m, occur in deep reef conditions swept by tidal currents, and in deepwater habitats (Colin and Arneson 1995; Veron 2000; Paulay personal communication). The branching *Solanderia* spp. is commonly found in exposed areas on wave swept shallow outer reefs, caves, or overhanging environments at depth ranges from 0 to more than 100 m (Colin and Arneson 1995). Hydroids mostly occur on rocky substrates exposed to wave action and surge, on artificial substrates in harbors (pilings, mooring buoys), in crevices, overhangs, and caves (Hoover 1998; Kirkendale and Calder 2003).

Life History—Hydrozoans typically alternate generations between motile medusoid and sessile polypoid phases (Fautin and Romano 1997; Fautin 2002; Ball et al. 2004). Sessile colonies bear polyps specialized for reproduction that asexually produce medusa buds which develop into free-swimming dioecious medusae. The medusae spawn freely in the water column. A fertilized egg develops into a planula that settles, metamorphoses into a polyp, and develops a sessile colony (Fautin and Romano 1997; Ball et al. 2004). In some cases, however, polyp or medusa stages are entirely lacking for some hydrozoans (e.g., trachymedusans do not have a polyp stage) (Collins 2002). The primary polyp can produce other polyps asexually to form a colony (Fautin and Romano 1997).

- **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 (Randall 2003) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). Major and minor coral (curio trade) fisheries exist within the western central Pacific (Hodgson 1998). Within the study area, coral collecting is banned in CNMI under regulations that prohibit the 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).

Distribution—Communities of scleractinian reef-building (hermatypic) and non-reef building (ahermatypic) corals grow in tropical and subtropical seas globally (Veron 1995; Veron 2000). The Pacific Ocean contains the most diverse coral fauna in the world (Colin and Arneson 1995; Veron 2000).

Habitat Preferences—Stony corals develop colonial forms that may be branching, tabulate, massive, or encrusting, or develop solitary, free-living forms (e.g., mushroom corals) (Veron 2000; WPRFMC 2001). Stony corals are found from the sea surface in nearshore environments down to the deep-sea in more than 6,000 m water depth (Veron 2000; CoRIS 2003; Freiwald et al. 2004; Roberts and Hirshfield 2004). The hermatypic coral fauna are found in a multitude of habitats including shallow surf zones and submerged areas of reef flats, lagoon patch-reef zones, patch reefs, and reef slopes (Veron 2000). Ahermatypic corals colonize areas of low scleractinian coral or algal occurrence including poorly illuminated or even dark biotopes in caves, trenches, and in deep zones of the reef (Sorokin 1995; WPRFMC 2001).

Life History—Hermatypic corals reproduce by sexual (external fertilization and development and brooded planulae, bisexual, unisexual) and asexual (brooded planulae, polyp-balls, polyp bail-out, fission, fragmentation, and re-cementation) development (Veron 2000; WPRFMC 2001; Fautin 2002). Corals may be free spawners (12 month maturation cycle) or brooders (several cycles per year) depending upon their geographic distribution (WPRFMC 2001). In the Marianas, for some corals spawning occurs 6 to 12 days following the June and July full moons (DoD 1999). Mushroom corals are asexual (budding, fragmentation or natural regeneration through fracture) or sexual (dioecious or unisexual) (Veron 2000).

- **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 et al. 2003b) and have EFH designated within the boundaries of the study area (WPRFMC 2001; NMFS 2004c). The collection of non-scleractinian anthozoans is banned in the CNMI (Green 1997).

Distribution—The communities of non-scleractinian corals are distributed in shallow tropical and subtropical habitats worldwide (Veron 1995).

Habitat Preferences—Members of the non-scleractinian anthozoans (hexacorals and octocorals) exist only as polyps, either solitary or as colonies. Non-scleractinian hexacorals consist of anemones, zoanthids, black corals, and cerianthids (Colin and Arneson 1995). Anemones have solitary polyps that are attached to hard substrate by their basal disc, burrowed into soft substrate, or become attached to sessile and mobile reef organisms (e.g., hermit crabs) (Colin and Arneson 1995). Some species of anemones also exhibit mimicry appearing like their background or other reef entities (e.g., hard coral or algae) (WPRFMC 2001). Zooanthids have species that are either colonial or solitary often forming large monospecific patch or belt associations on biotopes of reef flats (Colin and Arneson 1995). They usually colonize rock bottom substrates in reef-crest and reef-edge zones (*Palythoa*), rubble areas and dead corals (*Zoanthus*, *Isaurus*) (Sorokin 1995).

Octocorals in the study area consist of gorgonians (sea fans and sea whips; Order Gorgonacea); telestaceans (Order Telestacea); soft corals (Order Alcyonacea); organ-pipe corals (Order Stolonifera); sea pens and sea pansies (Order Pennatulacea); and blue corals (Order Helioporacea) (Paulay et al. 2003b). Few species of gorgonians occur in water depths less than 30 m within the study area. The diversity and abundance of gorgonians increases below the 30 m isobath particularly on steep and cavernous substrates exposed to strong currents. Many of the gorgonians Paulay et al. (2003b) found within the 30 to 60 m depth range in caverns of the southern Orote Peninsula also occur at deeper depths. (60 to 400 m) (Paulay et al. 2003b). The soft coral genera *Siphonogorgia* and *Dendronephthya* are more abundant and diverse in water depths deeper than 60 m in the study area (Paulay et al. 2003b). The organ-pipe coral (*Tubipora musica*) can be found in many habitats ranging from shallow lagoons to reef slopes (Colin and Arneson 1995; WPRFMC 2001). The blue coral (*Heliopora coerulea*) is typically observed on the intertidal reef flat and fore reef slope within the 1 m to 30+ m depth range (WPRFMC 2001; Paulay et al. 2003b).

Life History—Propagation of non-scleractinian anthozoans is mainly achieved by asexual (vegetative) reproduction (Fautin 2002). Internal brooding (vegetative embryogenesis) is common among anthozoans. In some cases, actinians (anemones) and octocorals asexually produce planulae by parthenogenesis. Polyps of black corals can produce planulae asexually (planuloids) that differ morphologically from sexually-produced planulae. A planuloid can develop into a polyp. Some actinians reproduce asexually by tentacle budding, and by tentacular autotomy and regeneration (the actinian will sever, ingest, and incubate its own tentacles to produce small individuals). Other modes of propagation include transverse fission (a polyp producing a polyp) which occurs in cerianthids, actinians, and zoanthids; longitudinal fission, a mode of asexual propagation commonly used by anemones and by some octocorals and corallimorpharia; and fragmentation which is used by soft corals (Order Alyonacea) and anemones (Order Actinaria) (Lasker 1988; Dahan and Benayahu 1997; Fautin 2002; Ball et al. 2004). Some soft corals produce stolons considered as a budding mechanism (Dahan and Benayahu 1997; Fautin 2002). Sexual reproduction of non-scleractinian anthozoans typically involves the production and release of gametes by the separate sexes, the fertilization of an egg, the development into a planula which will eventually develop tentacles and settle on the seafloor (Ball et al. 2004). Gorgonians and soft corals participate in mass spawning (Fautin 2002).

4.3 FISHERIES RESOURCES

The fishery resources within the Marianas MRA study area are diverse. The diverse number of species found and fished, coupled with the diverse geography, cultural practices, and economy contribute to the difficulty of defining fisheries (Carpenter 1998). The fisheries have been in transition since WWII. While many traditional fishing techniques are still employed on the islands, technology has made recently introduced methods much more efficient.

4.3.1 Introduction

The study area is in the Indo-West Pacific region – a tropical zone from east Africa across the Indian Ocean and out into the Pacific. Zoogeographers consider this the richest area in the world in terms of fish species (Amesbury and Myers 2001); 1,106 species of fish have been identified in the waters in and around the study area (Myers and Donaldson 2003). See Chapter 2 for detailed descriptions of the oceanographic and biological environment of the study area.

Commercial and recreational fishing endeavors rely on the ability to anticipate the occurrence of target species at a given place and time. The distribution and abundance of fishery species depends greatly on the physical and biological factors associated with the individual species such as salinity, temperature, dissolved oxygen, food/prey availability, habitat quality, reproductive/life cycles, seasonal movements, population dynamics, and recruitment success, among others (Helfman et al. 1999). The affinity of target species for particular habitats, the physiological tolerance to environmental factors (e.g., salinity, temperature, and dissolved oxygen levels), and the availability of food items are the primary factors influencing the spatial distributions of species. Life history stages and movements, along with seasonal environmental changes (e.g., salinity and temperature), are the primary factors that influence seasonal distribution (Helfman et al. 1999).

Successful fishermen are able to “read the signs” and make educated guesses about where and when to fish. Recent technologies such as sonar, radar, and GPS systems as well as detailed bottom topography maps and real-time meteorological/hydrological information assist in the search for fishery species. Variations in distribution and abundance of fishery species are influenced by both natural and anthropogenic activities (Waite et al. 1994).

4.3.1.1 Fisheries Problems

Although natural patterns of variation are expected in marine fishery stocks, human activities are known to have definite effects on 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 resulted in the depletion of certain species stocks (Waite et al. 1994; Parker and Dixon 1998). 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 which 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 for declining catch rates (Waite et al. 1994). As fishery landings diminish, species once targeted as commercially desirable have changed to include those species that are less attractive but still available in harvestable quantities. Smaller fish, as well as those species once discarded as bycatch, are now being targeted for commercial sales (Pauly et al. 1998).

4.3.1.2 Fisheries Management

Wise management has become crucial in protecting fishery industries and maintaining fishery resources in a harvestable condition. At the federal level, laws, executive orders, proclamations, and regulations have been created to aid in the conservation of fishery resources. One of the mandates of the SFA was the creation of a number of interstate management agencies, called fishery management councils (FMCs), to oversee the condition of fishery stocks in the federal waters of the EEZ (3 to 200 NM from shore). The FMCs use FMPs to set forth management objectives for specific fishery resources and formulates strategies for the best way to achieve those objectives. The NOAA Fisheries participates in fishery management efforts by providing fisheries data and analysis, and manages the highly migratory fishery species (over 80 species of sharks, tunas, and billfishes) (NMFS 2003a).

The WPRFMC 2001 FMP for CREs of the Western Pacific Region is the first ever ecosystem-based plan for fisheries developed in the U.S. (Simonds 2003). The goal of the ecosystem based fishery management plan is to maintain sustainable coral reef fisheries while preventing adverse impacts to stocks, habitat, protected species or the ecosystem (WPRFMC 2001). In order to achieve these goals, the following management measures have been implemented; 1) the designation of zoned MPAs for coral; 2) permit and reporting requirements to fish in designated low-use MPAs (reporting of fisheries information in non-MPA areas will continue to be collected through locally administered monitoring systems), and if needed, a general permit program for all EEZ reef fisheries; and 3) a prohibition on non-selective/destructive fishing gears and conditions on the types and uses of allowable gears (Simonds 2003).

4.3.1.3 Study Area Fisheries

The importance of commercial and recreational fishing in the Marianas study area has changed dramatically during recent years. The fisheries here are not separated into commercial, recreational and subsistence fishing; therefore, fisheries are discussed according to the type of fish caught (i.e., pelagic, reef fish, and bottomfish). Recreational and subsistence fisherman keep fish for home consumption and sell the remaining catch at local auctions (NMFS 1996). Until 1930, fishing in the study area was subsistence based and focused mainly on the coastal zone (Simonds 2003), when Japan began fishing in the Western Pacific Territories (Miller 2001). Traditional fishing methods are still practiced today, however, more efficient fishing methods (hook and line, net fishing, spear fishing, etc.) have begun. Recreational fishing ("catch and release") is not practiced in Guam and CNMI, since fish caught are either kept for personal use, distributed within the community, or sold in markets.

Three major fisheries occur in the Marianas MRA study area: pelagic (tuna, Indo-Pacific blue marlin, dolphinfish), bottomfish (snappers, groupers, and jacks), and reef fish fisheries (unicornfish, goatfish, snappers, rudderfish, and wrasses). These fisheries utilize various gear types in harvesting these species within the study area and are listed below with a brief description of their use and the target species (Amesbury et al. 1986, Amesbury and Myers 2001; WPRFMC 2001). Trolling is the most common gear type utilized on Guam in terms of total landings and is depicted along with other gear types in **Figure 4-1**.

- Cast nets are thrown and the net opens in the air and falls 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 during seasonal runs.

- Gill nets work by entangling fishes in the meshes of the net. They are not species-specific, but take fish similar to other netting methods. Gill nets are size-specific and dependent on mesh size.

- 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. They require several people and harvest a variety of species.

- Spearfishing occurs at night using underwater flashlights to target parrotfish, surgeonfish, and squirrelfish.

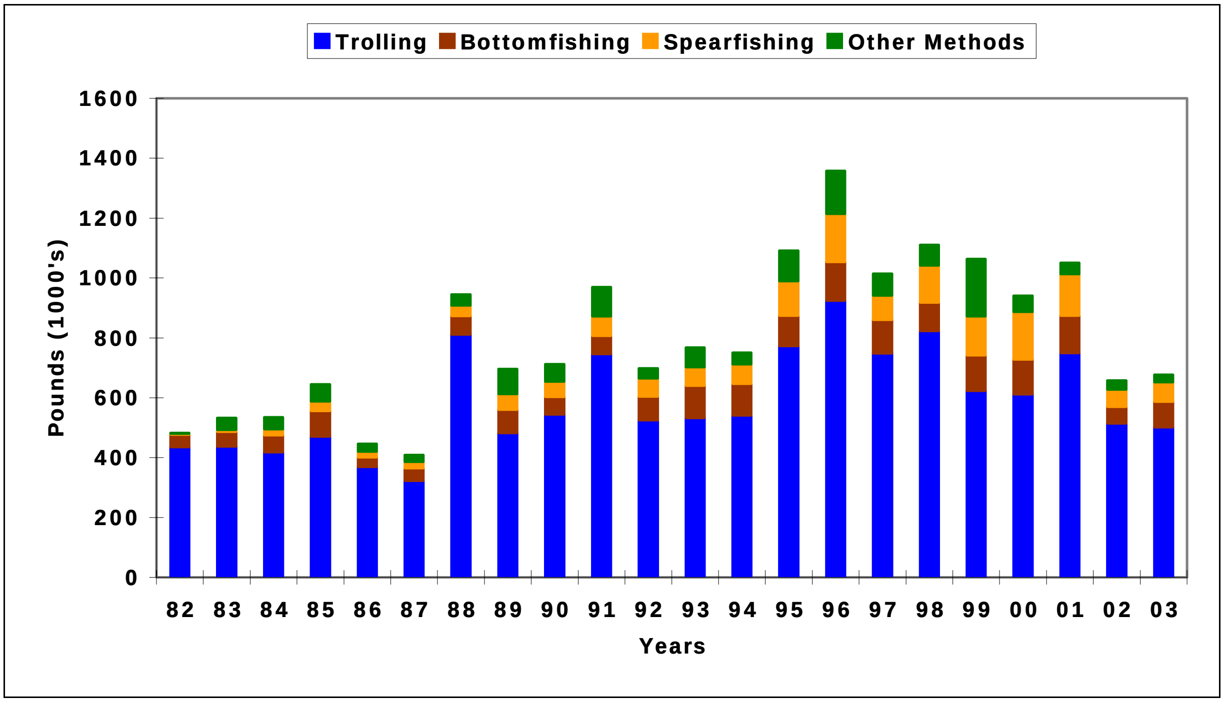

Figure 4-1. Annual boat based total landings by fishing method on Guam. Source: PIFSC (2004).

- Hook-and-line gear is very basic and is used to catch large numbers of bigeye scad in the study area during seasonal runs. Others species caught include snappers, groupers, jacks, and other carnivorous fishes on the reef margin.

- Trolling is the most popular method of small boat fishing in the study area (**Figure 4-1**) and consists of towing a lure or baited hook through the water to catch pelagic species that occur in nearshore waters. Major species targeted include dolphinfish, wahoo, skipjack tuna, yellowfin tuna, and Indo-Pacific blue marlin.

- Longlines are lines (variable length) with numerous baited hooks that are deployed (manually or mechanically) in pelagic waters attached to floats. Longlines target pelagic species such as tuna, dolphinfish, and marlin.

Total value of fisheries for the study area is represented separately by each island. Total pounds and value of catch for Guam and the Northern Marianas Islands increased gradually until 2000, after which, it declined (NMFS 2004e; **Figures 4-2** and **4-3**, respectively). Commercial fisheries of Guam recorded approximately 2.5 million pounds of fish worth about 5.5 million dollars from 1999 through 2003 (average of 500,000 lbs at ~ 1 million dollars/ year; **Figure 4-2**). The fisheries on CNMI landed over 2 million pounds of fish (net worth of 5 million dollars) from 1999 through 2003 and averaged over 400,000 lbs (approximately 1 million dollars per year; NMFS 2004e; **Figure 4-3**).

The pelagic fishery is dominant overall in terms of net landings and value (**Figure 4-4**). Pelagic species have a net worth of approximately $400,000 in Guam and over $400,000 in CNMI (NMFS 2004d). In terms of pounds landed in the Marianas MRA study area, the reef fish fishery ranks second and bottomfish third (**Figure 4-4**). Annual boat based landings are not available for CNMI. The domestic commercial fisheries in Guam and the Northern Marianas are relatively small; Guam offers an important location for trans-shipment and processing for the U.S. distant-water purse seine fishery, as well as for foreign purse seine and longline fisheries (NMFS 1996).

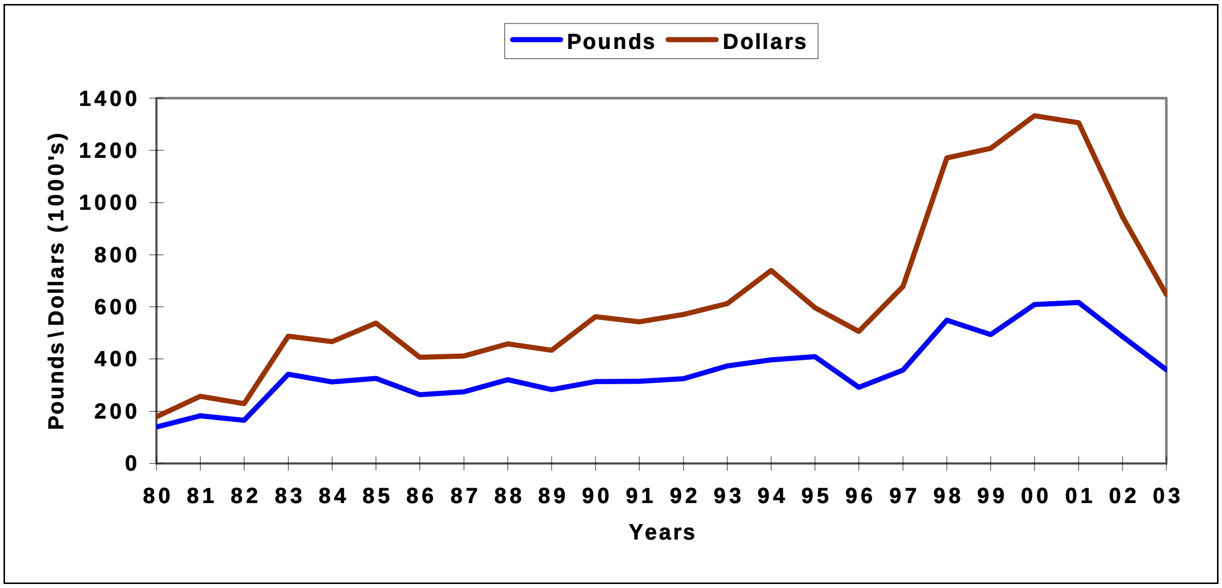

Figure 4-2. Total annual commercial fisheries landings (pounds and dollars) for Guam from 1980 to 2003. Source: PIFSC (2004).

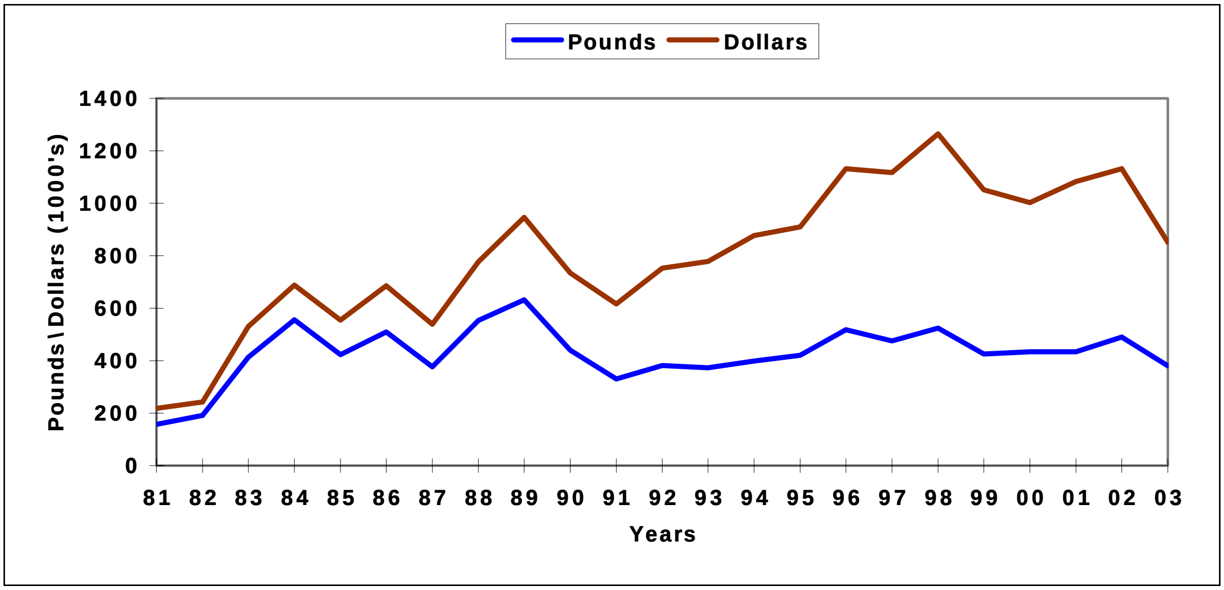

Figure 4-3. Seasonal commercial fisheries landings (pounds and dollars) for CNMI from 1981 to 2003. Source: PIFSC (2004).

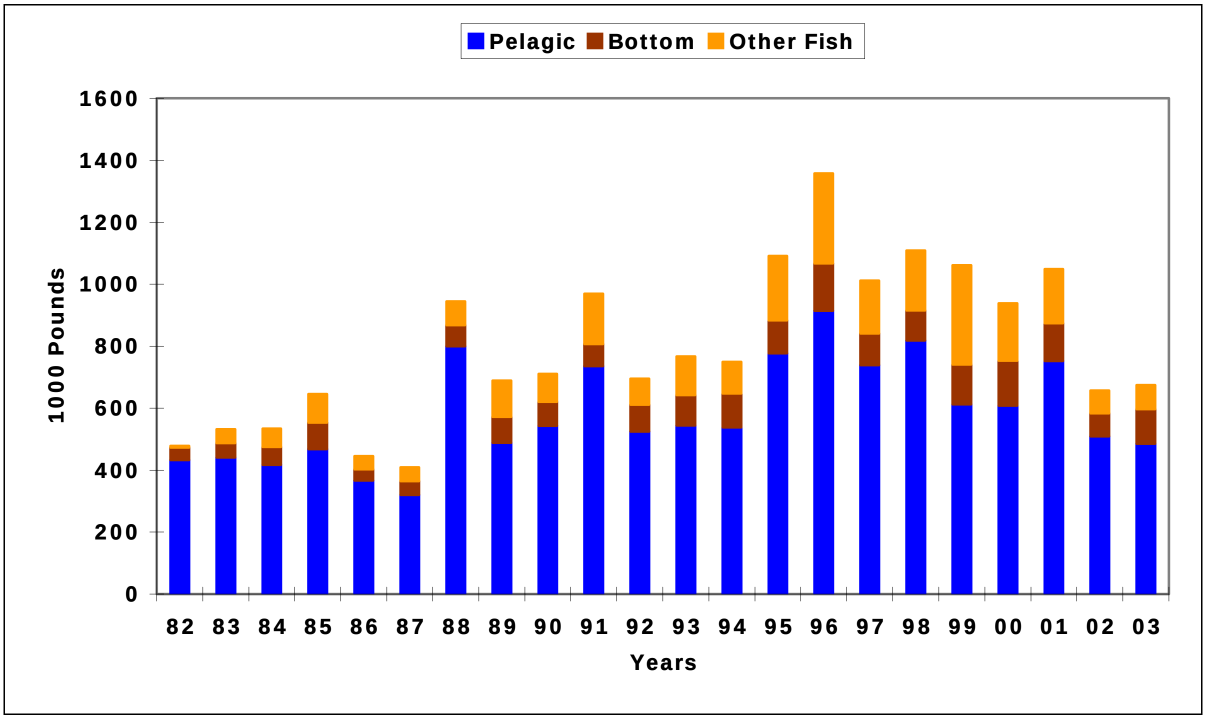

Figure 4-4. Annual boat-based total landings (1,000 pounds) of pelagic, bottom, and other fish for Guam from 1980 through 2003. Source: PIFSC (2004).

The level of fishing activity varies throughout the year within the Marianas MRA study area, and there are few regulations which govern these activities except fishing restrictions in marine preserves. These fisheries as a whole ignore conservation and lack restrictions on the size, number, species, or seasons of fish takes. The dominant fisheries are described below.

4.3.2 Pelagic Fishery

The Marianas MRA study area is located in an area of immense pelagic fishery resources which provide more than 40% of the world tuna catch, totaling over 1 million metric tons and $1.5 billion annually (WPRFMC 1999). Major pelagic fish species harvested in the study area include skipjack and yellowfin tuna, marlin, dolphinfish, and wahoo (NMFS 2004e).

Guam—Pelagic fisheries based on Guam are broken into two broad categories: 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 within and adjacent to the EEZ of the Northern Marianas Islands (PIFSC 2004). The domestic commercial pelagic fishing fleet on Guam is small, but by providing tuna processing facilities, transshipment and home-port industries, they have developed an alternative method to take advantage of the commercial fishing that occurs in the western Pacific. This has resulted in Guam gaining an economic advantage over other areas with the study area. Other advantages include proximity to fishing grounds, shipping routes, and markets; the availability and relatively low cost of fuel and other goods and services that support tuna fishing operations; tariff-free market access to the U.S.; and significant tax incentives (WPRFMC 1999). Guam has been one of the largest tuna transshipment centers in the Pacific over the last decade. Apra Harbor on Guam is home to several hundred longline and purse seine vessels (WPRFMC 1999). Fleet expenditures for fuel, provisions, and repairs enhance the island economy by boosting the job market and investment opportunities (WPRFMC 1999). Annual transshipment of tuna, and non-tuna species varied from 1990 to 2003 (**Figures 4-5**, **4-6** and **4-7**) with a dramatic decrease in all pelagic species in 1997.

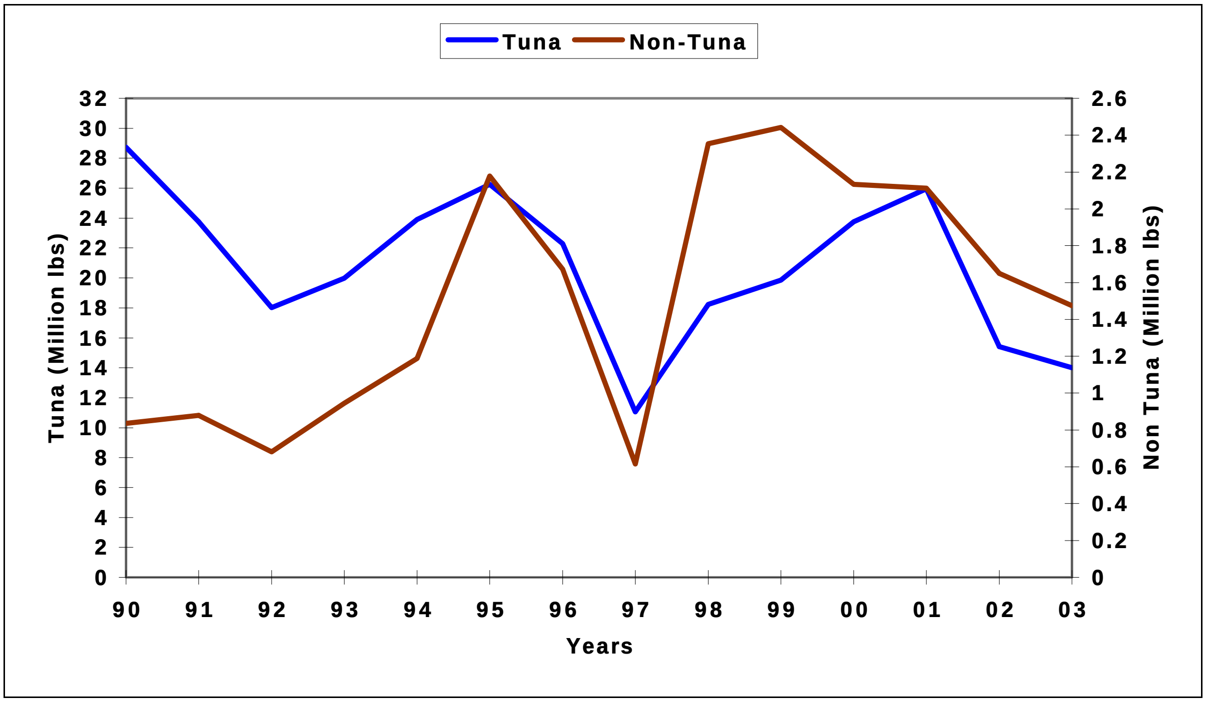

Figure 4-5. Annual estimated transshipment (million pounds) of tuna and non-tuna species on Guam from 1990 through 2003. Source: PIFSC (2004).

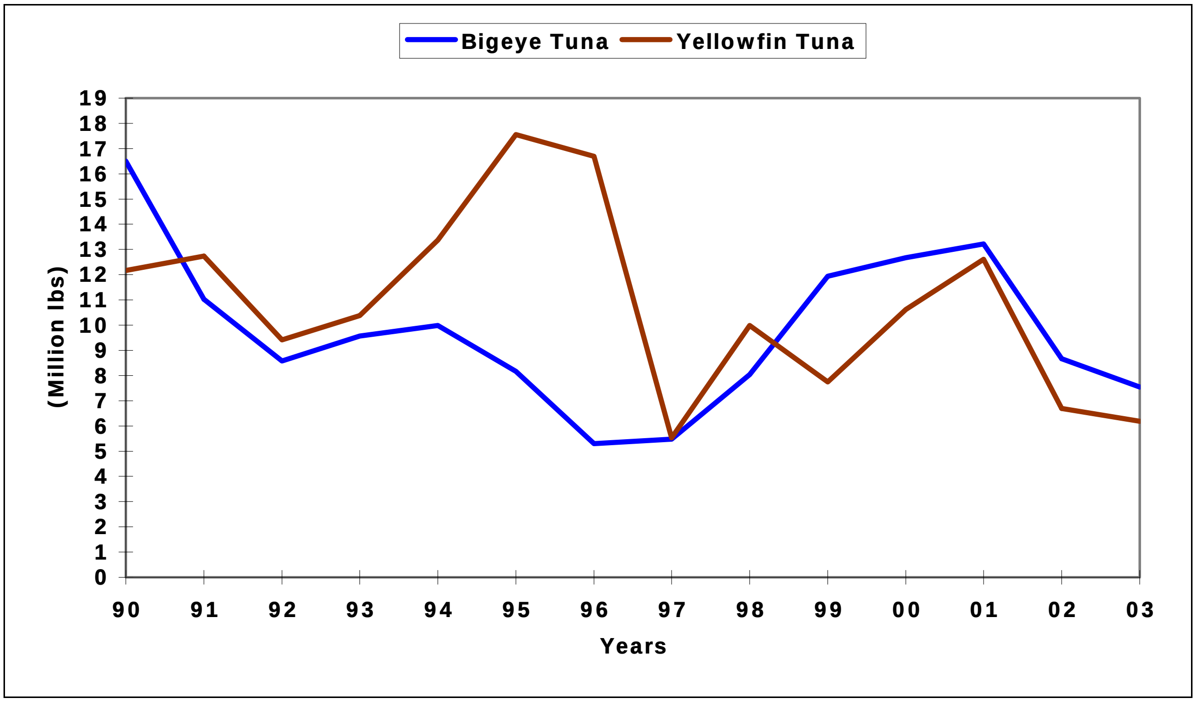

Figure 4-6. Annual estimated transshipment (million pounds) of bigeye tuna and yellowfin tuna on Guam from 1990 through 2003. Source: PIFSC (2004).

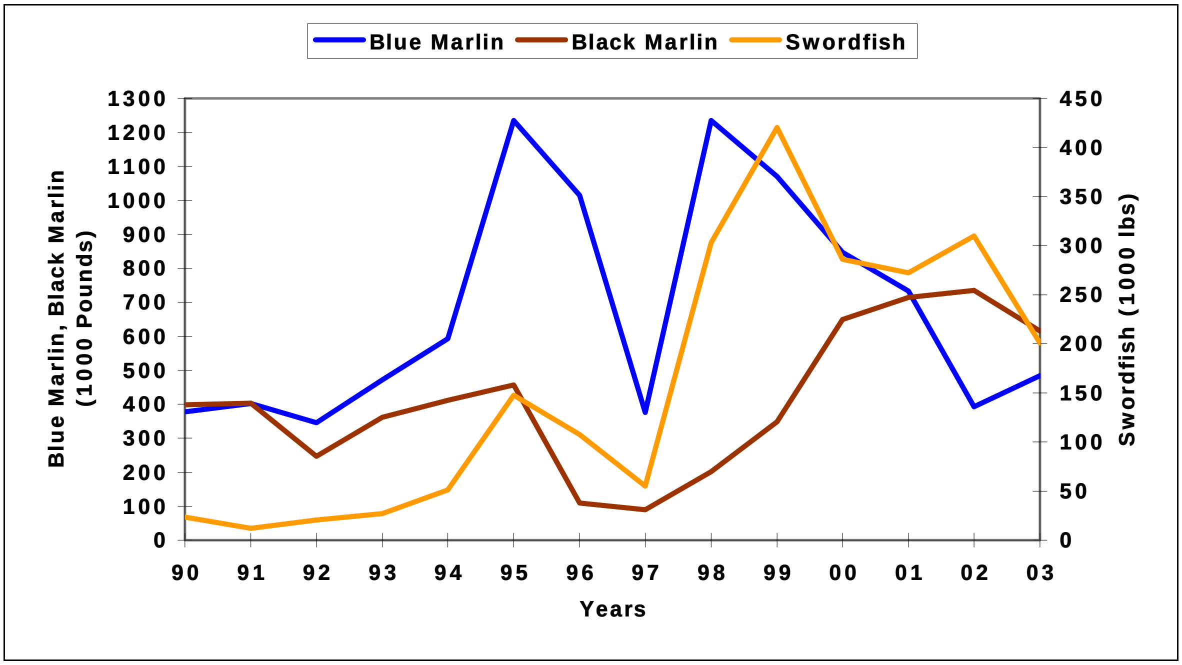

Figure 4-7. Annual estimated transshipment (1000 pounds) of top billfish species on Guam from 1990 through 2003. Source data: PIFSC (2004)

Currently, Guam employs a longline exclusion zone within 50 NM of the island. Therefore the purse seine and longline fisheries occur outside of the EEZ. The recreational trolling fishery is the most commonly practiced fishery within the EEZ around Guam. There has been a steady increase in the number of boats participating in Guam's pelagic fishery from 1981 (109 boats) through 1998 (469 boats). These numbers have decreased slightly from 1998 to the present (WPRFMC 2004c). The boats associated with this fishery are less than 10 m in length and are typically owner-operated by people earning a living by means other than fishing (WPRFMC 2004c).

Full-time charter vessels make up a small (usually <10%) but significant portion of the pelagic fleet. Charter boat activity in Guam has decreased since 1996, potentially due to a reduction in tourism due to the Asian economic crisis (WPRFMC 2004c). Charter boats account for the majority of trolling hours, trips, and pelagic catch on Guam (Simonds 2003; PIFSC 2004).

Annual estimated pelagic landings on Guam have varied widely throughout the years, ranging from 322,000 to 937,000 pounds (lbs) from 1982 through 2003 (WPRFMC 2004c; **Figure 4-8**). In 2003, pelagic landings totaled 506,000 lbs, a 5% decrease from 2002 (WPRFMC 2004c). Landings for pelagic species from 1982 through 2003 have consisted primarily of five species: dolphinfish, wahoo, skipjack tuna, yellowfin tuna, and Indo-Pacific blue marlin (NMFS 2004e; **Figure 4-9**). Other species taken in the pelagic fishery include rainbow runner (*Elagatis bipinnulatus*), great barracuda, kawakawa, sailfish, dogtooth tuna, and sharks (PIFSC 2004). Landings of PMUS have increased from 1982 through 2003 (WPRFMC 2004a; **Figure 4-8**). Landings of tuna PMUS increased 16% and non-tuna PMUS decreased 29% from 2002 to 2003 (WPRFMC 2004c). The direct hit of super typhoon Pongsona on Guam in December of 2002 crippled the charter and non-charter boat industry in early 2003. However, landings of pelagic species increased from 2002 to 2003 for bonita (*Sarda chiliensis* - 4%), Indo-Pacific blue marlin (23%), and yellowfin tuna (51%), while wahoo and dolphinfish landings decreased 12% and 52% respectively (WPRFMC 2004c; **Figure 4-9**).

Annual commercial landings for pelagic species increased from 1982-1995, but have fluctuated since 1996 (**Figure 4-8**). Commercial landings have ranged from 118,000 in 1982 to 400,000 in 1998. In 2003,

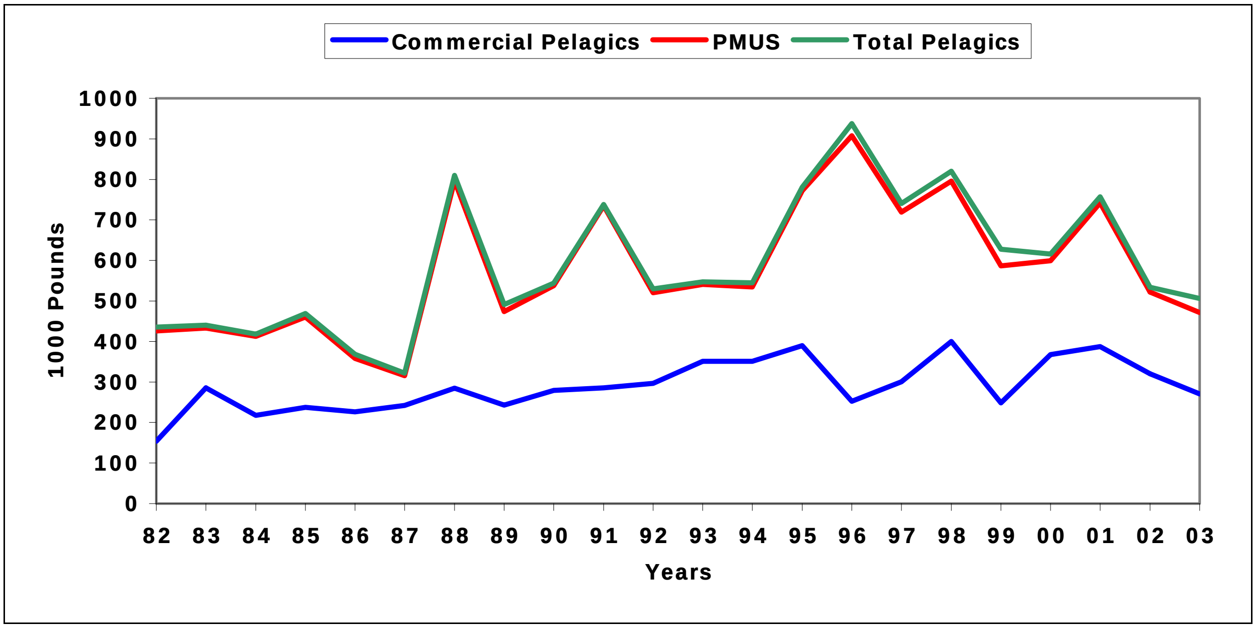

Figure 4-8. Annual estimated commercial, pelagic management unit species, and total landings (1000 pounds) for pelagic species on Guam from 1982 through 2003. Source: PIFSC (2004).

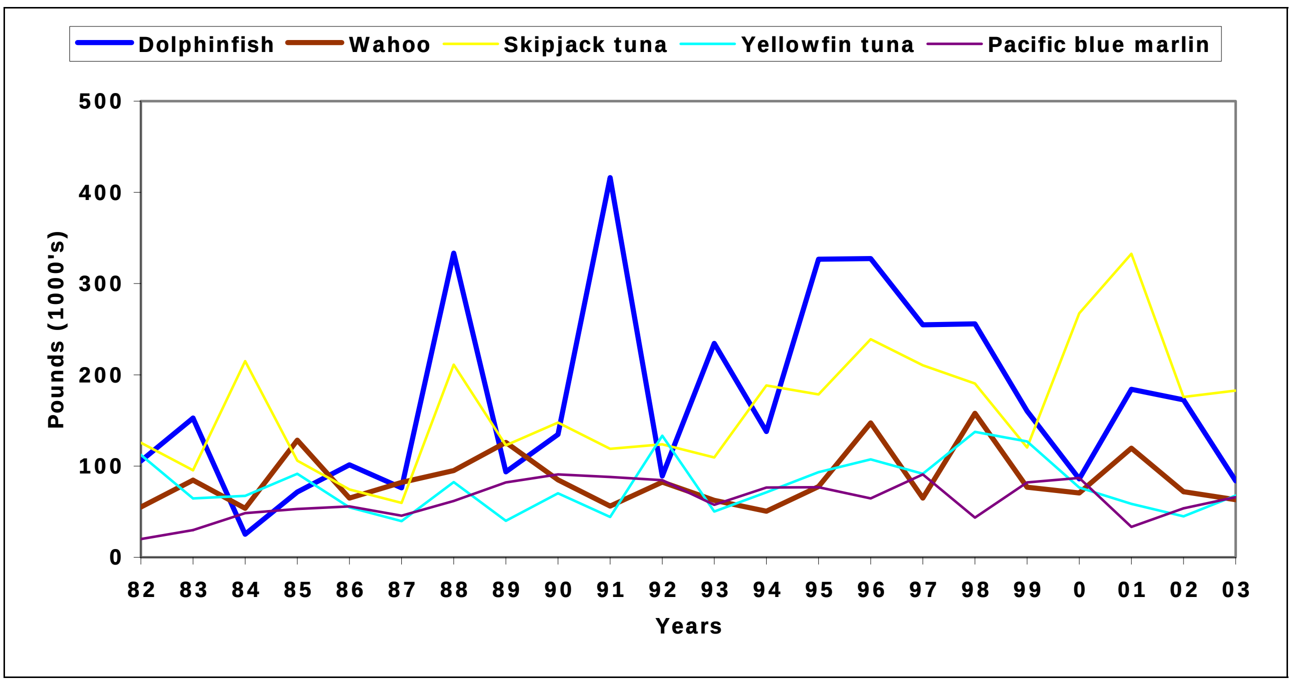

Figure 4-9. Annual estimated total landings (1000 pounds) for the five top pelagic species on Guam from 1982 through 2003. Source: NMFS (2004e).

commercial landings for pelagic species were 32% lower than the peak year of 1998 and have gradually decreased since 2001. Despite decreasing revenues and increasing costs of operations (fuel, boat maintenance and gear), the pelagic fishery continues, since it is a secondary source of income for many fishermen (WPRFMC 2004c).

Annual trolling activity (trips and hours) increased from 1982 and peaked in 1996, but has decreased since (**Figure 4-10**). Additionally, the numbers of trolling vessels and charter trips have continued to decline since 1996 (WPRFMC 2004c).

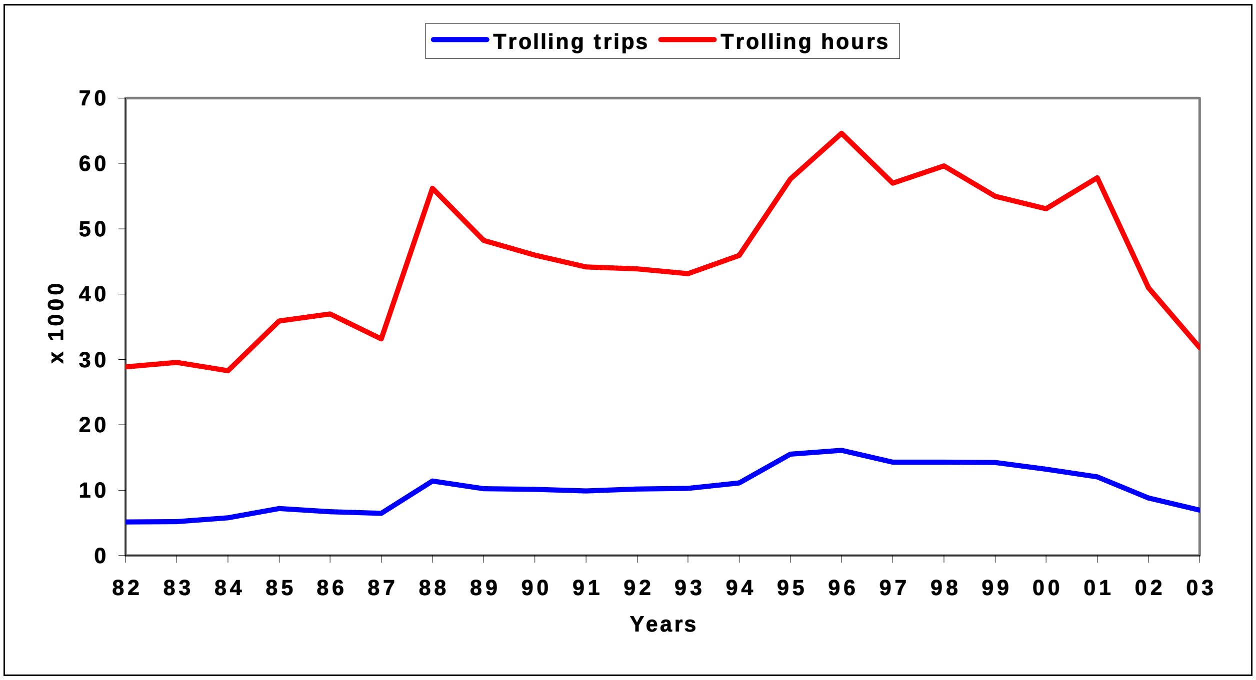

Figure 4-10. Annual trolling trips (1000) and hours (1000) on Guam from 1982 through 2003. Source: PIFSC (2004).

Several factors have negatively impacted the fisheries of Guam, including the Asian market decline, a decrease in tourism, and a decrease in outside capital investments. These factors coupled with rising fuel and boat maintenance costs, declining government finances, and environmental variations, such as El Niño events, have caused locals to turn to alternative sources of income. Pelagic fishing (specifically tuna) has provided additional income and resulted in the introduction of FADs. Tuna species are regularly taken using FADs in the waters surrounding Guam; however, no FADs are located within the Marianas MRA study area (DAWR 2004; WPRFMC 2004c; DFW CNMI 2005).

CNMI—The pelagic fishery in CNMI occurs from the island of FDM south to the island of Rota. Similar to Guam, the pelagic fishery is comprised of small, day-trolling boats (PIFSC 2004). Approximately 74% of the registered boats on the islands participate in some form of fishing activity (PIFSC 2004). Twenty-six charter vessels were registered with the Boating Safety Office in 2003. Charter vessels generally retain their catch, selling over half of it to local fish markets. No logbook system is currently in place. CNMI has seen an increase in boat numbers in recent years; about 70% of those are used in the commercial fisheries. In 2003, about 55 vessels were identified as being involved in full-time commercial fishing and 41 vessels were classified as part-time (WPRFMC 2004c). The pelagic fishing fleet, not including charter boats, consists of small (4 to 7 m) outboard powered boats with a limited (approximately 32 km) travel radius from the islands. Trolling is the most common fishery, with skipjack tuna making up the majority of the catch. Yellowfin tuna and dolphinfish are also harvested; during their seasonal runs, they can be found close to shore and are easy targets for local fishermen. Popularity of these species has increased due to the fact that Saipan's population is made up of over half non-native people (PIFSC 2004). All production from the domestic commercial fishery is consumed locally. No large-scale longline or purse seine activity occurs around the Northern Mariana Islands (Simonds 2003). Annual commercial catch of skipjack tuna, yellowfin tuna, and dolphinfish has varied dramatically from 1981 to 2003, with no discernable pattern (**Figure 4-11**).

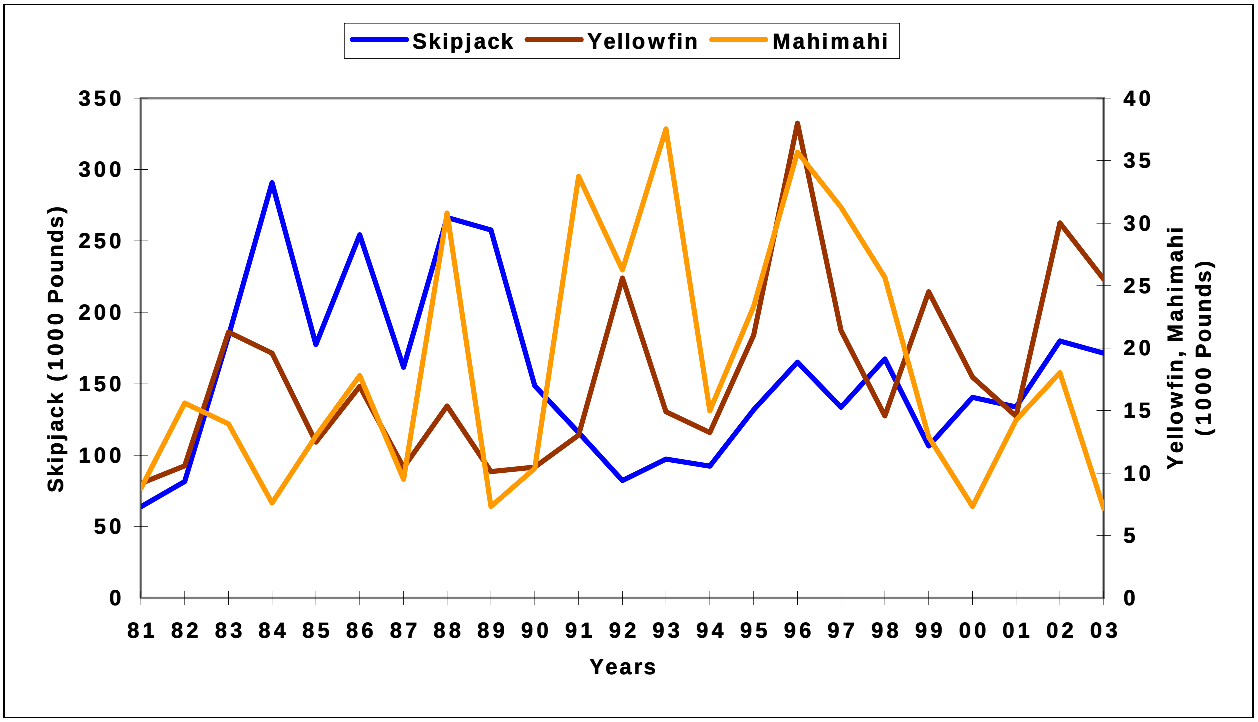

Figure 4-11. Annual commercial landings (1000 pounds) of skipjack tuna, yellowfin tuna, and dolphinfish on CNMI from 1981 through 2003. Source: PIFSC (2004).

4.3.3 Bottomfish Fishery

The bottomfish fishery is comprised of reef fishes (beyond the seaward margin of the reef) and deep-dwelling coastal fishes (depths ~300 m) taken by hook-and-line from anchored or drifting boats (Myers 1993). Bottomfishing in the area requires more skill than the pelagic fishery, and fisherman must be familiar with the location of submerged bottom features and hooking techniques to be successful.

Guam—Guam's bottomfish fishery is divided into shallow-water (<150 m) and deep-water (150 to 250 m) complexes (Myers 1993). The shallow-water complex includes reef-dwelling snappers (*Lutjanus* and *Aprion*), groupers (*Cephalopholis, Epinephelus,* and *Variola*), emperors (*Lethrinus*), and jacks (*Caranx*). The deep-water complex includes snappers and groupers, primarily of the genera *Pristipomoides*, *Etelis*, *Aphareus*, and *Epinephelus*, and *Cephalopholis* (PIFSC 2004). Of the two complexes, the shallow-water complex makes up the larger portion of the total bottomfish harvest on Guam. Bottomfishing on Guam is highly seasonal and is a combination of recreational, subsistence, and small-scale commercial fishing.

Fishing effort is concentrated on the western side (leeward side) of the island. However, fishing productivity is greatest on the eastern side (windward side) which can only be fished during calm weather conditions. The result is focused fishing effort in this region during calm conditions compared to other locations on Guam (WPRFMC 2004b).

The bottomfish fishery is made up of part-time recreational and subsistence fishermen operating small (10 m) vessels that concentrate on the shallow-water bottomfish complex (WPRFMC 2004b). These fishermen usually combine some amount of trolling effort for pelagic species to supplement the bottomfishing effort (Myers 1993). Increased demand for bottomfish, and therefore fishing effort, around Guam appears to be stressing bottomfish stocks (WPRFMC 2004b).

With tourism growth on Guam, the charter fishing industry has expanded. Charter fishing (due to increases in tourism) has increased and consists of several bottomfishing boats that make multiple 2 to 4 hour trips daily. These vessels can range in size from three to 30 passengers and target shallow-water species complex fishes (PIFSC 2004). Charter bottomfishing is responsible for a significant amount of all effort and bycatch in the shallow-water complex (WPRFMC 2004b).

The annual bottomfish harvest in Guam is highly variable (**Figure 4-12**) and appears to be due to variation in fishing effort rather than from changes in fish stocks (PIFSC 2004). BMUS species are harvested by both boat-based and inshore methods including spearing, trolling, and the use of nets such as gill nets, castnets, and surround nets (WPRFMC 2004b). Demand for fishes in the deep and shallow-water complexes continues to exceed the locally caught supply and may be contributing to the overall decline in nearshore and reef-associated bottomfish populations.

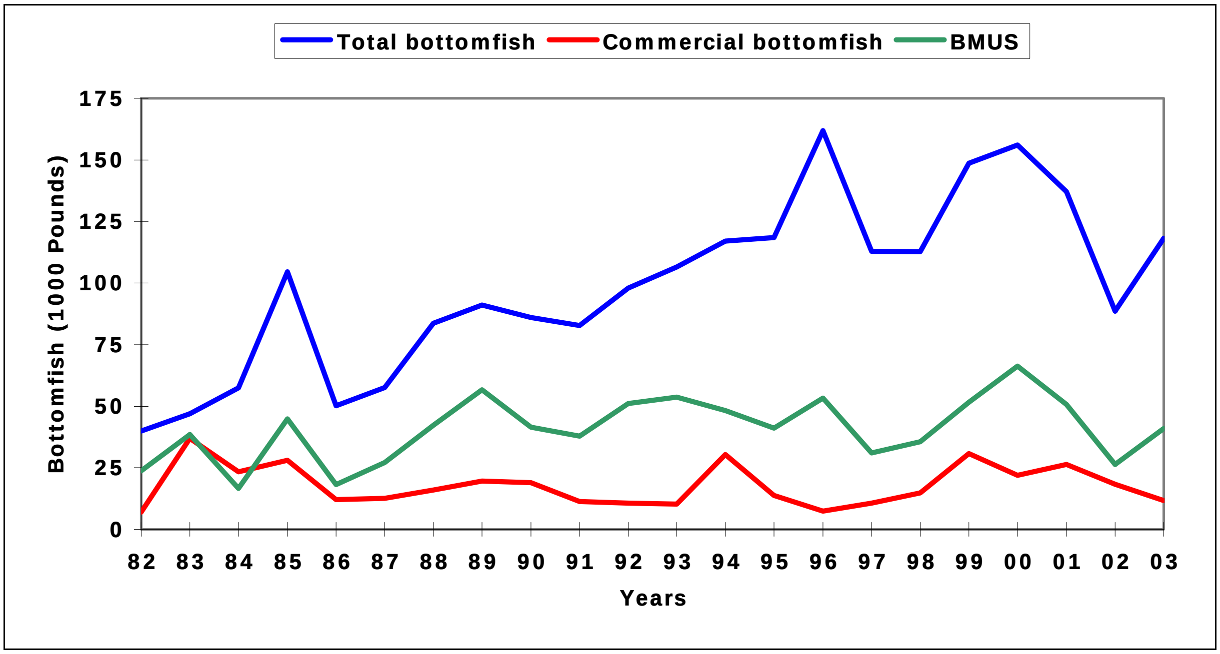

Figure 4-12. Annual estimated total landings (1000 pounds) of bottomfish species on Guam from 1982 through 2003. Source: (PIFSC 2004).

Total bottomfish and BMUS landings increased 33% and 57% respectively from 2002 to 2003 (**Figure 4-12**). While the commercial bottomfish landings have fluctuated though the years, total bottomfish landings steadily increased from 1982 to 1996, and have since decreased (WPRFMC 2004b; **Figure 4-12**). Total bottomfish trips and hours peaked in 1995 (**Figure 4-13**) due to several factors: a 60% increase in the number of boats participating in the fishery, the area experienced more calm days than in previous years, and the inclusion of Agat Marina into the offshore survey in 1994. Noticeable declines in 1996, 1997, and 2002 were the result of typhoons. Bottomfishing effort saw very little change from 2002 to 2003.

CNMI—The CNMI bottomfish fishery occurs primarily around the islands of Saipan, Tinian, and Rota. This discussion will focus on catches landed in Saipan, which has by far the largest market of the three islands (WPRFMC 2004b). CNMI's bottomfish fishery, like Guam, is composed of small fishing boats that engage in subsistence and commercial bottomfishing within a 17.3 NM radius of Saipan (PIFSC 2004). Similar to Guam, 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 (one day) and restricted to daylight hours. Common gears included 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 when 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 (PISFC

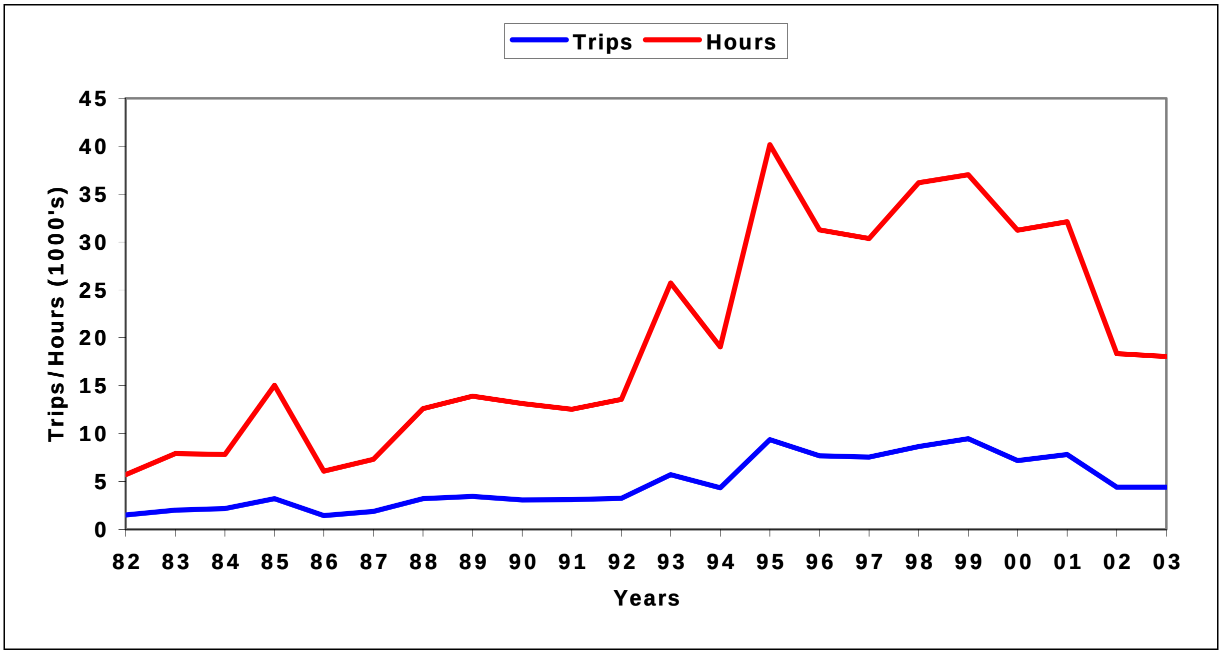

Figure 4-13. Annual estimated bottomfish trips and hours on Guam from 1982 through 2003. Source: WPRFMC (2004b).

2004; WPRFMC 2004b). These vessels utilize GPS, fathometers, and electric or hydraulic reels and it is thought that these larger fishing vessels have landed the majority of the deep-water bottomfish around CNMI (PIFSC 2004).

Deep-water species, such as snappers and groupers, are targeted largely by commercial fisherman, whereas shallow-water species, such as emperor-type fishes, are caught by both subsistence and commercial fisheries (PIFSC 2004). Snappers targeted in the deep-water fishery include members of *Etelis* (notably *Etelis coruscans* – longtail snapper) and *Pristipomoides*, whereas the eight-banded grouper (*Epinephelus octofasciatus*) is the only targeted grouper. The shallow-water fishery, targets the redgill emperor (*Lethrinus rubrioperculatus*). This fishery is primarily commercial, but does include subsistence fishing. 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. Of the bottomfish species caught on CNMI, deepwater snapper can be sold for the highest commercial prices (WPRFMC 2004b). Commercial bottomfish landings on CNMI have fluctuated from 1983 through 2003 with peaks in 1996 and 2001 (**Figure 4-14**). The increase in the number of large vessels participating in the deep-water bottomfishery can be attributed to the peak in 1996, whereas, the peak in 2001 probably reflects a change in DFW staff (WPRFMC 2004b). Overall, bottomfish landings showed a slight decrease from 2002 to 2003 probably due to rough sea conditions (WPRFMC 2004b). Shallow-water and deep-water bottomfish landings have mirrored each other from 1983 through 1995 when deep-water bottomfish landings increased significantly (**Figure 4-15**). This is likely due to an increase in the number and range of large vessels targeting deep-water bottomfish (WPRFMC 2004b). Since 1994, deep-water bottomfish landings have continuously been slightly higher than shallow-water bottomfish landings. Longtail snapper and emperor landings have fluctuated from 1983 through 2003, peaking in 1996 and 1997 respectively (**Figure 4-16**). Longtail snapper landings decreased by almost 50% while emperor landings increased by almost 50% from 2002 to 2003.

4.3.4 Reef Fishery

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 EEZ. In the study area, the harvest of coral

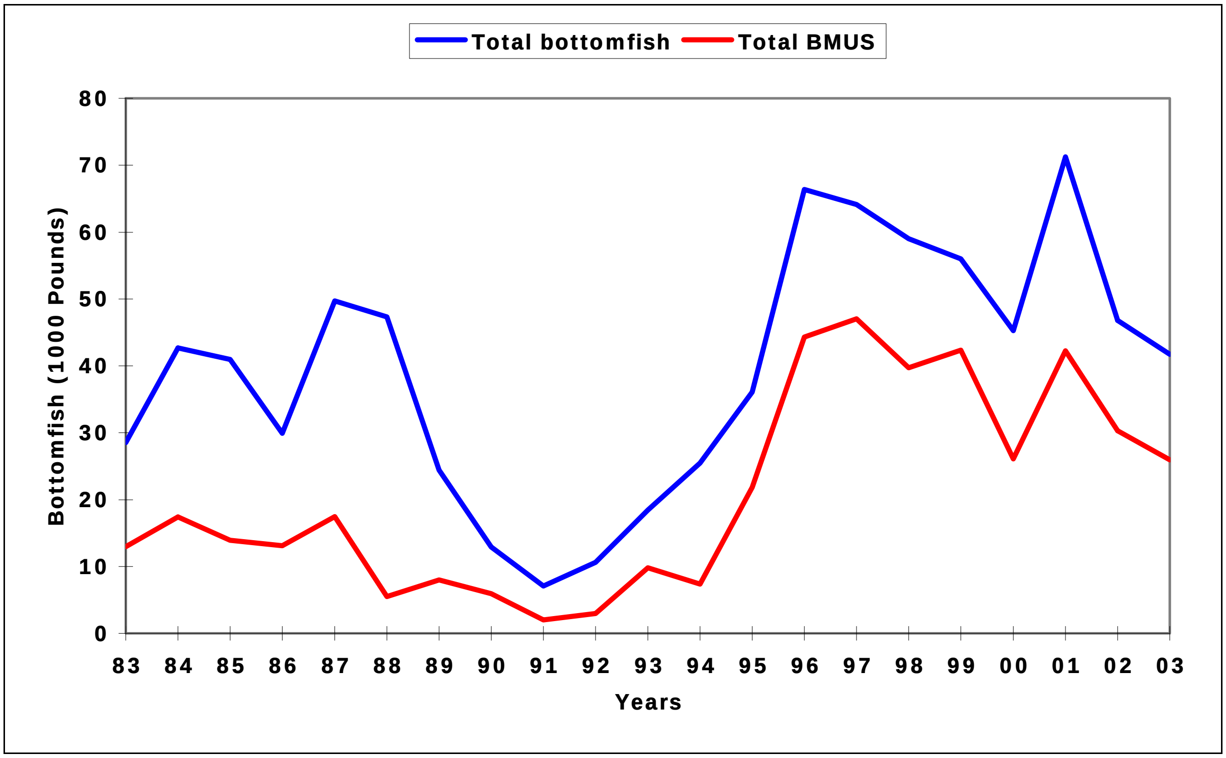

Figure 4-14. Annual commercial landings of all bottomfish and bottomfish management unit species on CNMI from 1983 through 2003. Source: WPRFMC (2004b).

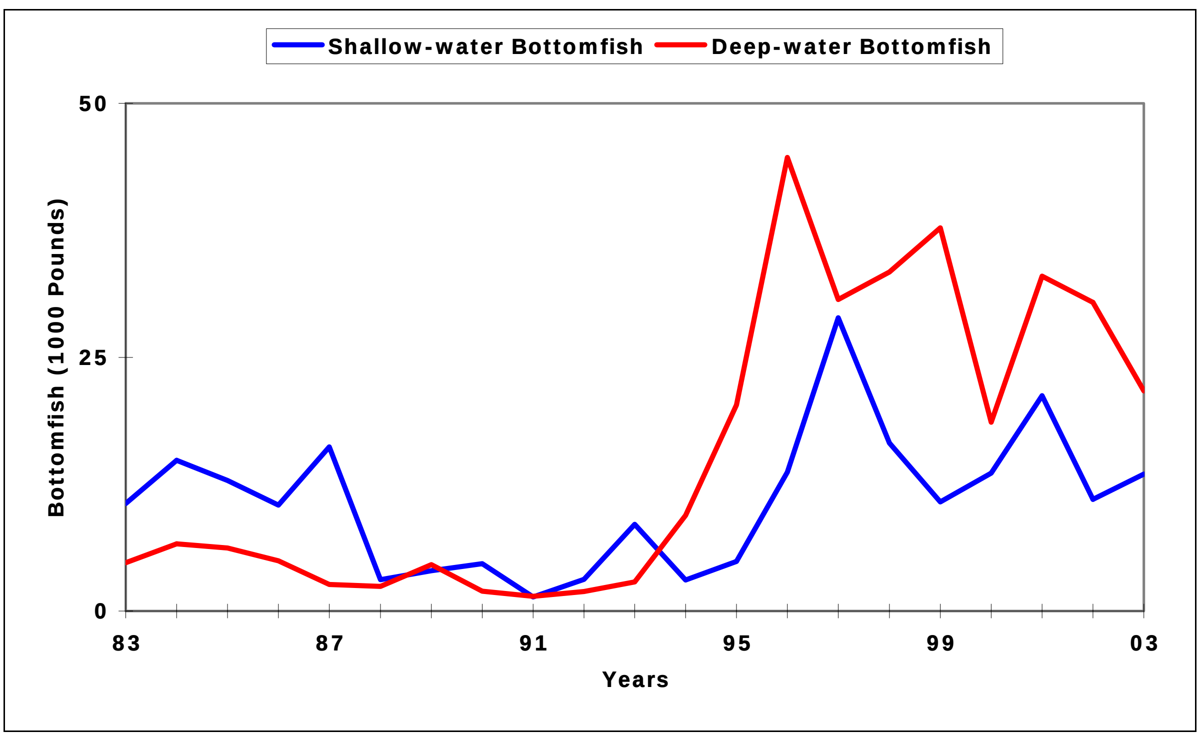

Figure 4-15. Annual commercial landings of all shallow-water and deep-water bottomfish species on CNMI from 1983 through 2003. Source: (WPRFMC 2004b).

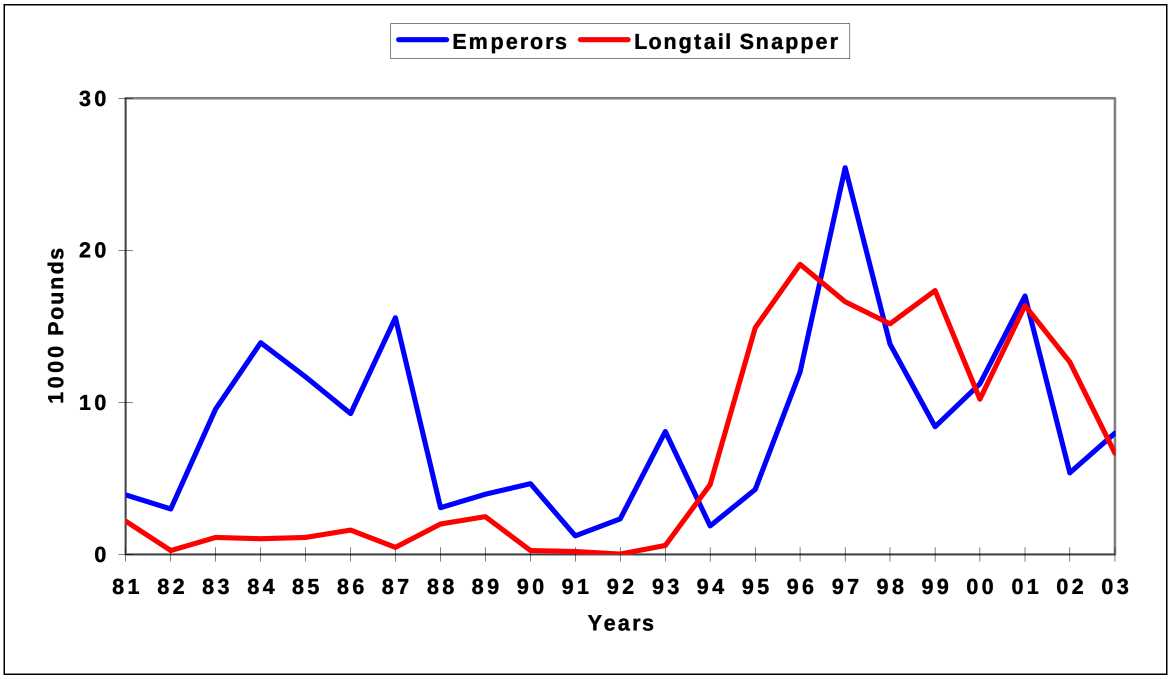

Figure 4-16. Annual estimated commercial landing (1000 pounds) of Emperors and Longtail Snapper on CNMI from 1981 through 2003. Source: PIFSC (2004).

reef species may fall into commercial fisheries, recreational fisheries, or both. The methods used to collect these species may range in sophistication from hand-collection to the use of complex traditional techniques or modern vessels and equipment. Various species of finfish are harvested using a range of modern and traditional gear types. Hook-and-line is currently the most common gear type used in the study area and may range from the use of handlines to rod and reels with lures and baited hooks (Hensley and Sherwood 1993). The Chamoru people (indigenous people of Guam) have a long history of net fishing but gill nets are a more recent introduction to the island (Hensley and Sherwood 1993). Gill nets are popular due to their availability, the comparative low cost, and the effectiveness of the material (Hensley and Sherwood 1993). Spearfishing is generally a highly selective fishery and targets fish of larger species such as parrotfish. SCUBA spearfishing and gill netting are still allowed on Guam, which is contrary to the prevailing conservation ethic.

Guam—Much of Guam's transition from traditional fishing methods to more modern techniques occurred since WWII (PIFSC 2004). This shift in fishing techniques has contributed to the decline of nearshore reef fish landings. Contemporary methods used on Guam include hook-and-line, net fishing, spear fishing, and hook-and-gaff (**Table 4-6**).

Finfish are the primary harvest (>95%) of the reef fish fishery and may include fish of all sizes (Hensley and Sherwood 1993). More than 100 species of fish are harvested from the coral reefs around Guam including the families Acanthuridae, Carangidae, Gerreidae, Holocentridae, Kyphosidae, Labridae, Lethrinidae, Lutjanidae, Mugilidae, Mullidae, Scaridae, and Siganidae (Hensley and Sherwood 1993). It was also noted that seven families (Acanthuridae, Mullidae, Siganidae, Carangidae, Mugilidae, Lethrinidae, and Scaridae) were consistently among the top ten species in any given year from 1991 through 1995, accounting for 45% of the annual fish harvest (WPRFMC 2001). The nearshore fishery harvests approximately 40 taxa of invertebrates including 12 crustacean taxa, 24 mollusk taxa, and 4 echinoderm taxa (Hensley and Sherwood 1993; WPRFMC 2001). Certain species such as the bumphead parrotfish, humphead wrasse, stingrays, parrotfish, jacks, emperors, and groupers are rare on shallow reefs due to intense fishing efforts (Green 1997).

Table 4-6. Top fishing gears used in Guam's coral reef fisheries, landings in metric tons, gear hours spent, and catch per unit effort. Source data: Gutierrez (2002).

Gear	Pounds	Gear Hours (g-hr)	CPUE (lbs/g-hr)
Hook-and-Line	75,574	230,627	0.327689
Cast Net	26,720	45,352	0.589169
Spear fishing (Snorkel)	23,501	14,789	1.589086
Surround Net	20,326	2,694	7.544915
Gill Net	15,948	14,063	1.13404
Hook and Gaff	3,108	3,695	0.841137
Drag Net	2,690	339	7.935103
Spearfishing (Scuba)	1,942	437	4.443936
Other	1,801	3,621	0.497376
Total	**342,775**	**631,234**	**Average = 2.54**

The majority of fish and invertebrates harvested from the coral reefs of Guam are taken by shore-based fishing. Spearfishing is the only significant boat-based fishery that targets reef fish (Myers 1993). In recent years, the estimated inshore harvest has ranged from 84,000 to 238,000 lbs, excluding highly variable catches of juvenile rabbitfish and bigeye scad by traditional fisheries that are still practiced seasonally (Myers 1993).

In the last few years, commercial spearfishing using SCUBA at night has increased. Improved technology (high capacity tanks, high tech lights, and bang sticks) has allowed spearing in deeper water (30 to 42 m) and catch rates have increased. For this reason, many larger species, such as bumphead parrotfish, humphead wrasse, stingrays, and larger scarid species that have already been heavily fished in shallow-water are now reappearing in the fishery catch statistics (Green 1997).

Less than 20% of the total coral reef resources harvested in Guam are taken from the EEZ, primarily because they are associated with less accessible offshore banks (WPRFMC 2001). Most of the catch from the EEZ is comprised of finfish. Most offshore banks are deep, remote, and subject to strong currents, which limits their accessibility to the calm weather of May to August/September. Galvez Bank is fished most often due to its proximity and accessibility (WPRFMC 2001). Other banks (White Tuna, Santa Rose, and Rota) are more remote and can only be fished during calm weather (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 (WPRFMC 2001). In recent years, the estimated catch in these fisheries has ranged from 30,000 to 49,000 lbs of shallow bottomfish and 6,500 to 24,000 lbs of bigeye scad (Green 1997). The shallow-water component accounted for almost 68% (35,002 to 65,162 lbs) of the aggregate bottomfish landings from 1992 through 1994 (WPRFMC 2001). Lethrinids make up the majority of the shallow-bottomfish catch composition, with a single species (redgill emperor) accounting for 36% of the total catch. Other important components of the bottomfish catch include lutjanids, carangids, serranids, and sharks. Holocentrids, mullids, labrids, scombrids, and balistids are minor components (WPRFMC 2001).

The bulk of bigeye scad fishing occurs in territorial waters, with some fishing taking place in federal waters. Estimated annual offshore landings for this species since 1985 have ranged from 6,393 to 44,500 lbs, with no apparent trend (WPRFMC 2001). It is unclear how much of this bigeye scad fishery has occurred in the EEZ.

The market for nearshore reef fish has increased on Guam largely due to the diverse cultures present on the island that rely on fish as a primary source of protein. The demand for fresh fish has driven up the price of reef fish on the island. Many net fishermen encountered on the inshore fishing areas are no longer subsistence fishermen, but are commercial fishermen. The reef fish catch on the island cannot keep up with the demand and, therefore, reef fish imports from Belau and Micronesia are increasing (Hensley and Sherwood 1993).

CNMI—Currently, very little information exists on the reef fisheries of CNMI making it difficult to assess the total harvest of present-day coral reef fisheries due to deficiencies in fisheries statistics. There is little information available for inshore subsistence and recreational catches of coral reef resources, but the harvest is assumed to be substantial, especially in the more accessible areas like Saipan Lagoon (WPRFMC 2001). The coral reef fisheries in CNMI are mostly limited to nearshore areas, especially off the islands of Saipan, Rota, and Tinian. Finfish and invertebrates are the primary targets of the coral reef fishery, however, small quantities of seaweed are also taken (WPRFMC 2001). Recent data for commercial landings shows harvests of 130,000 to 175,000 lbs/year of reef fish and 2,000 to 3,000 lbs/year of spiny lobster (WPRFMC 2001). In 1994, estimated annual coastal fishery production on CNMI was 5.9 million pounds, of which, 5.65 million pounds was from the subsistence fishery and 282,000 pounds 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 on CNMI (Green 1997).

4.3.5 Ports

Apra Harbor, located on the western side of Guam's central section, is the largest and busiest port in Micronesia. Additionally, Apra Harbor has the only deep lagoon (60 m) in the CNMI (Paulay 2003a). Its unique habitats host many species not found elsewhere in the archipelago. Apra Harbor contains well-developed reefs and boasts some of the highest coral cover on Guam (Paulay 2003a). For all practical purposes, this is the commercial hub of the island. It is a natural harbor, protected only by Orote Peninsula on the south and Cabras Island on the north.

4.3.6 Fishing Areas

Popular fishing sites commonly visited by recreational anglers are known as hot spots. Hot spots usually involve some structural features, such as shoals, rocks, and reefs (artificial and natural). Areas with greater vertical profiles, as found near bank ledges and canyons, help fishes regulate their temperatures by allowing them to quickly reach deep or shallow bottom habitats as needed, while maintaining close proximity to bottom habitat. Natural and man-made features that extend over the water or out into water are generally well-fished sites, such as piers, docks, rock and concrete jetties, and beach groins. Hydrographic features also concentrate fish and subsequently, anglers. Anglers often target currents and waters rich with nutrients. Potential fishing hot spots occur on all of the islands in the study area. However, there is a lack of adequate data to specify these locations. Recreational fishing hot spots will be most prevalent on the western side of all the study area islands.

4.3.7 Tournaments

There are few organized fishing tournaments in or around the study area. Government, organizations and companies usually sponsor a few small tournaments. Each tournament has its own set of rules, which include time limits and geographical boundaries. The sites fished by anglers within the tournament zones are still dependent on several factors, including the species targeted, tournament rules, or weather. Among the different tournaments, the level of participation varies between individual events, seasons, and years. Although most tournaments are annual events, the list of scheduled tournaments varies. Existing tournaments may be cancelled due to a lack of participation or support or new tournaments may be organized. The exact dates and weigh-in locations of annual tournaments will vary slightly year to year.

Currently, Guam has three annual fishing tournaments: the Guam Marianas International Fishing Derby sponsored by the Guam Fishermen's Cooperative Association (Calvo personal communication; NMFS 2003c); the Marianas Spearfishing Open (Calvo personal communication); and the Kid's Catch and Release Derby sponsored by the Division of Aquatic and Wildlife Resources, Department of Agriculture, Government of Guam, and the Anderson Air Force Base (DAWR 2005; Calvo personal communication).

In the CNMI, there are four main fishing tournaments: the Saipan International Fishing Tournament, the Cliff Fishing Derby Tinian, the Cliff Fishing Derby Rota, and the Kids International Fishing Derby Saipan (Benavente 2004; Micronesia 2005; MyMarianas.com 2005a, 2005b; Tinianonline.com 2005).

The Guam Marianas International Fishing Derby is a two-day event that has happened annually since 1995 (Calvo personal communication; NMFS 2003c). This Derby evolved from the Liberation Day Tournament which originated in 1976 (Eads 2001). Up to 100 boats take part in the tournament. In 2005, the Guam Marianas International Fishing Derby took place on June 25 and 26 to take advantage of calm sea conditions. Derby categories are marlin, wahoo, dolphinfish, bonita, and largest bottomfish (Calvo personal communication).

The Marianas Spearfishing Open is a one-day fishing tournament that takes place in the open water (Calvo personal communication). Up to 15 two-man freediver teams participate in this event. Fishing is allowed from Ritidian Point to Cocos Island. Open categories are two largest fish weighed in, largest unicornfish, largest parrotfish, and largest trevally (Calvo personal communication).

Kid's Catch and Release Derby in Guam is an annual rod and reel tournament (DAWR 2005; Calvo personal communication). It is limited to 75 children per day. In 2005, the event took place on July 9 and 10. Before the fishing takes place, children receive an environmental clean-up, rules, and safety briefing. Derby categories are most fish, longest fish, and most species caught (DAWR 2005; Calvo personal communication).

The Saipan International Fishing Tournament has been held in August each year since 1984 (Benavente 2004; Micronesia 2005; MyMarianas.com 2005a). This is the largest fishing tournament held in the CNMI, with over 50 boats and more than 150 participants. Prizes are awarded for the top three billfish, yellowfin tuna, wahoo, dolphinfish, and skipjack tuna (Benavente 2004). The 2005 Cliff Fishing Derby at Tinian took place in four locations of the Marianas MRA study area (South Dumpcoke, Fleming Point, Puntan Diapblo, and Puntan Masalok) and one area at the southwest end of the island (Wong/Target) (CNMI 2005). Three sites are used on Rota Island during their Cliff Fishing Derby. Prize categories include total weight, most variety, and biggest fish (CNMI 2005).

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5.0 ADDITIONAL CONSIDERATIONS

5.1 MARITIME BOUNDARIES: TERRITORIAL WATERS, CONTIGUOUS ZONE, AND EXCLUSIVE ECONOMIC ZONE

Maritime boundaries are critical elements that affect the planning of activities in the marine environment (GDAIS 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 5-1**). Since maritime boundaries are delimited, rather than demarcated, there is generally no physical evidence of the boundary. As a result, there can often be confusion, disagreement, and conflicting versions of marine boundaries between distinct nations and/or territories (NOAA 2002). Such is the case for Guam and the CNMI, where disputes between the two territorial governments and the U.S. federal government have been frequent.

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 U.S. 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 (Kapoor and Kerr 1986; Prescott 1987; **Figure 5-1**). 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 3 NM limit was the standard until the latter half of the twentieth century when the extent of U.S. territorial waters was redefined. In 1945, President Truman issued Presidential Proclamation No. 2667 (also known as the Truman Proclamation) claiming jurisdiction and control over all the natural resources of the seabed and subsoil of the entire continental shelf adjacent to the coasts of the U.S. The Truman Proclamation did not include jurisdiction or control over the waters overlying the U.S. continental shelf. In 1953, the Truman Proclamation was nullified and replaced by the Outer Continental Shelf (OCS) Act. The OCS Act placed the subsoil and seabed of the OCS under U.S. jurisdiction. Section 1331 of this act defines the OCS as "…all submerged lands lying seaward and outside of the area of lands beneath navigable waters as defined in section 1301 of this title…" (DOALOS 2004). Like the Truman Proclamation, the OCS Act did not give the U.S. authority over the waters above the continental shelf seabed, thereby leaving them open to navigation and fishing (**Table 5-1**).

In 1976, the U.S. followed the trend established by the United Nations (U.N.) by drafting a piece of legislation known as the FCMA. The FCMA established a 200 NM fishery conservation zone extending outward from the U.S. baseline. This 200 NM zone was designed to protect and conserve the fisheries of the U.S and its territories. With the official enactment of the FCMA in 1977, the U.S. formally claimed a 200 NM fishery conservation zone in which it exercised exclusive fishery management authority, except in cases where a country was situated within 400 NM (**Table 5-1**). In the Gulf of Mexico, for instance, Cuba and Mexico are located less than 400 NM away from the U.S. fishery conservation zone boundary. Pending the establishment of permanent maritime boundaries by treaty or agreement with these nations, the FCMA set forth fishery limits based on a median line drawn equidistantly between two nations where a 200 NM limit is not possible (DoS 1977).

By the early 1980s, it was evident that the U.S. needed to control more than fisheries outside of its territorial waters. In 1983, President Reagan recognized the necessity of protecting, controlling, and developing the ocean area adjacent to the territorial waters of the U.S. by issuing Presidential Proclamation No. 5030 (**Table 5-1**). This proclamation established an EEZ that extended 200 NM from the U.S. baseline and included all areas adjoining the territorial waters of the U.S. and its territories, except where another country is less than 400 NM from the U.S. The establishment of the EEZ gave the

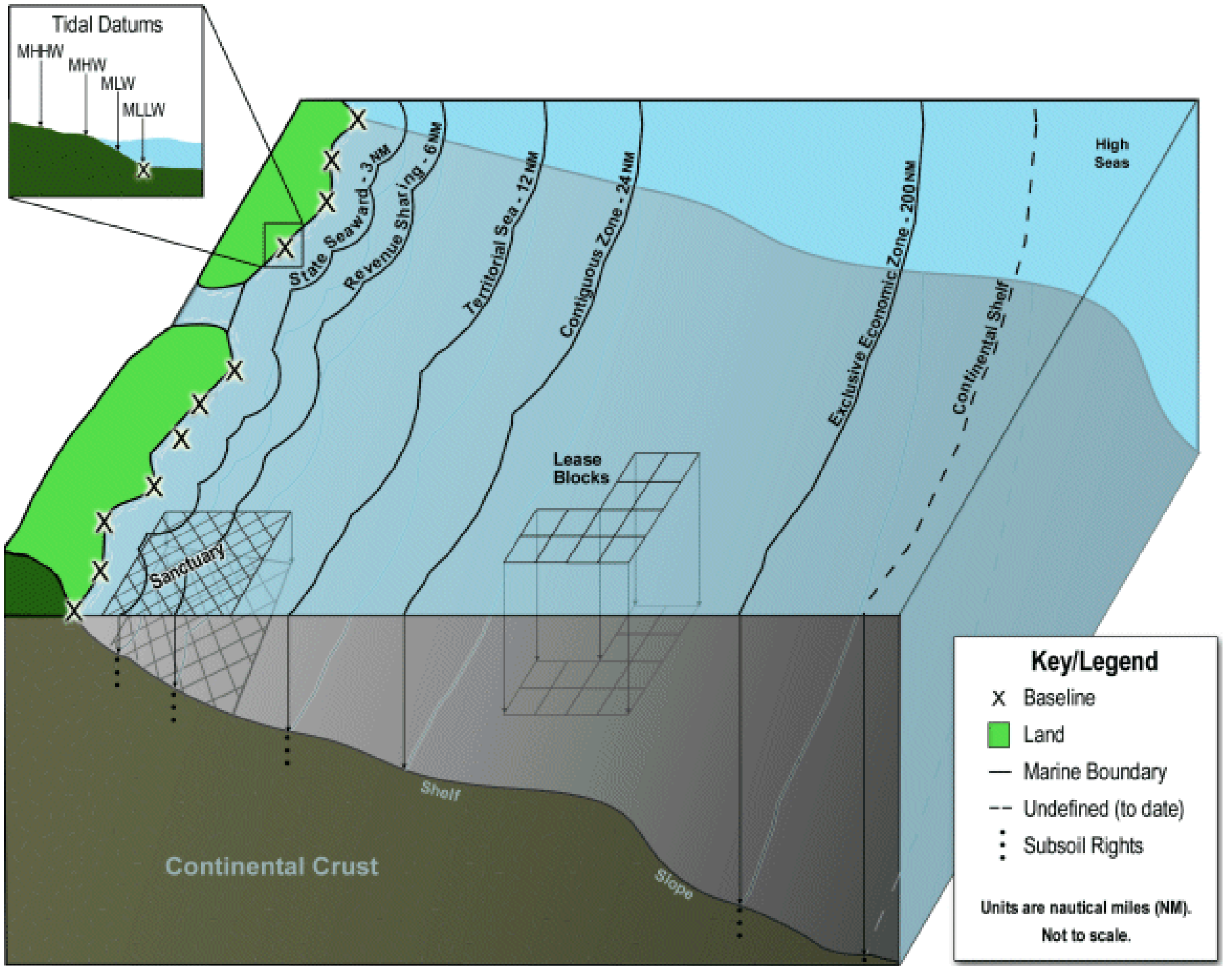

Figure 5-1. A 3-D depiction of the U.S. maritime boundaries. Tidal datums – Mean Higher High Water (MHHW), Mean High Water (MHW), Mean Low Water (MLW), and Mean Lower Low Water (MLLW). Image taken from: NOAA (2002), used with the permission of Mr. David Stein.

U.S. sovereign rights over the natural resources within the 200 NM zone, but it did not affect the lawful use of this zone by other nations for navigation or overflight (DOALOS 2004; **Table 5-2**). Sovereign rights include the rights to explore, exploit, conserve, and manage natural resources.

The U.S. EEZ covers approximately 7.8 million km^2 of ocean space, half of which is found in the western Pacific Ocean around U.S. possessions such as Hawai'i, American Samoa, Guam, and the CNMI. 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 country's EEZs are deemed to end at what is called the "median line," an imaginary line that is equidistant from the baseline of each country. Around Guam and the CNMI, two cases exist where the EEZs of two separate nations overlap. To the south of Guam, the U.S. EEZ runs along the median line between Guam and the Federated States of Micronesia (FSM), while to the north of Farallon de Pajaros, the U.S. EEZ runs along the median line between the CNMI and Japan's Ogasawara Islands.

The U.N. Law of the Sea Treaty, created in 1982 and entered into force in 1994, delimited 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 (54 FR 777). While the U.S. has not yet signed the Law of the

Table 5-1. Timeline detailing the establishment of U.S. jurisdiction and maritime boundaries in the Marianas MRA study area by treaty, legislation, and presidential proclamation. Sources: DoS (1977); U.S. Office of the President (1988); Glassner (1995); de Blij and Muller (1999); Office of the Attorney General 2002; DOALOS (2004); Rosenberg (2005).

- **From Antiquity to the Early Twentieth Century:** 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 U.S. 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. In creating this structure the Organic Act gave concurrent jurisdiction of submerged lands (from the line of mean high tide and seaward to a line three geographical miles distant from the coastline) to the Government of Guam.
- **1953–Outer Continental Shelf Act:** the subsoil and seabed of the OCS was declared to be under U.S. jurisdiction, control, and power. The waters overlying the OCS 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–U.N. Convention on the Law of the Sea I:** the U.N. convened the first international conference on maritime boundaries.
- **1960–U.N. Convention on the Law of the Sea II:** the second U.N. conference convened on international maritime boundaries.
- **1973–U.N. Convention on the Law of the Sea III:** the third U.N. conference convened on international 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 (USVI), 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 (FCMA), went into effect.
- **1982–U.N. Convention on the Law of the Sea Treaty:** an international treaty developed by the U.N. but not yet ratified by the U.S. The U.N. Convention on the Law of the Sea lays down a comprehensive regime of law and order in the world's oceans and seas by establishing rules governing all uses of the oceans and their resources. Most nations, including the U.S., 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 the development of ocean resources and promoted protection of the marine environment but did not affect other lawful uses of the zone, including navigation and overflight. 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–U.N. Convention on the Law of the Sea:** the U.N. entered into force the 1982 Law of the Sea Treaty. It has yet to be ratified by the U.S.
- **1999–Clinton Presidential Proclamation No. 7219 on the Contiguous Zone:** the contiguous zone of the U.S. 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 punish 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 states law and did not alter the rights of the U.S. in the EEZ.

Table 5-2. The maritime boundaries of the U.S. and their seaward and jurisdictional extents. Source: DOALOS (2004)

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 U.S. baseline	Federal jurisdiction over the air, sea, and seabed
Contiguous Zone	24 NM from U.S. baseline	Power to prevent and punish for infringement of fiscal, customs, immigration, and sanitary laws
Exclusive Economic Zone (EEZ)	200 NM from U.S. baseline	Sovereign rights over all natural resources and jurisdiction to protect the marine environment

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 U.S. to 12 NM from the baseline (**Table 5-1**). This expansion of federal territorial waters from 3 NM (or in some cases 9 NM) to 12 NM provided the U.S. with jurisdiction and supreme power over this area (**Table 5-2**). The seabed and its resources, the biota found in the water column, and the airspace above the territorial seas, as well as the use of surface waters, are all under the jurisdiction of the U.S. Although the territorial waters of the U.S. 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 Guam, the territorial government controls waters out to 3 NM (Environment Hawaii Inc. 1998).

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 punish infringement of these laws/regulations committed within the zone (DOALOS 2004). The establishment of the U.S. contiguous zone additionally advances both the law enforcement and public health interests of the U.S. (**Table 5-1**).

5.1.1 Maritime Boundaries in the Marianas MRA Study Area

Nearly all of the waters encompassed by the Marianas MRA study area are found within the limits of the U.S. EEZ (**Figure 5-2**). The study areas around FDM, Tinian, and Guam (which include Apra Harbor, Agat Bay, and waters off Andersen Air Force Base) are all located within U.S. territorial waters. The vast majority of Warning Area W-517 lies outside the territorial waters and contiguous zone, but within the U.S. EEZ. Only the southeast corner of W-517 is found beyond 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, which are 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 upon existing maritime boundary agreements (GDAIS 2004). The DoD has ownership of the submerged lands off of its federal lands on Guam.

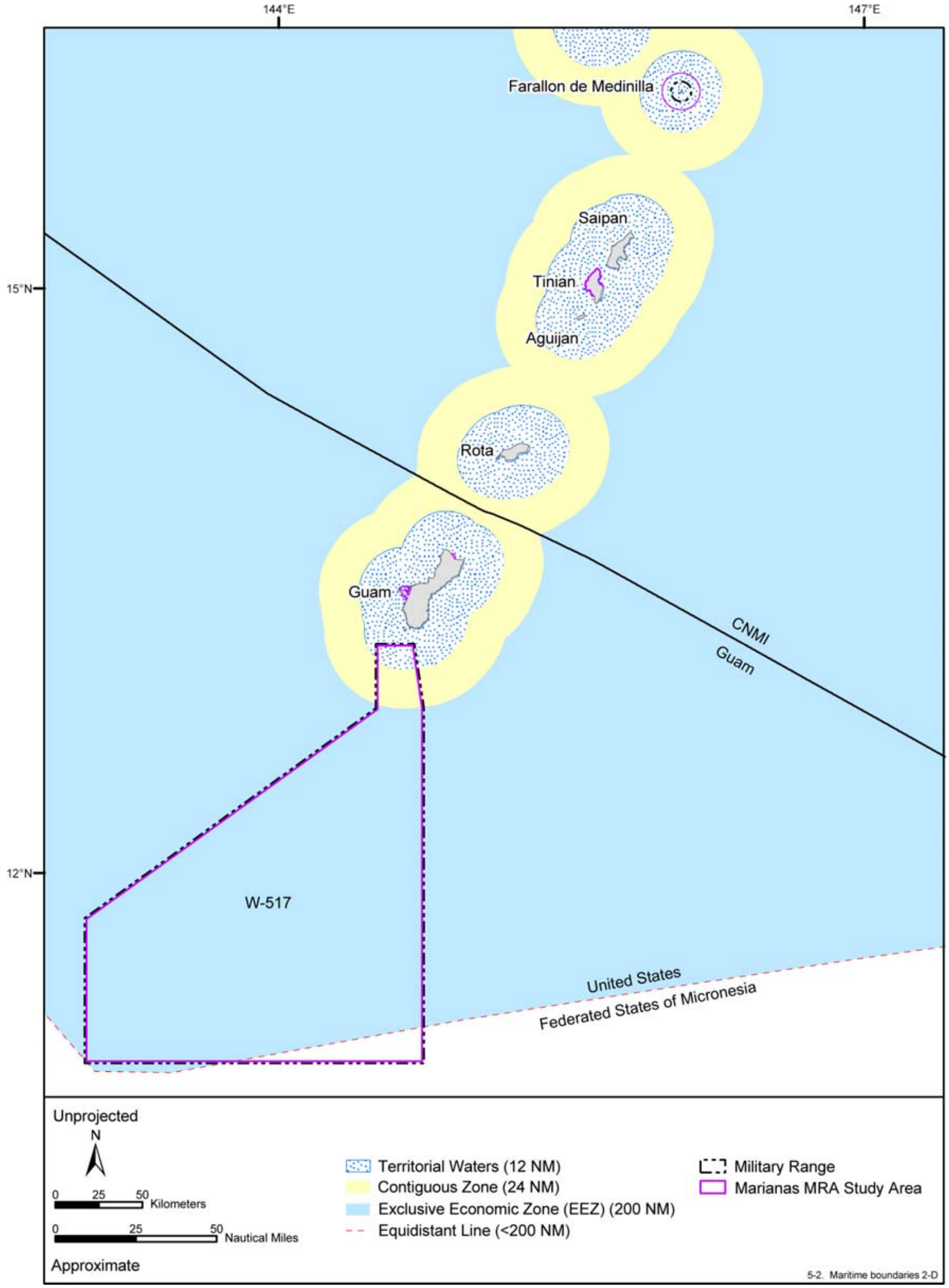

Figure 5-2. Proximity of the Marianas MRA study area to the U.S. maritime boundaries. The territorial waters (12 NM), contiguous zone (24 NM), and EEZ (200 NM) are each measured outward from the baseline (usually mean low-tide line) along the shore. To the south of Guam, the EEZ does not extend to the full 200 NM due to the proximity of the Federated States of Micronesia. Source data: GDAIS (2004).

5.1.2 U.S. Maritime Boundary Effects on Federal Legislation and Executive Orders

According to the 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 EOs have associated maritime zone or boundary limitations. The maritime boundary associations detailed in the legislation or orders relevant to the Marianas MRA study area are listed below (see Section 1.3 for a full description of the legislation and their applications). The term ‘high seas’ generally refers to international waters outside the jurisdiction of any single nation.

- The MMPA protects, conserves, and manages marine mammals in waters under the jurisdiction of the U.S., which are defined by the MMPA as the U.S. territorial seas, EEZ, and the eastern special areas between the U.S. 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 ESA regulates the 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 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 NEPA establishes a CEQ 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 U.S. to the limit of the territorial seas.

- The MPRSA regulates the 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 U.S. 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 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.

5.2 NAVIGABLE WATERWAYS AND COMMERCIAL SHIPPING LANES

Navigable waterways of the U.S. are those waters that are presently used to transport interstate or foreign commerce. A determination of navigability, once made, applies laterally over the entire surface of the water body and is not extinguished by later actions or events that impede or destroy navigable capacity (33 CFR 329.4). There are more than 40,000 km of commercially navigable waterways under the U.S. transportation system.

In the western Pacific Ocean, commercially navigable waterways link Guam and the CNMI with major ports to both the east and west (**Figure 5-3**). The two waterways running east serve ship traffic going to and from Hawai’i and the mainland U.S., while the waterway running west connects Guam and the CNMI with ports in Asia such as Okinawa. Commercial ships traveling from the mainland U.S. or Hawai’i 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).

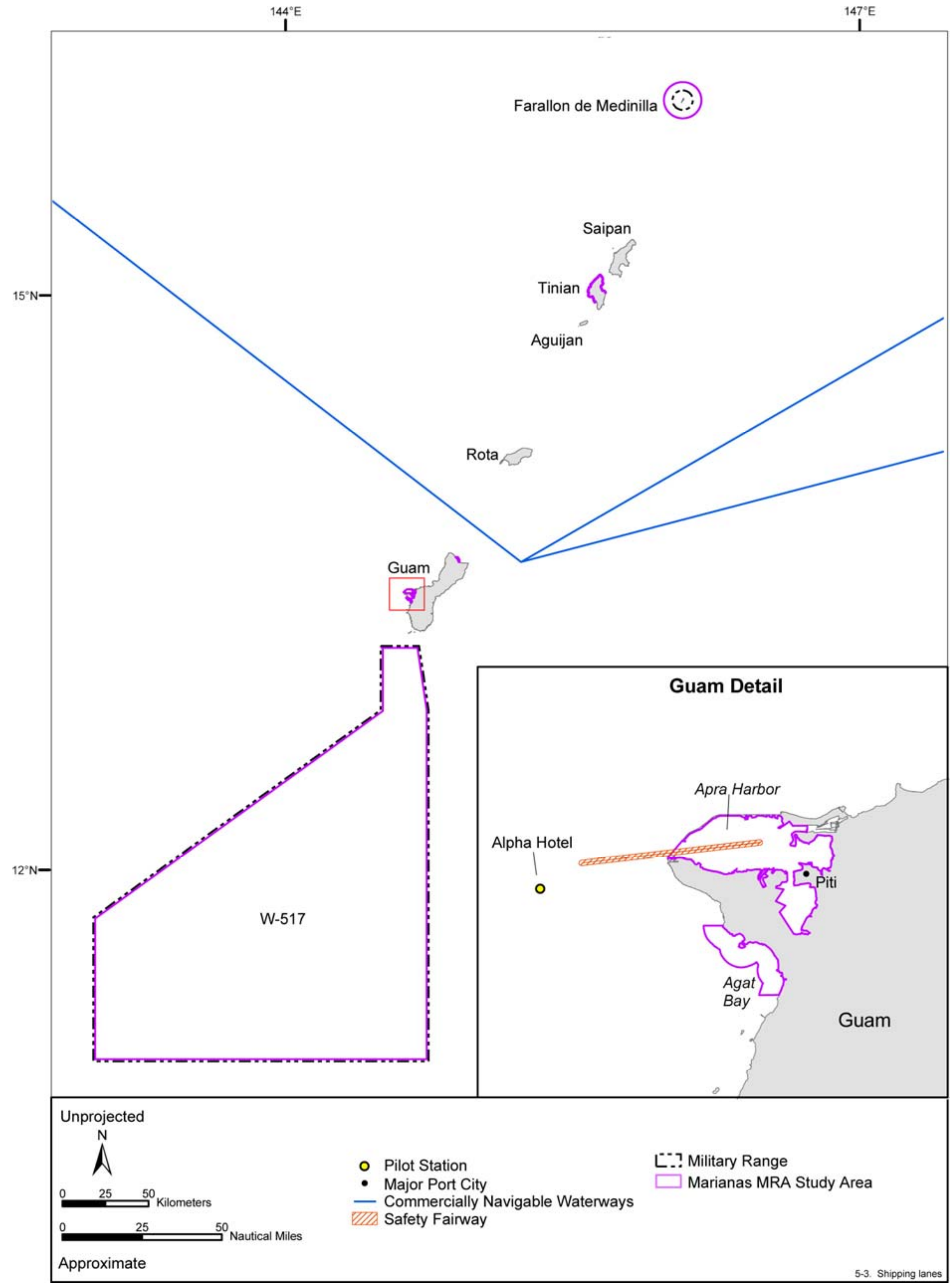

Figure 5-3. Commercially navigable waterways in the Marianas MRA study area and vicinity. Source data: DoT (2002), 33 CFR 165.1402, and Public Law 26-172.

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 Authority of Guam was established in 1975 and currently handles about two million tons of cargo per year (Port Authority of Guam 2004). The Port Authority's Harbor Rules and Regulations (also known as Public Law 26-172) state that all commercial vessels wishing 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 5-3**). At this station, a pilot will board the vessel and ensure that it is properly aligned on the entrance range.

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 where traffic is to be avoided (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, whether temporary or permanent, is permitted (33 CFR 167). These fairways, which are 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 for determining liability in the event of a collision with another ship or an underwater structure (CERES 2003). On Guam, a safety fairway has been established in order to regulate approaches into and out of Apra Harbor (**Figure 5-3**).

5.3 MARINE MANAGED AREAS

MPAs are considered effective conservation tools for sustaining ocean ecosystems (Agardy 1999; NRC 2000). A MPA, as defined in EO 13158, is "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." Section 5 of EO 13158 stipulates, "Each Federal agency whose actions affect the natural or cultural resources that are protected by an MPA shall identify such 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 an MPA." EO 13158 also calls for the preparation of annual reports by federal agencies describing the actions they have taken over the previous year to implement the order.

The most significant outcome of EO 13158 has been the strengthening and expansion of the nation's system of MPAs. The EO provides a formal, albeit vague, definition of a MPA. Since it is currently unclear as to what specifically constitutes a MPA, the National Marine Protected Area Center, which is part of the NOAA, is developing a MPA Classification System that will provide definitions and qualifications for the various terms used within the EO. In the fall of 2000, criteria were developed for six key terms in the EO definition: "area," "reserved," duration (lasting)," "protections," "marine," and "cultural." These working criteria, which were revised in the summer of 2002, were established to guide government agencies in identifying sites to be included in a national inventory of marine protected areas. This new classification scheme will allow efficient efforts to develop and disseminate the science, tools, and training needed for the effective design, management and evaluation of the nation's system of MPAs. Definitions of the above six criteria are found on the national MPA website at http://www.mpa.gov/inventory/criteria.html.

Several areas of the U.S. marine environment receive at least some level of management protection. The NOAA and the Department of the Interior (DoI) are documenting all marine sites receiving management protection. Concurrently, the National Marine Protected Area Center is compiling a comprehensive inventory of all federal, state, tribal, and local designated areas that meet certain criteria for either a MMA or a MPA. MMAs are similar to MPAs in that they have conservation or management purposes, defined boundaries, and some legal authority to protect their resources. MMAs encompass a wider range of management intents than MPAs. They include areas of protection for geological, cultural, or recreational resources that might not be included under the definition provided in EO 13158 for MPAs. MMAs may also include areas that are managed for reasons other than conservation (e.g., security zones, shellfish closures, sewage discharge areas, and pipeline and cable corridors).

The first step in redefining what constitutes MPAs is to establish a list of MMAs, from which a select few MPAs will eventually be chosen. To date, only federal MMAs have been added to the MMA Inventory; state, territorial, tribal, and local MMAs will be considered for addition to the inventory list at a later date. Once the MMA Inventory is complete, the MPA Classification System will be applied to sites in the MMA Inventory and official MPA designations will be made. Only those sites in the MPA list are subject to the ‘avoid harm’ stipulation stated in EO 13158.

In the Marianas MRA study area and vicinity, there are three federally designated, two Navy-designated, and 12 territory or commonwealth-designated MMAs (**Figure 5-4**). For the purposes of this section, federally designated MMAs include those designated by resource management agencies such as the NOAA, NOAA Fisheries, National Park System (NPS), and USFWS. Since Navy-designated MMAs are not yet included in the MMA inventory, they will be addressed separately.

5.3.1 Federally Designated Marine Managed Areas

Federally designated MMAs include national marine sanctuaries, NPS sites (e.g., national seashores, national parks, national monuments), national wildlife refuges (NWRs), national estuarine research reserves, threatened/endangered species protected areas and critical habitats, fisheries habitat conservation zones, and fisheries management zones. The three federal MMAs located in the Marianas MRA study area and vicinity include one National Parks System site, one NWR, and one fisheries management zone (NOAA 2004). Each of these MMAs is located on or around Guam. There are no federally designated MMAs located in the Northern Mariana Islands.

5.3.1.1 National Park System Sites

The NPS administers all areas that are protected and managed under the U.S. NPS. The National Parks Service Organic Act of 1916 established the NPS with “the fundamental purpose to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment for the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" (NPS 2003).

The NPS is composed of 388 areas covering more than 34.2 million ha in 49 states, the District of Columbia, American Samoa, Guam, Puerto Rico, Saipan, and the USVI (DoI 2004). The system includes national parks, monuments, seashores, memorials, preserves, historical parks, historical sites, recreational areas, and many other similarly named areas that are distinguished for their historic or prehistoric importance, scientific interest, or superior recreational assets. There is one NPS site in the Marianas MRA study area that is currently identified as a MMA: the War in the Pacific NHP (**Figure 5-4**).

Guam was the site of one the heaviest aerial and naval bombardments in WWII, as American forces fought to regain territories captured by the Japanese. The War in the Pacific NHP commemorates the bravery and sacrifice of both the soldiers and the Guam residents who lost their lives during the war. The park is comprised of seven historically significant sites on the island and 405 ha of ocean where submerged WWII military vessels and artifacts rest on the ocean floor next to coral reefs. The remains of caves, Japanese fortifications, pillboxes, and gun emplacements stand throughout the park as silent reminders of the fierce battles that took place on the island. The park looks to conserve natural resources and to preserve important natural features including plant communities, streams, and marine bed environments (Daniel 2004). Ecosystems focused on by the park include coral reefs, seagrass beds, wetlands, and offshore islets.

A second NPS site, American Memorial Park, is located within the CNMI on the island of Saipan; however, it is not currently identified as a MMA. This 54 ha park is located on the western side of the island and includes areas for picnicking, swimming, boating, fishing, athletic events, and ceremonial use (Cocke 2004). Its primary function is to honor those that died in the WWII Mariana Island Campaign and to discuss the role that the battle for Saipan played in the Pacific Theater as a whole (Cocke 2004). Secondary purposes include the protection of environmental and ecological resources found inside the

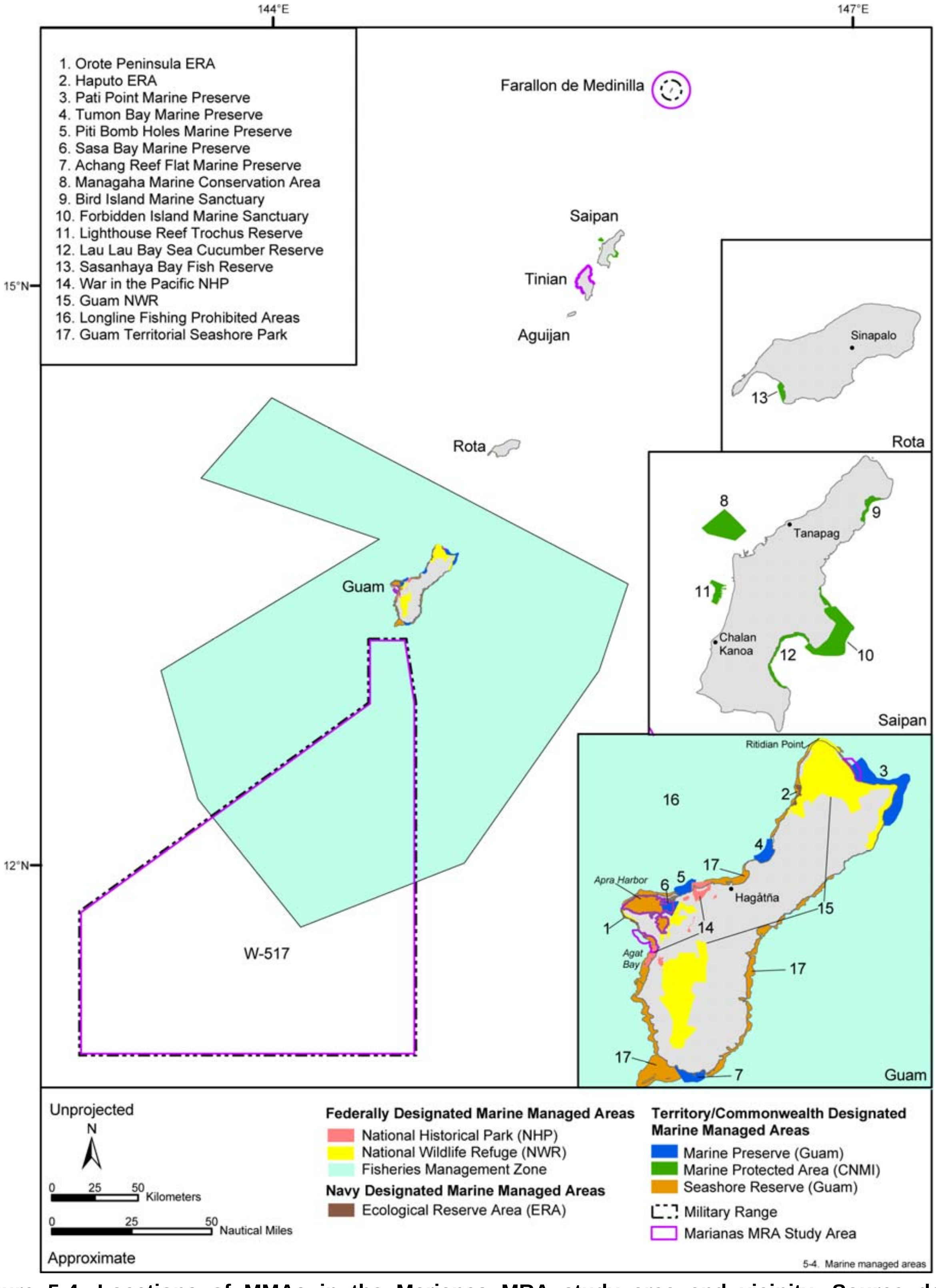

Figure 5-4. Locations of MMAs in the Marianas MRA study area and vicinity. Source data: Commonwealth of the Northern Mariana Islands Coastal Resources Management Office (2003), DoN (2004), Guam Bureau of Statistics and Plans (2004), NOAA (2004), University of Guam Marine Laboratory (2004), and 50 CFR 660.26.

park. Coastal waters, including coral reefs, are currently not encompassed within the park's boundaries; however, a case pending in U.S. Federal court (CNMI vs. U.S.; Civil Action No. 99-0028 at 35, D. N. Mar. I.; filed August 2003) could bring nearshore waters within the park's jurisdiction.

5.3.1.2 National Wildlife Refuges

The USFWS, which oversees the National Wildlife Refuge System (NWRS), protects more marine habitat area than any other federal agency. The NWRS is comprised of over 535 established NWRs, spanning many types of habitats. Approximately 140 to 150 refuges nation-wide contain marine and estuarine habitat. These MMAs provide habitat for a number of endangered plants and animals. The NWRS contains about 1.1 million ha of coral reefs and bordering ocean habitat. Overall, the entire U.S. EEZ is estimated to contain 1.7 million ha of coral reefs. For more information on corals found in the study area, see Chapter 4. There is one NWR found in close proximity to the Marianas MRA study area: Guam NWR (**Figure 5-4**).

The Ritidian Unit of Guam NWR was established in 1993 on excess land that was acquired from the Navy. The refuge is composed of 312 ha (150 ha of coral reefs and 162 ha of terrestrial habitat) owned by the USFWS and 9,088 ha (mostly forest) owned by the U.S. Department of Defense in Air Force and Navy installations that are classified as refuge overlay. Although military missions come first on these lands, the USFWS assists in protecting native species and habitats. Guam NWR provides habitat for the last remaining populations of the endangered Mariana fruit bat, Mariana crow, and *Serianthes nelsonii* tree. The refuge also protects significant cultural resources of the Chamorro people.

5.3.1.3 Fisheries Management Zones

Fisheries management zones are areas that are closed, at least partially, to fishing activities. The NOAA Fisheries has the jurisdiction to restrict or even prohibit the use of one or more fishing gear types in some areas in order to protect habitats, fishery stocks, or species assemblages and/or to promote the recovery of threatened or endangered species. Most of these area closures are seasonal or short-term; however, in some locations, they might be year-round for one or more years. In the Marianas MRA study area and vicinity, there is one year-round closure: the Longline Fishing Prohibited Area (**Figure 5-4**). This closure, which encompasses 43.7 million km^2 of ocean area surrounding Guam, was implemented to protect species that are often unintentionally caught in longline fishing gear, such as sea turtles, marine mammals, seabirds, and sharks.

5.3.2 Navy-Designated Ecological Reserve Areas

An Ecological Reserve Area (ERA) is a physical or biological unit in 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 (DoN 1986). To compensate for the loss of 5.7 ha of reef and limestone habitats caused during the construction of an ammunition wharf in Apra Harbor, the Navy set aside 168 ha of coastal habitat at two sites. These protected areas are known as the Orote Peninsula and Haputo ERAs (DoN 1984; **Figure 5-4**).

5.3.2.1 Orote Peninsula Ecological Reserve Area

Established in 1984, the Orote Peninsula ERA totals 66 ha and consists of two distinct regions. The first region spans from the shoreline cliffs to the mean low water line and encompasses 12 ha. The cliff area also encompasses a large limestone forest (DoN 1984). The second region is composed of submerged coastal lands spanning from the MLW line to the 36.6 m isobath. It is populated primarily by undisturbed coral reefs and encompasses an area totaling 54 ha (DoN 1984). Blue Hole, one of Guam's premier dive locations, is located off of the Orote Peninsula ERA (UNEP/IUCN 1988; Hanauer 2001).

5.3.2.2 Haputo Ecological Reserve Area

The Haputo ERA, also established by the Navy in 1984, 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 (DoN 1986), but also includes two sand beach coves (UNEP/IUCN 1988). The TU encompasses the area from the shoreline cliff boundary line to the MLW line. The marine unit (MU), with a total of 29 ha of submerged land, includes Double Reef. The MU 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 (DoN 1986). Double Reef has also become a favorite dive location on the island (Rock 1999).

5.3.3 Territory/Commonwealth Designated Marine Managed Areas

Territory/Commonwealth designated MMAs include marine preserves, territorial seashore parks, marine conservation areas, marine sanctuaries, and marine species reserves. Twelve local MMAs are located in the Marianas MRA study area and vicinity. Six are located at Guam and six are located in the CNMI.

5.3.3.1 Marine Preserves (Guam)

Guam's Marine Preserve System is comprised of 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; **Figure 5-4**). Although the Sasa Bay Marine Preserve includes Navy-owned submerged lands, the DoD does not recognize these lands as part of a designated marine preserve. All types of fishing as well as shell collecting, the use of gaffs, and the 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). There is a cooperative agreement between Guam's Marine Preserve System (Public Law 24-21) and Andersen Air Force Base (AAFB) that establishes a mirror conservation area at Pati Point (Davis personal communication; Twenty-Fourth Guam Legislature 1997; Pacific Air Forces 2000; University of Guam Marine Laboratory 2005). This makes the provisions of the Government Marine Preservation and AAFB regulations the same. In this particular area, the Government MPA initiative mirrors the Pati Point Preserve created by AAFB. In other areas of Guam, even though they may overlap with marine preserves, the submerged lands DoD owns off of its federal lands on Guam are not part of the marine preserves.

5.3.3.2 Territorial Seashore Parks (Guam)

The Guam Territorial Seashore Park encompasses the land and water area of Guam extending seaward to the 18 m contour, including all islands within the government's jurisdiction except Cabras Island and those villages wherein residences have been constructed along the shoreline prior to the effective date of the Guam Territorial Seashore Protection Act of 1974 (**Figure 5-4**). The Territorial Seashore Park also extends inland to the nearer of the following points: (1) from the mean high water line for a distance on a horizontal plane of 10 m or (2) from the MHW line to the inland edge of the nearest public right-of-way.

5.3.3.3 Marine Protected Areas (CNMI)

The DFW is the Commonwealth-level agency that is in charge of designating and overseeing MMAs in the CNMI. The purpose of the DFW is to establish and enforce regulations governing hunting, fishing, and the conservation of the fish and wildlife in the CNMI. The Protected Areas Program of the DFW has identified six sites as MPAs with the Marianas MRA study area and vicinity. 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 (**Figure 5-4**). Each of these MMAs occurs around the island of Saipan except for the Sasanhaya Bay Fish Reserve, which is found at Rota.

There is also a limited take zone being proposed for the waters around Tinian. The Tinian Fish Reserve, proposed in 2003 under CNMI House Bill #13-110, is still under debate. CNMI House Bill #13-178, known as the Fisheries Act, was also proposed in 2003 and called for the establishment of four MPAs in the northern islands of the CNMI. These MPAs, which are currently included in the National MMA Inventory, encompass ocean waters within a 1.6 km radius from the shore of the islands of Maug, Uracas, Asuncion, and Guguan. Each of these islands, however, is located beyond the study area map extent.

5.4 SCUBA Diving Sites

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 have become popular recreational activities throughout the region. In fact, some of the most popular destinations for SCUBA divers in all of the North Pacific Ocean are located around these islands. There are over 78 dive sites located in the Marianas archipelago that are particularly popular with divers (DoN 1999; Rock 1999; Hanauer 2001; Commonwealth of the Northern Mariana Islands Coastal Resources Management Office 2003; Michael 2004; **Figure 5-5**). Divers are attracted to the warm air and water temperatures found throughout the year, the clear underwater visibility, the unique shipwreck dive sites, and the coral reef diversity (Hanauer 2001). The vast majority of dive sites around Guam do not fall within the boundaries of the Marianas MRA study area, and the necessary infrastructure and access are not available for widespread diving along Tinian and FDM (Hanauer 2001).

The island of Guam has grown into a popular dive destination for Japanese tourists, and is gaining in popularity with divers from other Asian countries and the U.S. (Rock 1999) boasting over 50 dive sites around the island (Franko's Maps 2005). Major dive attractions include WWII shipwrecks and coral reefs. Although the majority of dive sites are nearshore and in shallow water, most of the diving is done by boat to increase the likelihood of seeing fish and other sea creatures and to prevent injury from the strong undercurrents and rips found along the surf zone (Rock 1999). Popular reef dive sites include Shark Pit along Agat Bay on the western coast and Tumon Bay and Gun Beach along the northwestern shoreline. Apra Harbor is also a popular location for divers due to 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 (Rock 1999; Hanauer 2001; Franko's Maps 2005).

SCUBA diving in the CNMI is not as widespread as diving at Guam. The majority of accessible dive sites can be found on Rota and Saipan. Divers often overlook Rota, even though the island contains what are arguably the clearest waters in all of Micronesia (Rock 1999; 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 Senhnom Cave, and the Coral Gardens. Saipan also offers divers excellent dive locations, although access to prime dive locations can be difficult (Hanauer 2001). Popular dive sites on Saipan include the Grotto, the Bomber Wreck (B-29), and Banzai Cliff. 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).

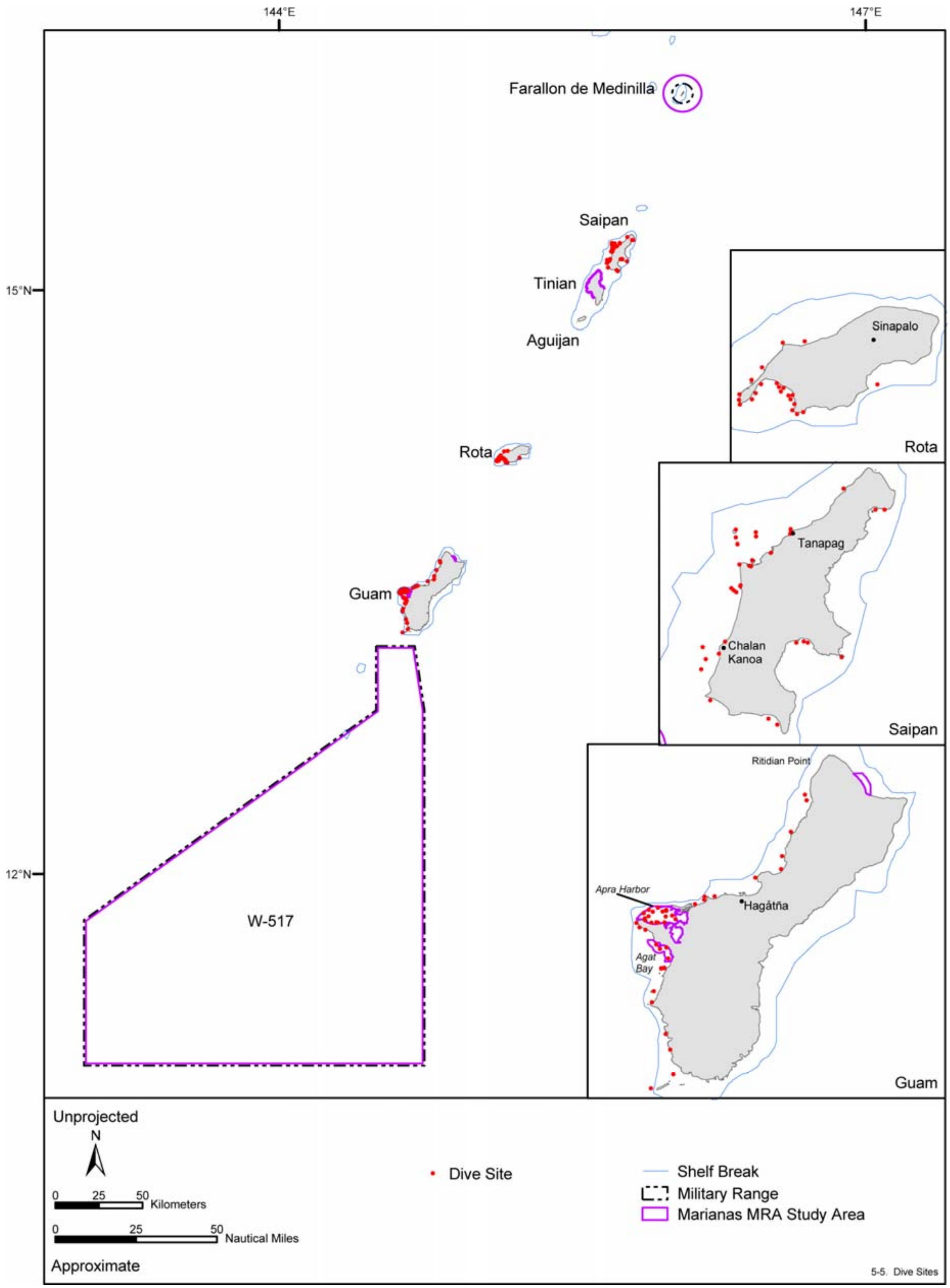

Figure 5-5. Locations of SCUBA diving sites in the Marianas MRA study area and vicinity. Source data: Commonwealth of the Northern Marianas Coastal Resources Management Office (2003) and Michael (2004). Source maps (scanned): DoD (1999), Rock (1999), and Hanauer (2001).

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6.0 RECOMMENDATIONS

The following recommendations are designed to acquire more information to address substantial data gaps and improve our understanding of the marine resources in the waters off of Guam and the CNMI, especially those resources potentially affected by Navy operations. Each recommendation is assigned a priority value of 1, 2, or 3; 1 is the highest priority while 3 is the lowest. The priority designations are relative to each other and in no way refer to a project's overall value. The relative cost of each recommendation is labeled low, moderate, or high. Low-cost recommendations may be completed at a cost of several hundred to a few thousand dollars. Moderate cost projects could range from thousands to tens of thousands of dollars, while high-cost research initiatives range from tens of thousands to more than one hundred thousand dollars.

The recommendations are grouped into those related to the production and evaluation of the MRA and those needed to adequately complete environmental documentation for the study area of the Marianas MRA.

6.1 MARINE RESOURCE ASSESSMENTS

- Revise the Marianas MRA every two to four years. The MRA would need a full revision of the text, data, GIS maps, and other informational components so that newly available datasets and published literature can be incorporated. The Navy needs the best (i.e., most recent, most complete, and most accurate) available information to evaluate future actions and consider adjustments to training exercises or operations in order to mitigate any potential impacts to protected marine resources. Periodic updates would be of moderate cost relative to the initial MRA. Cost: High. Priority: 1.

- Subject the Marianas MRA to peer review. Peer review by regulatory agencies (e.g., NOAA Fisheries and USFWS), the general scientific community, and potential government users (e.g., MMS and Marine Corps) would increase the effectiveness of this MRA. Biologists from universities and agencies (**Table 6-1**) could evaluate the collection, synthesis, and interpretation of data (including data completeness) and provide suggestions for improvements to the MRA. Cost: Low. Priority: 1.

Table 6-1. Suggested expert reviewers for the Marianas Islands.

Name	Affiliation
Mr. George Balazs	NOAA Fisheries, Pacific Island Fisheries Science Center
Dr. Scott Eckert	Wider Caribbean Sea Turtle Conservation Network (WIDECAST) Duke University
Dr. Patricia Fryer	Hawai'i Institute of Geophysics and Planetology University of Hawai'i at Manoa,
Dr. Robert Hofman (retired)	Marine Mammal Commission, Scientific Program Director
Mr. Peter Houk	Division of Environmental Quality, Saipan
Dr. Steven Kolinski	NOAA Fisheries, Joint Institute for Marine and Atmospheric Research, Pacific Island Regional Office
Dr. Tomio Miyashita	National Research Institute of Far Sea Fisheries, Japan
Dr. Gustav Paulay	Florida Museum of Natural History, University of Florida
Dr. Randall Reeves	Private consultant; marine mammal expert
Mr. John Starmer	CNMI Coastal Resources Management Office
Mr. Michael Trianni	CNMI Division of Fish and Wildlife

- Obtain marine mammal and sea turtle datasets for the Marianas MRA study area that may not have been available for inclusion in this assessment. While all available comprehensive data have been included (**Table A-1**), acquiring the following datasets may ensure more complete data coverage:

    - CNMI marine mammal database (contact: Mr. Michael Trianni, CNMI). Data have yet to be compiled into a working database and thus data are currently unavailable.

    - Fisheries Agency of Japan surveyed waters for whales in an area including the Marianas during 1993 (contact: Dr. Tomio Miyashita, FAJ). Per a directive from Navy, we did not compile data from Japan.

    - Humpback whale sighting surveys conducted at least during 1995 and 1996 (contact: Dr. M. Yamaguchi, Ogasawara Marine Center). Per a directive from Navy, we did not compile data from Japan.

    - Aerial survey sightings of sea turtles around Guam that have been documented since 1975 (contact: Jay Gutierrez, Guam DAWR or Gerry Davis, NOAA Fisheries-PIRO). All aerial sea turtle data available from Guam were requested from the Guam DAWR. Reports received did not include specific locations (e.g., coordinates or locations plotted on maps), species identifications, or dates.

    - Sea turtle nesting records at Guam that have been collected consistently since 1990 and most reliably from 2000 to present (contact: Jay Gutierrez, Guam DAWR). All available sea turtle nesting data from Guam were requested. Reports received did not include specific locations (e.g., coordinates or locations plotted on maps), species identifications, or dates.

    - Aquatic survey sightings and nesting records of sea turtles collected at Tinian in 1995 (contact: Susan Pultz, USFWS). The initial intent was to obtain data used to prepare a report authored by Susan Pultz (Pultz et al. 1999). We were unable to locate Susan Pultz. Yet, all available sea turtle data specific to Tinian were requested from the Pacific Islands Regional Office, NOAA Fisheries (contact: Dr. William Robinson, Regional Administrator), the CNMI DFW (contact: Paul Hamilton, Director), and the Guam DAWR (contact: Trina Leberer, Acting Chief). We obtained all the sighting and nesting records of sea turtles available for Tinian from Larry Ilo and Joseph Ruak from the CNMI DFW.

    - Opportunistic marine mammal and sea turtle sightings recorded during scuba diving excursions at Guam (contact: Pete Petersen, Micronesian Divers Association). Data were requested by phone and email with no response.

    - Opportunistic sea turtle sightings recorded during the Coral Reef Ecosystem Division (CRED) cruise (NOAA ship *Oscar Elton Sette*) around Guam and the CNMI in 2003 (contact: Dr. Steven Kolinski, NOAA Fisheries-PIRO). Julie Rivers (NAVFAC, Pacific) requested these data on behalf of GMI and has yet to receive the data from NOAA Fisheries.

- Acquisition and analysis of existing data is less expensive than collecting authentic marine mammal and sea turtle survey data. The potential contribution of these datasets to our understanding of the distribution of these protected species is high. <u>Cost</u>: Moderate. <u>Priority</u>: 1.

- Update EFH identifications/descriptions/maps and HAPC as revised, redesignated, or additional amendments (i.e., Amendment 8 to the Bottomfish and Groundfish FMP, Pelagic Squid Fishery Management under FMP Pelagic Fisheries of the Western Pacific Region) and/or plans (i.e., Archipelago Fisheries Ecosystem Plans) become available from the FMCs and NOAA Fisheries. <u>Cost</u>: Low. <u>Priority</u>: 1.

- Support the development of a database containing all the Marianas MRA study area EFH data and information, which would provide user-friendly access to all the EFH data and maps. Cost: Low to Moderate. Priority: 1.

- Support the development of a custom GIS-based application designed to provide functionally to the use of EFH data and use the EFH database proposed in the above recommendation as its base. This custom, stand-alone application would not require the purchase of any additional software or hardware and would allow for easy use of the EFH data in many different environments. Cost: Moderate. Priority: 2.

- Update the map and information relevant to MMAs (**Figure 5-4**). When this MRA report was prepared, the criteria for MPA designation were in development by the National Marine Protected Area Center, with 2005 as the estimated time of completion. The MMA Inventory was also in development as this MRA report was being prepared, with only the federal sites having been included in the MMA Inventory List; the state/territory, local, and tribal locations had not yet been incorporated. The MPA criteria will be applied to the sites in the MMA Inventory list and a list of MPA sites will be developed sometime after 2005. Cost: Low. Priority: 1.

6.2 ENVIRONMENTAL DOCUMENTATION

- Develop an integrated network capable of tracking current patterns in the Marianas MRA study area. Currently, little is known regarding the general ocean circulation patterns surrounding the Mariana Islands. It is also unknown how the island chain is capable of locally modified large-scale circulation patterns. Studies conducted on other island chains (e.g., Hawai'i) have recognized the ability of seamounts and isolated islands to alter the local currents. Current patterns in the region should be of high priority to the Navy for use in both general navigation and training missions. Investigation into large and small-scale current patterns in the Marianas MRA study area can be accomplished via several different methodologies. One method would involve the deployment of *in situ* oceanographic buoys in the waters encompassing the study area. It may also be possible to retrofit FADs in the region to monitor oceanographic and meteorological conditions. An alternative method would be to construct and operate Coastal Ocean Dynamics Radars (CODAR) along the shoreline to detect the velocity and direction of offshore waves. Either method would allow for the construction of long-term data sets for the region and improve the general knowledge of oceanographic processes in the region. Cost: High. Priority: 1.

- Use Navy ships as platforms-of-opportunity for the collection of marine mammal and sea turtle sighting data. Scientific survey vessels are few in number and their deployments may not correspond to regions of historically low survey effort within the Marianas MRA study area. Having experienced marine animal observers onboard Navy ships within the Marianas MRA study area could greatly add to our knowledge of the diversity and distribution of marine mammals and sea turtles in the western Pacific Ocean. Cost: Low. Priority: 1.

- Conduct aerial and shipboard (including acoustic) marine mammal surveys and expand aerial sea turtle survey coverage to in-water distribution. Aerial surveys are essentially non-existent except for Navy monitoring and USFWS surveys. There are no NOAA Fisheries shipboard surveys for marine mammals in this area, although Japanese sighting cruises have extended into this region. Understanding the spatial and temporal occurrence of protected species within the Marianas MRA study area would allow Navy planners to schedule operations in such a way as to avoid or minimize potential impacts. Acoustic surveys are particularly useful for vocal species, such as humpback and sperm whales. Sperm whales are deep divers and spend little time at the water's surface; therefore, they are often missed during visual sighting surveys. Aerial surveys flown at the same time a ship survey is underway may provide additional estimates of group sizes and expand the range of the vessel survey and verify both acoustic and visual detections of whales. Cost: High. Priority: 1.

- For the Marianas MRA study area, the advantages of using aerial surveys over boat or ship-based surveys are that aircraft can be used to cover a larger area more quickly; are able to survey regions such as coral reef and shoal areas that are common in Micronesia, but are shallow and hazardous to boats; and are able to wait out poor weather periods at a lower cost. Results of aerial surveys could be used to delineate areas where marine mammals and sea turtles concentrate and where intensive ship surveys, which include both visual and acoustic sampling, could be more efficiently conducted. Aerial surveys are expensive (thousands of dollars per day), but less so than shipboard surveys. Cost: Medium to High. Priority: 1.

- Continue to support aerial surveys over beaches where sea turtles are known to nest by focusing on specific locations and obtaining data from which population-level extrapolations can be made. Cost: Medium. Priority: 2.

- Conduct aerial surveys designed specifically to spot endangered sea turtles in the water in their foraging habitats. Index studies, in which specific locations are sampled repetitively in a systematic fashion over a long period of time, provide statistically robust data from which population-level extrapolations can be made. Important population-scale questions can only be answered by rigorous studies of index foraging habitats. The data collected would provide important information on hotspots utilized by sea turtles while at sea. Cost: Medium. Priority: 2.

- Establish year-round acoustic monitoring (via sonobuoys or hydrophone arrays) of key locations in this area to provide presence and absence information for specific cetacean species (i.e., humpback whale, fin whale, sperm whale) that could serve as an index of their seasonal arrival, residence, and departure from this region. Such acoustic monitoring could be conducted from small vessels, from bottom-mounted recorders or hydrophone arrays cabled to shore, or some combination of acoustic monitoring methods. CRED is developing subsurface acoustic monitoring platforms to collect year-round data (Parke personal communication). Cost: Medium to High. Priority: 2.

- Support the CNMI and NOAA Fisheries-PIFSC for any of their efforts to collect and analyze stranded marine mammal and sea turtle data in the Marianas MRA study area. Published stranding data was heavily utilized in this MRA to aid in determination of species diversity and occurrence here. Cost: Low. Priority: 2.

- Attempt to capture and tag sea turtles during future marine tow, snorkel, and SCUBA surveys in order to collect more accurate biological data. Employ biological sampling techniques (e.g., length and weight measurements, biopsy sampling) to determine the age, sex, health, and genetic make-up of sea turtles found in the area. This information can assist scientists in determining the age at which juveniles recruit to and leave the Marianas archipelago, the nesting stocks that contribute to foraging populations in the area, and the overall health status of resident sea turtles. Research efforts should focus on high-use habitats (e.g., backwaters of Apra Harbor, east coast of Tinian) to maximize time and resource utilization. Cost: Low to Moderate. Priority: 2.

- Recommend to the CNMI an improved data collection system for developing longline fishery (CNMI). Cost: Moderate. Priority: 2.

- Recommend that fishery data collection be extended to previously non-surveyed points (e.g., ports) in order to obtain more accurate landings data (Guam). Cost: Low to Moderate. Priority: 2.

- Recommend to the CNMI government to develop new legislation requiring fish vendors to participate in the “Commercial Fish Receipt Book Program” (Guam). Cost: Low to Moderate. Priority: 2.

- Assess the best way to obtain data necessary for fishery management (creel surveys, community development programs, commercial purchase systems, or other types of data collection systems), while considering the local social, political, legal, and economic constraints within the region (CNMI). Cost: Low to Moderate. Priority: 2.

- Support a baseline biological survey of the redgill emperor, *Lethrinus rubrioperculatus*. Cost: Low. Priority: 2.

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8.0 GLOSSARY

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

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

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

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

Algae—one-celled or many-celled plants that have no roots, stems or leaf systems

Allochthonous—material that has originated elsewhere, non-native

Alpha male—the dominant male

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

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)

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

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

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

Biogenic—originating from living organisms

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

Brackish—having a salinity between that of fresh and sea water

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

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

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

Cape—a darker region on the back of many species of dolphins and small whales, generally with a distinct margin

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

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

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

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

Circumglobal—the distribution pattern displayed by organisms around the world, within a range of latitudes

Circumtropical—organisms which occur around the tropics of the world (land or sea)

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

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)

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

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

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

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 boomies—coral outcroppings

Coral patches—rocky outcrops colonized by sessile organisms including hard coral, soft corals, hydroids, algae, and sponges

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

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

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

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

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

Cyclonic—counterclockwise circulation in the Northern Hemisphere or clockwise in the Southern Hemisphere; in oceanography, synonymous with cold-core ring

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

Deepwater—the area of the ocean that is past the continental shelf break, deeper than 100 to 200 m of water

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

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

Density—physical property measured by mass per unit volume; in biology, the number of organisms per unit of distance

Dermochelyidae—the family of sea turtles that includes only one species, the leatherback turtle

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)

Diatom—phytoplankton member of the class Bacillariophycea; posses a wall of overlapping silica valves

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

Dioecious—pertaining to an organism in which male and female reproductive systems are in different individuals

Display—any behavior that conveys information, usually to members of the same species or to predators; often used during mating or territory defense

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)

Diurnal—active or occurring during daylight hours; having a daily cycle

Dorsal—relating to the upper surface of an animal

Dredge spoils—materials dredged out of an area

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

Echolocation—the production of high-frequency sound waves and reception of echoes to locate objects and investigate the surrounding environment

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

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

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

Encrusting—form a crust or a hard layer

Endangered species—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

Endemic—occurring in a specific area

Endolithic—living inside rock

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

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

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

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

Euryhaline—an organism that can tolerate living in waters with a wide range of salinity

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

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

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

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

Fjord—a deep, steep-walled, U-shaped valley formed by erosion by a glacier and submerged with seawater

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)

Flank—side of the body; used mainly to refer to the side of the posterior half of the body

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

Gametes—mature egg or sperm, capable of reproduction after fertilization with sperm or egg from same species

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

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

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)

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

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

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

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

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

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

Ichthyofauna—all fish that live in a particular area

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

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

Intertidal—the area of shore exposed between high and low tide

Irruptive—entering an area where not characteristically seen

Isobath—bathymetric contour of equal depth; usually shown as a line linking points of the same depth

Isotherm—contour of equal temperature; usually shown as a line linking points of the same temperature

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)

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*)

Kuroshio—the fast-flowing western boundary current of the North Pacific subtropical gyre

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

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

Larval—young fish between time of hatching and attainment of juvenile characteristics

Lee—the side (as of a ship) that is sheltered from the wind

Leptocephalic—small, elongate, transparent, planktonic larva of eel

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

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 occurrence—an area where the likelihood of encountering a species is rare or not known

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

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 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

Masking—obscuring of sounds of interest by interfering sounds, generally at similar frequencies

Mean—(arithmetic) average

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

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

Monospecific—genus with only one species

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

Mysticeti—suborder of cetaceans comprised of the baleen whales

Nanoplankton—plankton less than 50 m in length that cannot be captured in a plankton net and must be removed from water by centrifuge or special microfilters

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

Nearshore—an indefinite zone that extends seaward from the shoreline

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

Not 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

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

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

Omnivore—an animal that feeds on both plant and animal tissue

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

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 rock. Live cover 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

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 plankton, which are the base of the food chain on which ultimately most shellfish, fish, birds, and marine mammals depend

Picoplankton—small plankton within the size ranging 0.2 to 2.0 m 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

Plankton—organisms that drift in the water column or on the water's surface, with no means of propelling or moving themselves

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

Point—single x, y coordinate pair that represents a single geographic feature (e.g., sea turtle sighting)

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

Precision—number of significant digits used to store coordinate values; imperative for accurate feature representation, analysis, and mapping

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

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

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"

Radiolarian—planktonic or benthic protozoan that possesses protective coverings usually made of silica

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 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 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

Relief—the inequalities (elevations and depressions) of the sea bottom

Remigration interval—the amount of time between successive sea turtle nesting seasons

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

Saddle—a light-colored patch behind the dorsal fin of some cetaceans

Salinity—the concentration of salt in water, measured in practical salinity units (psu)

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

Sargassum—a genus of brown algae commonly found in temperate and tropical waters

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

Scutes—long, thickened scales that cover underlying bony plates of carapace and plastron of sea turtles that are used for protection

Sea anemones—large, heavy, complex polyps that belong to the cnidarian class Anthozoa

Sea surface temperatures (SST)—the temperature of the layer of seawater (approximately 0.5 m deep) nearest the atmosphere

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

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

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 (continental)—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

Silicate compensation depth—depth at which almost all silica dissolves, approximately 8,000 m

Siliceous—composed of silica

Sirenia—the order of marine mammals that consists of manatees and the dugong

Site fidelity—the tendency to return to the same site repeatedly

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

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

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

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

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

Subadult—maturing individuals that are not yet sexually mature

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

Subnertitic zone—the benthic environment extending from the shoreline across the continental shelf to the shelf break

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

Surge—long wave, which is longer than wind wave, but shorted than tidal wave

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

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)

Territory—an area occupied exclusively by one animal and defended by aggressive behavior or displays

Thalli—plural of thallus; the vegetative body of algae

Thalliod—having no roots, stems, or leaves

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—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

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

Transverse fission—asexual reproduction of two genetically similar individuals

Triangular irregular networks (TINs)—surface representation developed from sample points and breakline features; a TIN dataset contains topological relationships between points and their neighboring triangles where each sample point has an x and y coordinate and a z value; these points are connected by edges, which make up a set of non-overlapping triangles that represent the surface; a TIN is also referred to as an irregular triangular mesh or an irregular triangular surface model

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

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

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

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

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

Viviparous—type of development in which the young are born alive after having been nourished in the uterus by blood from the placenta

Water mass—a body of water that can be identified by a specific temperature or salinity

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

Whistle—a narrow band frequency sound produced by some toothed whales and used for communication; they typically have energy below 20 kHz

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

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APPENDIX A: INTRODUCTION

TABLE OF CONTENTS

APPENDIX A

LIST OF TABLES

Appendix A-1. Data confidence and Marianas MRA study area geographic information system (GIS) maps.

The level of data confidence is dependent upon three factors: precision, accuracy, and currency. Each of these three factors are in turn affected by all the variables involved in obtaining data and putting the data into a GIS in order to display the data on a map. Following is a brief description of the three main factors and some of the subsequent variables that figure into overall level of confidence.

- ***Precision***—Refers to whether or not the description of the data is specific or non-specific. It is possible to have data recorded very precisely but with very low accuracy. In other words, we may say that 2 + 2 = 5.12546732, where the sum is given very precisely but inaccurately. GPS (global positioning systems) offer the highest level of precision for recording locations.

- ***Accuracy***—Refers to how well the data reflect reality. There may be 10 sightings of bottlenose dolphins in an area, but they may actually have been common dolphins. Even if the locations were precisely recorded, the data are still not accurate. Some variables that affect accuracy are who originally recorded the data (source reliability), how many people have processed/altered the data since it originated (number of iterations), and the methods used to record the data.

- ***Currency***—Refers to how recently the data were obtained. Because recent developments in equipment and methods have improved precision and accuracy, confidence is higher for data that have been recorded more recently.

Marianas MRA Map Examples	Description of Map Data	Confidence Level
Marine mammal and sea turtle occurrence maps, bathymetry, benthic habitats, chlorophyll, sea surface temperature, maritime boundaries, and marine managed areas	Data from original/reliable sources. Provided in a digital format with geographic coordinates given. Identified as "*source data*" in map captions.	**High** 49 maps (62% of total number of maps)
Dive sites and surface circulation	First- or second-hand data sources. Locations obtained through scanning geo-referenced* maps. Identified as "*source map(s) scanned*" in map captions.	**Medium** 4 maps (5% of total number of maps)
Migration maps and EFH	First- or second-hand data sources. Locations obtained by digitizing from written descriptions with no coordinate data or by altering and/or interpreting raw data. Identified respectively as "*source information*" or "*map adapted from*" in map captions.	**Low** 25 maps (33% of total number of maps)

* Geo-referenced–Refers to data, maps, and images with points that can be matched to real world coordinates so that the data can be accurately positioned in a GIS.

Appendix A-2. Map projections.

Since understanding the role map projections play in the creation of valid and usable maps is so critical, further explanation of this issue is provided. A geographic reference system (such as latitude and longitude) is based on the angles measured from the earth's center. A planar coordinate system, on the other hand, is based on measurements on the surface of the earth. To meaningfully transfer real world coordinates (in three dimensions) to planar coordinate (two dimensions), a transformation process has to be applied. This transformation process is called a projection. Such a transformation involves the distortion of one or more of the following elements: shape, area, distance, and/or direction. The user typically dictates the choice of a projection type to ensure the least distortion to one or more of the four elements. Choice of a particular projection is dictated by issues such as the location of the place on Earth, purpose of the project, user constraints, and others.

The length of one degree of longitude will vary depending on what latitude on Earth the measurement is taken. The geographic coordinate system measures the angles of longitude from the center of the Earth and not distance on the Earth's surface. One degree of longitude at the equator measures 111 km versus 0 km at the poles. Using a map projection mitigates this difference or seeming distortion when using geographic coordinates. However, when multiple data sources with multiple projection systems are used, the most flexible system to standardize the disparate data is to keep all data unprojected. Thus, the maps in this MRA are untransformed, meaning they are shown unprojected on the map figures and their associated geographic data are delivered unprojected.

Since the measurement units for unprojected, geographic coordinates are not associated with a standard length, they cannot be used as an accurate measure of distance. Since the maps in the MRA report are in geographic coordinates, the map figures should not be used for measurement and the scale information only provides approximate distances. The map scales and reference datum used on all maps in this MRA are presented in nautical miles.

Appendix A-3. Overview of research efforts that provide occurrence information for marine mammals and sea turtles in the Marianas MRA study area.

There have been few systematic efforts (i.e., aerial and boat-based surveys) to document marine mammal and sea turtle occurrence around Guam and the CNMI. To determine seasonal or year-round occurrence patterns, attempts were made to compile all available sighting, stranding, incidental fisheries bycatch, tagging/marking, and nesting records for marine mammals and sea turtles in the study area. The following is intended to be a comprehensive review of the various research efforts conducted and/or sponsored by federal and territory/commonwealth agencies and other individuals/groups directed to the protected marine mammal and sea turtle species in the study area and vicinity. For a variety of reasons, it was not always possible to obtain every data source; only a subset of the available occurrence data for this region is included in this MRA (**Table A-1**).

Protected species data sources included in this MRA

Sea Turtle Assessments

The CNMI DFW, in association with the NMFS, has performed nearshore assessments of sea turtles and their habitats at three of the main islands of the CNMI: Saipan, Tinian, and Aguijan. The assessment at Saipan was conducted from 15 to 29 August 1999, while the assessment at Tinian and Aguijan was conducted from 12 to 21 March 2001. These assessments included both terrestrial and aquatic surveys. At Saipan, surveys included infrequent surveys of beaches for nesting activity; marine tow, snorkel, and shoreline surveys to record visual observations of sea turtles; a tag and release component; and sampling of algae and seagrass species along established transects to identify potential green turtle forage. The survey methodologies at Tinian and Aguijan were similar, but did not include surveys of nesting beaches or tag and release efforts. In-water sighting data (including geographic coordinates, dates, and species identifications) from these assessments are available from the following technical reports: Kolinski et al. (1999) and Kolinski (2001).

In 2001, the CNMI DFW also performed a sea turtle assessment at Rota (Seman 2002); however, data from those surveys were not available for inclusion in this report. The technical report for this assessment, which was prepared for the CNMI DFW, possibly contains geographic coordinates and dates for each of the recorded sea turtle sightings at Rota. This report is currently being requested from Dr. Steven Kolinski, NMFS-Pacific Islands Regional Office (PIRO).

Marine and Fisheries Resource Assessments

In 1995, the CNMI DFW and the U.S. Navy agreed to perform biological surveys at FDM, which included a marine survey (DoN 2004). An initial survey took place from 8 to 10 July 1997. It was later agreed that annual marine surveys would be undertaken to determine if military training activities (e.g., bombing) were causing significant impacts to the nearshore marine environment, including the fringing coral reef community. A partnership for accomplishing the surveys was established among the Navy, NMFS, USFWS, and CNMI DFW. The first set of surveys were conducted from 11 to 16 July 1999, the second from 8 to 13 July 2000, the third from 8 to 13 July 2001, the fourth from 21 to 25 October 2002, the fifth from 9 to 13 July 2003, and the most recent from 12 to 15 July 2004 (DoN 2005). These surveys included low-altitude helicopter reconnaissance as well as in-water marine tow, snorkel, and scuba surveys around the entire perimeter of the island. No threatened or endangered marine mammals were sighted during the 1997 or any of the annual 1999 through 2004 surveys (DoN 2005). Schools of spinner dolphins, which are neither threatened nor endangered, were sighted twice during the 1999 survey and once during the 2001 survey; Trianni and Kessler (2002) provided details of the sightings. Green turtles have been sighted during each annual survey at FDM, while hawksbill turtles were only sighted during the 2001 and 2004 surveys (DoN2005). The estimated sighting locations recorded during these marine surveys were available from the following reports: Trianni (1998, 1999) and DoN (2001, 2003, 2004, 2005).

Table A-1. Inventory of the marine mammal and sea turtle data sources included in the marine resources assessment for the Marianas MRA study area.

DATA SOURCE	RECORD DATES
Sea Turtle Assessments	
Saipan – Kolinski et al. (1999)	1999
Tinian and Aguijan – Kolinski (2001)	2001
Marine and Fisheries Resource Assessments	
Farallon de Medinilla – Trianni (1998, 1999) and DoN (2001, 2003, 2004, 2005)	1997, 1999-2004
Opportunistic Sighting Programs	
NMFS Platforms of Opportunity Program (POP) Database	1993-1997
Mark Michael – marine mammal and sea turtle sightings during dive excursions	1999-2004
DoN and Curt Kessler – marine mammal sightings during helicopter flights	2002-2004
Published Literature – Marine Mammal Sighting and Stranding Records	
Anonymous	1962
Anonymous	1974
Berggren	1996
Birkeland	1977
Bordallo	1965
Darling and Mori	1993
Davis	1978
Donaldson	1983
Eldredge	1991
Eldredge	2003
Kami and Hosmer	1982
Kami and Lujan	1976
Masaki	1972
Miyazaki and Wada	1978
Randall et al.	1975
Schulz	1980
Taitano	1991
Trianni and Kessler	2002
Wilson et al.	1987
Worth	2003

Opportunistic Sighting Programs

- The National Marine Mammal Laboratory's (NMML) **Platforms of Opportunity Program (POP)** collects data on opportunistic sightings of marine mammals throughout the world (particularly in the North Pacific Ocean). These data are used to plan surveys to examine the distribution and abundance of marine mammal species and to document habitat use in order to minimize the affects of human-caused disturbances (NMML 2004). POP sighting data are opportunistically collected aboard NOAA, Navy, and USCG vessels as well as aboard commercial fishing and tourist boats. While at sea, observers are stationed on the ship's bridge and asked to record marine mammal sightings. However, observer effort is entirely dependent upon the observer's level of interest and their workload. Detailed biological data such as sex or size of the animal is never collected, yet observers are encouraged to describe the animal by narrative or sketch. Afterwards, the quality of the sighting is then graded at the NMML in Seattle, Washington. The NMML will assign a species identification as either "sure," "likely," "unsure" or "not possible." POP sighting data used in this MRA were provided by Dr. Sally Mizroch and only represent confirmed (i.e., "sure") sightings. From 1993 to 1997, there were three confirmed POP sightings of marine mammals in the Marianas MRA study area: a Bryde's whale, a killer whale, and a sperm whale. All three sightings were collected from USCG vessels.

- **Mr. Mark Michael**, owner of Dive Rota, has recorded opportunistic sightings of marine mammals and sea turtles during SCUBA diving excursions at Rota from 1999 through 2004. These records, which include protected species encounters at 17 different dive sites, were provided for inclusion in this report. Although Mr. Michael is not a trained scientist, he is an experienced SCUBA diver with nearly 20 years of experience in the Marianas region. For several of the sighting records provided, species identifications and group sizes were unable to be determined. However, geographic coordinates for each of the dive sites where marine mammals and sea turtles had been observed were provided.

- **Mr. Scott Vogt**, biologist with the Naval Facilities Engineering Command, Pacific, and **Mr. Curt Kessler**, wildlife biologist with the USFWS, provided a number of opportunistic marine mammal sighting records that were collected during helicopter overflights of the study area. Several incidental sightings were recorded during monthly seabird surveys performed by USFWS and Navy personnel over FDM. Other opportunistic sightings were documented during helicopter transit flights between Saipan, Sarigan, and Anatahan. A land-based observation of a pod of spinner dolphins was also provided. Nearly all of these sightings were documented as occurring at an estimated geographic position (e.g., about 500 m northeast from Sarigan, CNMI) rather than at a specific set of latitude/longitude coordinates.

Published Literature—Marine Mammal Sighting and Stranding Records

Published literature (e.g., journal articles, technical reports, and press releases) is often the most useful media for presenting opportunistic sightings, strandings, and even whaling catches. For several of the marine mammal species presented in this assessment, the sighting and stranding records or anecdotal information contained within the following documents were the only sources of information available on their occurrence patterns in the study area and vicinity. Since there have been no dedicated surveys focusing on this group of animals around Guam and the CNMI, there is very little information available regarding their occurrence in this area of the western North Pacific Ocean.

- **Anonymous (1962)** described the stranding of a sperm whale off the coast of Inarajan, Guam in September 1962 and provided a summary of other whale stranding events around Guam and Saipan in years prior. **Bordallo (1965)** also mentioned this stranding in an article written about cetacean intelligence and affection.

- **Anonymous (1974) and Randall et al. (1975)** documented the sighting of an endangered dugong in the center of Cocos Lagoon, Guam on 16 February 1974. This sighting was recorded during a marine survey in which scientists attempted to determine the physiography, marine biota, and, to a lesser extent, water circulation patterns within the lagoon.

- **Berggren (1996)** detailed the opportunistic sighting of what appeared to be a group of humpback whales in ocean waters off the entrance to Apra Harbor, Guam in January 1996. Recreational scuba divers sighted this group of a dozen or more whales while aboard a charter boat.

- **Birkeland (1977)** recounted his observation of a group of pilot whales moving northward off Uruno Point, Guam in April 1977. Also commented on was a small school of unidentified dolphins that was regularly seen at Double Reef (off Guam's northwest coast) during the 1970s.

- **Darling and Mori (1993)** took a trip to Saipan in February 1990, during which they interviewed residents and listened for humpback whale songs. The authors concluded that humpback whales were not regularly seen around the Northern Mariana Islands.

- **Davis (1978)** recounted the stranding of an unidentified baleen whale at Agaga Beach, Guam in August 1978. Agaga Beach is located in southwestern Guam between Facpi Point and Umatac. Two Umatac fishermen discovered the beached whale.

- In 1995, the United Nations Environment Programme (UNEP) developed a project to develop a global plan of action to protect the marine environment (which includes marine mammals) from land-based activities. In conjunction with this plan, regional studies are carried out to investigate the status of marine mammals. The Pacific Regional Environment Programme, formerly known as the South Pacific Regional Environment Program (SPREP), serves the region of Guam and the CNMI. Eldredge (1989) provided the first compilation of published and unpublished records for marine mammals occurring in Micronesia. Information on 18 species of marine mammals was documented in this report and made more publicly available as a peer-reviewed publication by **Eldredge (1991)**. **Donaldson (1983)**, **Kami and Hosmer (1982)**, **Kami and Lujan (1976)**, **Trianni and Kessler (2002)**, and **Eldredge (2003)** have published additional records.

- In 1949, Japanese agencies involved in the management of whaling began a research program of whale marking (or tagging) in the North Pacific Ocean (Omura and Kawakami 1956; Ohsumi and Masaki 1975). Many thousands of whales from several different species were marked. Marks were shot into whales' bodies from a shotgun and were recovered when the whales were killed and cut-up or flensed. The data on the marks were then used to obtain information on the movements of the animals (Omura and Kawakami 1956). Until 1972, the number of whales marked in low-latitude areas was very small (Ohsumi and Masaki 1975).

  Masaki (1972) described a comprehensive marking program for whales in the waters surrounding the Ogasawara and Mariana Islands, which lasted a span of 32 days from 16 January to 16 February 1972. During this period, 19 of 50 sperm whales and all of 36 "sei whales" sighted north of the Mariana Islands (20° to 25°N) were marked. In the area immediately surrounding the Mariana Islands (10° to 20°N), 13 "sei whales" were sighted and 8 were tagged. South of the Mariana Islands (5° to 10°N), two Bryde's whales were sighted and both were marked.

  Miyazaki and Wada (1978) presented a synthesis of biological data collected during a whale sighting and marking cruise in the western tropical Pacific Ocean from 20 January to 19 March 1976. The tracklines for this cruise, which began in Japan and went as far south as the Solomon Islands (east of Papua New Guinea), passed along both sides of the Marianas archipelago. Geographic coordinates, dates, and species identifications for each cetacean sighting/marking were provided in the report.

- **Schulz (1980)** chronicled the stranding of a pilot whale on a reef at Ipan, Guam on 6 July 1980. A Guam resident saw the whale struggling in the shallow waters over the reef and attempted to push it off the reef. However, the man was unsuccessful and later shot the whale to put it out of its misery. Also mentioned in this newspaper article were hypotheses as to why pilot whales most often strand.

- **Taitano (1991)** reported on the sighting of a group of three unidentified whales outside the reef at Alupang Cove, Guam on 12 February 1991. The whales, which were believed to be either pilot or humpback whales, were first observed by a group of children and were later seen up close by a pair of charter boat captains and a beach club manager.

- **Wilson et al. (1987)** is a summary of worldwide occurrence records for striped dolphins. The data sets presented are currently housed at the NMFS-Southwest Fisheries Science Center (SWFSC) in La Jolla, California. Included in this report are a few sighting records from the waters around Guam and the CNMI.

- **Worth (2003)** described the recent stranding of a pilot whale on Guam in August 2003. The individual washed ashore at Inarajan and was later dragged offshore (by boat) by technicians from the Guam Division of Aquatic and Wildlife Resources (DAWR). Within the article, the director of the Guam DAWR stated that pilot whales commonly beach themselves because they are injured by boats.

Protected species data sources not represented or available for use in this MRA

- Marine mammal stranding networks are under the jurisdiction of the NMFS and are nominally based on its distinct administrative regions (Geraci and Lounsbury 1993). Wilkinson and Worthy (1999) discuss the genesis of marine mammal stranding networks in the U.S. Legal authority for stranding networks is contained in the MMPA. In the Marine Mammal Health and Stranding Response Act (in the 1992 Amendments to the MMPA), Congress made it a national policy to monitor the various factors affecting the health of marine mammal populations. Collection and analyses of stranded marine mammals have contributed much to what is known about each species (Becker et al. 1994). The NMFS assumes regional coordination over marine mammal strandings in the U.S. Pacific Islands (Hawai'i, American Samoa, Guam, and the CNMI). Stranding data for the Marianas MRA study area were received from Mr. Bradley Ryon of the NMFS-PIRO as part of a stranding data package for the Hawaiian Islands MRA. However, none of these data were used in this MRA as all the stranding records received were already available from the scientific literature. In fact, there were more stranding records available from the scientific literature than the NMFS-PIRO was able to provide. Since marine mammal strandings in the U.S. Pacific Islands are often responded to on a case-by-case basis, oftentimes by a local marine resource or wildlife authority in consultation with the NMFS (Nitta 1991), stranding data were also requested from the CNMI DFW. The CNMI DFW documents marine mammal strandings in its area of jurisdiction, yet no data were received from this agency.

- The North Pacific Right Whale Database is a review of all available twentieth century records of this species in the North Pacific Ocean. There have been a total of 1,965 recorded sightings since 1900; of these 988 came from the western North Pacific, 693 from the eastern North Pacific, and 284 had no location specified. Thirteen strandings (all but one from the western North Pacific) were recorded. Known catches for commercial or scientific purposes totaled 742 (331 in the western North Pacific, 411 in the eastern North Pacific). Overall, the data support the hypothesis that at least two stocks of right whales exist in the North Pacific (Brownell et al 2001). This database was provided by Ms. Caroline Good (Duke University) with the permission of Dr. Phillip Clapham (NMFS-Northeast Fisheries Science Center [NEFSC]); however, none of the records in this database were documented in the Marianas MRA study area and vicinity.

- Humpback whale research (e.g., photo-identification) in the western North Pacific Ocean is coordinated by the Ogasawara Marine Center. Yamaguchi et al. (2002) mentioned that sighting surveys were conducted in the water of the Mariana Islands in 1995 and 1996. Records from these surveys, which are likely available from Manami Yamaguchi, were not requested for use in this MRA.

- The Fisheries Agency of Japan has conducted systematic whale sighting surveys in the western North Pacific since 1983. During the winter of 1994, *Kanki-maru No. 38* surveyed the area from 7° to 25°N and 123° to 150°E, which is in the near vicinity of the Marianas archipelago (Miyashita et al. 1996), but outside of the map view for the Marianas MRA study area.

- Mr. Bob Odell, owner of Blue Ocean Visions, collected marine mammal sighting information for Guam from 1995 through 2001. While his information was useful for determining spinner dolphin occurrence around Guam, neither geographic locations (e.g., coordinates or good physical descriptions) nor dates could be provided. As a result, these data were not included in the maps in **Appendix B**.

- The CNMI DFW has a marine mammal sighting database, with a special interest in humpback whales (CNMI DFW 2004). Data were requested from Mr. Michael Trianni, Fisheries Research Supervisor, but were not received for inclusion in this MRA.

- In 2003, scientists with the NOAA and other research institutions conducted the Marianas Archipelago Reef Assessment and Monitoring Program (MARAMP) cruise aboard the NOAA Ship *Oscar Elton Sette* (cruise OES-03-07). The purpose of this cruise was to assess and map the coral reef ecosystems of the Marianas archipelago. During Leg I (22 August to September 21), work was conducted around thirteen islands and four to five shallow banks of the CNMI. During Leg II (23 to 29 September), work was conducted around the Guam and three of its shallow banks. Opportunistic sighting data for marine mammals were received from Ms. Stephani Holzwarth (NOAA), but were located outside of the study area map view. Dr. Steven Kolinski (NMFS-PIRO) has been asked to provide any opportunistic sighting data for sea turtles collected during this cruise in the hopes that records can be included in a future version of the MRA.

- Aerial surveys for sea turtles have been conducted around Guam since the mid-1970s. Between 1975 and 1979, the entire coastline of Guam, except for areas within Apra Harbor, was surveyed on a monthly basis (Pritchard 1995). The next known sets of aerial surveys began in 1989 and have continued on a yearly basis until the present (Davis n.d.; Cummings 2002). These data were not available for inclusion in this MRA. It is not known whether the sightings from these surveys are available in coordinate (latitude/longitude) form or whether they are simply counts of sea turtles by survey region or transect.

- Mr. Scott Vogt, Navy Pacific Division, provided sea turtle counts from monthly surveys at FDM (sightings) and Tinian (nestings) between 1997 and 2004.His documentation of nesting beaches was used to develop turtle nesting maps shown in Chapter 3.2. Mr. Scott Vogt also provided a synopsis of marine mammal sightings during his surveys over FDM including Vogt (2004).

- Mr. Joseph Ruak, CNMI DFW, provided sea turtle nesting records for Saipan between 1997 and 2003. However, the data were not in the preferred format and were only received recently. Thus, they could not be included in the MRA at this time. It is hoped that this data can be included in a future version of the MRA, but much work would need to be done to match up the nesting records with the actual beaches on which they occurred. Sea turtle nesting records by beach name have a much lower level of accuracy than nesting records presented by geographic (latitude/longitude) coordinates.

- Mr. Jay Gutierrez, Guam DAWR, is the project leader of the Guam Sea Turtle Recovery Program. Nesting data for the island of Guam were requested, but not received. Mr. Gutierrez did, however, provide a copy of the latest annual progress report which describes the nest monitoring program at Guam and the eight stretches of beach that are regularly surveyed for sea turtle nesting activity.

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APPENDIX B: MARINE MAMMALS

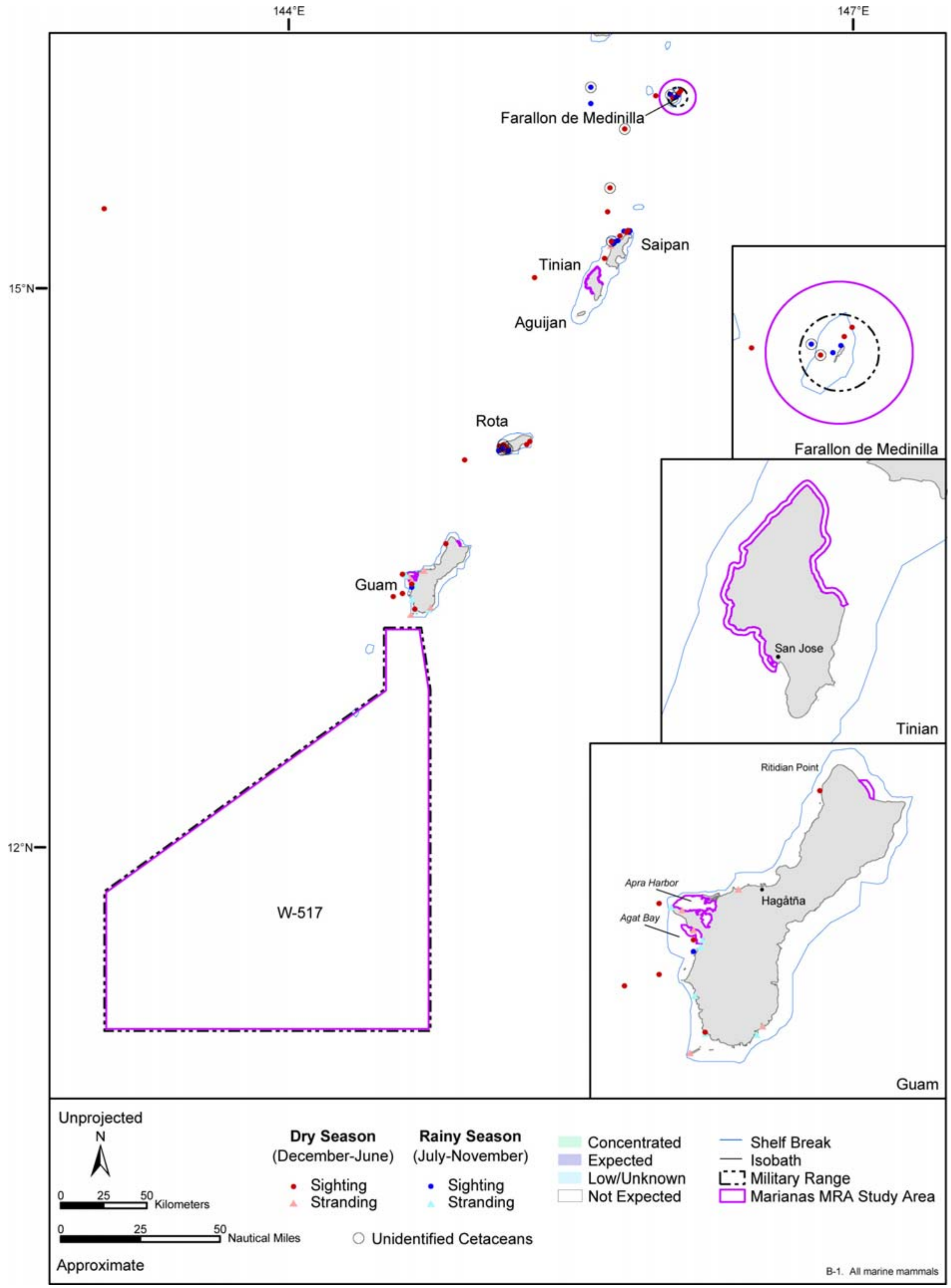

Figure B-1. Occurrence of all marine mammals in the Marianas MRA study area and vicinity. Available sighting and stranding records are represented. Source data: refer to Table A-1.

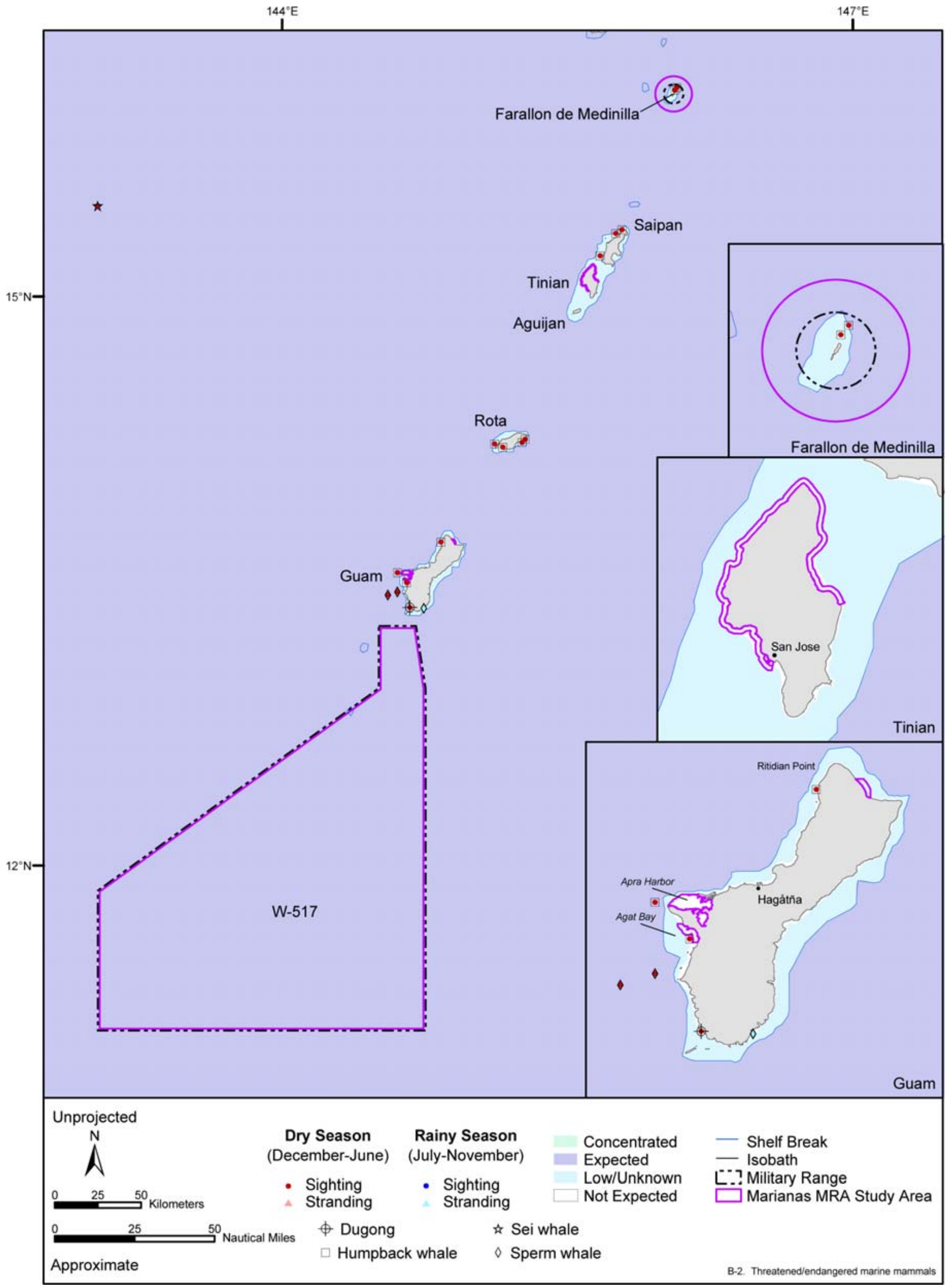

Figure B-2. Occurrence of endangered marine mammals in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year except June through September when occurrence is not expected in lagoons. Available sighting and stranding records are represented. Source data: refer to Table A-1.

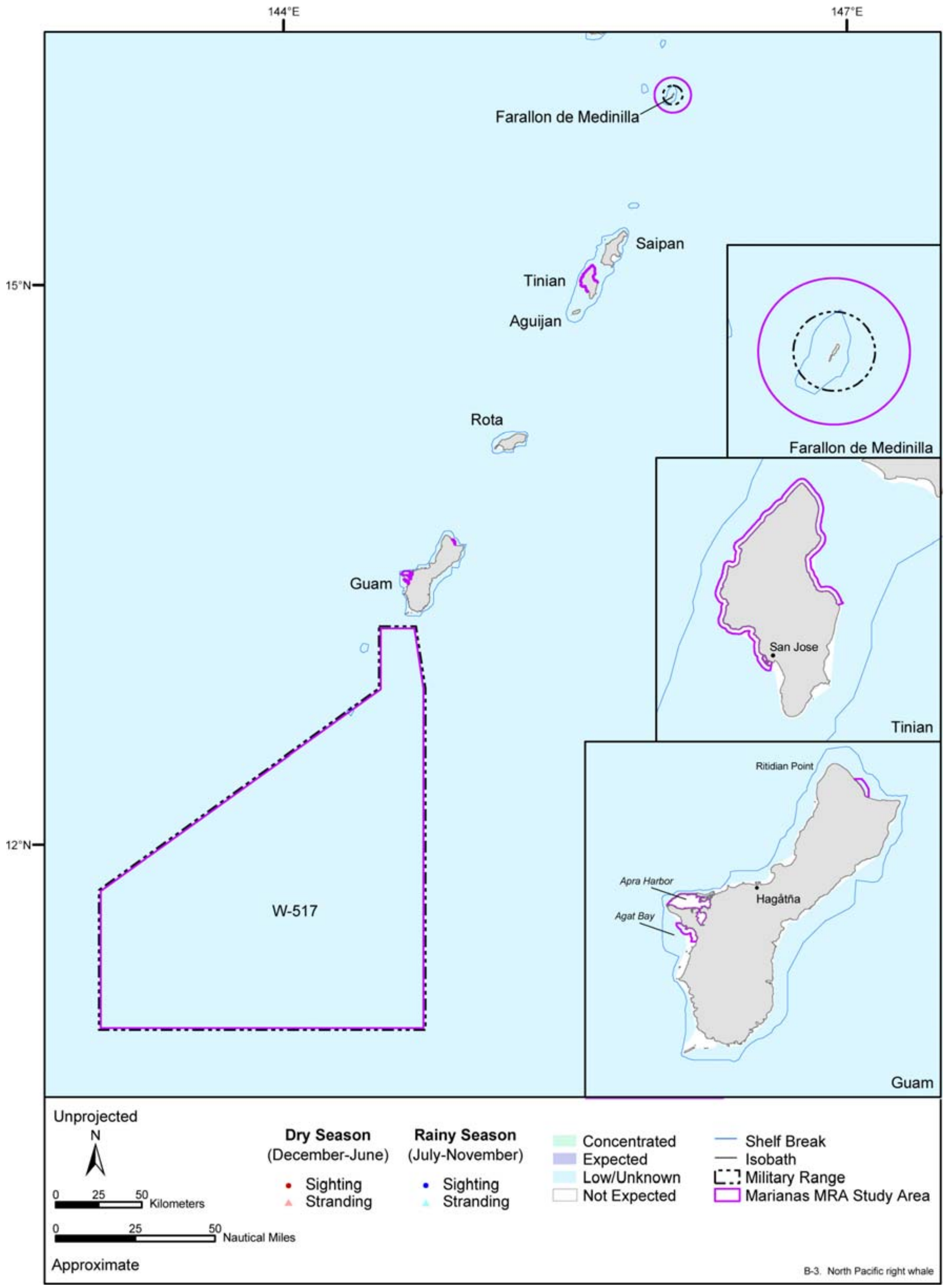

Figure B-3. Occurrence of the North Pacific right whale in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. There are no sighting and stranding records presented for this species within the map extent either because they are not known or because one of the two following criteria was missing: date of observation and specific location (coordinates or triangulated position).

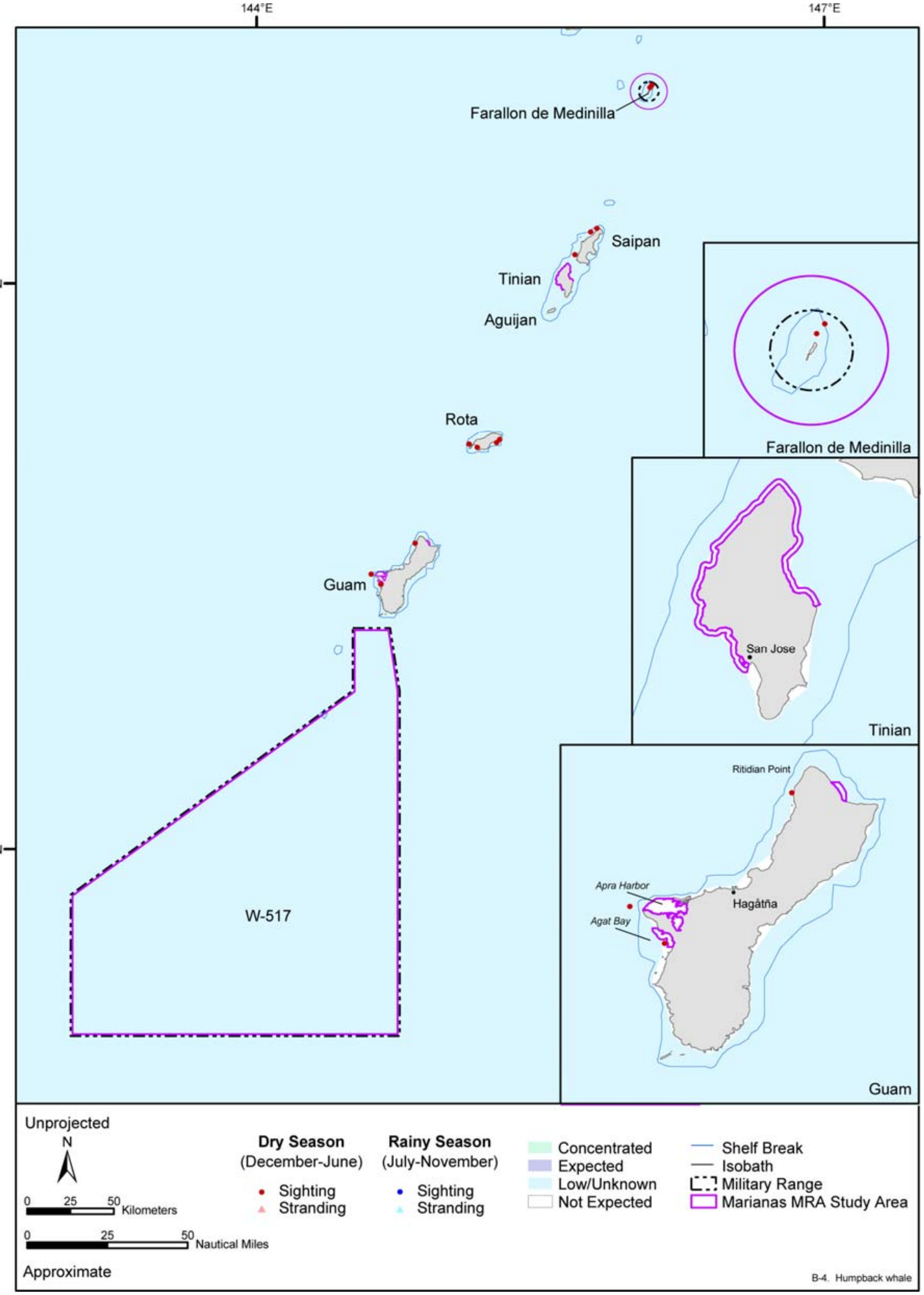

Figure B-4. Occurrence of the humpback whale in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year except June through September when this species is not expected in the area. Available sighting and stranding records are represented. Source data: refer to Table A-1.

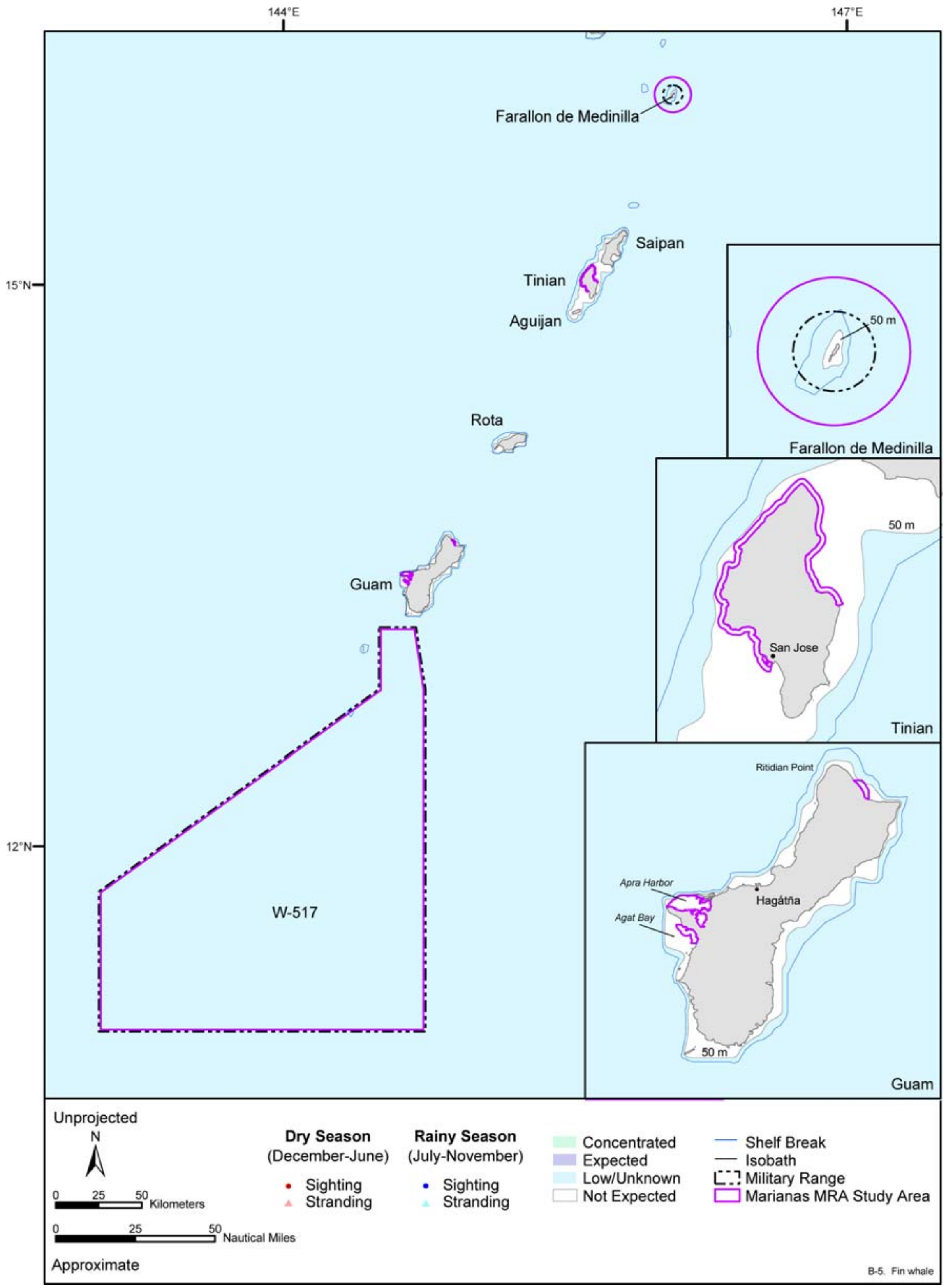

Figure B-5. Occurrence of the fin whale in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. There are no sighting and stranding records presented for this species within the map extent either because they are not known or because one of the two following criteria was missing: date of observation and specific location (coordinates or triangulated position).

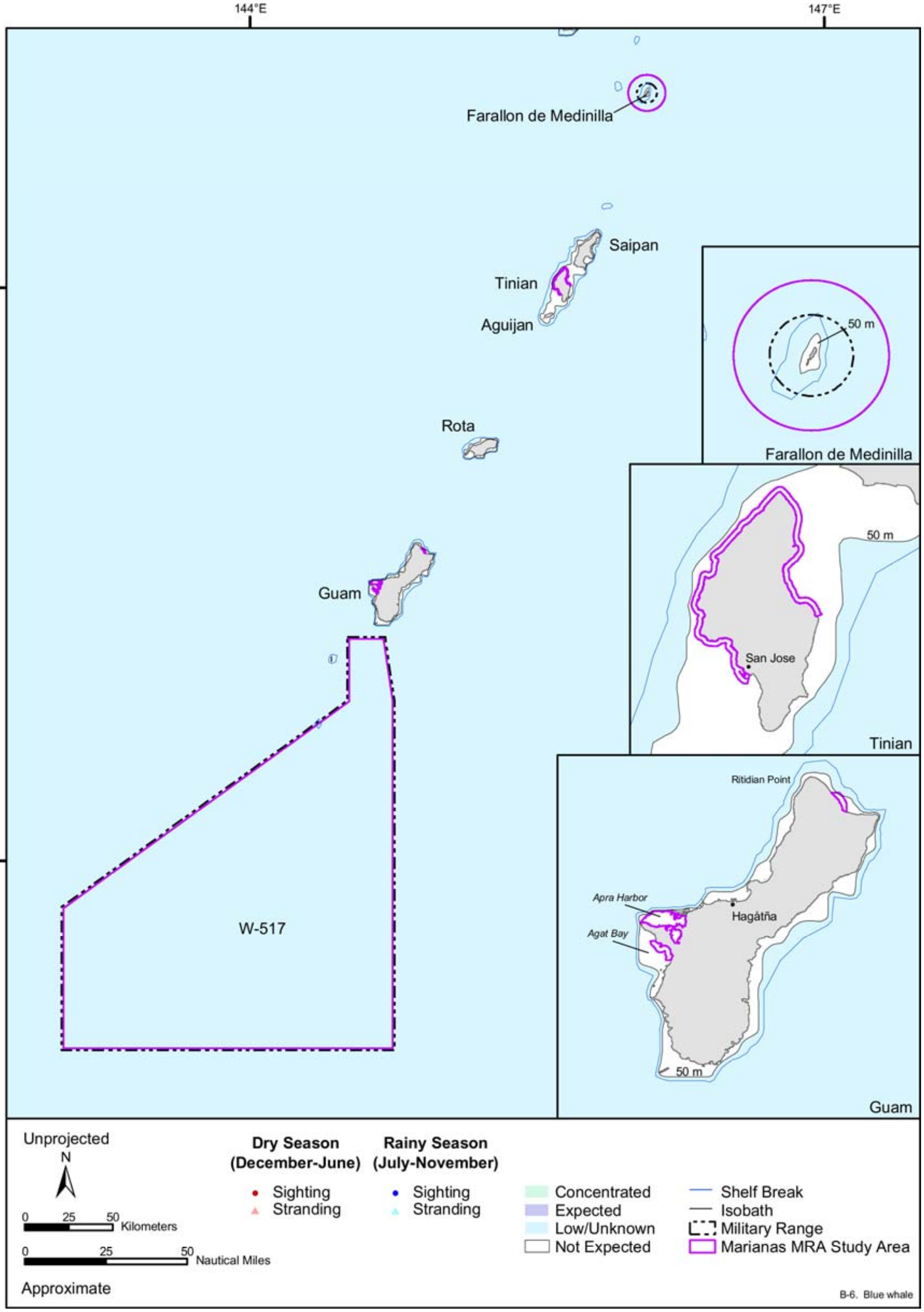

Figure B-6. Occurrence of the blue whale in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. There are no sighting and stranding records presented for this species within the map extent either because they are not known or because one of the two following criteria was missing: date of observation and specific location (coordinates or triangulated position).

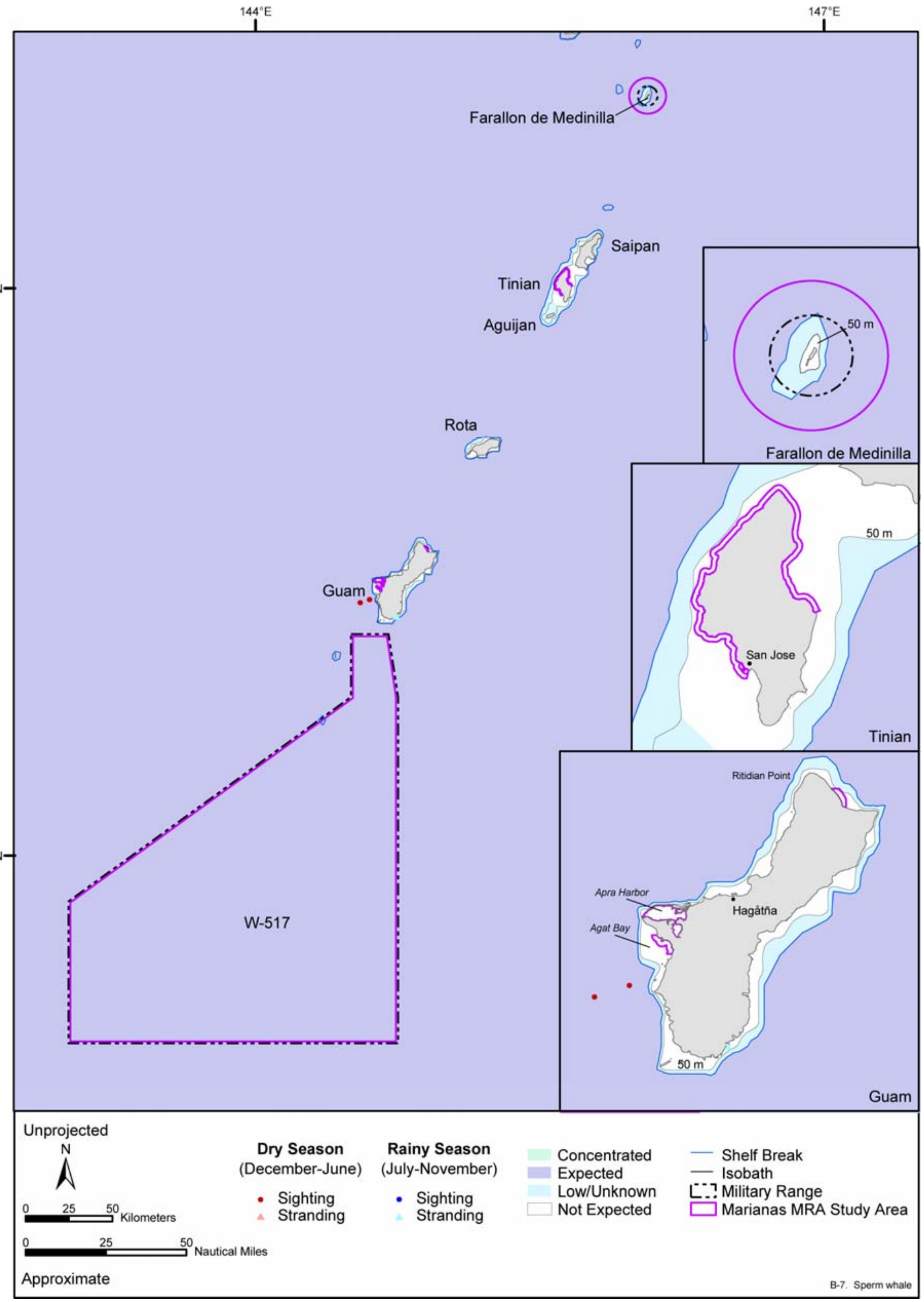

Figure B-7. Occurrence of the sperm whale in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. Available sighting and stranding records are represented. Source data: refer to Table A-1.

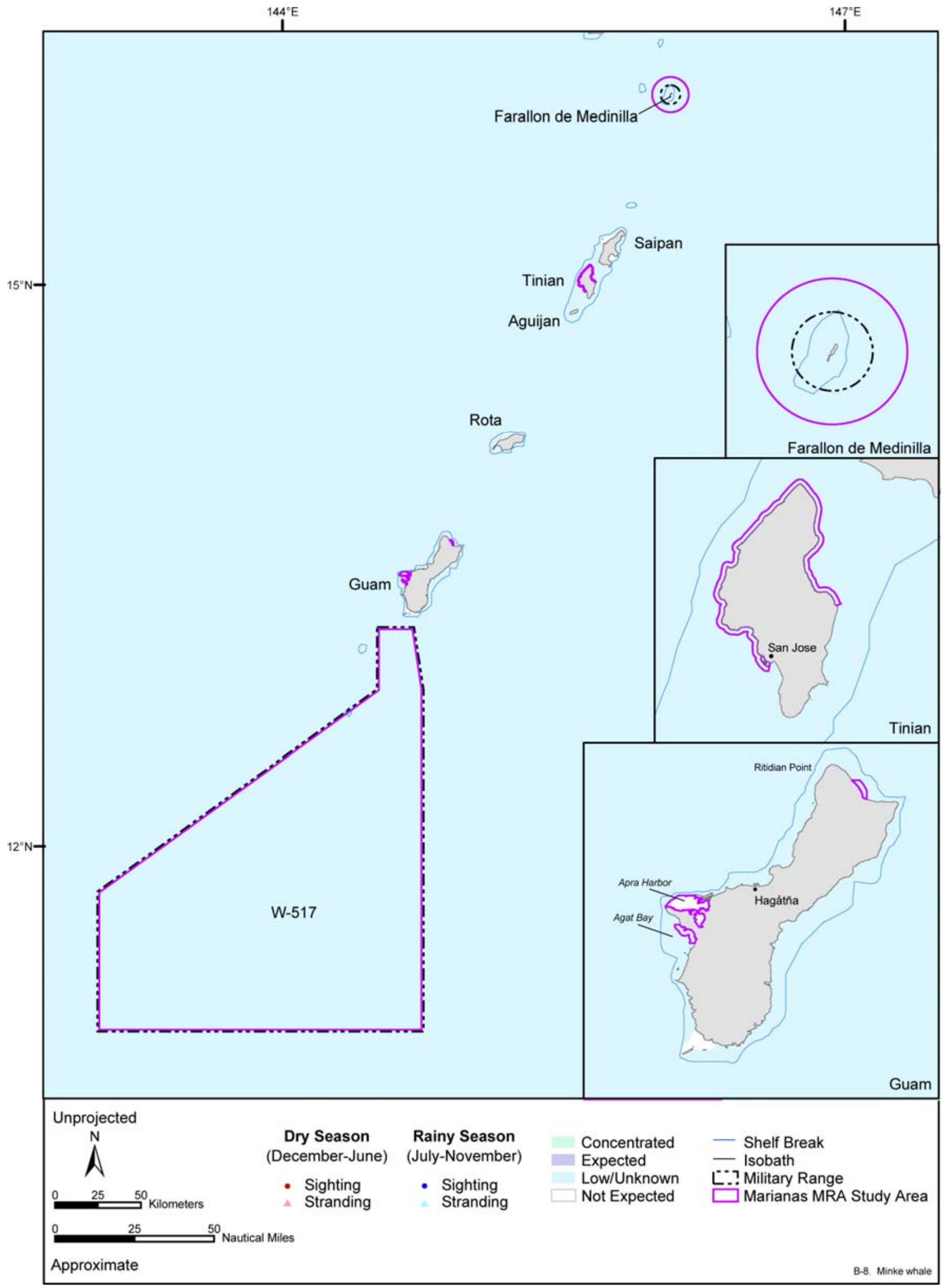

Figure B-8. Occurrence of the minke whale in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. There are no sighting and stranding records presented for this species within the map extent either because they are not known or because one of the two following criteria was missing: date of observation and specific location (coordinates or triangulated position).

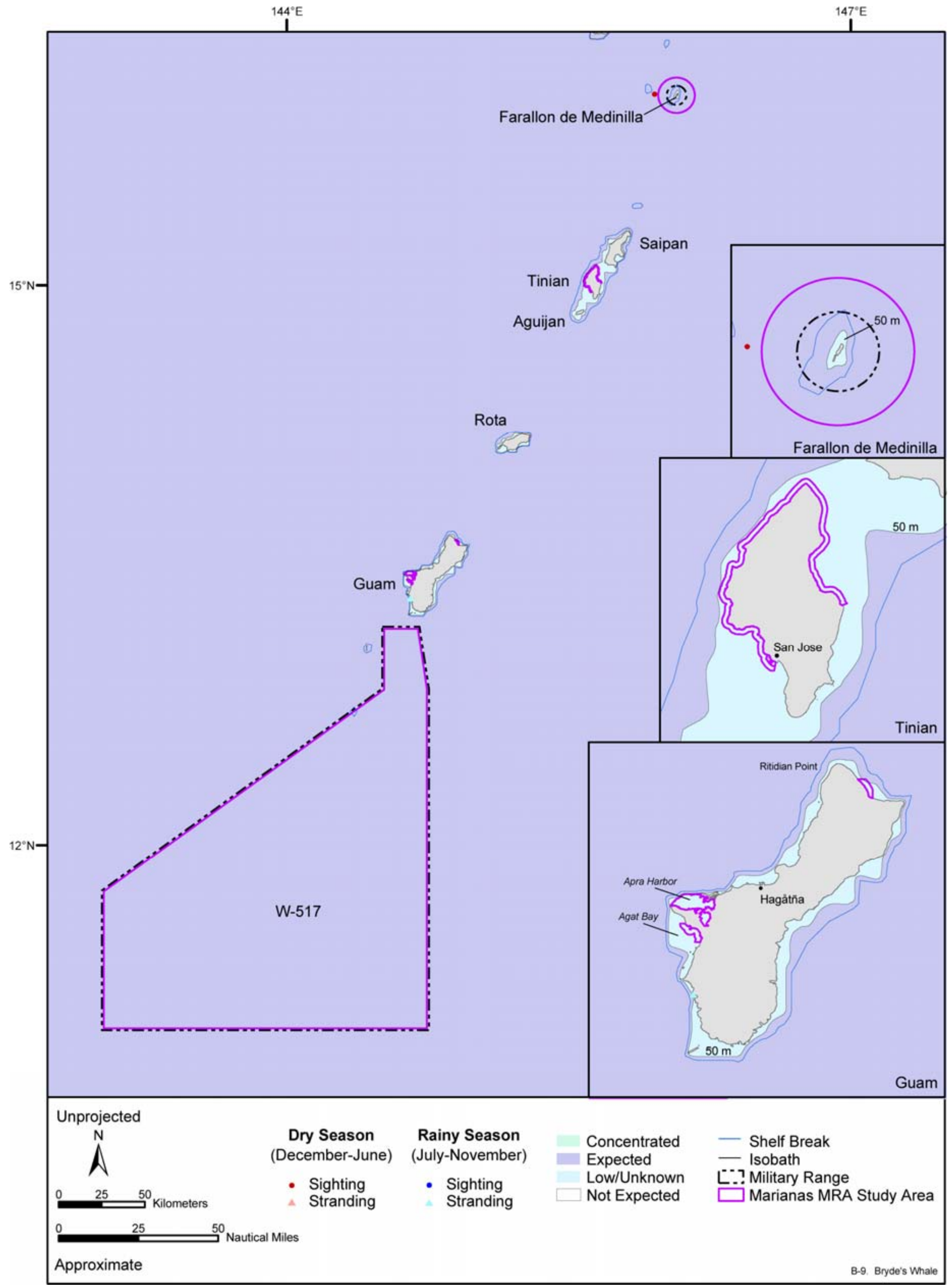

Figure B-9. Occurrence of the Bryde's whale in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. Available sighting and stranding records are represented. Source data: refer to Table A-1.

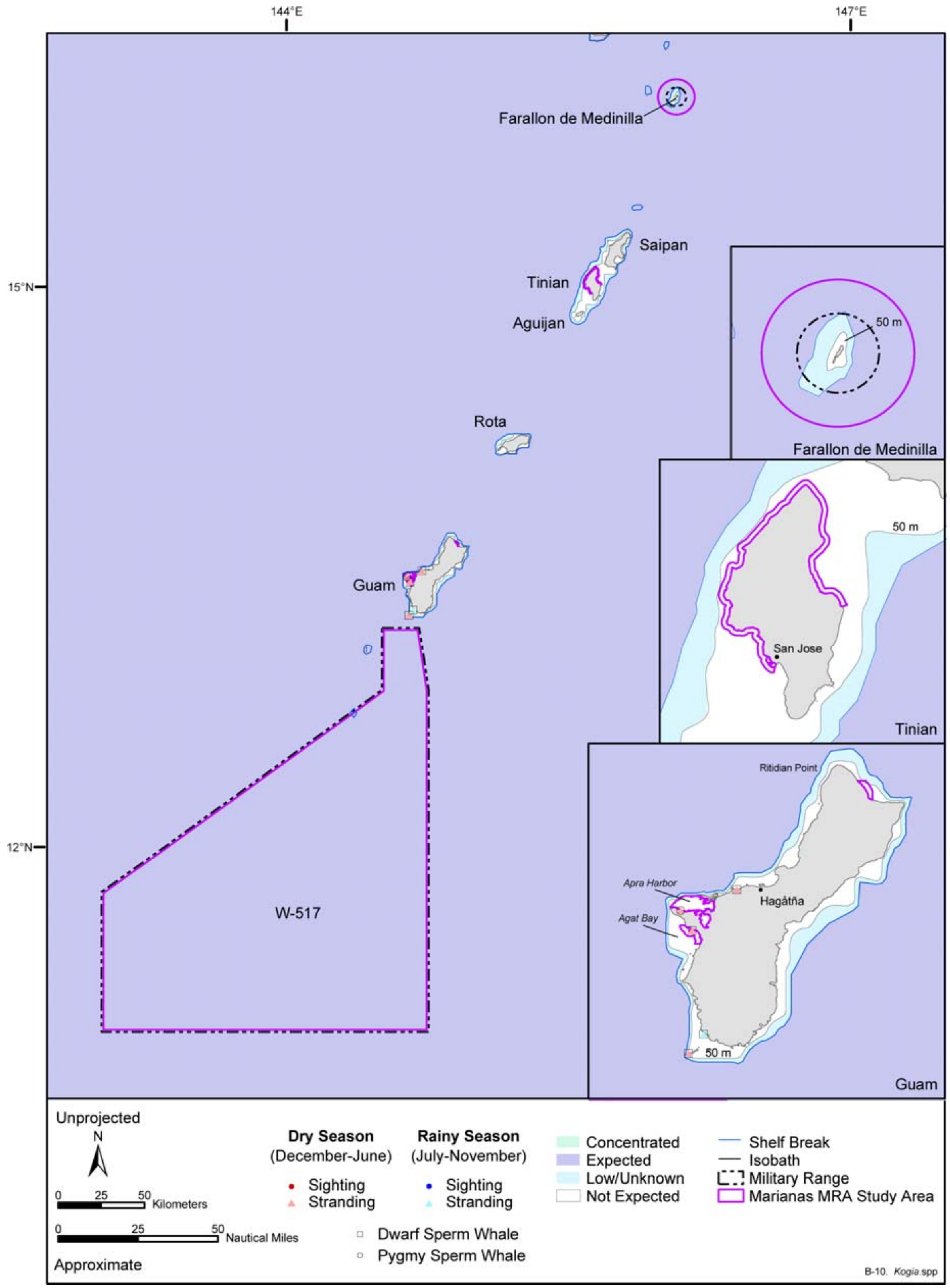

Figure B-10. Occurrence of *Kogia* spp. in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. Available sighting and stranding records are represented. Source data: refer to Table A-1.

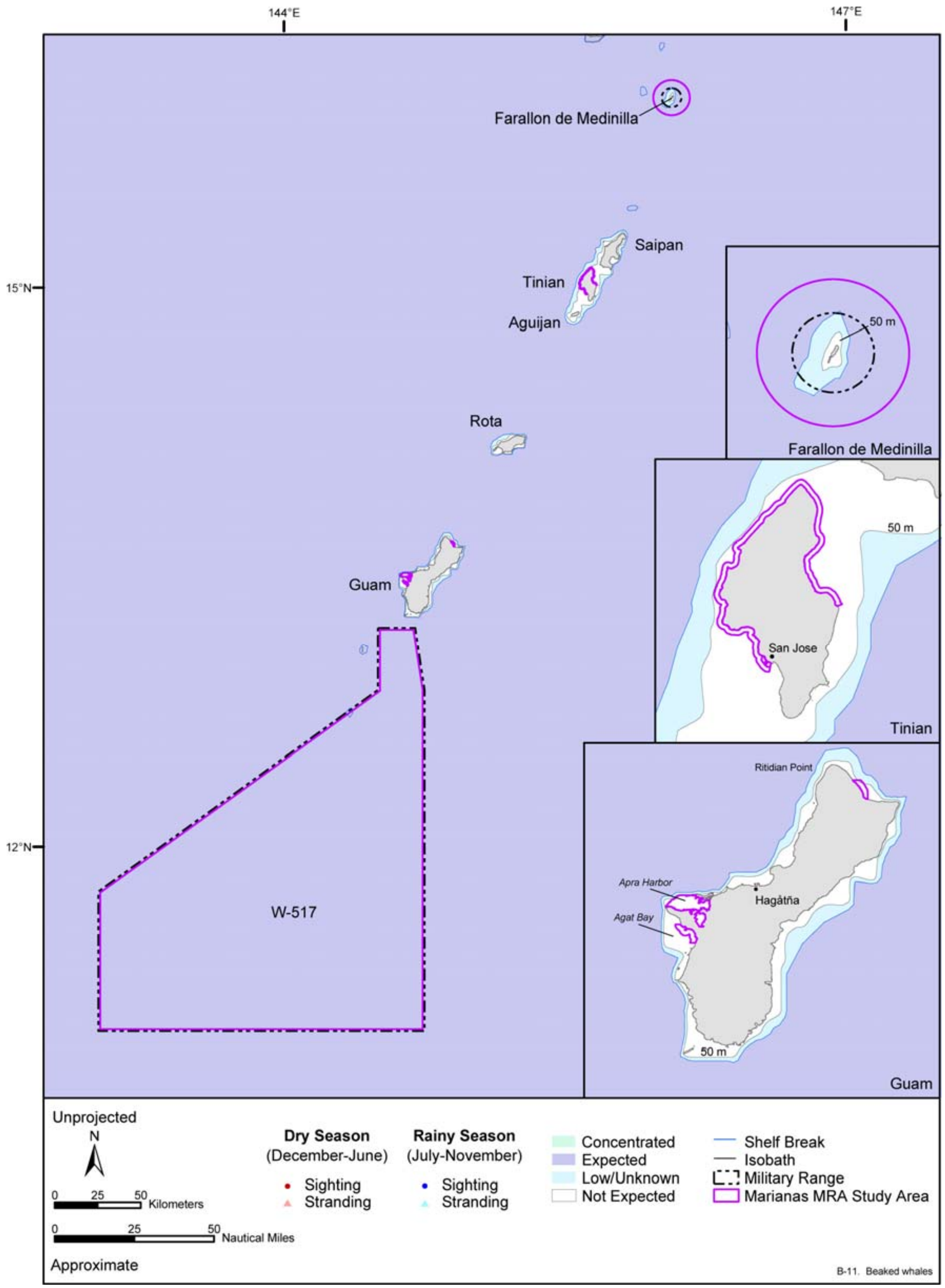

Figure B-11. Occurrence of beaked whales in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. There are no sighting and stranding records presented for this species within the map extent either because they are not known or because one of the two following criteria was missing: date of observation and specific location (coordinates or triangulated position).

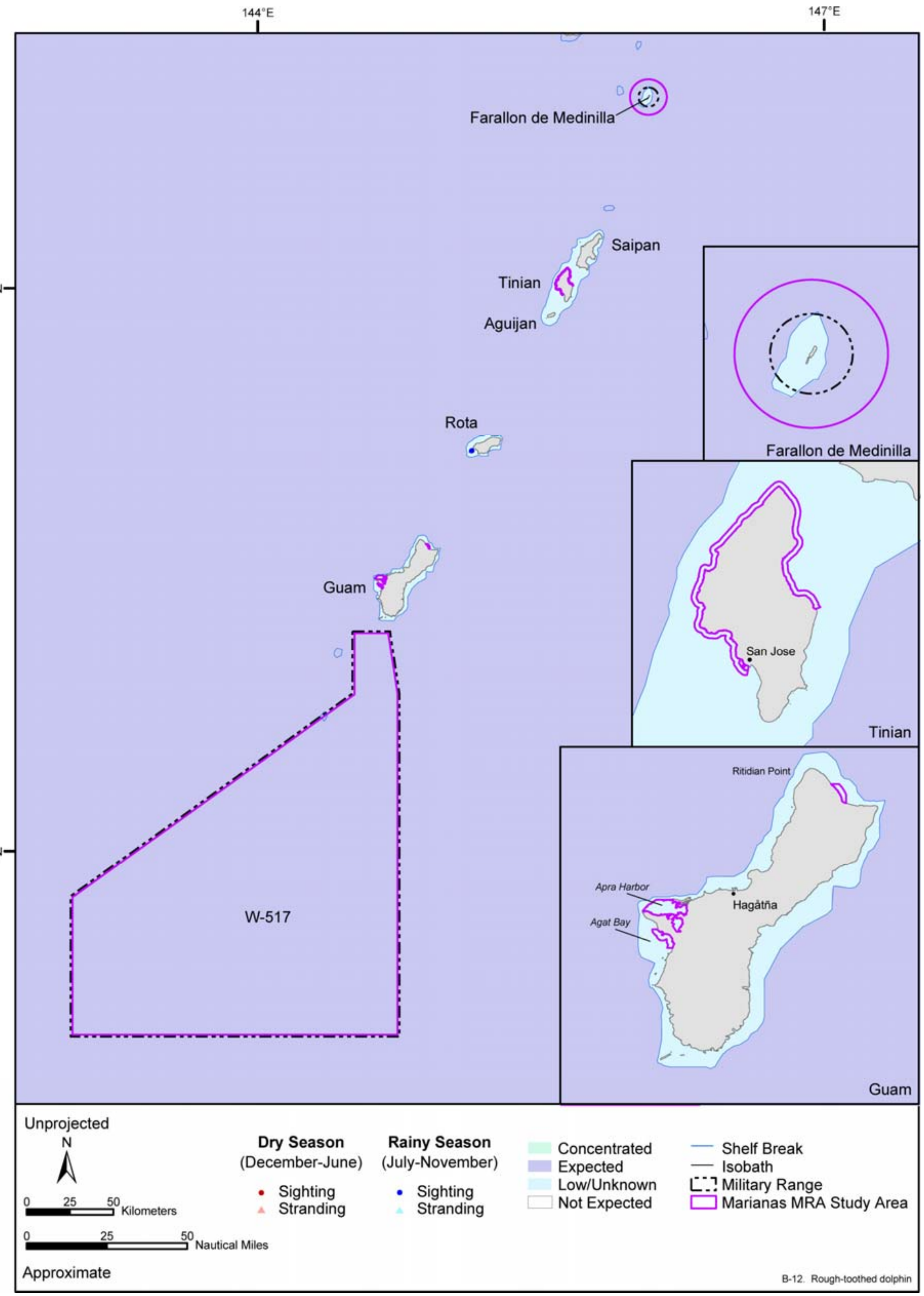

Figure B-12. Occurrence of the rough-toothed dolphin in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. Available sighting and stranding records are represented. Source data: refer to Table A-1.

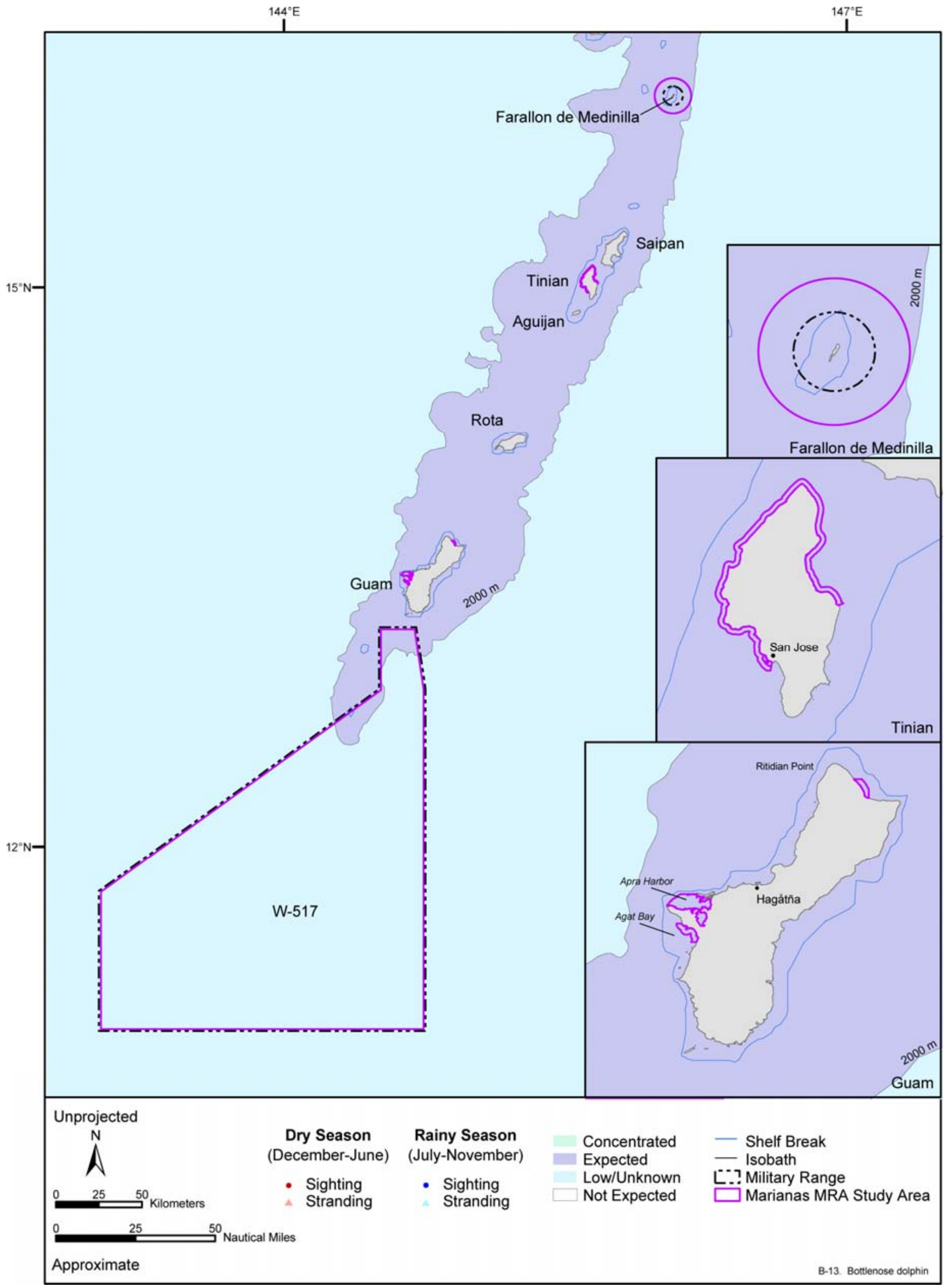

Figure B-13. Occurrence of the common bottlenose dolphin in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. Available sighting and stranding records are represented. Source data: refer to Table A-1.

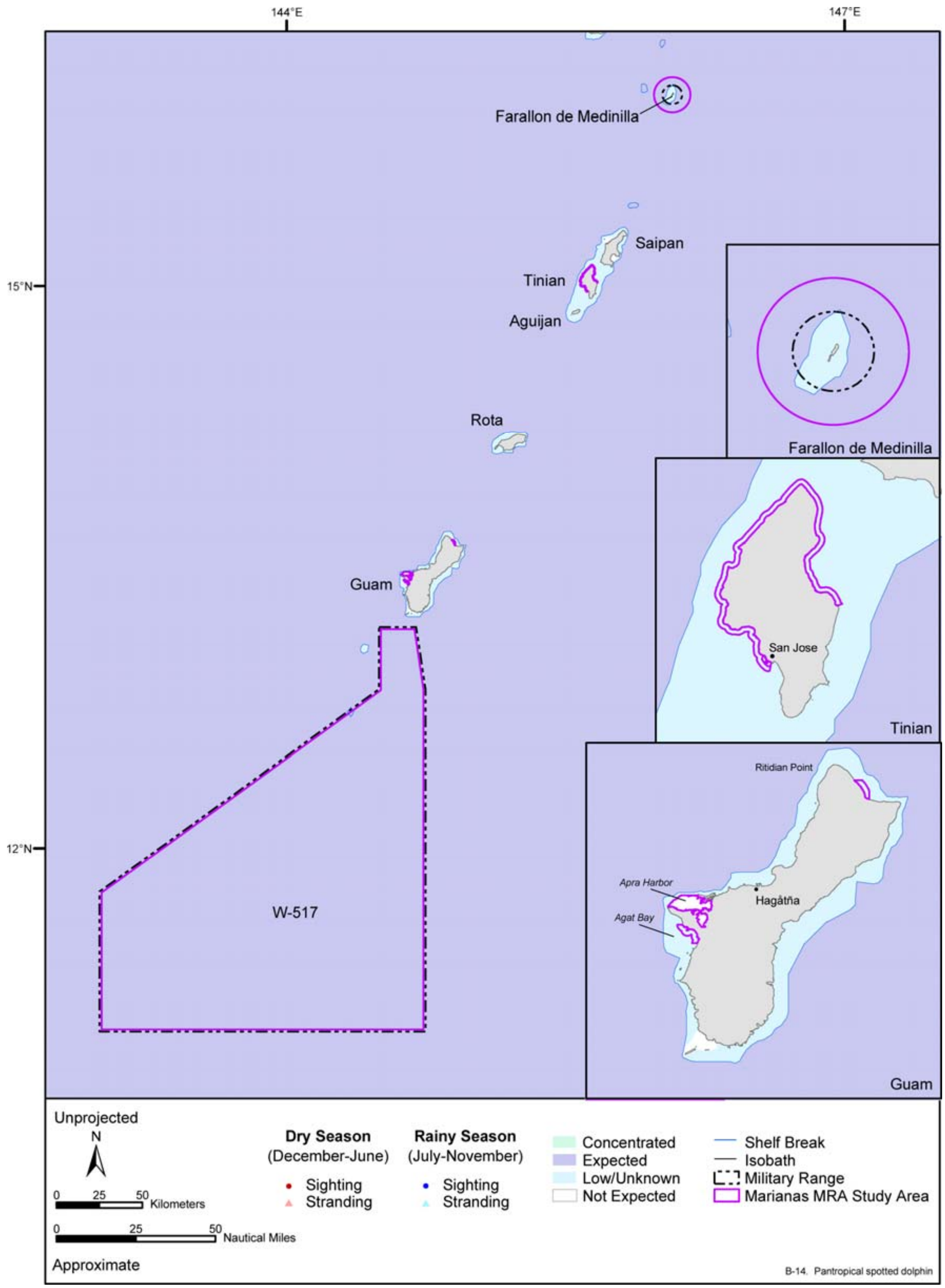

Figure B-14. Occurrence of the pantropical spotted dolphin in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. There are no sighting and stranding records presented for this species within the map extent either because they are not known or because one of the two following criteria was missing: date of observation and specific location (coordinates or triangulated position).

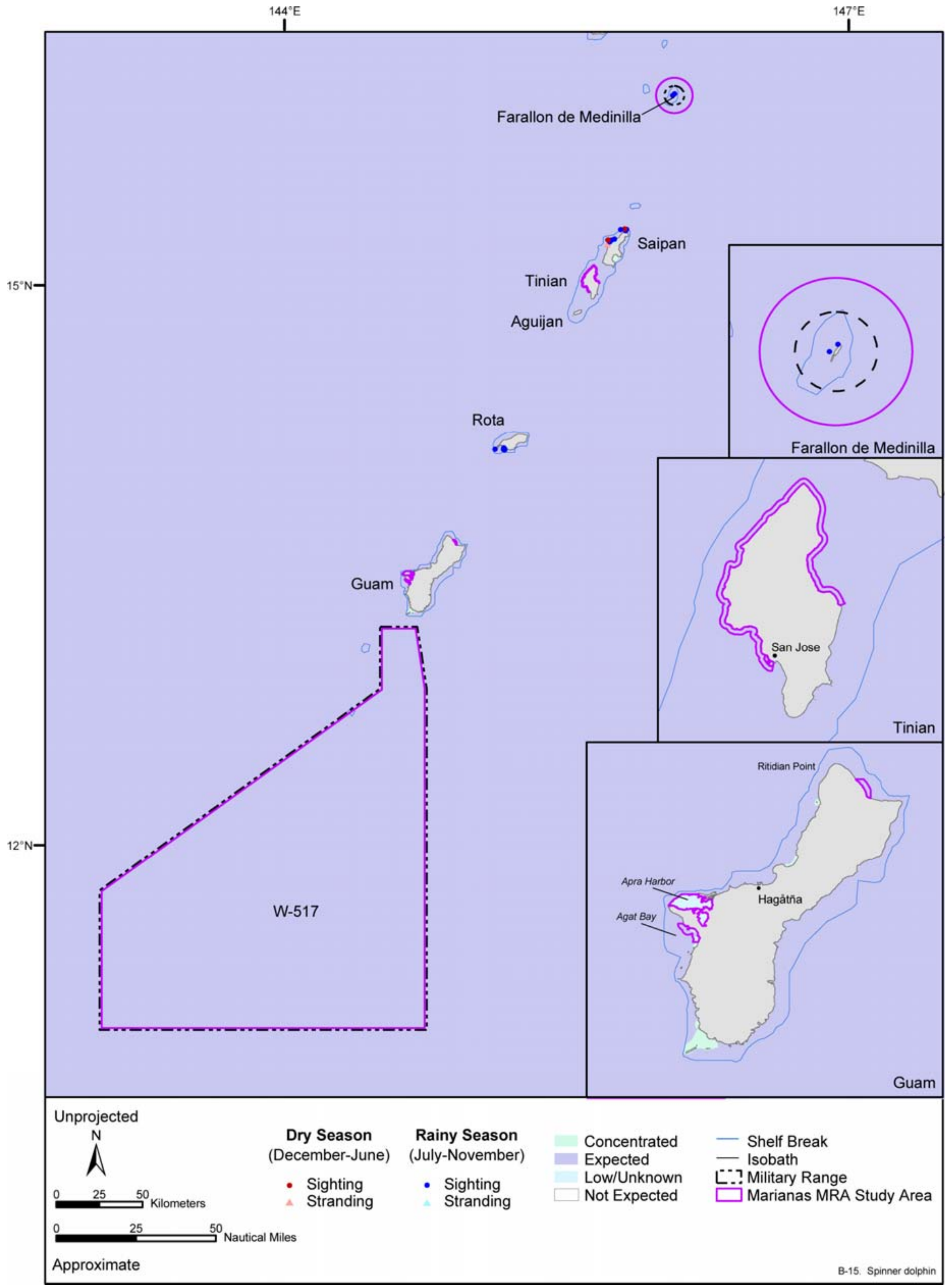

Figure B-15. Occurrence of the spinner dolphin in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. Available sighting and stranding records are represented. Source data: refer to Table A-1.

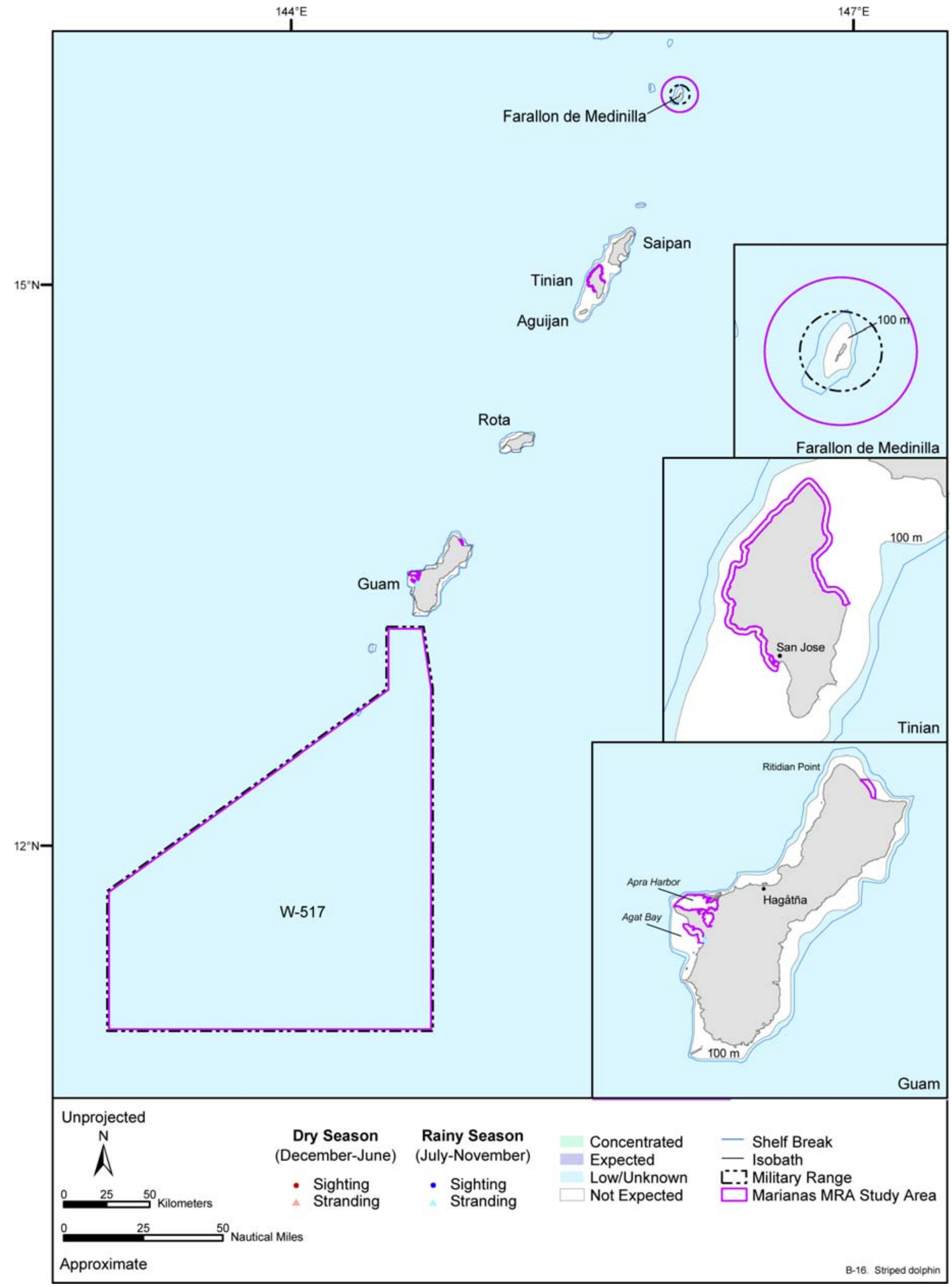

Figure B-16. Occurrence of the striped dolphin in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. Available sighting and stranding records are represented. Source data: refer to Table A-1.

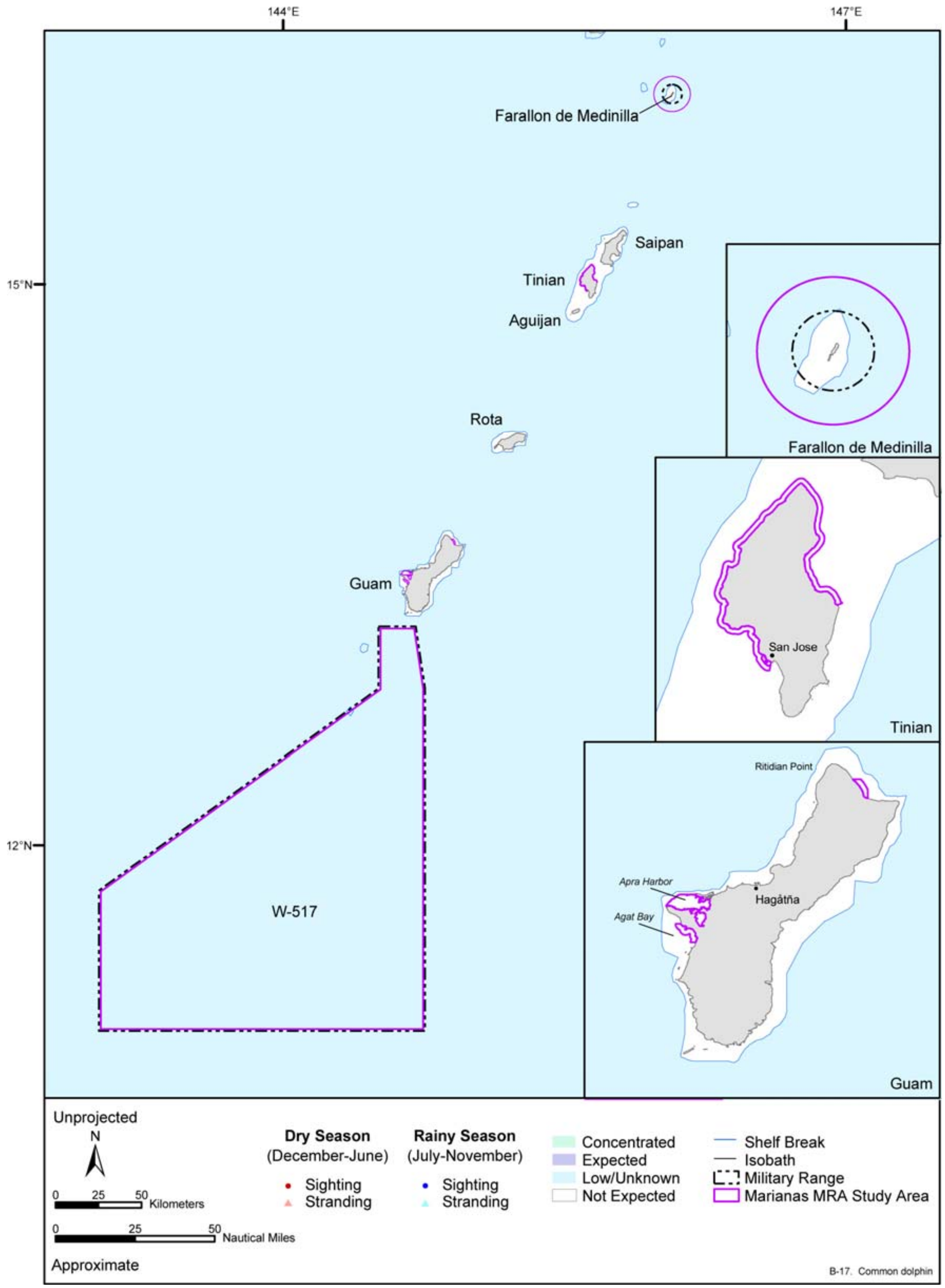

Figure B-17. Occurrence of the short-beaked common dolphin in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. There are no sighting and stranding records presented for this species within the map extent either because they are not known or because one of the two following criteria was missing: date of observation and specific location (coordinates or triangulated position).

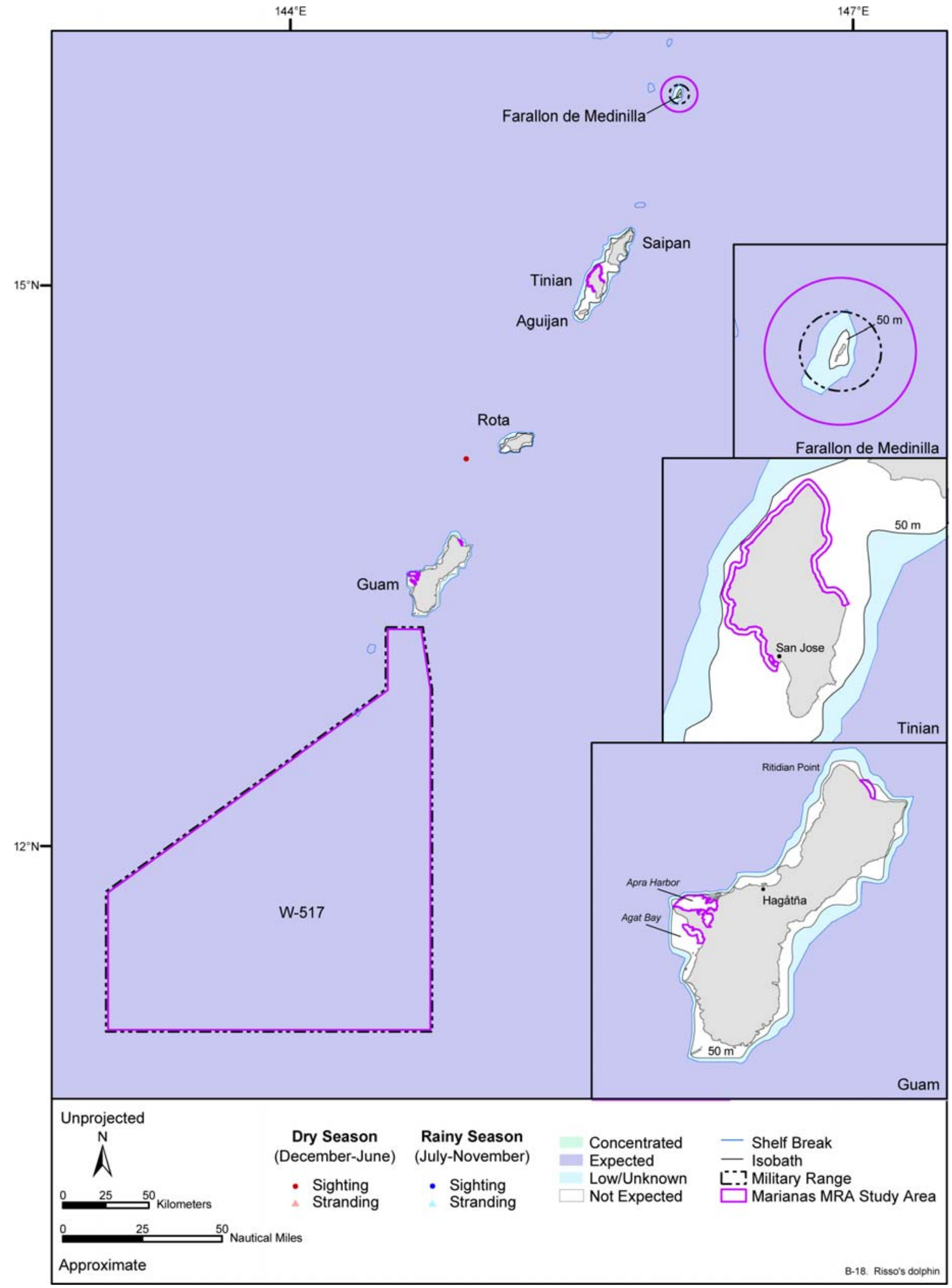

Figure B-18. Occurrence of the Risso's dolphin in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. Available sighting and stranding records are represented. Source data: refer to Table A-1.

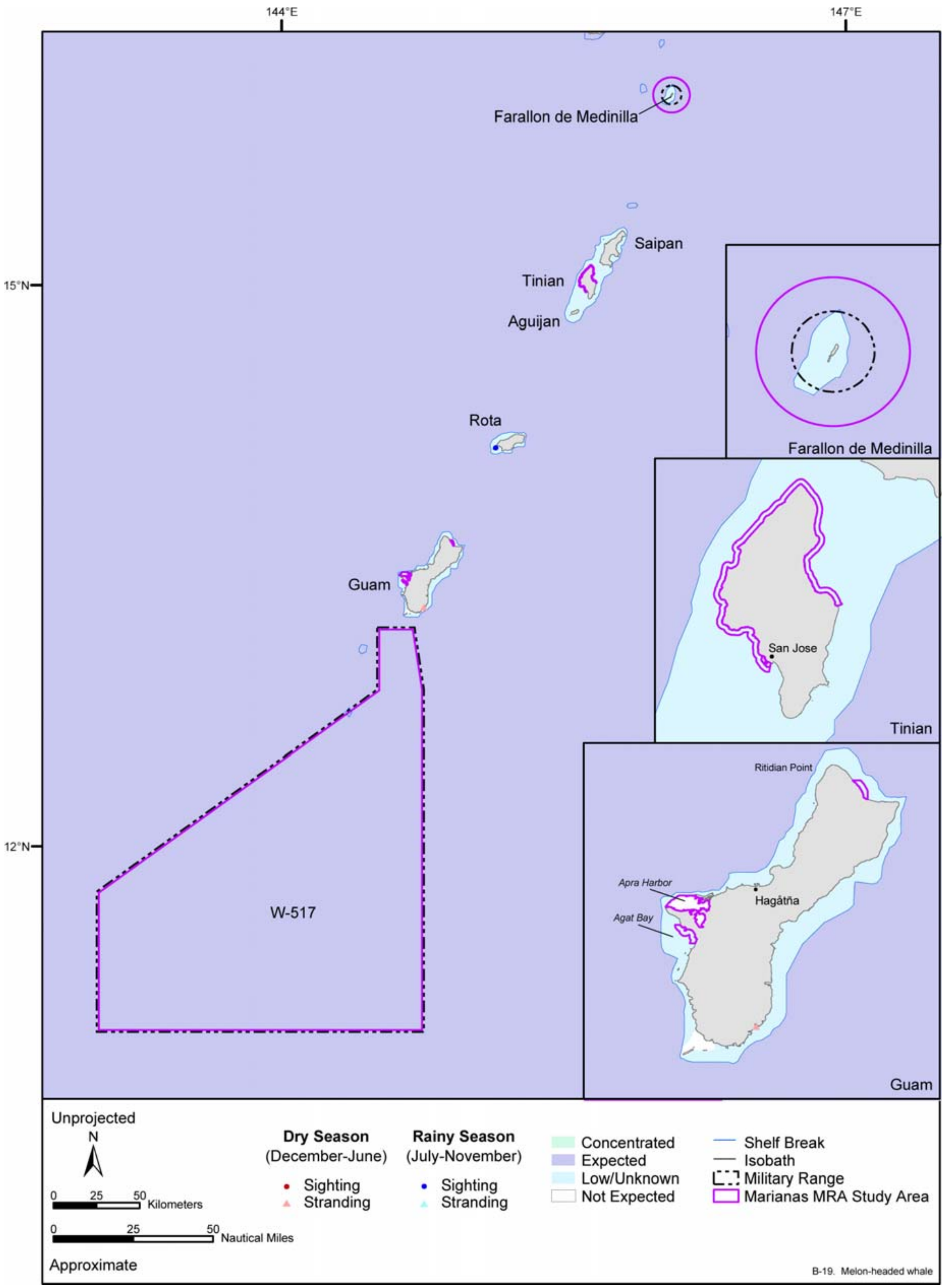

Figure B-19. Occurrence of the melon-headed whale in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. Available sighting and stranding records are represented. Source data: refer to Table A-1.

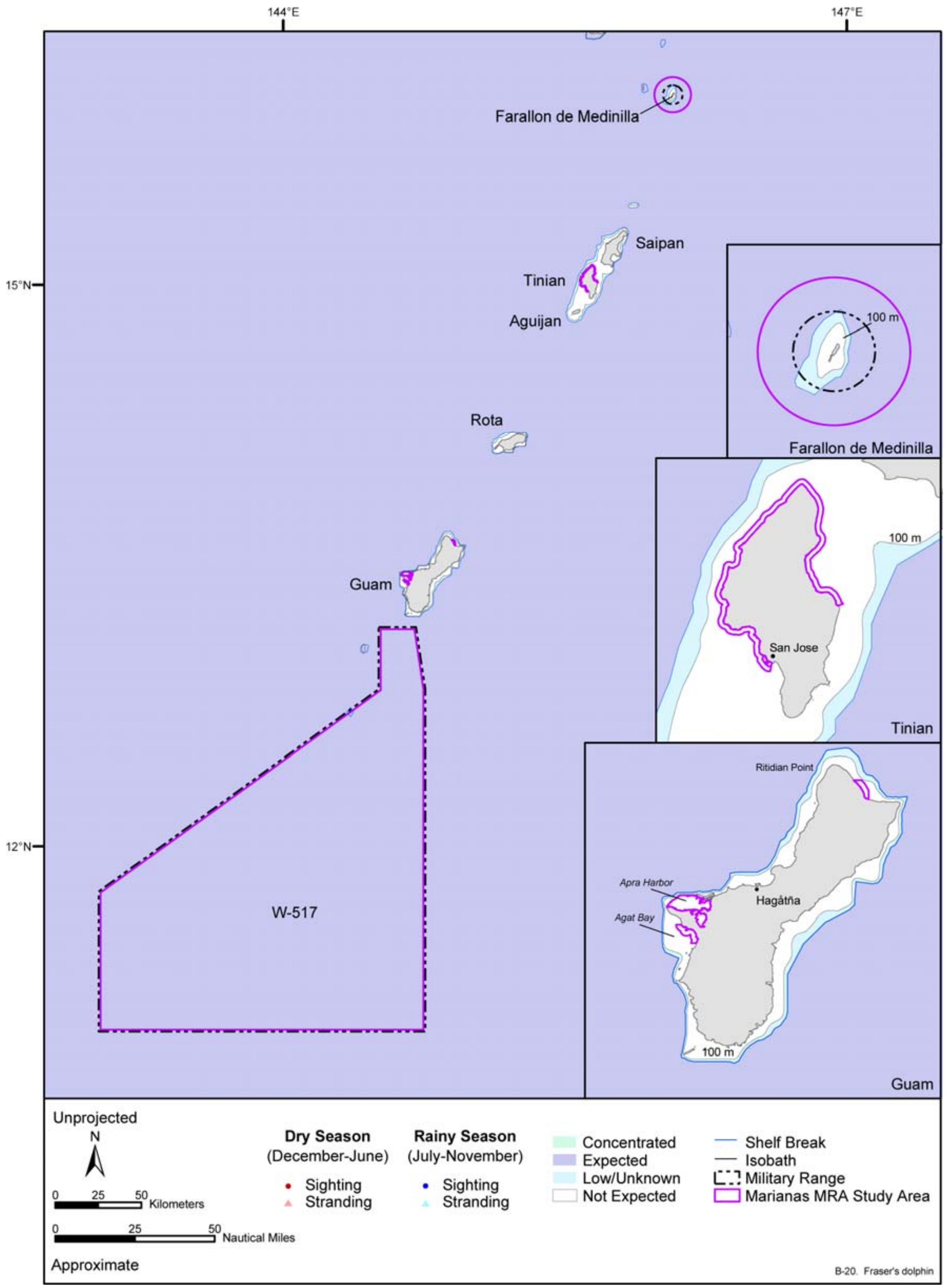

Figure B-20. Occurrence of the Fraser's dolphin in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. There are no sighting and stranding records presented for this species within the map extent either because they are not known or because one of the two following criteria was missing: date of observation and specific location (coordinates or triangulated position).

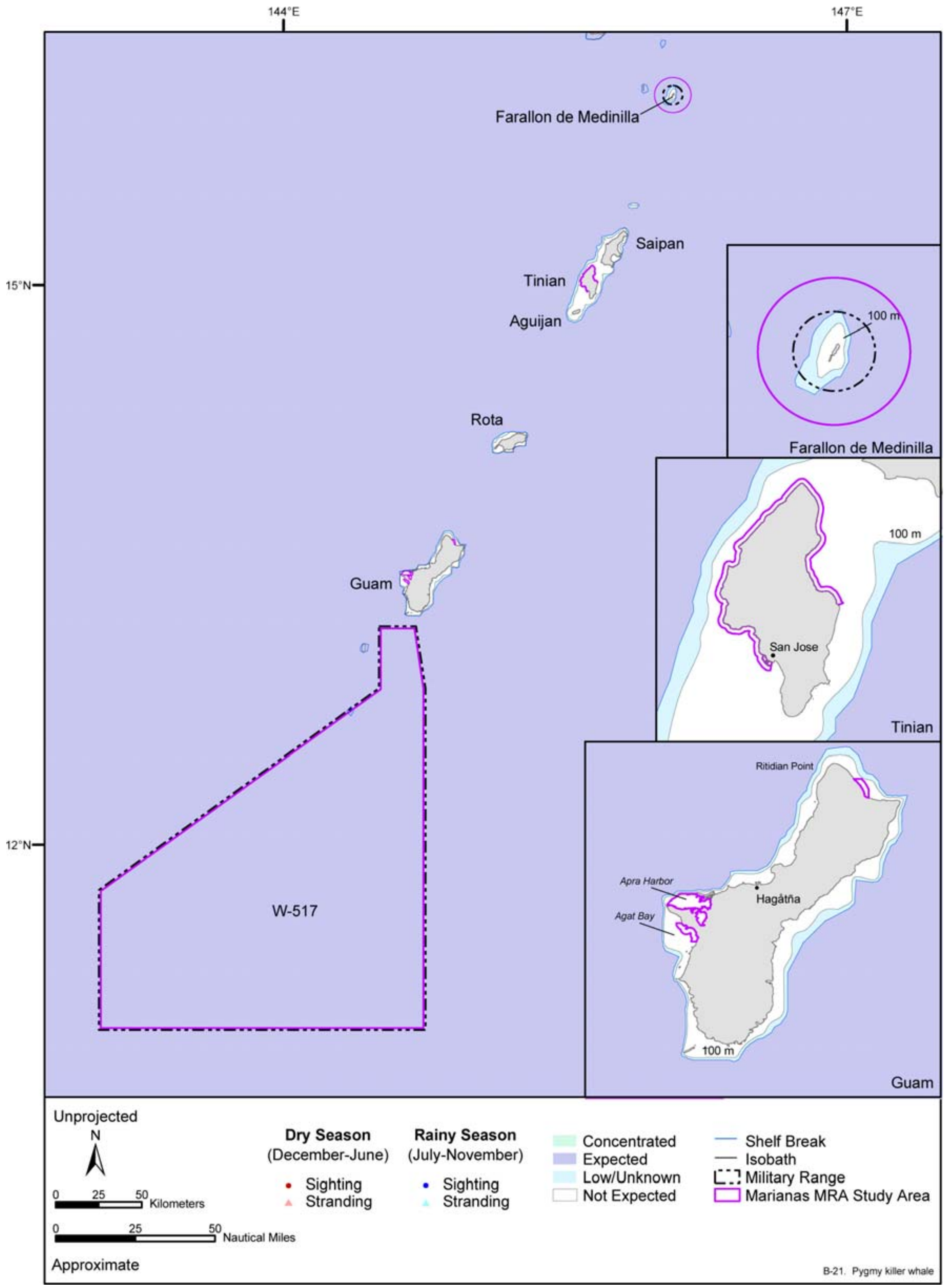

Figure B-21. Occurrence of the pygmy killer whale in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. There are no sighting and stranding records presented for this species within the map extent either because they are not known or because one of the two following criteria was missing: date of observation and specific location (coordinates or triangulated position).

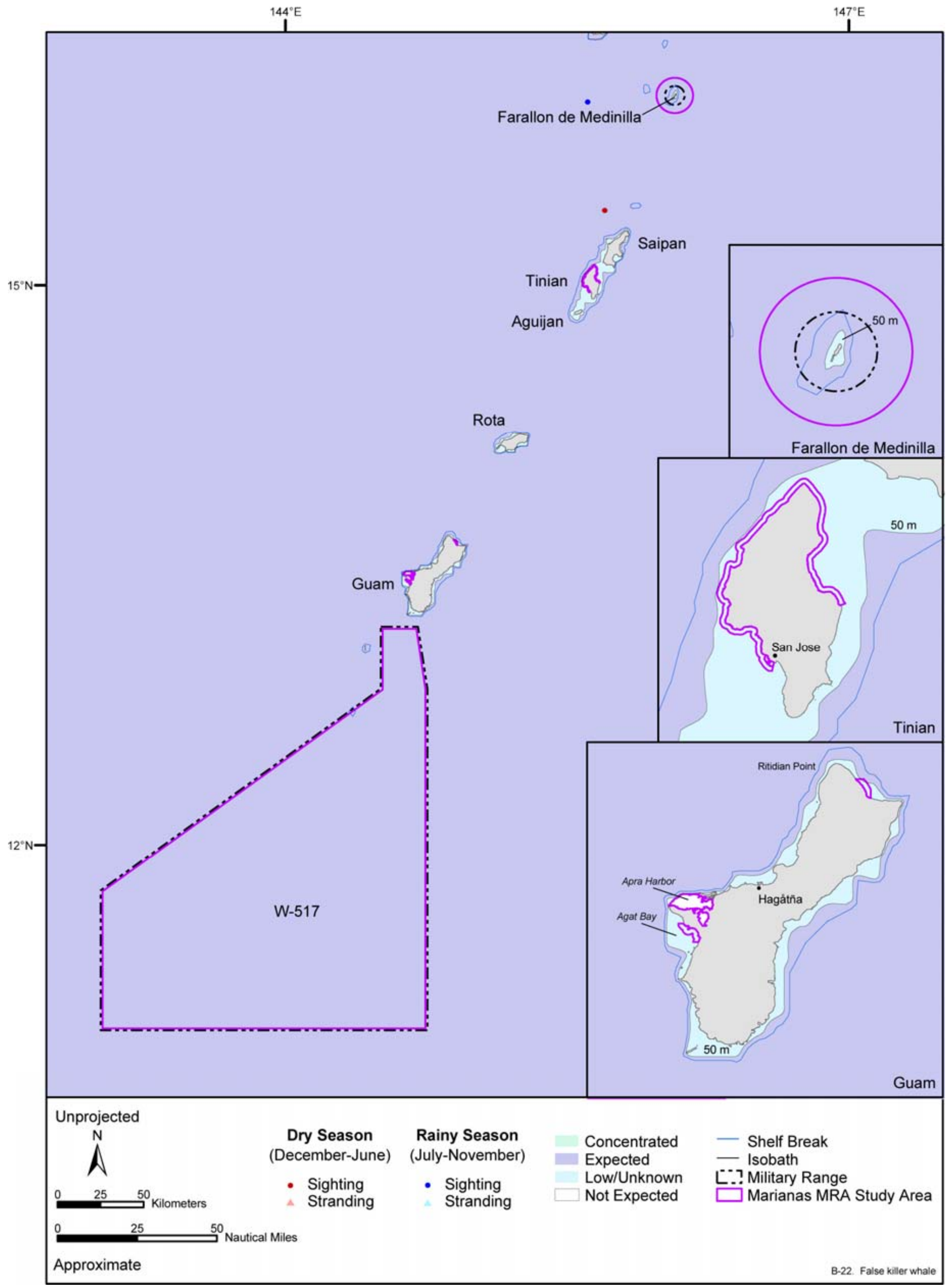

Figure B-22. Occurrence of the false killer whale in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. Available sighting and stranding records are represented. Source data: refer to Table A-1.

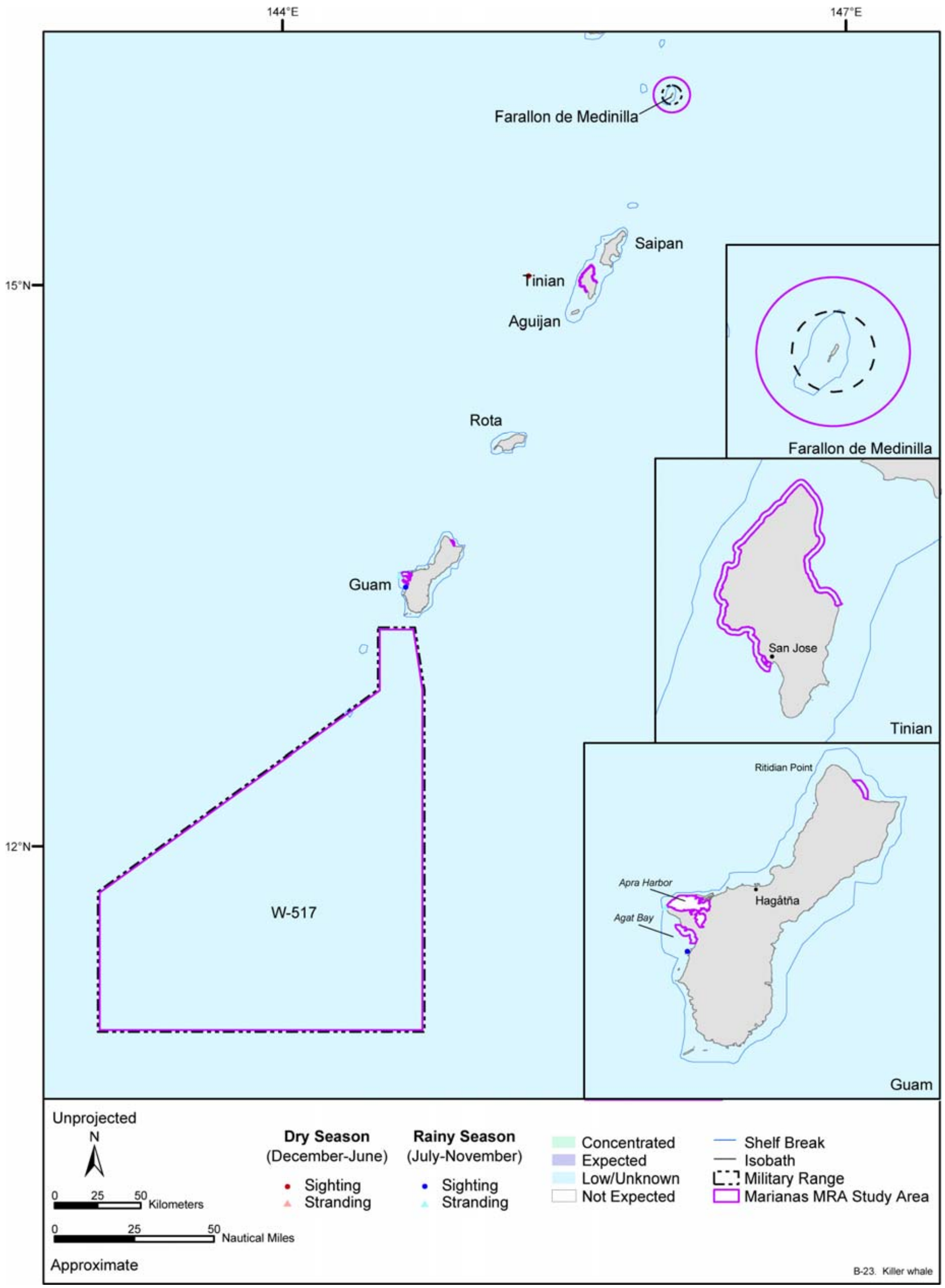

Figure B-23. Occurrence of the killer whale in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. Available sighting and stranding records are represented. Source data: refer to Table A-1.

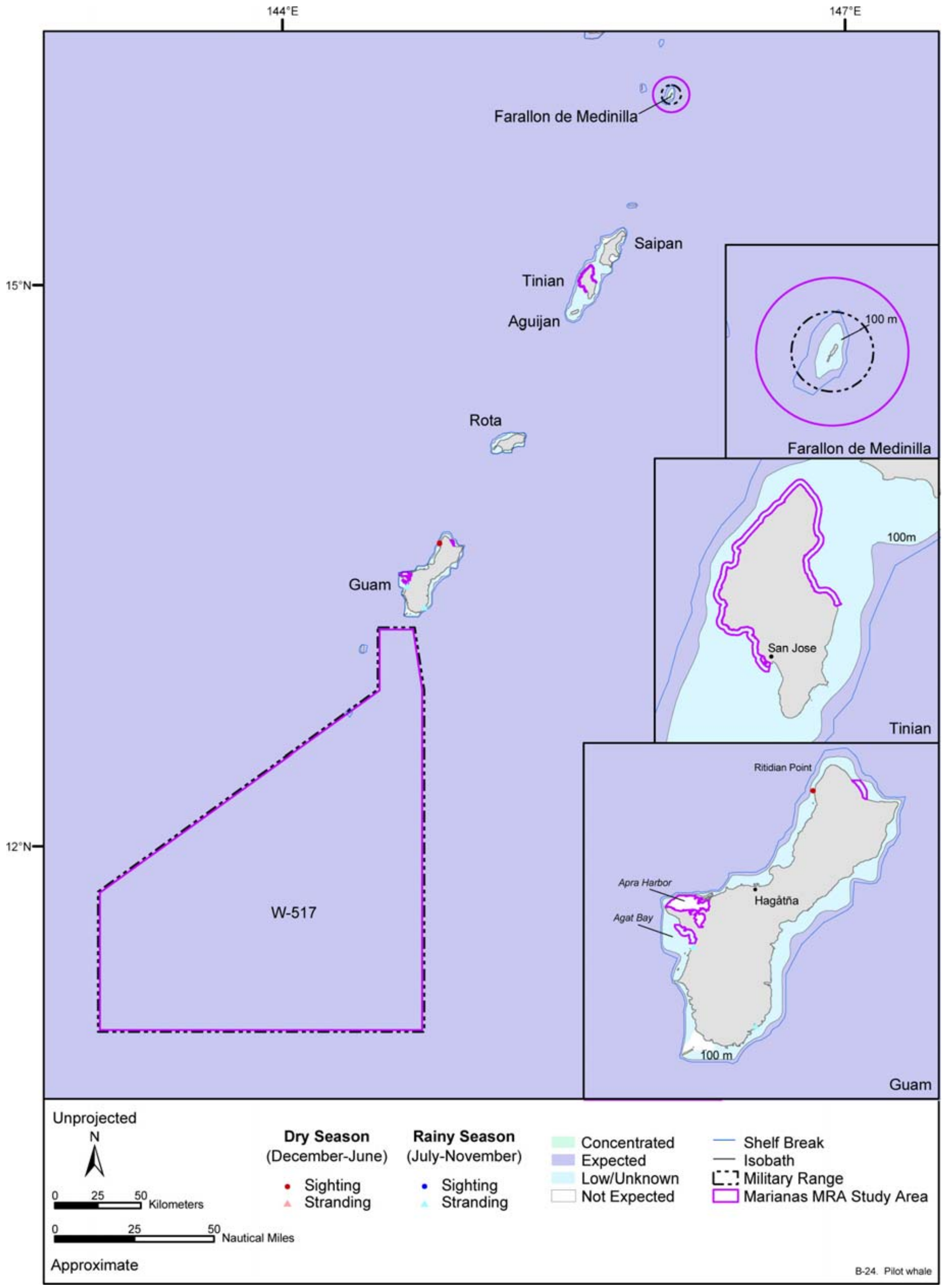

Figure B-24. Occurrence of the short-finned pilot whale in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. Available sighting and stranding records are represented. Source data: refer to Table A-1.

APPENDIX C: SEA TURTLES

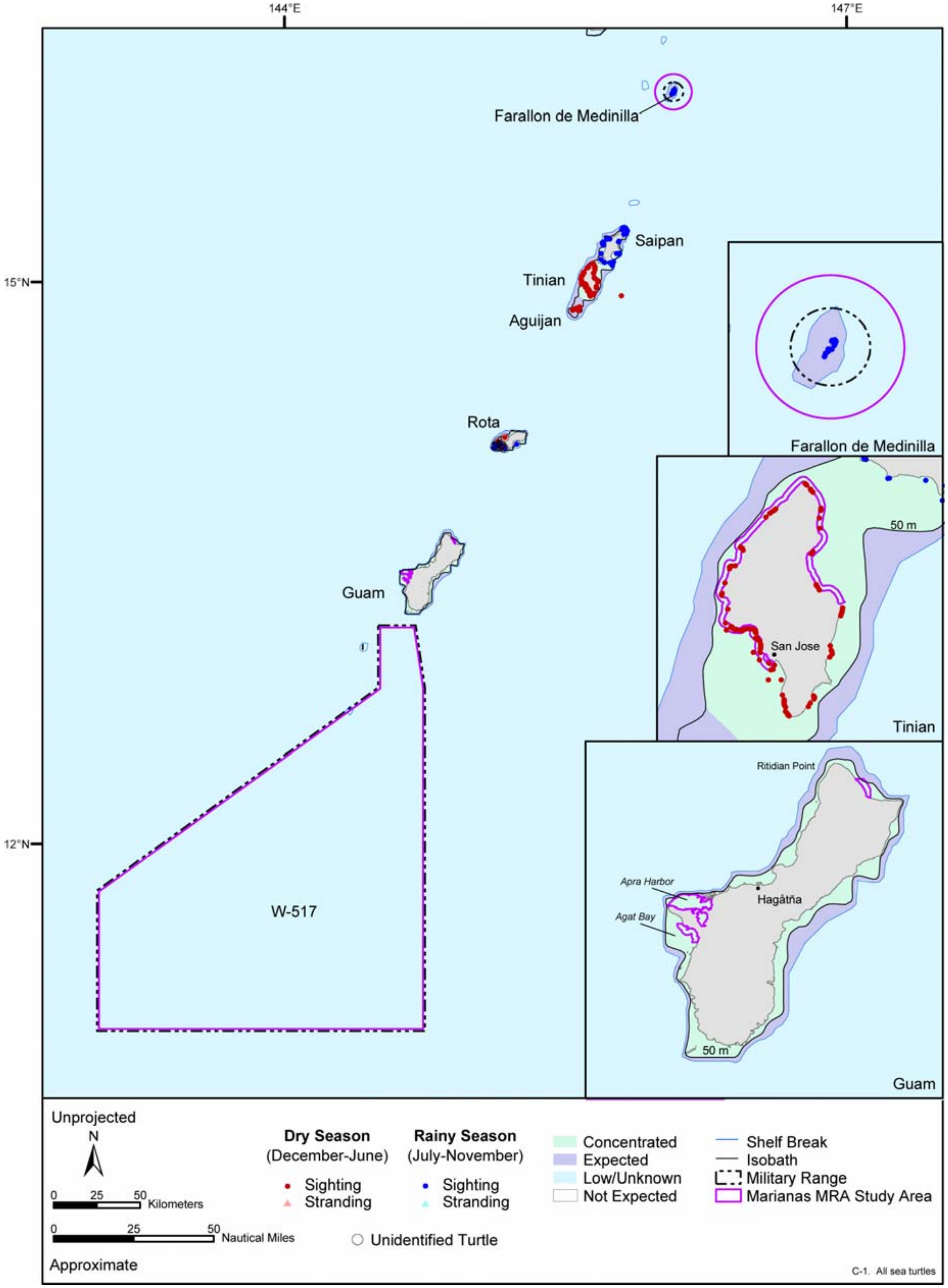

Figure C-1. Occurrence of all sea turtles in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. Available sighting and stranding records are represented. Source data: refer to Table A-1.

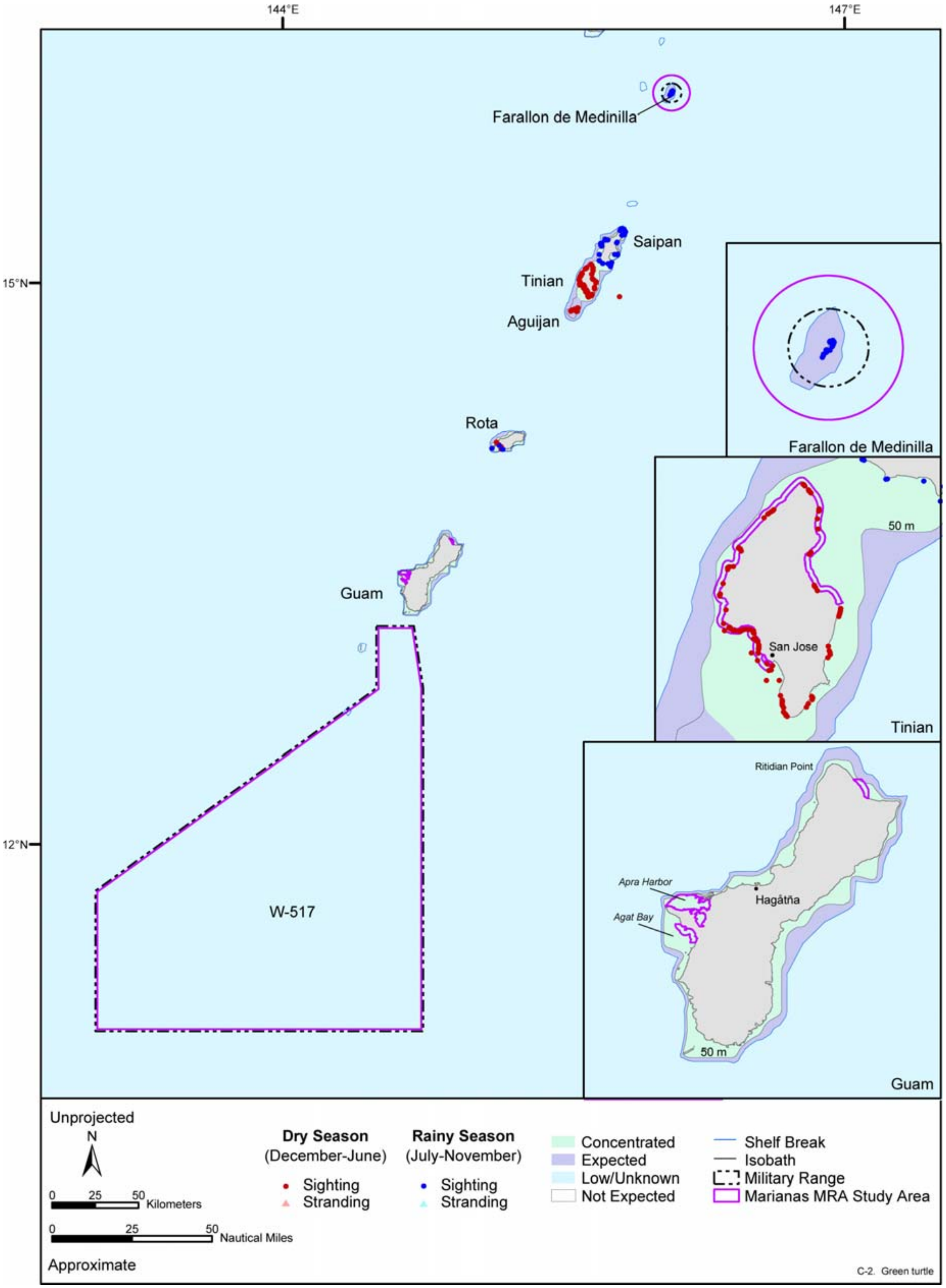

Figure C-2. Occurrence of the green turtle in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. Available sighting and stranding records are represented. Source data: refer to Table A-1.

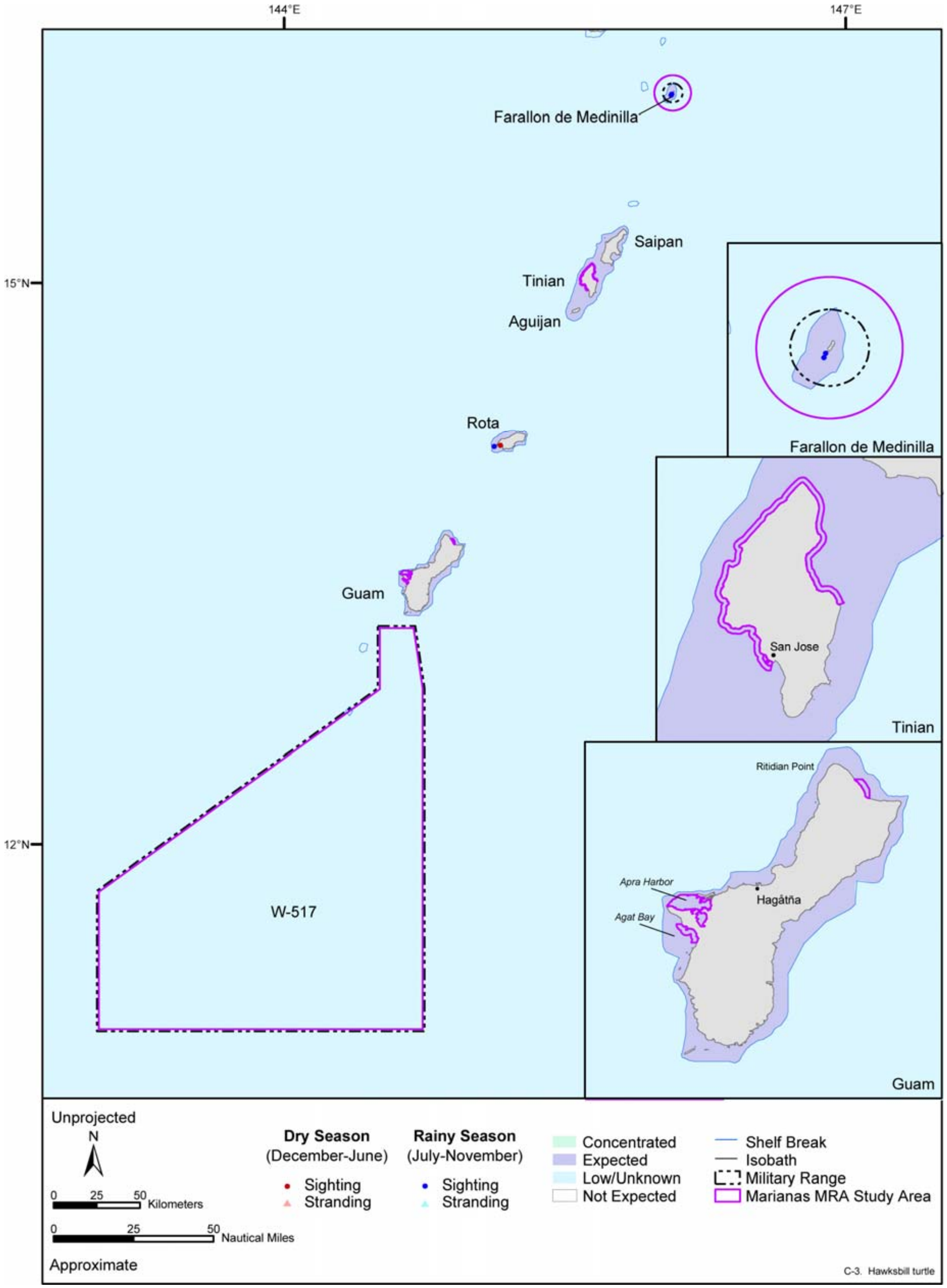

Figure C-3. Occurrence of the hawksbill turtle in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. Available sighting and stranding records are represented. Source data: refer to Table A-1.

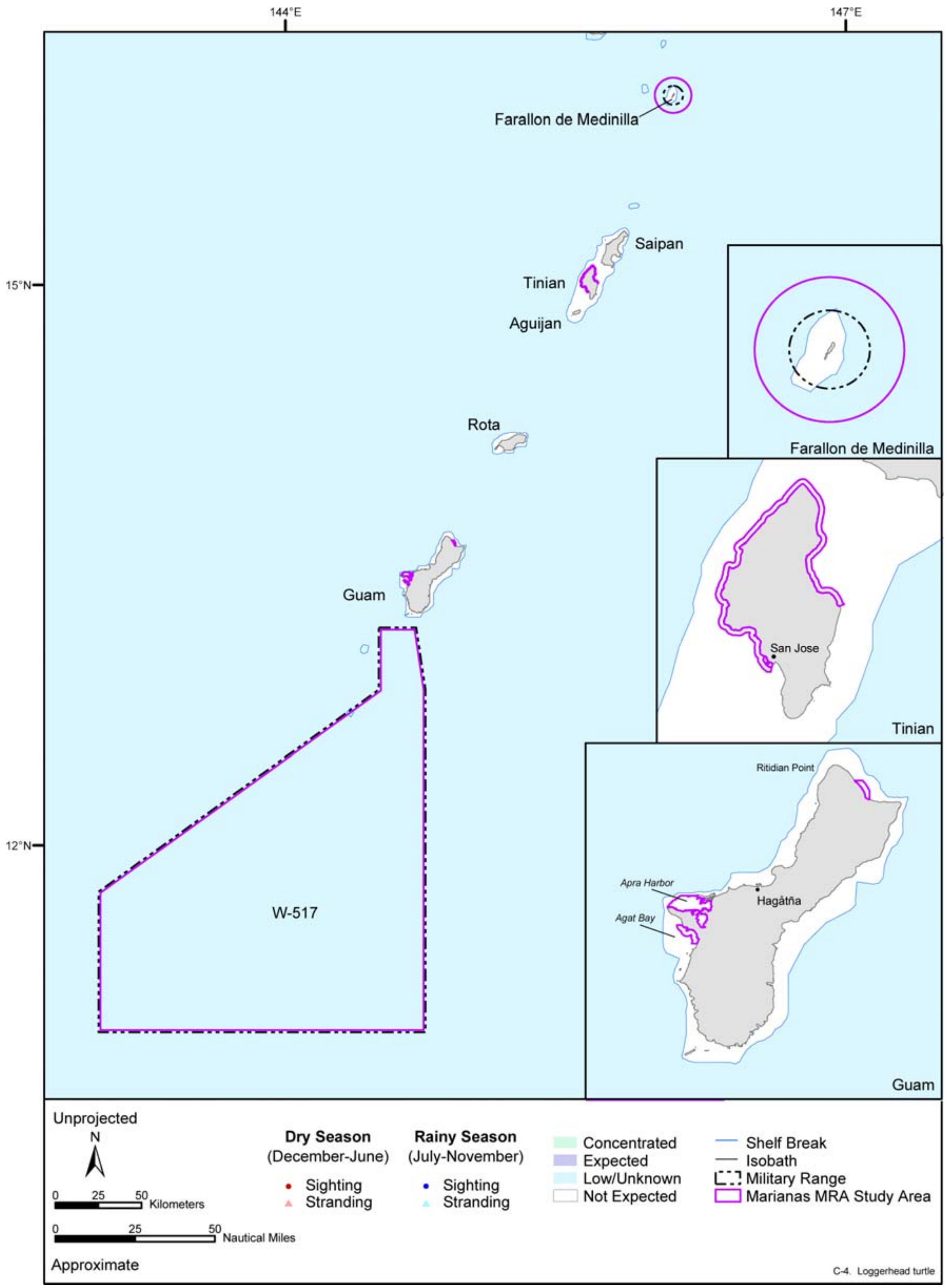

Figure C-4. Occurrence of the loggerhead turtle in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. There are no sighting and stranding records presented for this species within the map extent either because they are not known or because one of the two following criteria was missing: date of observation and specific location (coordinates or triangulated position).

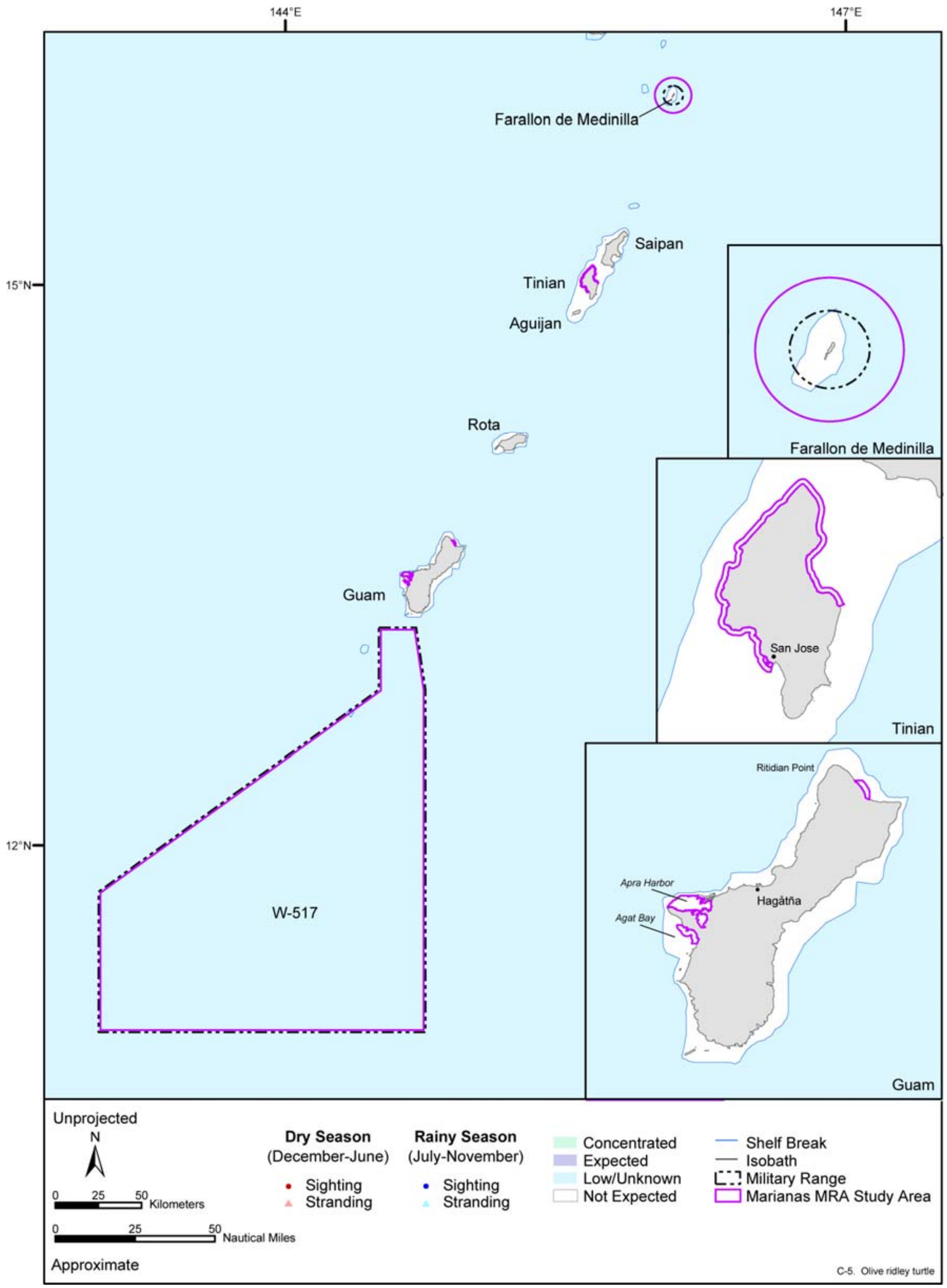

Figure C-5. Occurrence of the olive ridley turtle in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. There are no sighting and stranding records presented for this species within the map extent either because they are not known or because one of the two following criteria was missing: date of observation and specific location (coordinates or triangulated position).

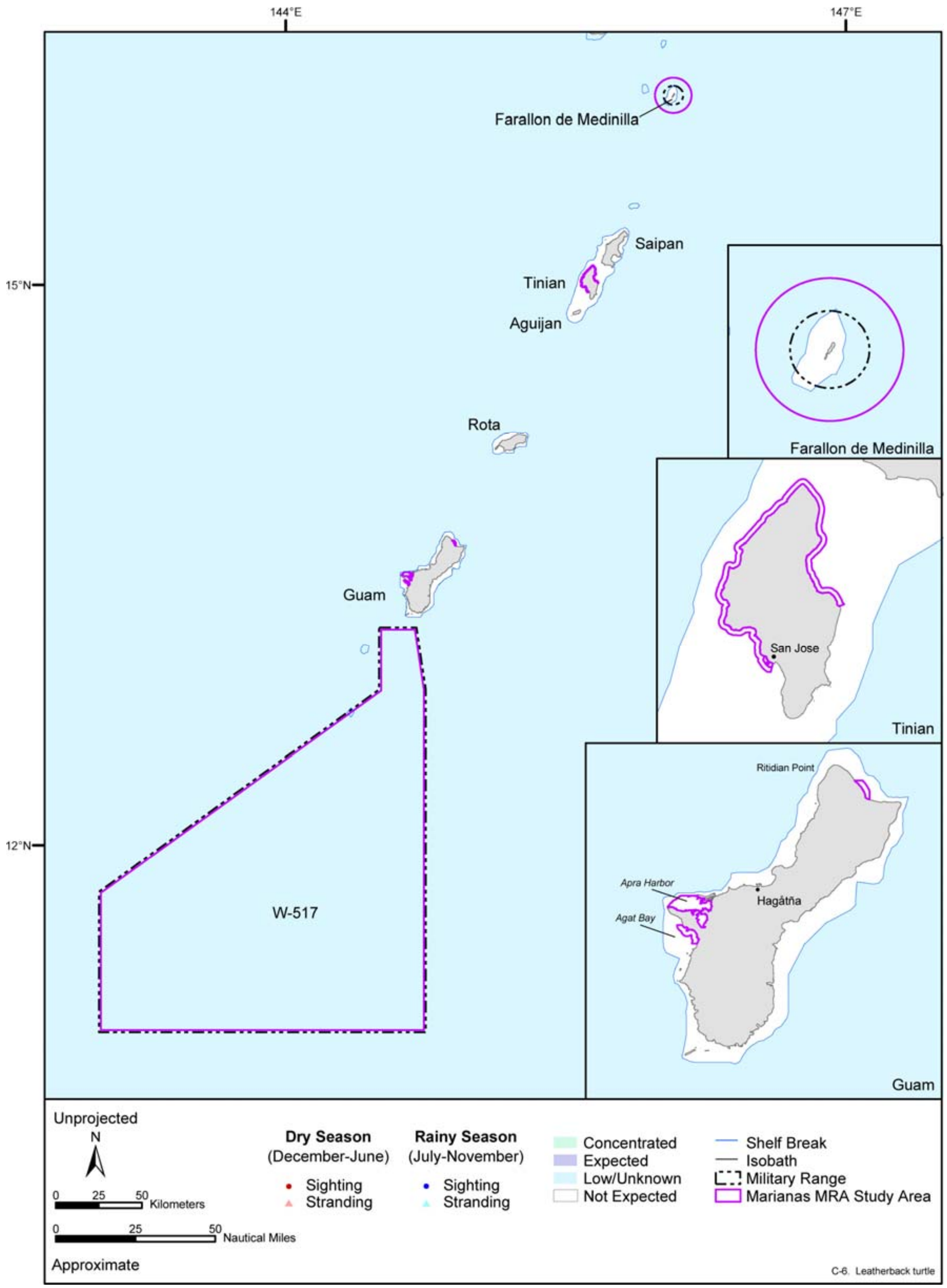

Figure C-6. Occurrence of the leatherback turtle in the Marianas MRA study area and vicinity. These occurrence patterns are applicable throughout the year. There are no sighting and stranding records presented for this species within the map extent either because they are not known or because one of the two following criteria was missing: date of observation and specific location (coordinates or triangulated position).

APPENDIX D: FISH

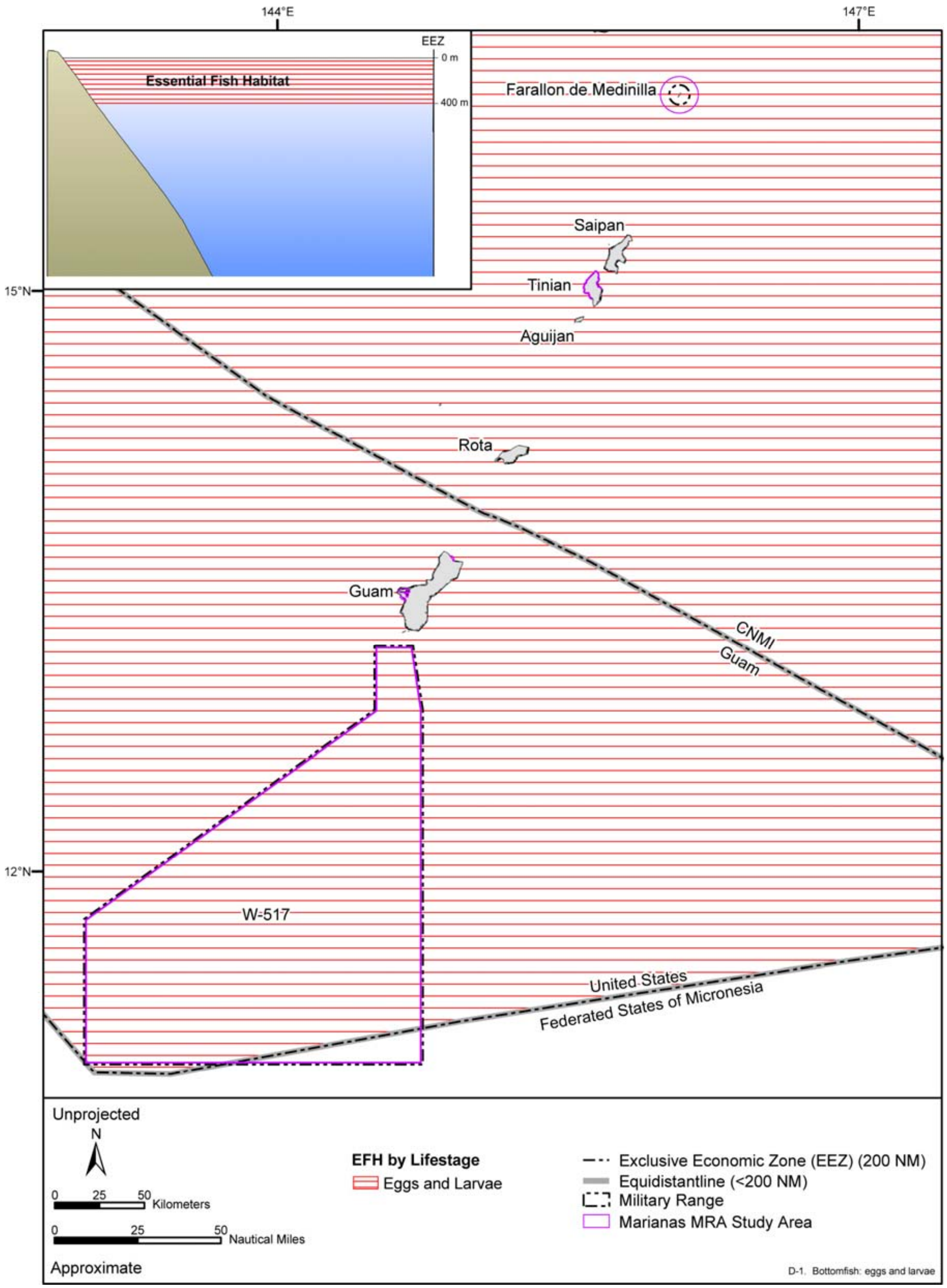

Figure D-1. Essential fish habitat (EFH) for all eggs and larval lifestages of bottomfish designated on Guam, Tinian, and Farallon de Medinilla in the Marianas MRA study area and vicinity. Depth ranges noted in legend apply from shoreline to the outer limit of the EEZ. Map adapted from: WPRFMC (1998) and GDAIS (2004).

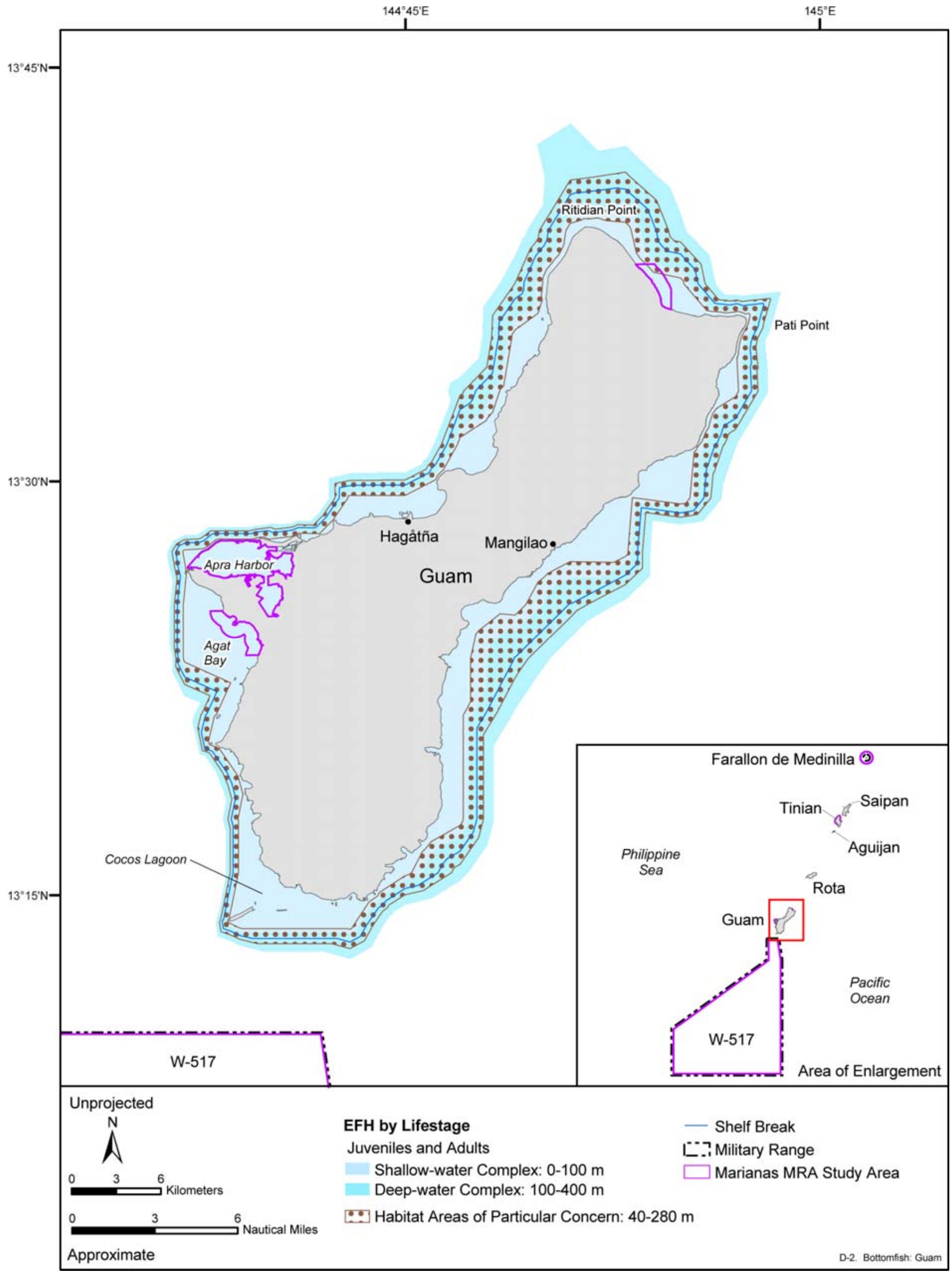

Figure D-2. EFH for all juvenile and adult lifestages of bottomfish and HAPC designated on Guam in the Marianas MRA study area and vicinity. Map adapted from: WPRFMC (1998).

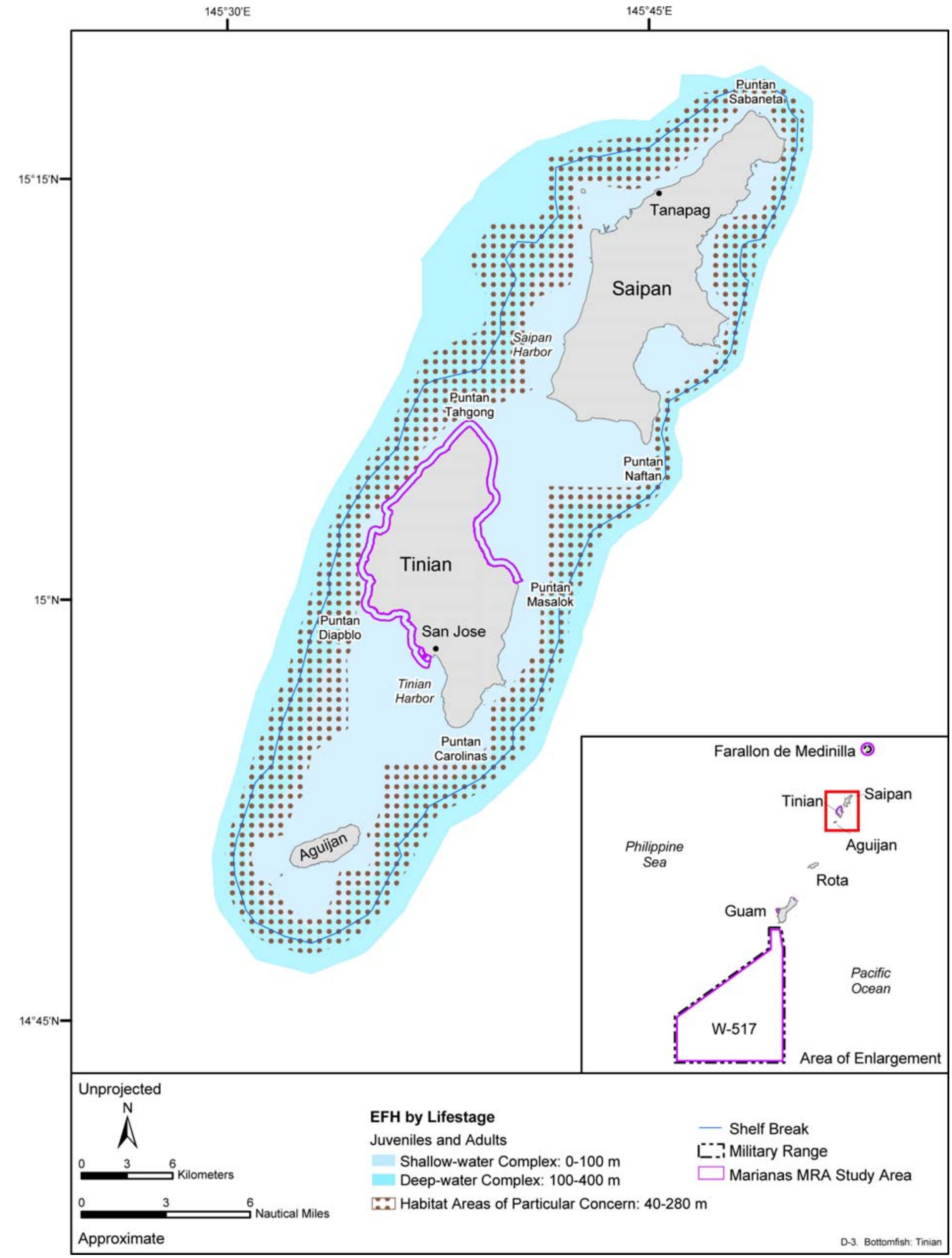

Figure D-3. EFH for all juvenile and adult lifestages of bottomfish and HAPC designated on Tinian in the Marianas MRA study area and vicinity. Map adapted from: WPRFMC (1998).

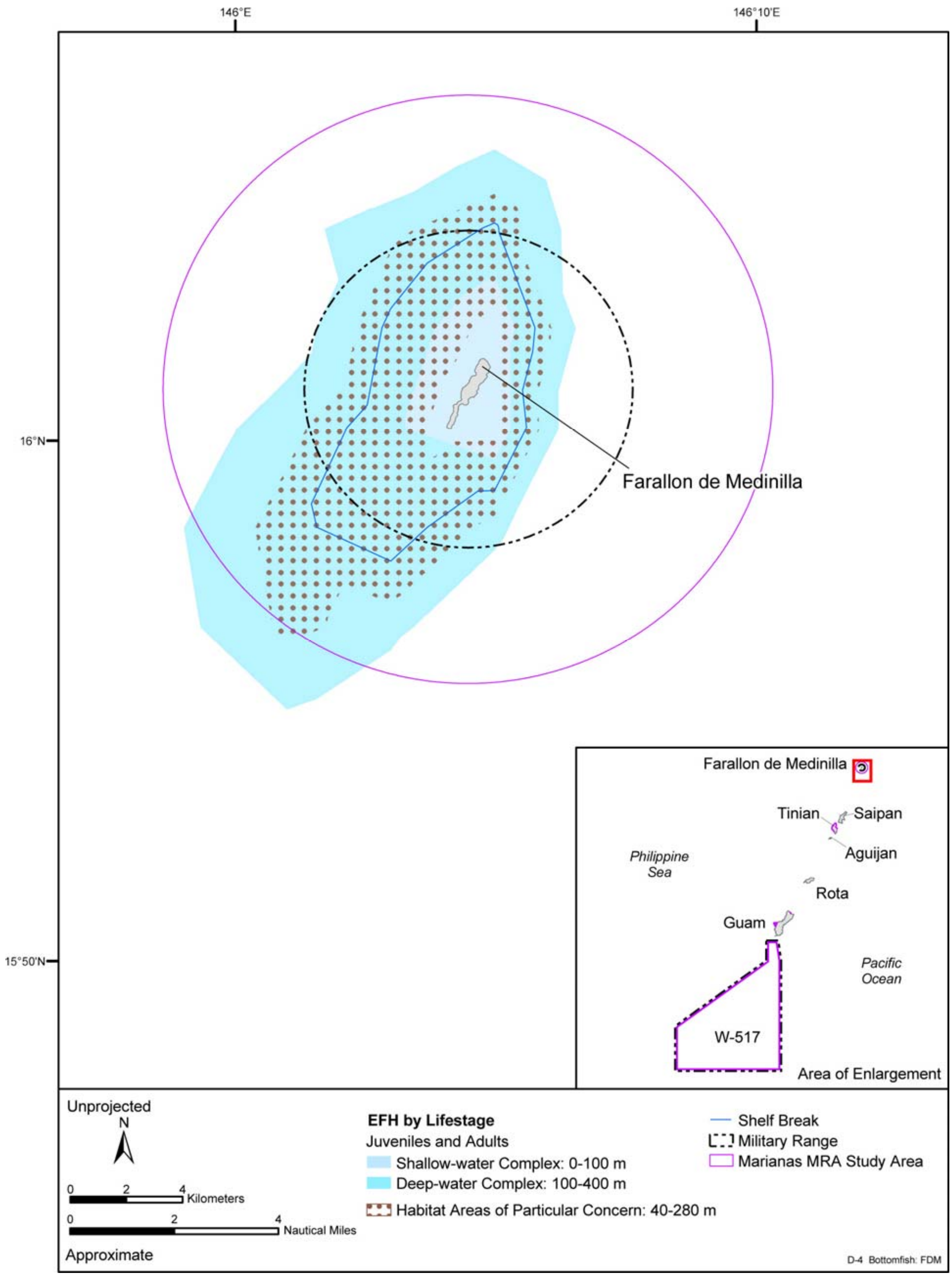

Figure D-4. EFH for all juvenile and adult lifestages of bottomfishes designated on Farallon de Medinilla (FDM) in the Marianas MRA study area and vicinity. Map adapted from: WPRFMC (1998).

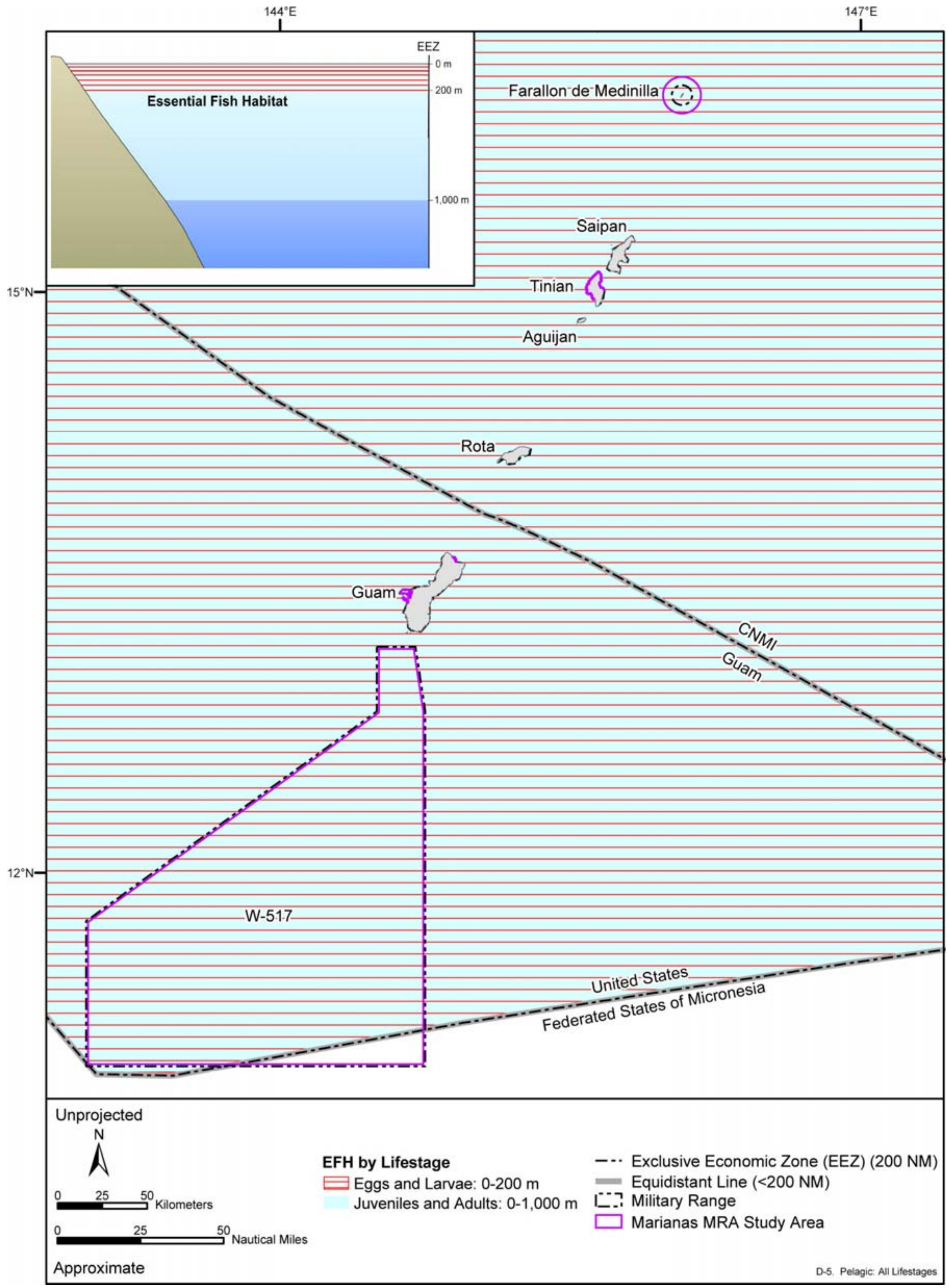

Figure D-5. EFH for all lifestages of pelagic fishes designated on Guam, Tinian, and FDM in the Marianas MRA study area and vicinity. Depth ranges noted in legend apply from the shoreline to the outer limit of the EEZ. Map adapted from: WPRFMC (1998) and GDIAS (2004).

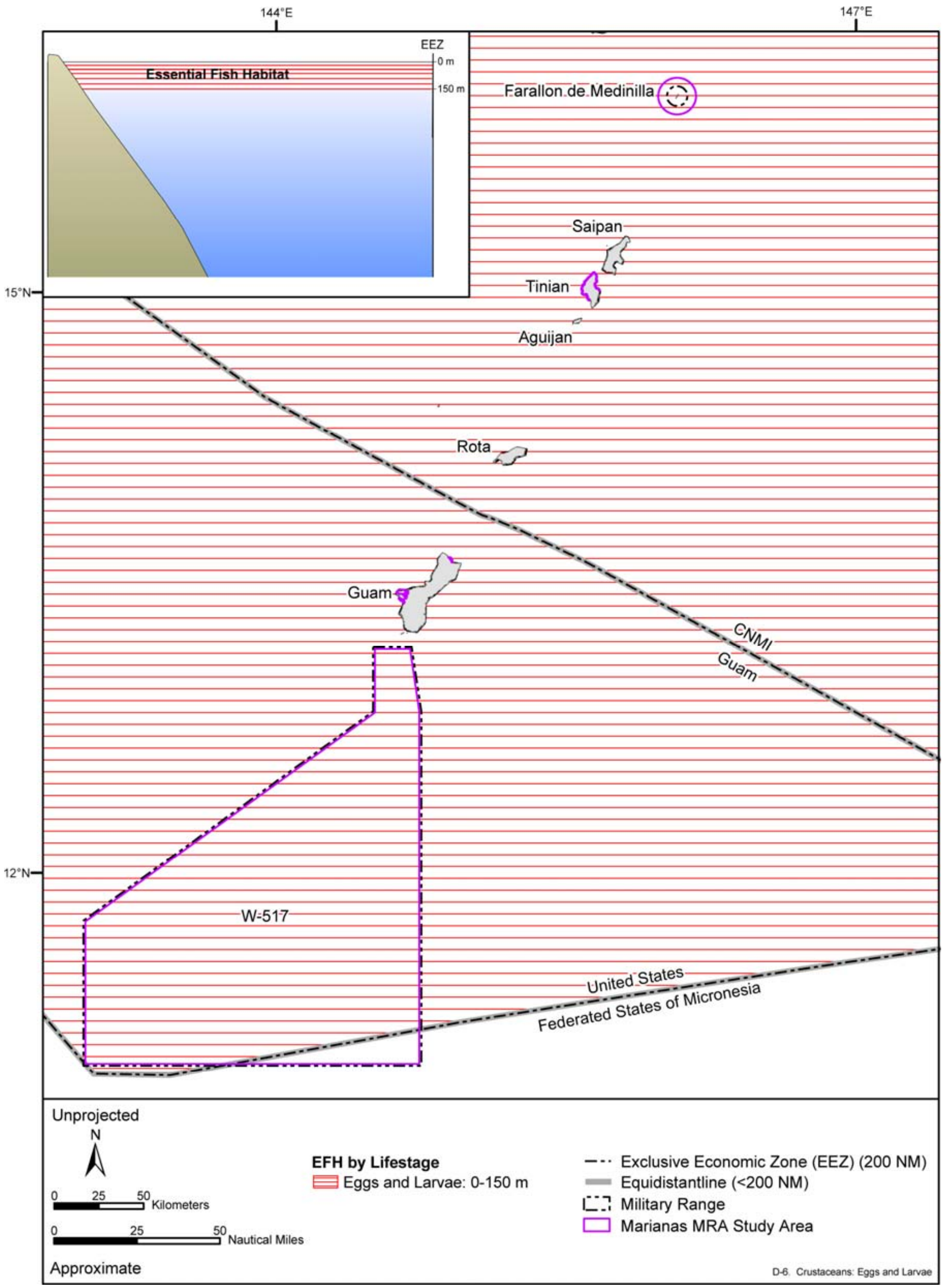

Figure D-6. EFH for all eggs and larval lifestages of crustaceans designated on Guam, Tinian, and FDM in the Marianas MRA study area and vicinity. Depth ranges noted in legend from the shoreline to the outer limit of the EEZ. Map adapted from: WPRFMC (1998) and GDAIS (2004).

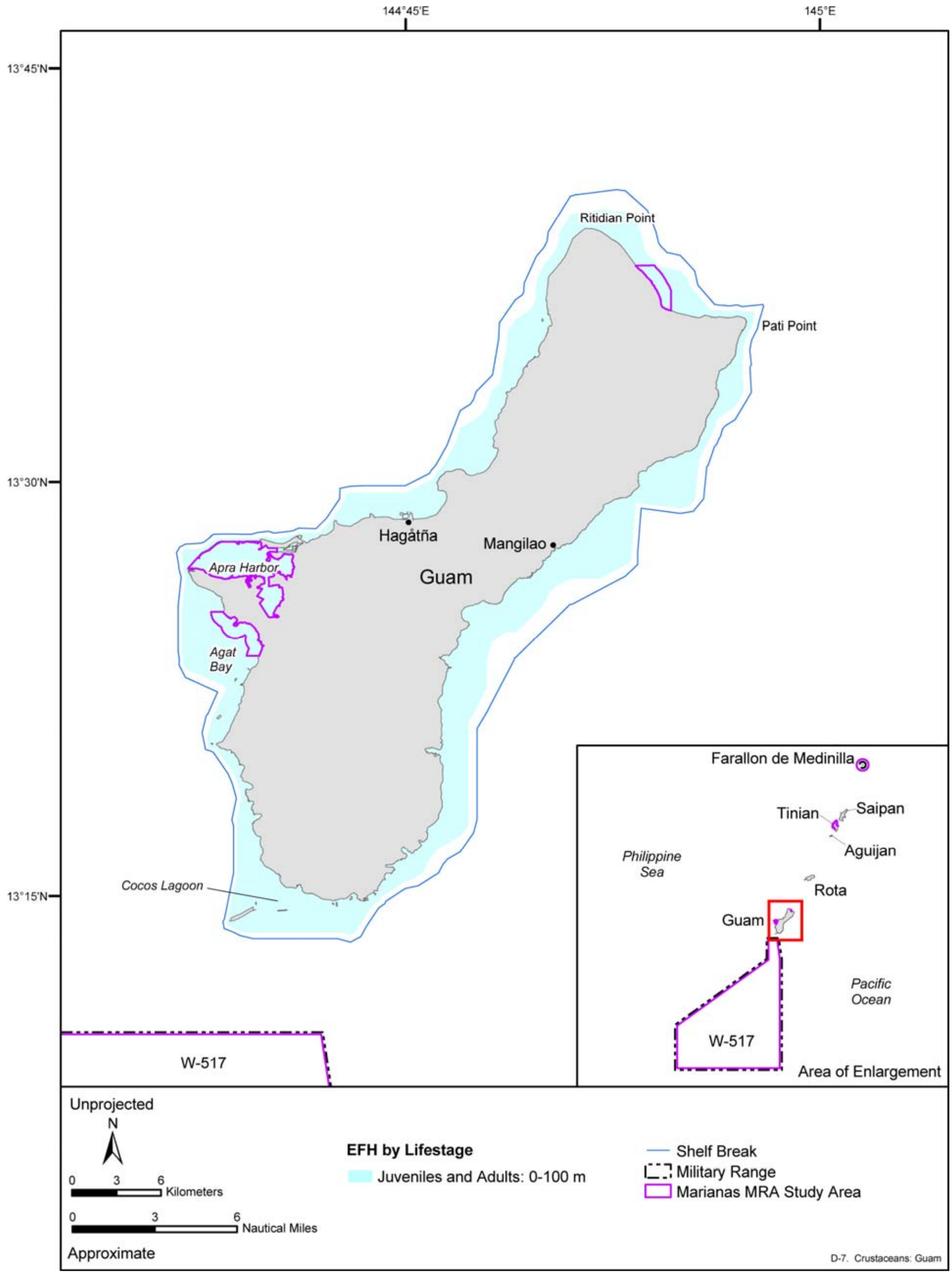

Figure D-7. EFH for all juvenile and adult lifestages of crustaceans designated on Guam in the Marianas MRA study area and vicinity. Map adapted from: WPRFMC (1998).

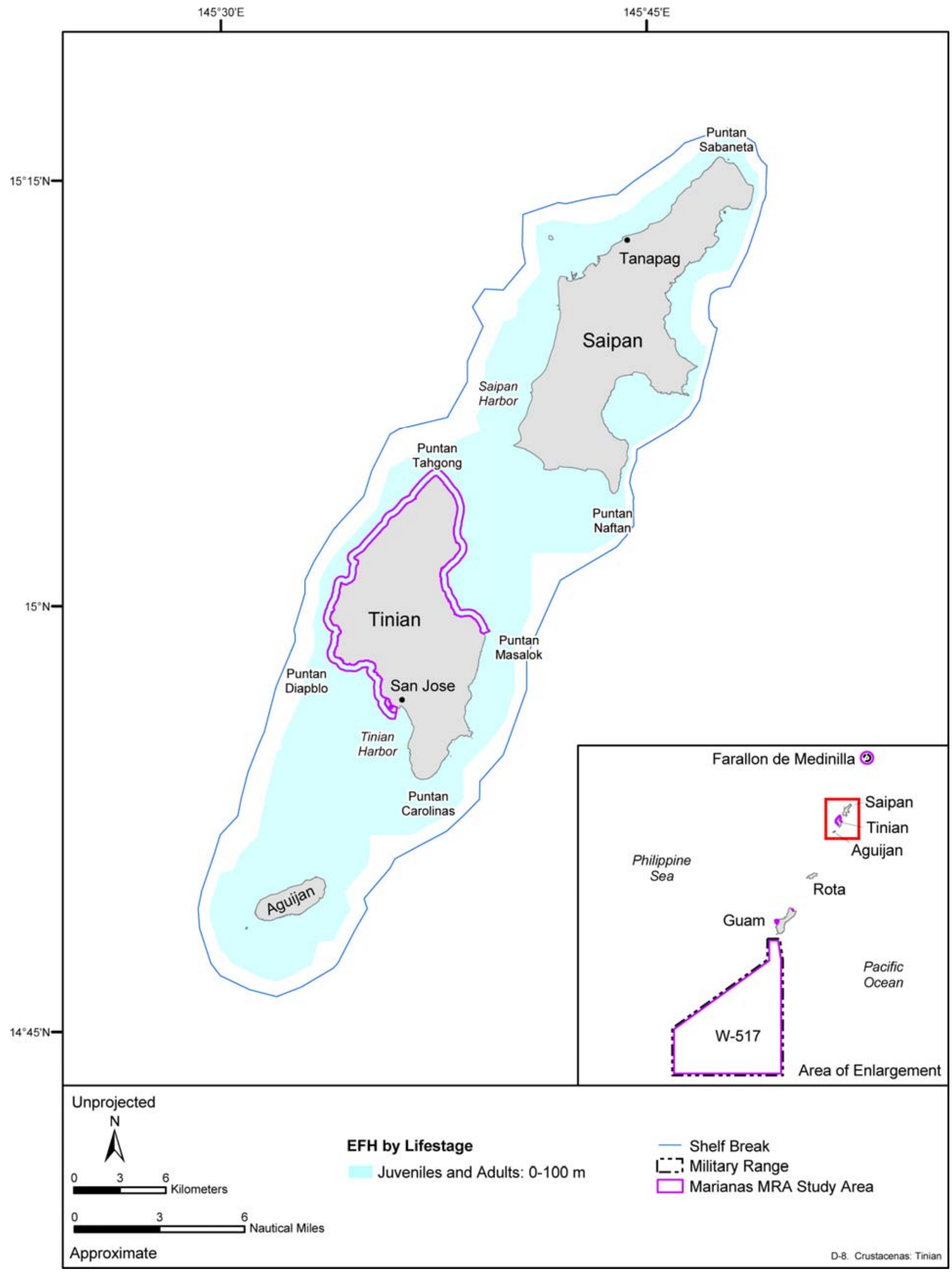

Figure D-8. EFH for all juvenile and adult lifestages of crustaceans designated on Tinian in the Marianas MRA study area and vicinity. Map adapted from: WPRFMC (1998).

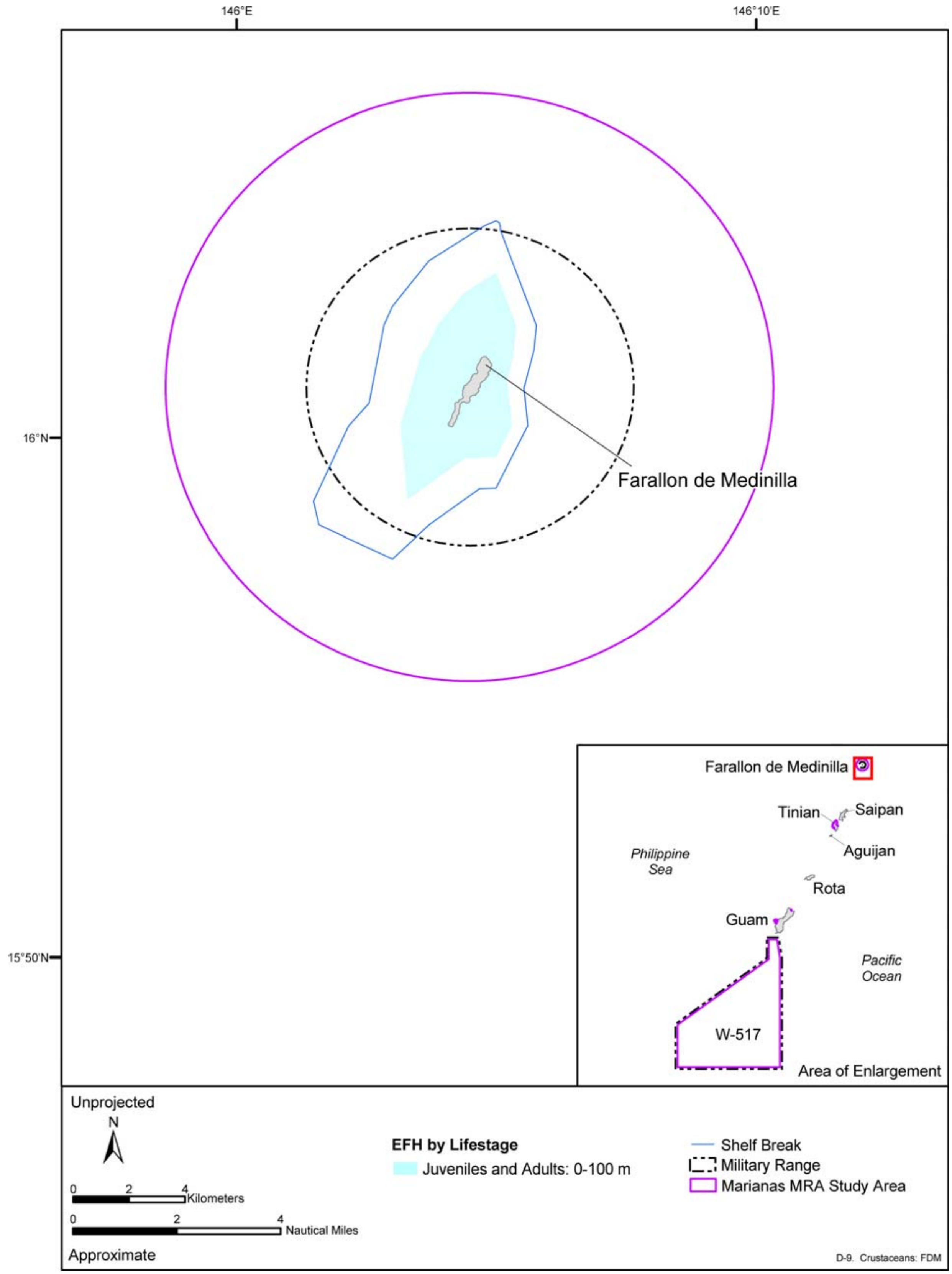

Figure D-9. EFH for all juvenile and adult lifestages of crustaceans designated on FDM in the Marianas MRA study area and vicinity. Map adapted from: WPRFMC (1998).

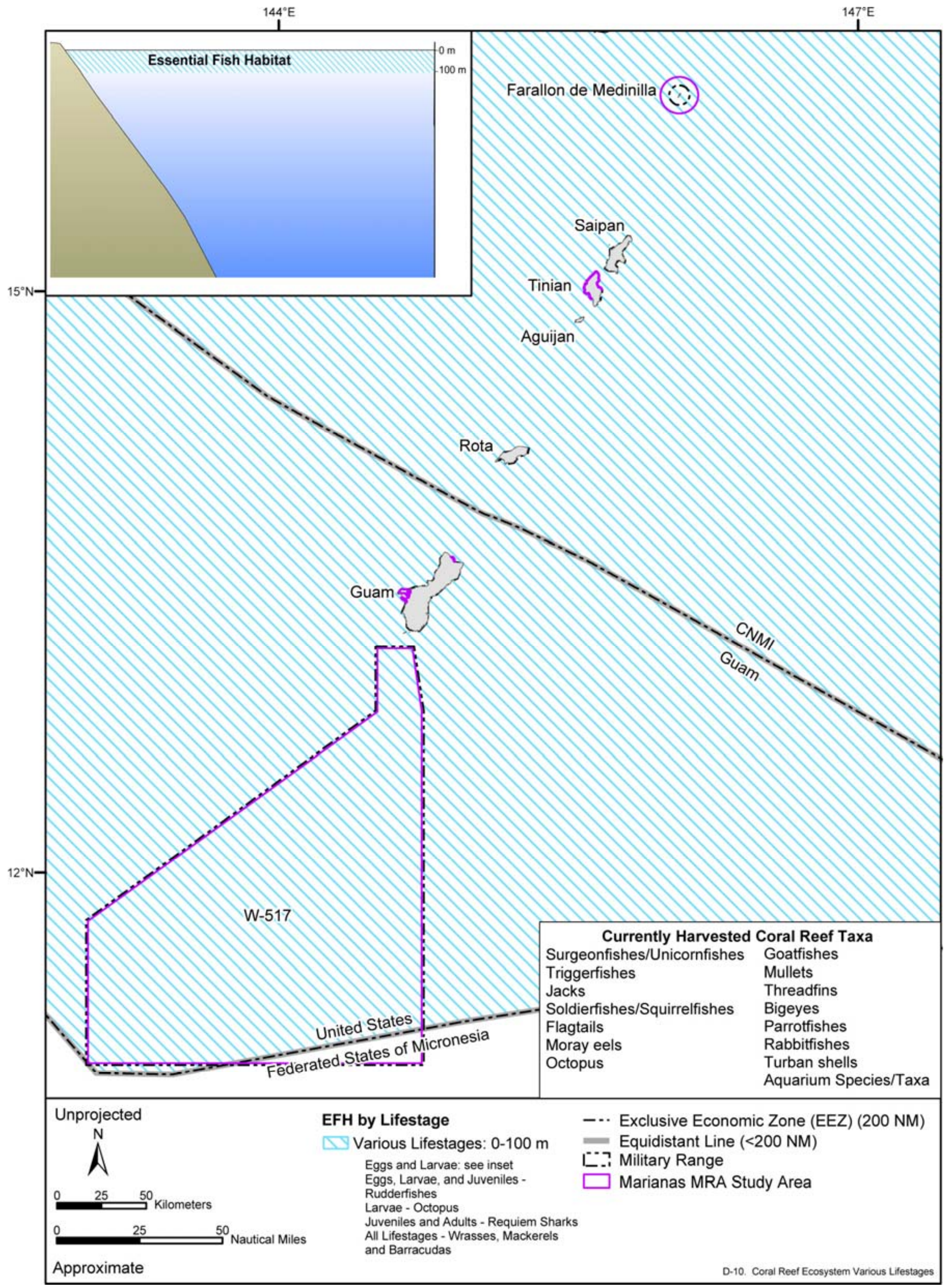

Figure D-10. EFH for various lifestages of the currently harvested coral reef taxa (CHCRT-coral reef ecosystem) and HAPC designated on Guam, Tinian, and FDM in the Marianas MRA study area and vicinity. Depth ranges noted in legend apply from the shoreline to the outer limits of EEZ. Map adapted from: WPRFMC (2001) and GDAIS (2004).

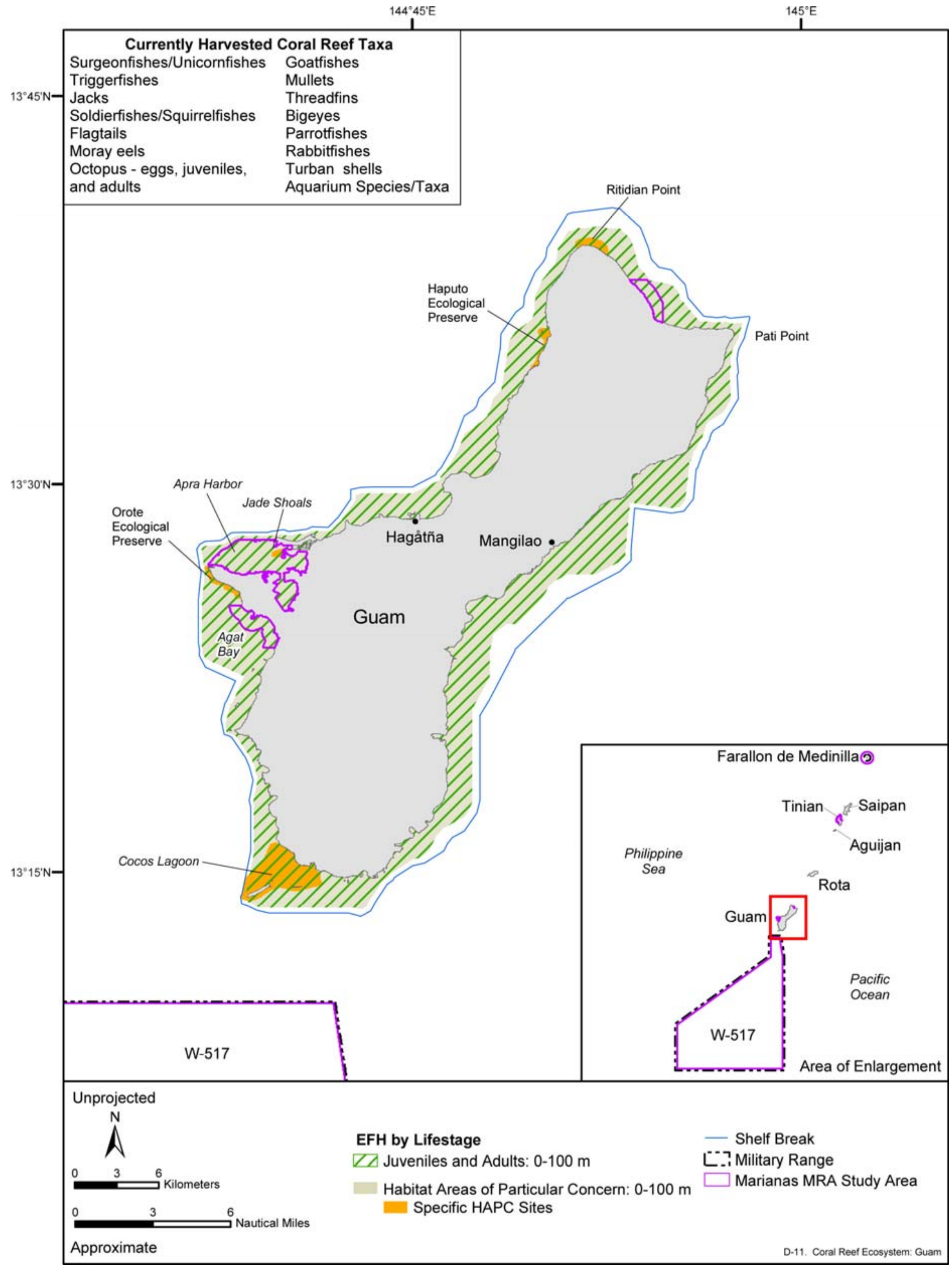

Figure D-11. EFH for all juvenile and adult lifestages of the CHCRT-coral reef ecosystem and HAPC designated on Guam in the Marianas MRA study area and vicinity. Map adapted from: WPRFMC (2001).

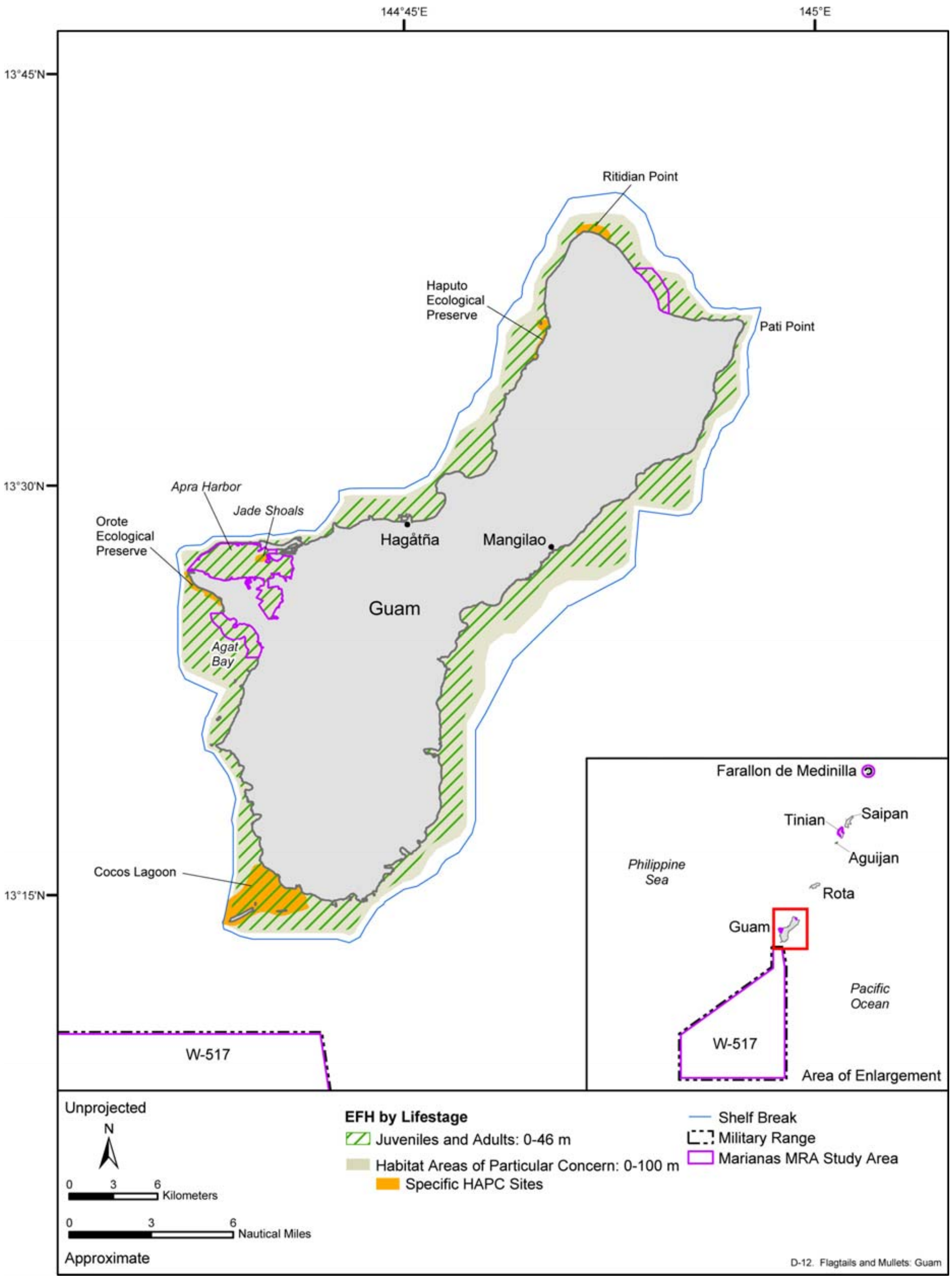

Figure D-12. EFH for all juvenile and adult lifestages of flagtails and mullets (CHCRT-coral reef ecosystem) and HAPC designated on Guam in the Marianas MRA study area and vicinity. Map adapted from: WPRFMC (2001).

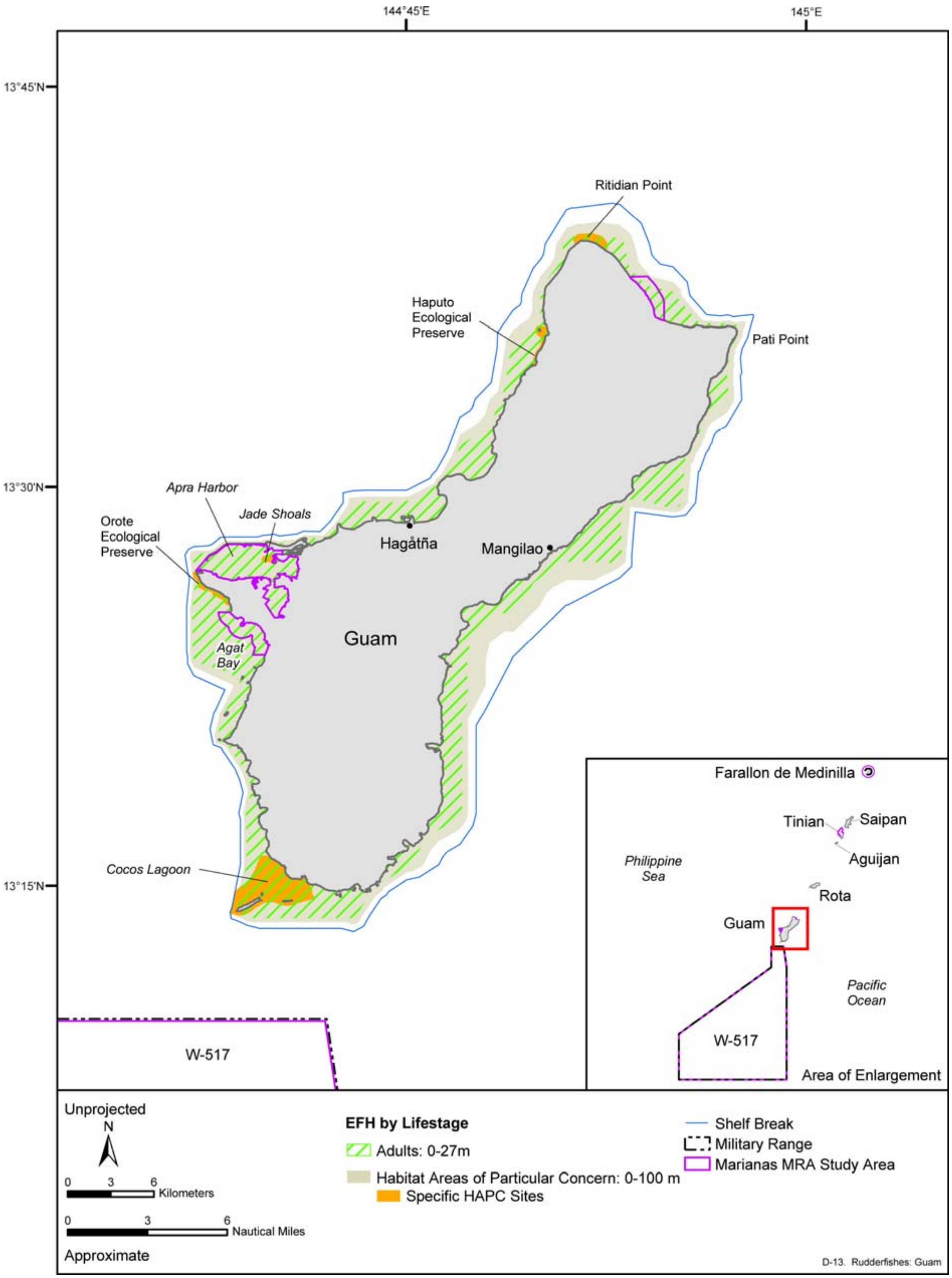

Figure D-13. EFH for all adult lifestages of rudderfishes (CHCRT-coral reef ecosystem) and HAPC designated on Guam in the Marianas MRA study area and vicinity. Map adapted from: WPRFMC (2001).

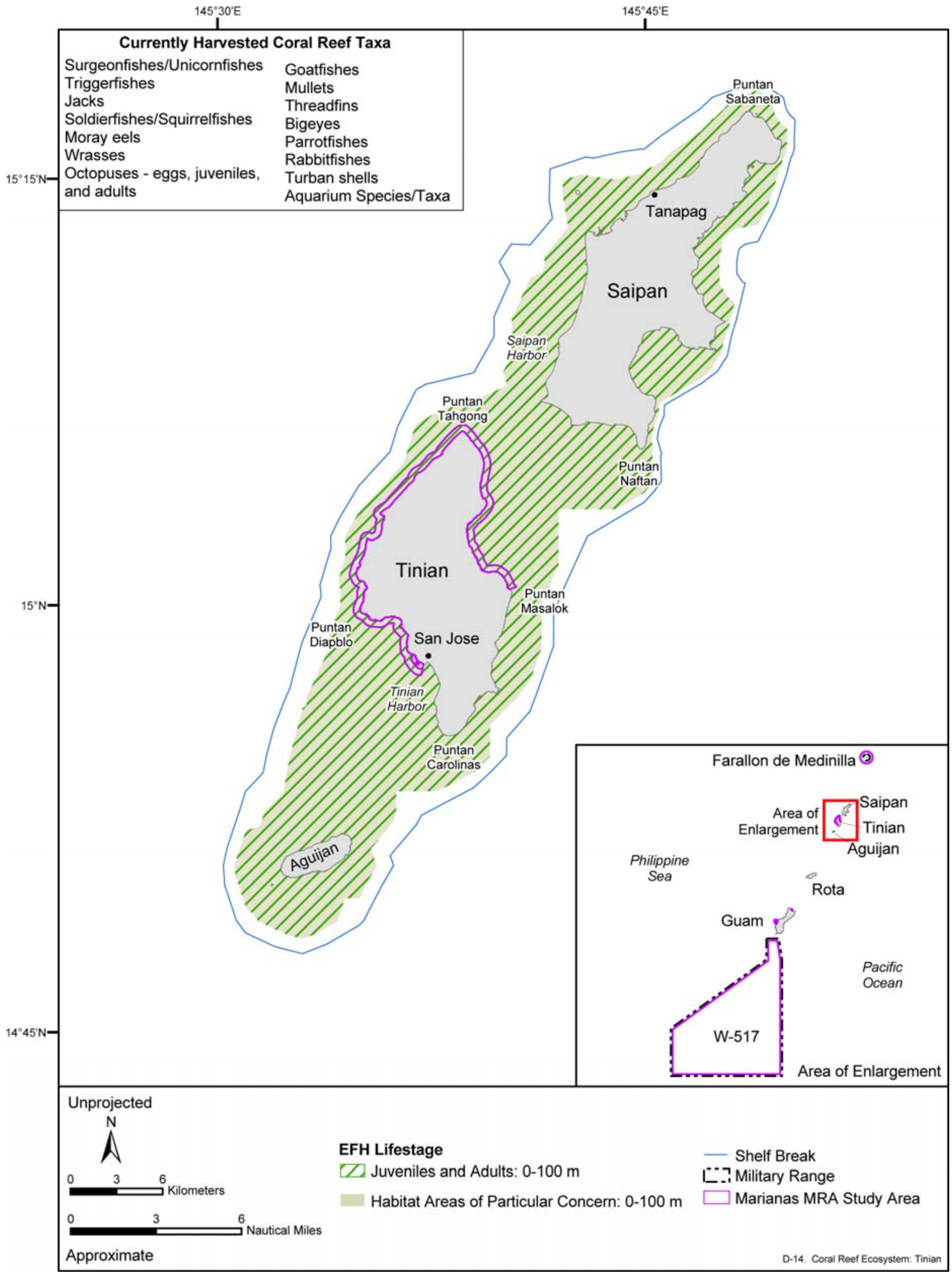

Figure D-14. EFH for all juvenile and adult lifestages of the CHCRT-coral reef ecosystem and HAPC designated on Tinian in the Marianas MRA study area and vicinity. Map adapted from: WPRFMC (2001).

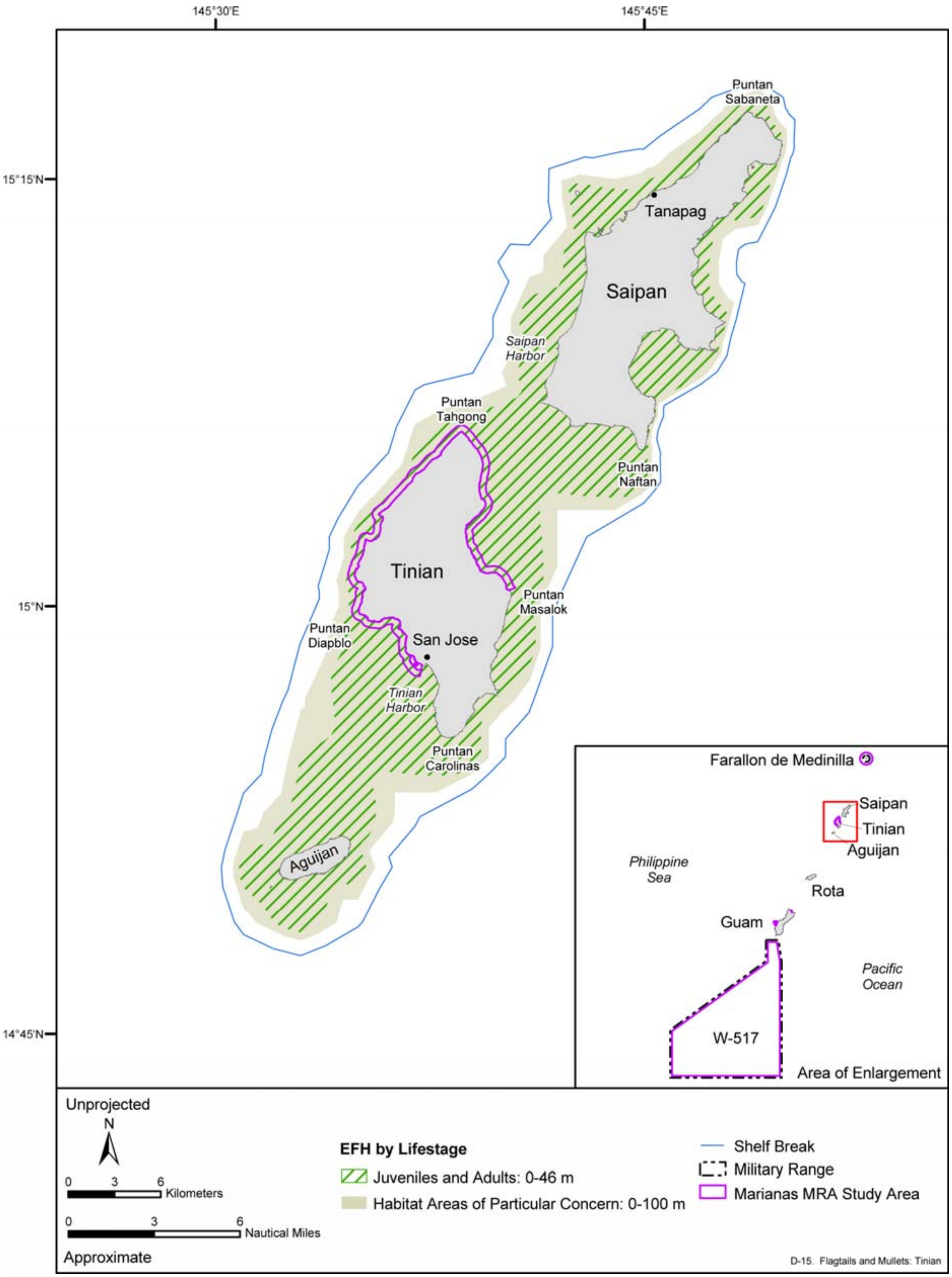

Figure D-15. EFH for all juvenile and adult lifestages of flagtails and mullets (CHCRT-coral reef ecosystem) and HAPC designated on Tinian in the Marianas MRA study area and vicinity. Map adapted from: WPRFMC (2001).

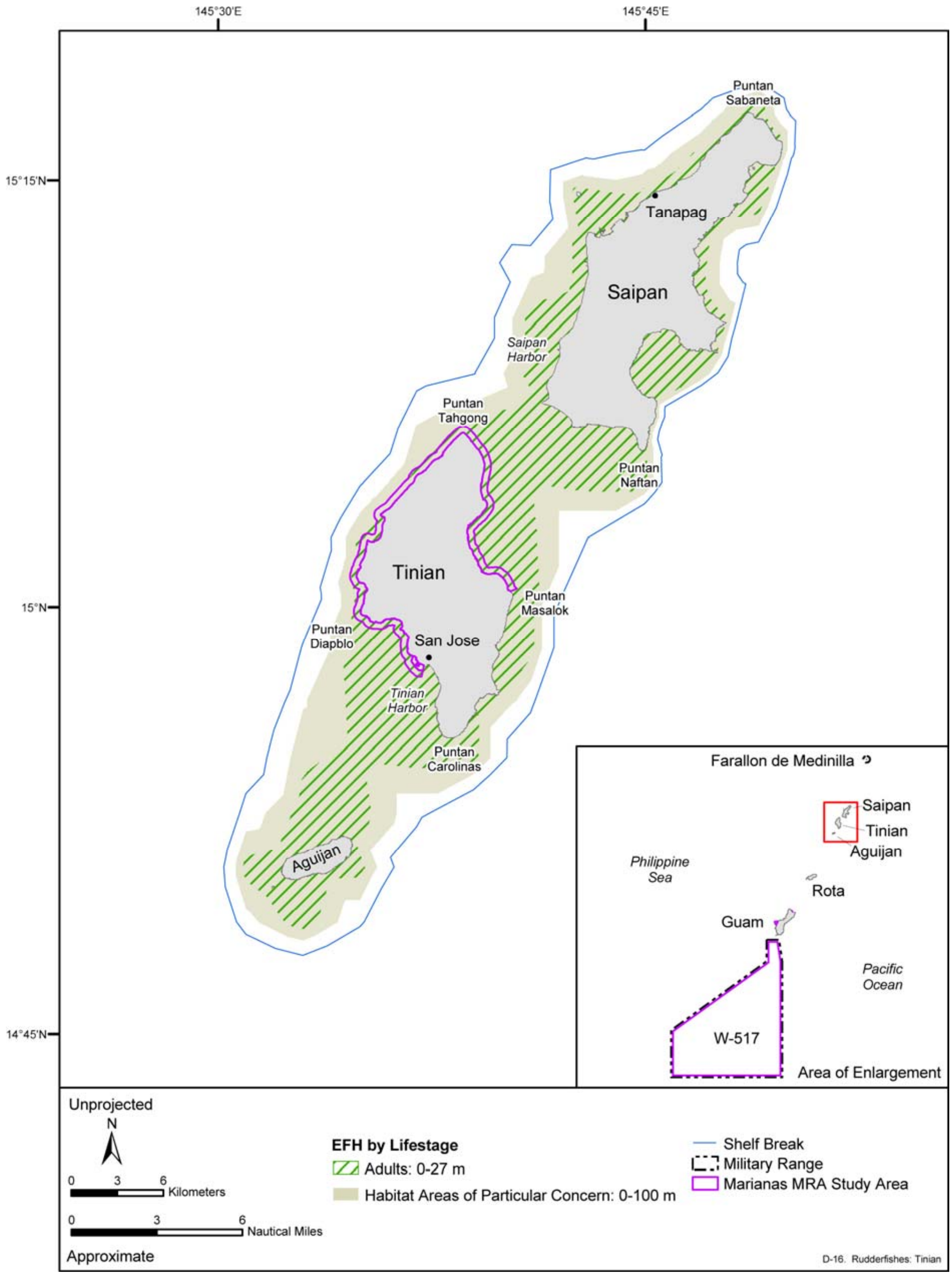

Figure D-16. EFH for all adult lifestages of rudderfishes (CHCRT-coral reef ecosystem) and HAPC designated on Tinian in the Marianas MRA study area and vicinity. Map adapted from: WPRFMC (2001).

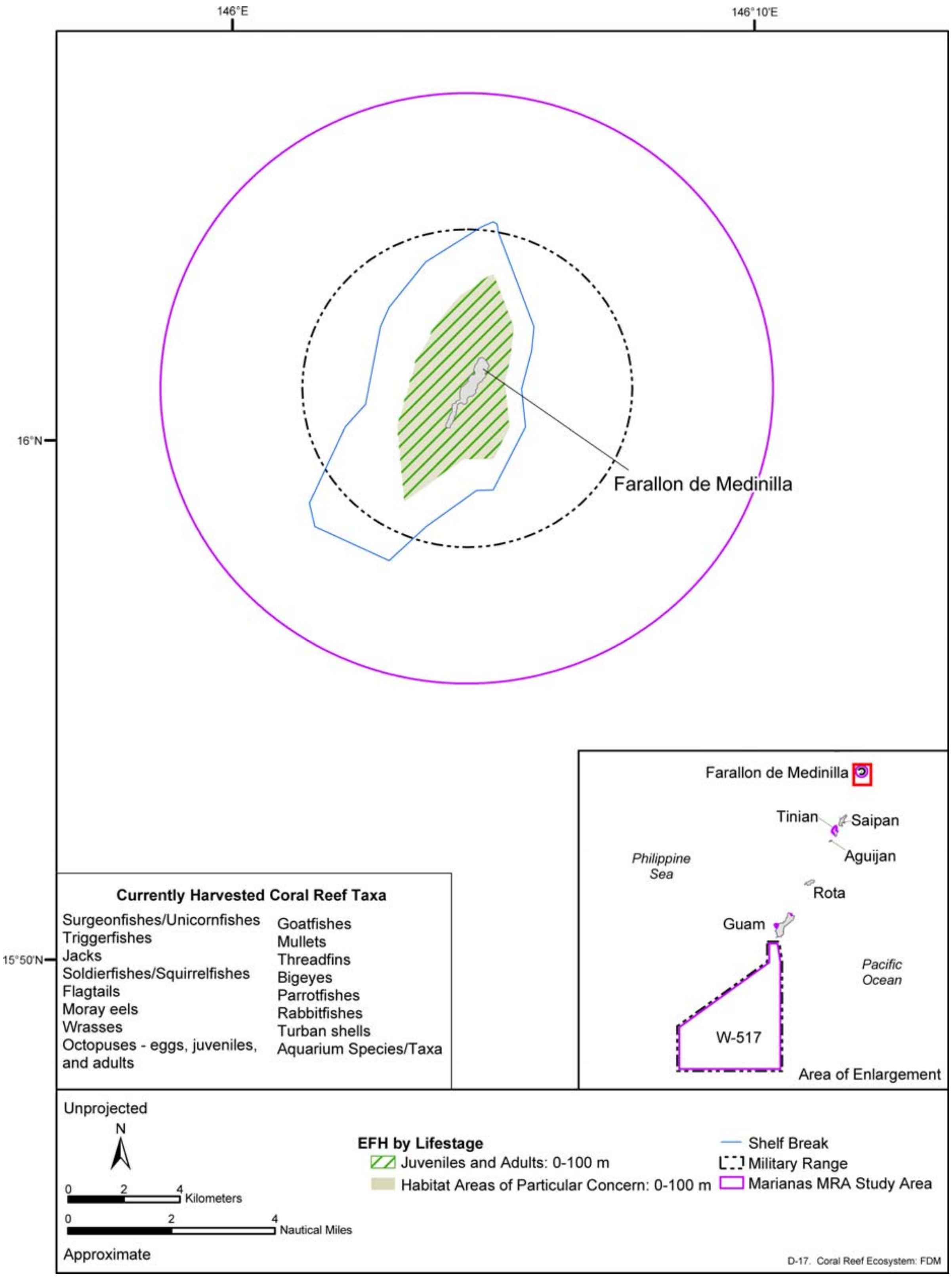

Figure D-17. EFH for all juvenile and adult lifestages of the CHCRT-coral reef ecosystem and HAPC designated on Farallon de Medinilla in the Marianas MRA study area and vicinity. Map adapted from: WPRFMC (2001).

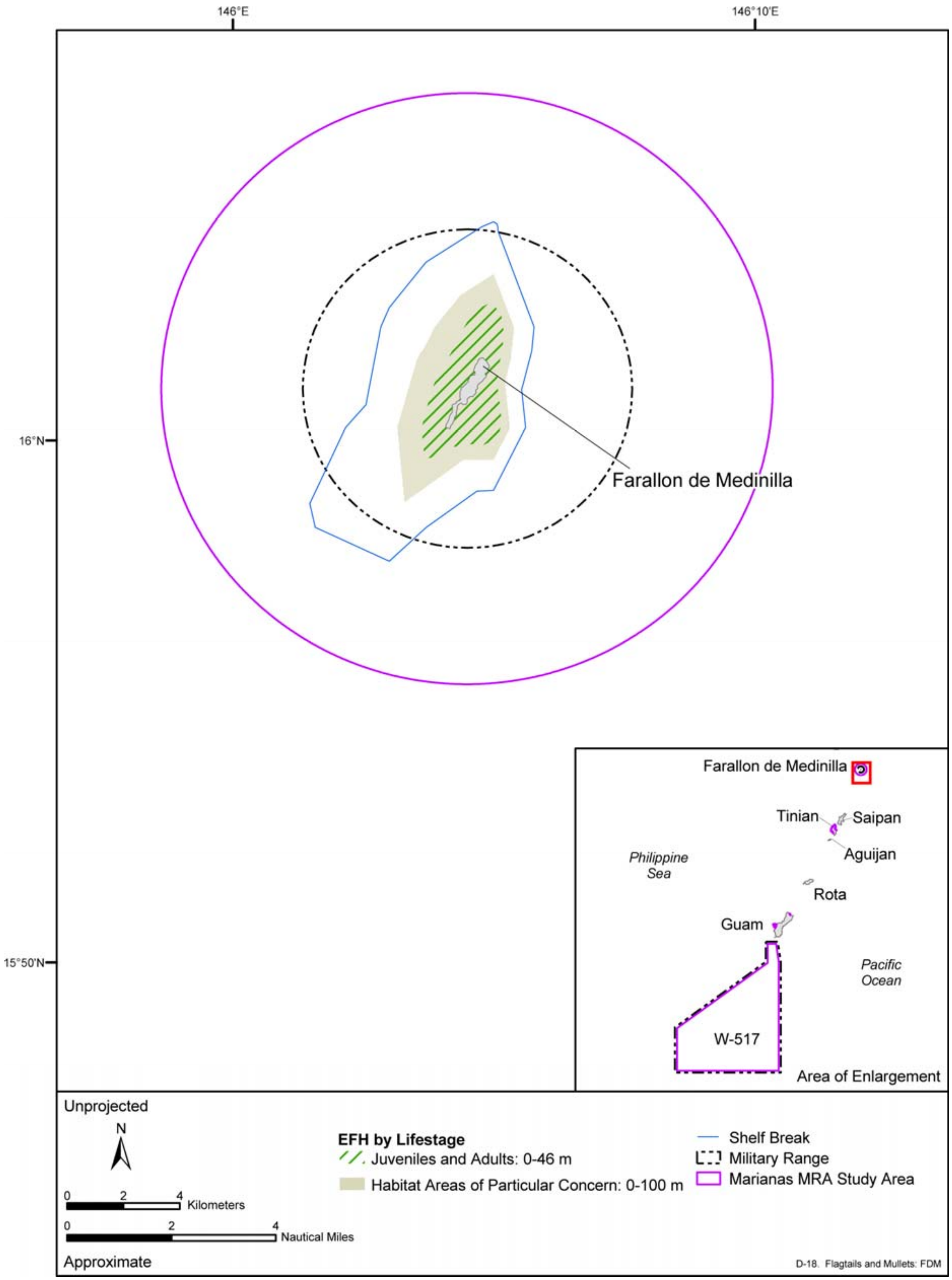

Figure D-18. EFH for all juvenile and adult lifestages of the flagtails and mullets (CHCRT-coral reef ecosystem) and HAPC designated on FDM in the Marianas MRA study area and vicinity. Map adapted from: WPRFMC (2001).

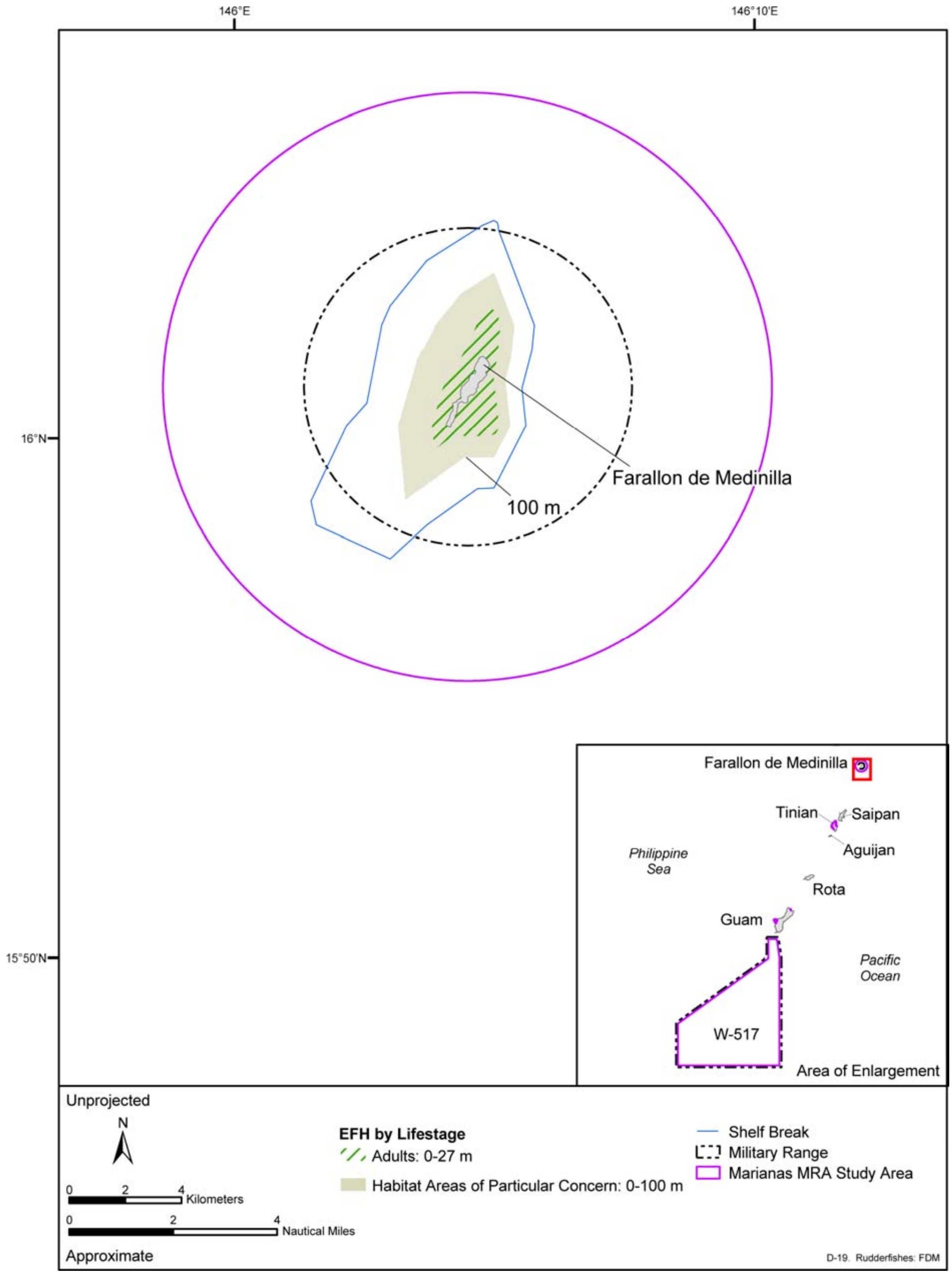

Figure D-19. EFH for all adult lifestages of rudderfishes (CHCRT-coral reef ecosystem) and HAPC designated on FDM in the Marianas MRA study area and vicinity. Map adapted from: WPRFMC (2001).

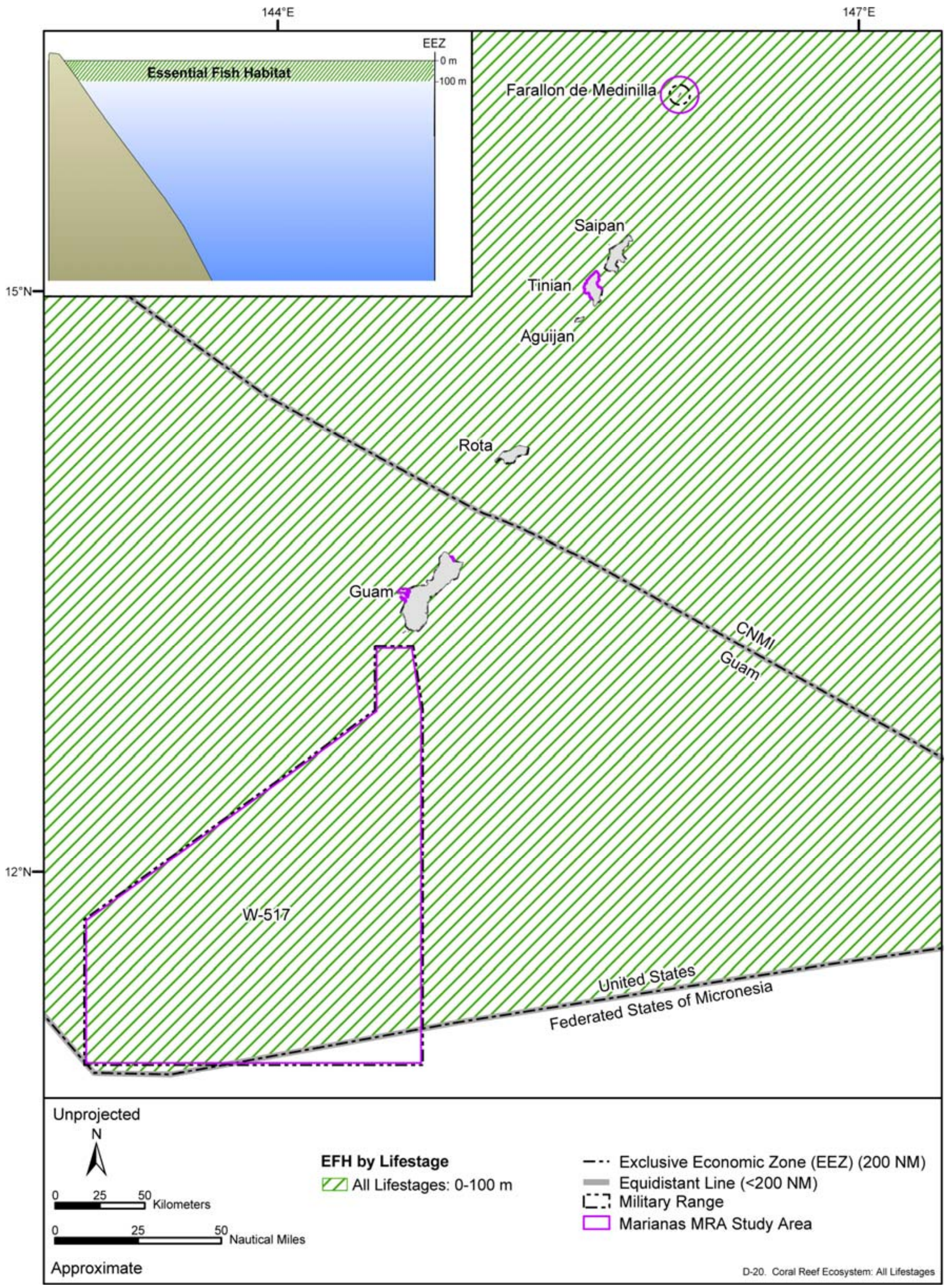

Figure D-20. EFH for all lifestages of the potentially harvested coral reef taxa (PHCRT-coral reef ecosystem) and HAPC designated on Guam, Tinian, and FDM in the Marianas MRA study area and vicinity. Depth ranges noted in legend apply from the shoreline to the outer limit of the EEZ. Map adapted from: WPRFMC (2001) and GDAIS (2004).