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MARIANA ISLANDS RANGE COMPLEX

ENVIRONMENTAL IMPACT STATEMENT/

OVERSEAS ENVIRONMENTAL IMPACT STATEMENT

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Final

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Acronyms and Abbreviations

µg/L	micrograms per liter
µm	micrometers
µg/m^3	micrograms per cubic meter
µPa^2-s	squared micropascal-second
µPa	micropascal
A-	Alert Area
A-A	Air-to-Air
A-G	Air-to-Ground
A-S	Air-to-Surface
AFB	Air Force Base
AAFB	Andersen Air Force Base
AAMEX	Air-to-Air Missile Exercise
AAV	Amphibious Assault Vehicle
AAW	Anti-Air Warfare
ABR	Auditory Brainstem Response
ACHP	Advisory Council on Historic Preservation
ACM	Air Combat Maneuvers
ADAR	Air Deployed Active Receiver
ADC	Acoustic Device Countermeasure
ADV	SEAL Delivery Vehicle
AEER	Advanced Extended Echo Ranging
AEP	Auditory Evoked Potentials
AESA	Airborne Electronically Scanned Array
AFAST	Atlantic Fleet Active Sonar Training
AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
AFI	Air Force Instruction
AGE	Aerospace Ground Equipment
AGL	Above Ground Level
AICUZ	Air Installations Compatible Use Zones
AIM	Air Intercept Missile
AK	Alaska
AMRAAM	Advanced Medium-Range Air-to-Air Missile
AMSP	Advanced Multi-Static Processing Program
AMW	Amphibious Warfare
ANNUALEX	Annual Exercise
AOR	area of responsibility
APCD	Air Pollution Control District
APZ	Accident Potential Zones
AQCR	Air Quality Control Region
AR	Army Reserves
AR-Marianas	Army Reserves Marianas
Army	U.S. Army
ARPA	Archaeological Resources Protection Act
ARS	Advance Ranging Source
ARTCC	Air Route Traffic Control Center
AS	Assault Support
ASDS	Advanced SEAL Delivery System
ASL	Above Sea Level
ASTA	Andersen South Training Area
ASTM	American Society for Testing and Materials
ASUW	Anti-Surface Warfare
ASW	Anti-Submarine Warfare
AT	Anti-Terrorism
AT/FP	Anti-Terrorism/Force Protection
ATC	Air Traffic Control
ATCAA	Air Traffic Control Assigned Airspace
atm	atmosphere (pressure)
ATOC	Acoustic Thermometry of Ocean Climate
ATSDR	Agency for Toxic Substances and Disease Registry
AUPM	Above & Underground Storage Tanks and Pesticide Management
AUTEC	Atlantic Undersea Test and Evaluation Center
AV-8B	Vertical/Short Takeoff and Landing Strike Aircraft
AW	Air Warfare
B-1	Strategic Bomber
B-2	Stealth Bomber
B-52	Strategic Bomber
BA	Biological Assessment
BAMS	Broad Area Maritime Surveillance
BASH	Bird Aircraft Strike Hazard
BDA	Battle-Damage Assessment
BDU	Bomb Dummy Unit
BH	Breacher House
BMDTF	Ballistic Missile Defense Task Force
BMP	Best Management Practices
BO	Biological Opinion
BOMBEX	Bombing Exercise
BQM	Aerial Target Drone Designation
BRAC	Base Realignment and Closure
BSP	Bureau of Statistics and Plans
BSS	Beaufort Sea State
BZO	Battle Sight Zero
°C	degrees Centigrade
C2	Command and Control
C-4	Composition 4
C-130	Military Transport Aircraft
CA	California
CAA	Clean Air Act
CAL	Confined Area Landing
CAN	Center for Naval Analysis
CAS	Close Air Support
CASS	Comprehensive Acoustic System Simulation
CASS-GRAB	Comprehensive Acoustic System Simulation Gaussian Ray Bundle
CATM	Combat Arms and Training Maintenance
CATMEX	Captive Air Training Missile Exercise
cc	cubic centimeter(s)
CCD	Carbonate Compensation Depth
CCF	Combined Control Facility
CDF	Cumulative Distribution Function
CDS	Container Delivery System
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CG	Cruiser
CHAFFEX/FLAREX	Chaff/Flare Exercise
CHESS	Chase Encirclement Stress Studies
CI	Confidence Interval
CIP	Capital Improvements Program
CITES	Convention on International Trade In Endangered Species
CIWS	Close-in Weapons System
cm	centimeters
CMC	Northern Mariana Islands Commonwealth Code

CMP	Coastal Management Plan
CNEL	Community Noise Equivalent Level
CNO	Chief of Naval Operations
CNRM	Commander, Navy Region Marianas
CNMI	Commonwealth of the Northern Mariana Islands
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COMNAVREG	Commander, Navy Region Marianas
COMNAVMAR	Commander, United States Naval Forces Marianas
COMPACFLT	Commander, Pacific Fleet
COMPTUEX	Composite Training Unit Exercise
COMSUBPAC	Commander, Submarine Forces Pacific
CONEX	Container Express (Shipping Container)
CONUS	Continental United States
CPF	Commander, U.S. Pacific Fleet
CPRW	Commander, Patrol and Reconnaissance Wing
CPX	Command Post Exercise
CQC	Close Quarters Combat
CR	Control Regulation
CRE FMP	Coral Reef Ecosystem Fishery Management Plan
CRG	Contingency Response Group
CRM	Coastal Resources Management
CRRC	Combat Rubber Raiding Craft
CRU	Cruiser
CSAR	Combat Search and Rescue
CSG	Carrier Strike Group
CSS	Commander, Submarine Squadron
CT	Computerized Tomography
CTF	Cable Termination Facility
CUC	Commonwealth Utilities Corporation
CV	Coefficients of Variation
CVN	Aircraft Carrier, Nuclear
CW	Continuous Wave
CWA	Clean Water Act
CY	Calendar Year
CZ	Clear Zones
CZMA	Coastal Zone Management Act
DARPA	Defense Advanced Research Programs Agency
DAWR	Division of Aquatic and Wildlife Resources
dB	Decibel
dBA	A-Weighted Sound Level
DBDBV	Digital Bathymetry Data Base Variable
DDG	Guided Missile Destroyer
DDT	Dichlorodiphenyltrichloroethane
DES	Destroyer
DESRON	Destroyer Squadron
DEQ	Department of Environmental Quality
DFW	CNMI Division of Fish and Wildlife
DICASS	Directional Command Activated Sonobuoy System
DLCD	Department of Land Conservation and Development
DNL	Day-Night Average A-Weighted Sound Level
DNT	Dinitrotoluene
DoD	Department of Defense
DoD REP	DoD Representative Guam, Commonwealth of Northern Mariana Islands, Federated States of Micronesia and Republic of Palau
DoN	Department of Navy
DPW	Department of Public Works
DTR	Demolition Training Range
DZ	Drop Zone
EA-6	Electronic Attack Aircraft
EA-18	Electronic Warfare Aircraft
EA	Electronic Attack
EA	Environmental Assessment
EAC	Early Action Compact
EC	Electronic Combat
EC OPS	Chaff and Electronic Combat
ECSWTR	East Coast Shallow-Water Training Range
EDS	Emergency Detonation Site
EER	Extended Echo Ranging
EEZ	Exclusive Economic Zone
EFD	Energy Flux Density
EFH	Essential Fish Habitat
EFSEC	Energy Facility Site Evaluation Council
EGTTR	Eglin Gulf Test and Training Range
EIS	Environmental Impact Statement
EL	Sound Energy Flux Density Level
EMATT	Expendable Mobile ASW Training Target
EMR	Electromagnetic Radiation
EMUA	Exclusive Military Use Area
ENP	Eastern North Pacific
ENSO	El Niño/Southern Oscillation
EO	Executive Order
EOD	Explosive Ordnance Disposal
EODMU	Explosive Ordnance Disposal Mobile Unit
EPA	Environmental Protection Agency
EPAct	Energy Policy Act
EPCRA	Emergency Planning and Community Right to Know Act
ER	Extended Range
ES	Electronic Support
ESA	Endangered Species Act
ESG	Expeditionary Strike Group
ESGEX	Expeditionary Strike Group Exercise
ESQD	Explosive Safety Quantity Distance
ET	Electronically Timed
ETP	Eastern Tropical Pacific
EW	Electronic Warfare
EX	Exercise
EXTORP	Exercise Torpedo
°F	degrees Fahrenheit
FA-18	Flight/Attack Strike Fighter
FAA	Federal Aviation Administration
FAC	Forward Air Control
FACSFAC	Fleet Area Control and Surveillance Facility
FAD	Fish Aggregating Devices
FARP	Fuel and Armament Replenishment Point
FAST	Floating At-Sea Target
FAST	Fleet Anti-Terrorism Security Team
FCLP	Field Carrier Landing Practice
FDM	Farallon de Medinilla
FDNF	Forward Deployed Naval Forces
FEA	Final Environmental Assessment
FEIS	Final Environmental Impact Statement
FEMA	Federal Emergency Management Agency
FFG	Frigate
FHA	Federal Housing Administration
FICUN	Federal Interagency Committee On Urban Noise
FIP	Federal Implementation Plan
FIREX	Fire Support
FIRP	Flood Insurance Rate Map
FISC	Fleet and Industrial Supply Center
FHA	Federal Housing Administration
FL	Flight Level
FM	Frequency Modulated

FMC	Fishery Management Council
FMP	Fishery Management Plan
FONSI	Finding of No Significant Impact
FP	Force Protection
FP	fibropapillomatosis
FR	Federal Register
FRP	Facility Response Plan
FRTP	Fleet Response Training Plan
FSAR	Finegayan Small Arms Ranges
FSM	Federated States of Micronesia
ft	feet
ft^2	square feet
FTX	Field Training Exercise
FUTR	Fixed Underwater Tracking Range
FY	Fiscal Year
FY04 NDAA	National Defense Authorization Act For Fiscal Year 2004
g	gram
GBU	Guided Bomb Unit
GCA	Guam Code Annotated
GCA	Ground Controlled Approach
GCE	Ground Combat Element
GCMP	Guam Coastal Management Plan
GDEM	Generalized Digital Environmental Model
GDP	Gross Domestic Product
GEPA	Guam Environmental Protection Agency
GHG	greenhouse gas
GIAA	Guam International Airport Authority
GIAT	Guam International Air Terminal
GJMMP	Guam Joint Military Master Plan
GLUP	Guam Land Use Plan
GNWR	Guam National Wildlife Refuge
GovGuam	Government of Guam
GRAB	Gaussian Ray Bundle
GUANG	Guam Air National Guard
GUARNG	Guam Army National Guard
GUNEX	Gunnery Exercise
GVB	Guam Visitors Bureau
HABS	Historic American Building Survey
HADR	Humanitarian and Disaster Relief
HAER	Historic American Engineering Record
HAPC	Habitat Areas of Particular Concern
HARM	High Speed Anti-radiation Missile
HC	Helicopter Coordinator
HC(A)	Helicopter Coordinator (Airborne)
HCN	Hydrogen Cyanide
HE	High Explosive
HELO	Helicopter
HFA	High-Frequency Active
HFBL	High-Frequency Bottom Loss
HFM3	High Frequency Marine Mammal Monitoring Sonar System
HH	Helicopter Designation (Typically Search/Rescue/Medical Evacuation))
HMMWV	High Mobility Multipurpose Wheeled Vehicle
HMX	High Melting Explosive
HPA	Hypothalamic-pituitary-adrenal
HPO	Historic Preservation Officer
hr	hour
HRST	Helicopter Rope Suspension Training
HSC	Helicopter Sea Combat
HSWA	Hazardous and Solid Waste Act
HUD	Department of Housing and Urban Development
Hz	hertz
IAH	Inner Apra Harbor
IBB	International Broadcasting Bureau
ICAP	Improved Capability
ICMP	Integrated Comprehensive Monitoring Program
ICRMP	Integrated Cultural Resource Management Plan
ICWC	International Whaling Commission
IED	Improvised Explosive Device
IEER	Improved Extended Echo Ranging
IFR	Instrument Flight Rules
IHA	Incidental Harassment Authorization
III MEF	Third Marine Expeditionary Force
in.	inch
in^3	cubic inch
INRMP	Integrated Natural Resource Management Plan
IOC	Initial Operating Capability
IP	Implementation Plan
IR	infrared
ISR	Intelligence, Surveillance, and Reconnaissance
ISR/Strike	Intelligence, Surveillance, and Reconnaissance/Strike
IUCN	The World Conservation Union
IWC	International Whaling Commission
JDAM	Joint Direct Attack Munition
JFCOM	Joint Forces Command
JGPO	Joint Guam Program Office
JLOTS	Joint Logistics over the shore
JNTC	Joint National Training Capability
JSOW	Joint Stand-Off Weapon
JTFEX	Joint Task Force Exercise
JUCAS	Joint Unmanned Combat Air System
KD	Known Distance
KE	Kinetic Energy
kg	kilogram
kHz	kilohertz
km	kilometer
km^2	square kilometer
kts	knots
LAV	Light Armored Vehicle
lb	pound
LBA	Lease Back Area
LCAC	Landing Craft Air Cushion
LCE	Logistics Combat Element
LCS	Littoral Combat Ship
LCU	Landing Craft Utility
LFA	Low-Frequency Active
LFBL	Low-Frequency Bottom Loss
L_{eq}	Equivalent Sound Level
LHA	Amphibious Assault Ship
LHD	Amphibious Assault Ship
L_{max}	Maximum Sound Level
LGB	Laser Guided Bomb
LGTR	Laser Guided Training Round
LMRS	Long-Term Mine Reconnaissance System
ln	natural log
LOA	Letter of Agreement
LOA	Letter of Authorization
LPD	Amphibious Transport Dock
LSD	Amphibious Assault Ship
LT	Limited Training
LZ	Landing Zone
m	meters
m^2	square meters
m^3	cubic meters
M-4	Assault Rifle
M-16	Assault Rifle

M-203	40 mm Grenade Launcher
M-240G	Medium Machine Gun
M-249 SAW	Light Machine Gun, Squad Automatic Weapon
MAGTF	Marine Air Ground Task Force
MARPOL 73/78	Marine Pollution Convention '73, modified in '78
MAW	Marine Air Wing
MBTA	Migratory Bird Treaty Act
MCM	Mine Countermeasure
MCMEX	Mine Exercise
MEDEVAC	Medical Evacuation
MEF	Marine Expeditionary Force
MEMC	Military Expended Material Constituent
METOC	Meteorological and Oceanographic Operations
MEU	Marine Expeditionary Unit
MFA	Mid-Frequency Active
MFAS	Medium-Frequency Active Sonar
MG	Machine Gun
mgd	million gallons per day
mg/L	milligrams per liter
MH	Helicopter Designation (Typically Multi-mission)
MHWM	Mean High Water Mark
mi.	miles
mi^2	square miles
MI	Maritime Interdiction
MILCON	Military Construction
min	minutes
MINEX	Mine Laying Exercise
MIO	Maritime Interception Operation
MIRC	Mariana Islands Range Complex
MISSILEX	Missile Exercise
MISTCS	The Mariana Islands Sea Turtle and Cetacean Survey
MIW	Mine Warfare
MLA	Military Lease Area
mm	millimeters
MMA	Multi-mission Maritime Aircraft
MMHSRA	Marine Mammal Health and Stranding Response Act
MMHSRP	Marine Mammal Health and Stranding Response Program
MMPA	Marine Mammal Protection Act
MMR	Military Munitions Rule
MOA	Military Operations Area
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
MOUT	Military Operations in Urban Terrain
MPA	Maritime Patrol Aircraft
MPRSA	Marine Protection, Research, and Sanctuaries Act
MRA	Marine Resources Assessment
MRUUV	Mission Reconfigurable Unmanned Undersea Vehicle
MSA	Munitions Storage Area
MSE	Multiple Successive Explosions
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
MSL	Mean Sea Level
MSS	Mobile Security Squadron
MTH	Marianas Training Handbook
MVA	Marianas Visitors Authority
MWR	Morale, Welfare, and Recreation
NA	Not Applicable
NAAQS	National Ambient Air Quality Standards
NAS	Naval Air Station
NAS	National Academies of Science
NATO	North Atlantic Treaty Organization
NAVBASE	Naval Base
NAVFAC PAC	Naval Facilities Engineering Command Pacific
NAVMAG	Naval Magazine
NAVSTA	Naval Station
NAWQC	National Ambient Water Quality Criteria
NCA	National Command Authority
NCRD	No Cultural Resource Damage
NCTAMS	Naval Communications Area Master Station
NCTS	Naval Computers and Telecommunications Station
NDAA	National Defense Authorization Act
NDE	National Defense Exemption
NEC	North Equatorial Current
NECC	Navy Expeditionary Combat Command
NEO	Noncombatant Evacuation Operations
NEPA	National Environmental Policy Act
NEW	Net Explosive Weight
NHL	National Historic Landmark
NHPA	National Historic Preservation Act
NITTRSS	Navy Integrated Training and Test Range Strategic Study
NLNA	Northern Land Navigation Area
nm	nautical mile
nm^2	square nautical mile
NMFS	National Marine Fisheries Service
NMMTB	National Marine Mammal Tissue Bank
NO_2	Nitrogen Dioxide
NO_x	Oxides of Nitrogen
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NOTAM	Notice to Airmen
NOTMAR	Notice to Mariners
NPAL	North Pacific Acoustic Laboratory
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NRC	National Research Council
NRFCC	National Recreational Fisheries Coordination Council
NRHP	National Register of Historic Places
NRIS	National Register Information System
NRL	Naval Research Laboratory
NS	Naval Station
NSCT	Naval Special Clearance Team
NSFS	Naval Surface Fire Support
NSR	New Source Review
NSW	Naval Special Warfare
NSWG	Naval Special Warfare Group
NSWU	Naval Special Warfare Unit
NT	No Training
NUWC	Naval Undersea Warfare Center
NVG	Night Vision Goggle
NWD	No Wildlife Disturbance
NWF	Northwest Field
NWR	National Wildlife Refuge

NZ	Noise Zones
O_3	Ozone
OAH	Outer Apra Harbor
OAMCM	Organic Airborne Mine Countermeasure
OCE	Officer-In-Charge of the Exercise
OEA	Overseas Environmental Assessment
OEIS	Overseas Environmental Impact Statement
OLF	Outlying Landing Field
OP	Orote Point
OPA	Oil Pollution Act
OPAREA	Operating Area
OPCQC	Orote Point Close Quarters Combat
OPFOR	Opposition Forces
OPKDR	Orote Point Known Distance Range
OPNAV	Office of the Chief of Naval Operations
OPNAVINST	Chief of Naval Operations Instruction
OPS	Operations
OR	Oregon
ORMA	Ocean Resources Management Act
OSS	Operations Support Squadron
OTB	Over-the-Beach
OTH	Over the Horizon
Pa	Pascal
PA	Programmatic Agreement
Pa•s	Pascal•seconds
PACAF	Pacific Air Forces
PACFIRE	Pre-action Calibration Firing
PACOM	U.S. Pacific Command
PAG	Port Authority of Guam
PAH	Polycyclic Aromatic Hydrocarbons
Pb	Lead
PCB	Polychlorinated Biphenyl
PETN	Pentaerythritol Tetranitrate
pH	Hydrogen Ion Concentration
PIFSC	Pacific Islands Fisheries Science Center
PIRO	Pacific Islands Regional Office
PL	Public Law
$PM_{2.5}$	Particulate Matter 2.5 Microns in Diameter
PM_{10}	Particulate Matter 10 Microns in Diameter
PMAR	Primary Mission Area
POL	Petroleum, Oils, and Lubricants
POW	Prisoner of War
PPA	Pollution Prevention Act
ppb	parts per billion
PPF	Polaris Point Field
ppm	parts per million
PRI	Primary Training Area
psf	pounds per square foot
psi	pounds per square inch
psi-ms	pounds per square inch - milliseconds
PTP	Pre-deployment Training Phase
PTS	Permanent Threshold Shift
PUTR	Portable Underwater Tracking Range
PWC	Public Works Center
PWSS	Public Water Supply Systems
QDR	Quadrennial Defense Review
R-	Restricted Area
R&S	Reconnaissance and Surveillance
RAICUZ	Range Air Installations Compatible Use Zones
RCA	Range Condition Assessment
RCB	Reserve Craft Beach
RCD	Required Capabilities Document
RCMP	Range Complex Management Plan
RCRA	Resource Conservation and Recovery Act
RDT&E	Research, Development, Test, and Evaluation
RDX	Royal Demolition Explosive
re 1 µPa-m	referenced to 1 micropascal at 1 meter
RED HORSE	Rapid Engineer Deployable Heavy Operational Repair Squadron Engineer
REXTORP	Recoverable Exercise Torpedo
RFRCP	Recreational Fisheries Resources Conservation Plan
RHA	Rivers and Harbors Act
RHIB	Rigid Hull Inflatable Boat
RICRMP	Regional Integrated Cultural Resources Management Plan
RIMPAC	Rim of the Pacific
RL	Received Level
rms	root mean square
RNM	Rotorcraft Noise Model
ROD	Record of Decision
ROWPU	Reverse Osmosis Water Purification Unit
RSIP	Regional Shore Infrastructure Plan
RSO	Range Safety Officer
S-A	Surface-to-Air
S-S	Surface-to-Surface
S&R	Surveillance and Reconnaissance
SACEX	Supporting Arms Coordination Exercise
SAM	Surface-to-Air Missile
SAMEX	Surface-to Air Missile Exercise
SAR	Search and Rescue
SARS	Severe Acute Respiratory Syndrome
SAW	Squad Automatic Weapon
SBU	Special Boat Unit
SCD	Silicate Compensation Depth
SCUBA	Self-Contained Underwater Breathing Apparatus
SD	Standard Deviation
SDV	SEAL Delivery Vehicle
SDWA	Safe Drinking Water Act
SDZ	Surface Danger Zone
SEAD	Suppression of Enemy Air Defense
SEAL	Sea, Air, and Land Forces
sec	second
SEC	Secondary Training Areas
§	Section
SEIS	Supplemental Environmental Impact Statement
SEL	Sound Exposure Level
SEPA	State Environmental Policy Act
SFCP	Shore Fire Control Parties
SFS	Security Forces Squadron
SH	Helicopter Designation (Typically Anti-Submarine)
SHAREM	Ship ASW Readiness and Evaluation Measuring
SHPO	State Historic Preservation Officer
SINKEX	Sinking Exercise
SIP	State Implementation Plan
SLAM-ER	Stand-off Land Attack Missile - Extended Range
SLC	Submarine Learning Center
SLNA	Southern Land Navigation Area
SM	Standard Missile
SMA	Shoreline Management Act
SNS	Sympathetic Nervous System
SO_2	Sulfur Dioxide
SOCAL	Southern California
SOC	Special Operations Capable
SOCEX	Special Operations Capable Exercise

SOF Special Operations Forces
SONAR Sound Navigation and Ranging
SOP Standard Operating Procedure
SPCC Spill Prevention, Control, and Countermeasure
SPIE Special Purpose Insertion and Extraction
SPL Sound Pressure Level
SPMAGTF Special Purpose Marine Air Ground Task Force
SPORTS Sonar Positional Reporting System
sqrt Square Root
SRBOC Super Rapid Bloom Off-board Chaff
SRF Ship Repair Facility
SRP Scientific Research Program
SSBN Ship, Submersible, Ballistic, Nuclear (Submarine)
SSC SPAWAR Systems Center
SSG Surface Strike Group
SSGN Guided Missile Submarine
SSN Fast Attack Submarine
SSN Nuclear Submarine
STD Standard
STOM Ship to Objective Maneuver
STW Strike Warfare
SUA Special Use Airspace
SURC Small Unit River Craft
SURTASS Surveillance Towed-Array Sensor System
SUS Signal Underwater Sound
SUW Surface Warfare
SVP Sound Velocity Profile
SWFSC Southwest Fisheries Science Center
SWPPP Storm Water Pollution Prevention Plans
T&E Threatened and Endangered Species
TACP Tactical Air Control Party
TALD Tactical Air-Launched Decoy
TAP Tactical Training Theater Assessment And Planning
TDU Target Drone Unit
TGEX Task Group Exercise
TM Tympanic Membrane
TMDL Total Maximum Daily Loads
TNT Trinitrotoluene
TORPEX Torpedo Exercise
TP Training Projectile
TRACKEX Tracking Exercise
TRUEX Training in Urban Environment Exercise
TS Threshold Shift
TSCA Toxic Substances Control Act
TSPI Time, Space, Position, Information
TSV Training Support Vessel
TTS Temporary Threshold Shift
UAS Unmanned Aerial System
UAV Unmanned Aerial Vehicle
UCRMP Updated Cultural Resources Management Plan
UDP Unit Deployment Program
UJTL Universal Joint Task List
ULT Unit-level Training
UME Unusual Mortality Event
UN United Nations
UNDET Underwater Detonations
U.S. United States
USACE United States Army Corps of Engineers
USAF United States Air Force
USC United States Code
USCG United States Coast Guard
USCINCPAC REP Commander In Chief, U.S. Pacific Command Representative
USCINCPAC REP GUAM/CNMI Commander In Chief, U.S. Pacific Command Representative Guam and the Commonwealth of the Northern Mariana Islands
USDA United States Department of Agriculture
USDA WS United States Department of Agriculture Wildlife Services
USEPA United States Environmental Protection Agency
USFF United States Fleet Forces
USFWS United States Fish and Wildlife Service
USGS United States Geological Survey
USGS – BRD United States Geological Survey Biological Resources Division
USMC United States Marine Corps
USNS U.S.Naval Ship
USPACOM United States Pacific Command
USWEX Undersea Warfare Exercise
USWTR Undersea Warfare Training Range
UTR Underwater Tracking Range
UUV Unmanned Underwater Vehicle
UXO Unexploded Ordnance
V&VE coastal flood hazard zones
VAST-IMPASS Virtual At-Sea Training Integrated Maritime Portable Acoustic Scoring and Simulator
VBSS Visit, Board, Search, and Seizure
VFR Visual Flight Rules
VoA-IBB Voice of America - International Broadcasting Bureau
VOC Volatile Organic Compounds
VTNF Variable Timed, Non-Fragmentation
VTOL Vertical Takeoff and Landing
VTUAV Vertical Take-off and Land UAV
W- Warning Area
WestPac Western Pacific
WISS Weapons Impact Scoring System
WPRFMC Western Pacific Regional Fisheries Management Council
WS Wildlife Service
WWII World War Two
ZOI Zone of Influence

Volume III

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APPENDIX F

MARINE MAMMAL MODELING

This section contains a description of the modeling performed of MIRC noise sources.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDIX F Marine Mammal Modeling

F.1 Background and Overview

All marine mammals are protected under the Marine Mammal Protection Act (MMPA). The MMPA prohibits, with certain exceptions, the unauthorized take of marine mammals in U.S. waters and by U.S. citizens on the high seas, and the importation of marine mammals and marine mammal products into the United States.

The Endangered Species Act of 1973 (ESA) provides for the conservation of species that are endangered or threatened throughout all or a significant portion of their range, and the conservation of their ecosystems. A species is considered endangered if it is in danger of extinction throughout all or a significant portion of its range. A species is considered threatened if it is likely to become an endangered species within the foreseeable future. There are marine mammals, already protected under MMPA, listed as either endangered or threatened under ESA, and afforded special protections. Actions involving sound in the water include the potential to harass marine animals in the surrounding waters. Demonstration of compliance with MMPA and the ESA, using best available science, has been assessed using criteria and thresholds accepted or negotiated, and described here.

Sections of the MMPA (16 United States Code [U.S.C.] 1361 et seq.) direct the Secretary of Commerce to allow, upon request, the incidental, but not intentional, taking of small numbers of marine mammals by U.S. citizens who engage in a specified activity, other than commercial fishing, within a specified geographical region. Through a specific process, if certain findings are made and regulations are issued, or if the taking is limited to harassment, notice of a proposed authorization is provided to the public for review.

Authorization for incidental takings may be granted if the National Marine Fisheries Service (NMFS) finds that the taking will have no more than a negligible impact on the species or stock(s), will not have an unmitigable adverse impact on the availability of the species or stock(s) for subsistence uses, and that the permissible methods of taking, and requirements pertaining to the mitigation, monitoring, and reporting of such taking are set forth.

NMFS has defined negligible impact in 50 Code of Federal Regulations (CFR) 216.103 as an impact resulting from the specified activity that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival.

Subsection 101(a) (5)(D) of the MMPA established an expedited process by which citizens of the United States can apply for an authorization to incidentally take small numbers of marine mammals by harassment. The National Defense Authorization Act of 2004 (NDAA) (Public Law 108-136) removed the small numbers limitation and amended the definition of "harassment" as it applies to a military readiness activity to read as follows:

> (i) *any act that injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild [Level A Harassment]; or*
>
> (ii) *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 [Level B Harassment].*

The sound sources generated by the proposed action will be located in an area that is inhabited by species listed as threatened or endangered under the Endangered Species Act (ESA, 16 USC §§ 1531-1543). Operation of the sound sources, that is, transmission of acoustic signals in the water column, could potentially cause harm or harassment to listed species.

"Harm" defined under ESA regulations is "…an act which actually kills or injures…" (50 CFR 222.102) listed species. "Harassment" is an "intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering" (50 CFR 17.3).

F.2 Acoustic Sources

The MIRC acoustic sources are categorized as either broadband (producing sound over a wide frequency band) or narrowband (producing sound over a frequency band that is small in comparison to the center frequency). In general, the narrowband sources in this exercise are Anti-Submarine Warfare (ASW) sonars and the broadband sources are explosives. This delineation of source types has a couple of implications. First, the transmission loss used to determine the impact ranges of narrowband ASW sonars can be adequately characterized by model estimates at a single frequency. Broadband explosives, on the other hand, produce significant acoustic energy across several frequency decades of bandwidth. Propagation loss is sufficiently sensitive to frequency as to require model estimates at several frequencies over such a wide band.

Second, the types of sources have different sets of harassment metrics and thresholds. Energy metrics are defined for both types. However, explosives are impulsive sources that produce a shock wave that dictates additional pressure-related metrics (peak pressure and positive impulse). Detailed descriptions of both types of sources are provided in the following subsections.

F.2.1 Sonars

F.2.1.1 Sonar Device Descriptions

The majority of training and research, development, testing, and evaluation activities in the MIRC involve five types of narrowband sonars. Exposure estimates are calculated for each sonar according to the manner in which it operates. For example, the AN/SQS 53 and AN/SQS 56 are hull-mounted, mid-frequency active (MFA) surface ship sonars that operate for many hours at a time (although sound is output—the "active" portion—only a small fraction of that time), so it is most useful to calculate and report surface ship sonar exposures per hour of operation. The BQQ-10 submarine sonar is also reported per hour of operation. However, the submarine sonar is modeled as pinging only twice per hour. The AN/AQS-22 is a helicopter-deployed sonar, which is lowered into the water, pings several times, and then moves to a new location; this sonar is used for localization and tracking a suspected contact as opposed to searching for contacts. For the AN/AQS-22, it is most helpful to calculate and report exposures per dip. The AN/SSQ-62 is a sonobuoy that is dropped into the water from an aircraft or helicopter and pings about 10 to 30 times in an hour. For the AN/SSQ-62, it is most helpful to calculate and report exposures per sonobuoy. For the MK-48 torpedo, the sonar is modeled for a typical training event and the MK-48 reporting metric is the number of torpedo runs. Table F-1 presents the deployment platform, frequency class, the metric for reporting exposures, and the units for each sonar.

Table F-1: Active Sonars Modeled in the MIRC

Sonar	Description	Frequency Class	Exposures Reported	Units
MK-48[1]	Torpedo sonar	High-frequency	Per torpedo	One torpedo run
AN/SQS-53	Surface ship sonar	Mid-frequency	Per hour	120 sonar pings per hour
AN/SQS-56	Surface ship sonar	Mid-frequency	Per hour	120 sonar pings per hour
AN/SSQ-62	Sonobuoy sonar	Mid-frequency	Per sonobuoy	8 sonobuoys per hour
AN/SSQ-125 AEER	Sonobuoy sonar	Mid-frequency	Per sonobuoy	1 sonobuoy per hour; 50 pings total
AN/AQS-22	Helicopter-dipping sonar	Mid-frequency	Per dip	2 dips per hour
BQQ-10[2]	Submarine sonar	Mid-frequency	Per hour	2 sonar pings per hour
MK-84 Pinger	Range tracking pinger mounted on ships, submarines, and UUV	High Frequency	Per pinger	Day of operation
PUTR Transponder	Array of bottom mounted transponders	High or Mid-Frequency (selectable)	Per PUTR transponder array	Day of operation

Note[1]: MK-48 source described here is the high-frequency active (HFA) sonar on the torpedo; the explosive source of the detonating torpedo is described in the next subsection. MK-48 torpedo sonar is modeled as representative of all torpedo sonar (MK-46, MK-50, and MK-54).

Note[2]: BQQ-10 is modeled as representative of all MFA submarine sonar (BQQ-10, BQQ-5, and BSY-1)

The acoustic modeling that is necessary to support the take estimates for each of these sonars relies upon a generalized description of the manner of the sonar's operating modes. This description includes the following:

- "Effective" sound exposure level – This is the level relative to 1 μPa^2-s of the integral over frequency and time of the square of the pressure and is given by the total sound exposure level across the band of the source, scaled by the pulse length (10 $\log_{10}$ [pulse length]).
- Source depth – Depth of the source in meters.
- Nominal frequency – Typically the center band of the source emission. These are frequencies that have been reported in open literature and are used to avoid classification issues. Differences between these nominal values and actual source frequencies are small enough to be of little consequence to the output impact volumes.
- Source directivity – The source beam is modeled as the product of a horizontal beam pattern and a vertical beam pattern. Two parameters define the horizontal beam pattern:
  - Horizontal beam width – Width of the source beam (degrees) in the horizontal plane (assumed constant for all horizontal steer directions).
  - Horizontal steer direction – Direction in the horizontal in which the beam is steered relative to the direction in which the platform is heading

  The horizontal beam is assumed to have constant level across the width of the beam with flat, 20-dB down sidelobes at all other angles.

  Similarly, two parameters define the vertical beam pattern:

  - Vertical beam width – Width of the source beam (degrees) in the vertical plane measured at the 3-dB down point. (assumed constant for all vertical steer directions).
  - Vertical steer direction – Direction in the vertical plane that the beam is steered relative to the horizontal (upward looking angles are positive).

  To avoid sharp transitions that a rectangular beam might introduce, the power response at vertical angle θ is

  $$\text{Power} = \max \{ \sin^2 [n(\theta_s - \theta)] / [n \sin (\theta_s - \theta)]^2,\ 0.01 \},$$

  Where θ_s is the vertical beam steer direction, and
  $n = 2*L/\lambda$ (L = array length, λ = wavelength),

  The beamwidth of a line source is determined by n (the length of the array in half-wavelengths) as $\theta_w = 180^o/n$.

- Ping spacing – Distance between pings. For most sources this is generally just the product of the speed of advance of the platform and the repetition rate of the sonar. Animal motion is generally of no consequence as long as the source motion is greater than the speed of the animal (nominally, 3 knots). For stationary (or nearly stationary) sources, the "average" speed of the animal is used in place of the platform speed. The attendant assumption is that the animals are all moving in the same constant direction.

Many of the actual parameters and capabilities of these sonars are classified. Parameters used for modeling were derived to be as representative as possible taking into account the manner with which the sonar would be used in various training scenarios. However, when there was a wide range of potential modeling input values, the default was to model using a nominal parameter likely to result in the most impact, so that the model would err towards the maximum potential exposures.

For the sources that are essentially stationary (AN/SSQ-62 , AN/SSQ-125, and AN/AQS-22), emission spacing is the product of the ping cycle time and the average animal speed.

F.2.1.2 Metrics for Physiological Effect Thresholds

Effect thresholds used for acoustic impact modeling in this document are expressed in terms of Sound Exposure Level (SEL), which is total sound exposure received over time in an area, or in terms of Sound Pressure Level (SPL), which is the level (root mean square) without reference to any time component for the exposure at that level. Marine and terrestrial mammal data show that, for continuous-type sounds of interest, Temporary Threshold Shift (TTS) and Permanent Threshold Shift (PTS) are more closely related to the sound exposure than to the exposure SPL.

The SEL for each individual ping is calculated from the following equation:

$$SEL = SPL + 10\log_{10}(\text{duration})$$

The SEL includes both the ping SPL and duration. Longer-duration pings and/or higher-SPL pings will have a higher SEL.

If an animal is exposed to multiple pings, the sound exposure level in each individual ping is summed to calculate the total SEL. Since mammalian Threshold Shift (TS) data show less effect from intermittent exposures compared to continuous exposures with the same energy (Ward 1997), basing the effect thresholds on the total received SEL is a conservative approach for treating multiple pings; in reality, some recovery will occur between pings and lessen the effect of a particular exposure. Therefore, estimates are conservative because recovery is not taken into account (given that generally applicable recovery times have not been experimentally established) and as a result, intermittent exposures from sonar are modeled as if they were continuous exposures.

The total SEL depends on the SPL, duration, and number of pings received. The TTS and PTS thresholds do not imply any specific SPL, duration, or number of pings. The SPL and duration of each received ping are used to calculate the total SEL and determine whether the received SEL meets or exceeds the effect thresholds. For example, the TTS threshold would be reached through any of the following exposures:

- A single ping with SPL = 195 dB re 1 μPa and duration = 1 second.
- A single ping with SPL = 192 dB re 1 μPa and duration = 2 seconds.
- Two pings with SPL = 192 dB re 1 μPa and duration = 1 second.
- Two pings with SPL = 189 dB re 1 μPa and duration = 2 seconds.

F.2.1.3 Derivation of an Effects Threshold for Marine Mammals Based on Sound Exposure Level

As described in detail in Section 3.7 of this EIS/OEIS, SEL (EFD level) exposure threshold established for onset-TTS is 195 dB re 1 μPa^2-s. This result is corroborated by the short-duration tone data of Finneran *et al*. (2000, 2003) and the long-duration sound data from Nachtigall *et al*. (2003a, b). Together, these data demonstrate that TTS in small odontocetes is correlated with the received SEL and that onset-TTS exposures are fit well by an equal-energy line passing through 195 dB re 1 μPa^2-s. Absent any additional data for other species and being that it is likely that small odontocetes are more sensitive to the mid-frequency active/high-frequency active (MFA/HFA) frequency levels of concern, this threshold is used for analysis for all cetacea.

The PTS thresholds established for use in this analysis are based on a 20 dB increase in exposure SEL over that required for onset-TTS. The 20 dB value is based on estimates from terrestrial mammal data of PTS occurring at 40 dB or more of TS, and on TS growth occurring at a rate of 1.6 dB/dB increase in exposure SEL. This is conservative because: (1) 40 dB of TS is actually an upper limit for TTS used to approximate onset-PTS, and (2) the 1.6 dB/dB growth rate is the highest observed in the data from Ward et al. (1958, 1959). Using this estimation method (20 dB up from onset-TTS) for the Mariana Islands Range Complex (MIRC) analysis, the PTS threshold for cetacea is 215 dB re 1μPa^2-s, and for monk seals it is 224 dB re 1μPa^2-s.

F.2.1.4 Derivation of a Behavioral Effect Threshold for Marine Mammals Based on Sound Pressure Level (SPL)

Over the past several years, the Navy and NMFS have worked on developing alternative criteria to replace and/or to supplement the acoustic thresholds used in the past to estimate the probability of marine mammals being behaviorally harassed by received levels of MFA and HFA sonar. Following publication of the Draft Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS), the Navy continued working with NMFS to refine a mathematically representative curve for assessment of behavioral effects modeling associated with the use of MFA/HFA sonar. As detailed in Section 4.1.2, the NMFS Office of Protected Resources made the decision to use a risk function and applicable input parameters to estimate the probability of behavioral responses that NMFS would classify as harassment for the purposes of the MMPA given exposure to specific received levels of MFA/HFA sonar. This decision was based on the recommendation of the two NMFS scientists, consideration of the independent reviews from six scientists, and NMFS MMPA regulations affecting the Navy's use of Surveillance Towed Array Sensor System Low-Frequency Active (SURTASS LFA) sonar (U.S. Department of the Navy 2002; National Oceanic and Atmospheric Administration 2007).

The particular acoustic risk function developed by the Navy and NMFS is derived from a solution in Feller (1968) with input parameters modified by NMFS for MFA/HFA sonar for mysticetes, odontocetes, and pinnipeds. In order to represent a probability of risk in developing this function, the function would have a value near zero at very low exposures, and a value near one for very high exposures. One class of functions that satisfies this criterion is cumulative probability distributions, a type of cumulative distribution function. In selecting a particular functional expression for risk, several criteria were identified:

- The function must use parameters to focus discussion on areas of uncertainty;
- The function should contain a limited number of parameters;
- The function should be capable of accurately fitting experimental data; and

- The function should be reasonably convenient for algebraic manipulations.

As described in U.S. Department of the Navy (2001), the mathematical function below is adapted from a solution in Feller (1968):

$$R = \frac{1-\left(\frac{L-B}{K}\right)^{-A}}{1-\left(\frac{L-B}{K}\right)^{-2A}}$$

Where: *R* = risk (0 – 1.0);

L = Received Level (RL) in dB

B = basement RL in dB (120 dB)

K = the RL increment above basement in dB at which there is 50 percent risk

A=risk transition sharpness parameter (8 for Mysticetes and 10 for Odontocetes)

It is important to note that the probabilities associated with acoustic modeling do not represent an individual's probability of responding; they identify the proportion of an exposed population (as represented by an evenly distributed density of marine mammals per unit area) that is likely to respond to an exposure. In addition, modeling does not take into account reductions from any of the Navy's standard protective mitigation measures which should significantly reduce or eliminate actual exposures that may have otherwise occurred during training.

F.2.2 Explosives

Explosives detonated underwater introduce loud, impulsive, broadband sounds into the marine environment. The acoustic energy of an explosive is, generally, much greater than that of a sonar, so careful treatment of them is important, since they have the potential to injure. Three source parameters influence the effect of an explosive: the weight of the explosive warhead, the type of explosive material, and the detonation depth. The net explosive weight (NEW) accounts for the first two parameters. The NEW of an explosive is the weight of only the explosive material in a given round, referenced to the explosive power of trinitrotoluene (TNT).

F.2.2.1 Explosive Source Descriptions

The detonation depth of an explosive is particularly important due to a propagation effect known as surface-image interference. For sources located near the sea surface, a distinct interference pattern arises from the coherent sum of the two paths that differ only by a single reflection from the pressure-release surface. As the source depth and/or the source frequency decreases, these two paths increasingly, destructively interfere with each other, reaching total cancellation at the surface (barring surface-reflection scattering loss). Since most MIRC explosive sources are munitions that detonate essentially upon impact, the effective source depths are quite shallow, and therefore the surface-image interference effect can be pronounced. In order to limit the cancellation effect (and thereby provide exposure estimates that tend toward the worst case), relatively deep detonation depths are used. A source depth of 1 foot is used for gunnery rounds. For the missile and bombs, a source depth of 2 meters (m) is used. For Extended Echo Ranging/Improved Extended Echo Ranging (EER/IEER) a nominal depth of 20 m is used to ensure that the source is located within any significant surface duct, resulting in maximum potential exposures. Table F-2 gives the ordnances of interest in the MIRC, their NEWs, and their expected detonation depths.

Table F-2: Explosive Sources Modeled in MIRC

Ordnance	Net Explosive Weight for Modeling	Detonation Depth for Modeling
5" Naval gunfire	9.54 lbs	1 ft
76 mm Rounds	1.6 lbs	1 ft
HELLFIRE	16.4 lbs	2 m
Maverick	78.5 lbs	2 m
Harpoon / SLAM-ER	448 lbs	2 m
MK-82/GBU-31 JDAM/GBU-10	945 lbs	2 m
MK-83/GBU-32 JDAM	574 lbs	2 m
MK-84/GBU-38 JDAM/GBU-12	238 lbs	2 m
MK-48	851 lbs	50 ft
Demolition Charges	10 lbs	Bottom
EER/IEER	5 lbs	20 m

The exposures expected to result from these ordnances are generally computed on a per in-water explosive basis. The cumulative effect of a series of explosives can often be derived by simple addition if the detonations are spaced widely in time or space, allowing for sufficient animal movement as to ensure that a different population of animals is harassed by each ordnance detonation. There may be rare occasions when multiple successive explosions (MSEs) are part of a static location event. For these events, the Churchill FEIS approach was extended to cover MSE events occurring at the same location. For MSE exposures, accumulated energy over the entire training time is the natural extension for energy thresholds since energy accumulates with each subsequent shot; this is consistent with the treatment of multiple arrivals in Churchill. For positive impulse, it is consistent with the Churchill FEIS to use the maximum value over all impulses received.

For MSEs, the acoustic criterion for sub-TTS behavioral disturbance is used to account for behavioral effects significant enough to be judged as harassment, but occurring at lower sound energy levels than those that may cause TTS. For MSE events potential behavioral disturbances were modeled at the 177 dB sub-TTS threshold. A special case in which simple addition of the exposure estimates may not be appropriate is addressed by the modeling of a "representative" Sink Exercise (SINKEX). In a SINKEX, a decommissioned surface ship is towed to a specified deep-water location and there used as a target for a variety of weapons. Although no two SINKEXs are ever the same, a representative case derived from past exercises is described in the *Programmatic SINKEX Overseas Environmental Assessment* (March 2006) for the Western North Atlantic.

In a SINKEX, weapons are typically fired in order of decreasing range from the source with weapons fired until the target is sunk. A torpedo is used after all munitions have been expended if the target is still afloat. Since the target may sink at any time during the exercise, the actual number of weapons used can vary widely. In the representative case, however, all of the ordnances are assumed expended; this represents the worst case with maximum exposure.

The sequence of weapons firing for the representative SINKEX is described in Table F-3. Guided weapons are nearly 100 percent accurate and are modeled as hitting the target (that is, no underwater acoustic effect) in all but two cases: (1) the Maverick is modeled as a miss to represent the occasional miss, and (2) the MK-48 torpedo intentionally detonates in the water column immediately below the hull of the target. Unguided weapons are more frequently off-target and are modeled according to the statistical hit/miss ratios. Note that these hit/miss ratios are artificially low in order to demonstrate a worst-case scenario; they should not be taken as indicative of weapon or platform reliability.

Table F-3: Representative SINKEX Weapons Firing Sequence

Time (Local)	Event Description
0900	Range Control Officer receives reports that the exercise area is clear of non-participant ship traffic, marine mammals, and sea turtles.
0909	2 HELLFIRE missiles fired, both hit target.
0915	2 HARM missiles fired, both hit target (5 minutes apart).
0940	8 Maverick missiles fired, 6 hit target, 2 misses (5 minutes apart).
1205	5 Harpoon/4 SLAM-ER missiles fired, all hit target (1 minute apart).
1300-1335	7 live and 3 inert MK 82 bombs dropped – 7 hit target, 2 live and 1 inert miss target (4 minutes apart).
1355-1410	4 MK 83/84 series bombs dropped – 3 hit target, 1 misses target (5 minutes apart).
1500	Surface gunfire commences – 400 5-inch rounds fired (one every 6 seconds), 280 hit target, 120 miss target.
1700	MK 48 Torpedo fired, hits, and sinks target.
As required.	2 Demolition Charges if needed to sink target.

F.2.2.2 Explosive Source Criteria

For explosions of ordnance planned for use in the Mariana Islands Range Complex (MIRC), in the absence of any mitigation or monitoring measures, there is a very small chance that a marine mammal could be injured or killed when exposed to the energy generated from an explosive force. Analysis of noise impacts is based on criteria and thresholds initially presented in U.S. Navy Environmental Impact Statements for ship shock trials of the Seawolf submarine and the Winston Churchill (DDG 81), and subsequently adopted by NMFS. Explosive source criteria thresholds are presented in Table F-4.

Non-lethal injurious impacts (Level A Harassment) are defined in those documents as tympanic membrane (TM) rupture and the onset of slight lung injury. The threshold for Level A Harassment corresponds to a 50-percent rate of TM rupture, which can be stated in terms of an Sound Exposure Level (SEL) value of 205 dB re 1 μPa^2-s. TM rupture is well-correlated with permanent hearing impairment. Ketten (1998) indicates a 30-percent incidence of permanent threshold shift (PTS) at the same threshold.

Table F-4: Level A and B Harassment Threshold–Explosives

Threshold Type (Explosives)	Threshold Level
Level A – 50 percent Eardrum rupture	205 dB
Temporary Threshold Shift (TTS) (peak one-third octave energy)	182 dB
Sub-TTS Threshold for Multiple Successive Explosions (peak one-third octave energy)	177 dB
Temporary Threshold Shift (TTS) (peak pressure)	23 psi
Level A – Slight lung injury (positive impulse)	13 psi-ms
Mortality – 1 percent Mortal lung injury (positive impulse)	31 psi-ms

The criteria for onset of slight lung injury were established using partial impulse because the impulse of an underwater blast wave was the parameter that governed damage during a study using mammals, not peak pressure or energy (Yelverton 1981). Goertner (1982) determined a way to calculate impulse values for injury at greater depths, known as the Goertner “modified” impulse pressure. Those values are valid only near the surface because as hydrostatic pressure increases with depth, organs like the lung, filled with air, compress. Therefore the “modified” impulse pressure thresholds vary from the shallow depth starting point as a function of depth.

The shallow depth starting points for calculation of the “modified” impulse pressures are mass-dependent values derived from empirical data for underwater blast injury (Yelverton 1981). During the calculations, the lowest impulse and body mass for which slight, and then extensive, lung injury found during a previous study (Yelverton *et al*. 1973) were used to determine the positive impulse that may cause lung injury. The Goertner model is sensitive to mammal weight such that smaller masses have lower thresholds for positive impulse so injury and harassment will be predicted at greater distances from the source for them. Impulse thresholds of 13.0 and 31.0 psi-ms, found to cause slight and extensive injury in a dolphin calf, were used as thresholds in the analysis contained in this document.

Level B (non-injurious) Harassment includes temporary (auditory) threshold shift (TTS), a slight, recoverable loss of hearing sensitivity. One criterion used for TTS, the total SEL of the signal, is a threshold of 182 dB re 1 μPa^2-s maximum SEL level in any 1/3-octave band above 100 Hz for toothed whales (e.g., dolphins). A second criterion, a maximum allowable peak pressure of 23 psi, has recently been established by NMFS (NMFS 2005; DoN 2008a, 2008b) to provide a more conservative range for TTS when the explosive or animal approaches the sea surface, in which case explosive energy is reduced, but the peak pressure is not. NMFS applies the more conservative of these two.

F.3 Environmental Provinces

Propagation loss ultimately determines the extent of the Zone of Influence (ZOI) for a particular source activity. In turn, propagation loss as a function of range responds to a number of environmental parameters:

- Water depth
- Sound speed variability throughout the water column
- Bottom geo-acoustic properties, and
- Surface roughness, as determined by wind speed

Due to the importance that propagation loss plays in ASW, the Navy has, over the last four to five decades, invested heavily in measuring and modeling these environmental parameters. The result of this effort is the following collection of global databases of these environmental parameters, which are accepted as standards for Navy modeling efforts.

- Water depth – Digital Bathymetry Data Base Variable Resolution (DBDBV)
- Sound speed – Generalized Digital Environmental Model (GDEM)
- Bottom loss – Low-Frequency Bottom Loss (LFBL), Sediment Thickness Database, and High-Frequency Bottom Loss (HFBL), and
- Wind speed – U.S. Navy Marine Climatic Atlas of the World

This section provides a discussion of the relative impact of these various environmental parameters. These examples then are used as guidance for determining environmental provinces (that is, regions in which the environmental parameters are relatively homogenous and can be represented by a single set of environmental parameters) within the MIRC.

F.3.1 Impact of Environmental Parameters

Within a typical operating area, the environmental parameter that tends to vary the most is bathymetry. It is not unusual for water depths to vary by an order of magnitude or more, resulting in significant impacts upon the ZOI calculations. Bottom loss can also vary considerably over typical operating areas, but its impact on ZOI calculations tends to be limited to waters on the continental shelf and the upper portion of the slope. Generally, the primary propagation paths in deep water, from the source to most of the ZOI volume, do not involve any interaction with bottom. In shallow water, particularly if the sound velocity profile directs all propagation paths to interact with the bottom, bottom loss variability can play a larger role.

The spatial variability of the sound speed field is generally small over operating areas of typical size. The presence of a strong oceanographic front is a noteworthy exception to this rule. To a lesser extent, variability in the depth and strength of a surface duct can be of some importance. In the mid-latitudes, seasonal variation often provides the most significant variation in the sound speed field. For this reason, both summer and winter profiles are modeled for each selected environment.

F.3.2 Environmental Provincing Methodology

The underwater acoustic environment can be quite variable over ranges in excess of 10 kilometers. For ASW applications, ranges of interest are often sufficiently large as to warrant the modeling of the spatial variability of the environment. In the propagation loss calculations, each of the environmental parameters is allowed to vary (either continuously or discretely) along the path from acoustic source to receiver. In such applications, each propagation loss calculation is conditioned upon the particular locations of the source and receiver.

On the other hand, the range of interest for marine animal harassment by most Naval activities is more limited. This reduces the importance of the exact location of source and marine animal and makes the modeling required more manageable in scope.

In lieu of trying to model every environmental profile that can be encountered in an operating area, this effort utilizes a limited set of representative environments. Each environment is characterized by a fixed water depth, sound velocity profile, and bottom loss type. The operating area is then partitioned into homogeneous regions (or provinces) and the most appropriately representative environment is assigned to each. This process is aided by some initial provincing of the individual environmental parameters. The Navy-standard high-frequency bottom loss database in its native form is globally partitioned into nine classes. Low-frequency bottom loss is likewise provinced in its native form, although it is not considered in the process of selecting environmental provinces. Only the broadband sources produce acoustic energy at the frequencies of interest for low-frequency bottom loss (typically less than 1 kHz); even for those sources the low-frequency acoustic energy is secondary to the energy above 1 kHz. The Navy-standard sound velocity profiles database is also available as a provinced subset. Only the Navy-standard bathymetry database varies continuously over the world’s oceans. However, even this environmental parameter is easily provinced by selecting a finite set of water depth intervals. For this analysis “octave-spaced” intervals (10, 20, 50, 100, 200, 500, 1,000, 2,000, and 5,000 m) provide an adequate sampling of water depth dependence.

ZOI volumes are then computed using propagation loss estimates derived for the representative environments. Finally, a weighted average of the ZOI volumes is taken over all representative environments; the weighting factor is proportional to the geographic area spanned by the environmental province.

The selection of representative environments is subjective. However, the uncertainty introduced by this subjectivity can be mitigated by selecting more environments and by selecting the environments that occur most frequently over the operating area of interest.

As discussed in the previous subsection, ZOI estimates are most sensitive to water depth. Unless otherwise warranted, at least one representative environment is selected in each bathymetry province. Within a bathymetry province, additional representative environments are selected as needed to meet the following requirements.

- In shallow water (less than 1,000 meters), bottom interactions occur at shorter ranges and more frequently; thus significant variations in bottom loss need to be represented.
- Surface ducts provide an efficient propagation channel that can greatly influence ZOI estimates. Variations in the mixed layer depth need to be accounted for if the water is deep enough to support the full extent of the surface duct.

Depending upon the size and complexity of the operating area, the number of environmental provinces tends to range from 5 to 20.

F.3.3 Description of Environmental Provinces

The MIRC encompasses a large area about the Mariana Islands. For this analysis, the general operating area is bounded to the north and south by latitude lines of 7°N and 20°N and to the east and west by meridians of 138°E and 150°E.

7° 0' 30.07"	149° 16' 14.85"
6° 59' 24.6"	138° 1' 29.72"
20° 0' 24.56"	138° 0' 11.24"
20° 3' 27.55"	149° 17' 41.03"

SINKEX operations may occur anywhere within the general operating area as long as the water depth is greater than 1,000 fathoms and the nearest land is at least 50 nm away. This SINKEX region is partitioned into three sub-areas as described below.

- SINKEX East: An area east of Guam; bounded in latitude by 14° N and 16° N, and in longitude by 146° 30'E and 149° 12'E.
- SINKEX South: All of Warning Area 517 that is more than 50 nm offshore. W-517 is an irregularly-shaped region with the following vertices:

  13°-10'N 144°-30'E

  13°-10'N 144°-42'E

  12°-50'N 144°-45'E

  11°-00'N 144°-45'E

  11°-00'N 143°-00'E

  11°-45'N 143°-00'E

  11°-50'N 144°-30'E
- SINKEX General: All suitable SINKEX areas other than SINKEX East and SINKEX South.

The acoustic sonars described in subsection F.2 are deployed throughout the general operating area. The explosive sources, other than demolition charges, are limited to the three SINKEX sub-areas. The use of demolition charges is limited to Agat Bay and Outer Apra Harbor inshore areas.

This subsection describes the representative environmental provinces selected for the MIRC. For all of these provinces, the average wind speed, winter and summer, is 11 knots.

The general operating area of the MIRC contains a total of 9 distinct environmental provinces. These represent various combinations of five bathymetry regions, 10 Sound Velocity Profile (SVP) provinces, and 6 High-Frequency Bottom Loss (HFBL) regions.

The bathymetry provinces represent depths ranging from 200 meters to typical deep-water depths (more than 5,000 meters). Nearly all of the MIRC is characterized as deep-water (depths of 2,000 meters or more). The remaining water depths (1,000 meters and less) provide only small contributions to the analysis. The distribution of the bathymetry provinces over the MIRC is provided in Table F-5.

Table F-5: Distribution of Bathymetry Provinces in MIRC

Province Depth (m)	Frequency of Occurrence
200	0.23 %
500	0.64 %
1,000	1.98 %
2,000	17.69 %
5,000	79.46 %

Ten SVP provinces describe the sound speed field in the MIRC; however, the variability among the 10 provinces is relatively small as demonstrated by the summer profiles presented in Figure F-1. The dominant difference among the profiles is the steepness of the thermocline.

The seasonal variation is likewise of limited dynamic range, as might be expect given that the range is located in temperate waters. The surface sound speed of the winter profile is only a few m/s slower than the summer profile as depicted in Figure F-2. Both seasons exhibit a well-formed surface duct with average mixed layers of approximately 50 meters and 75 meters in the summer and winter, respectively.

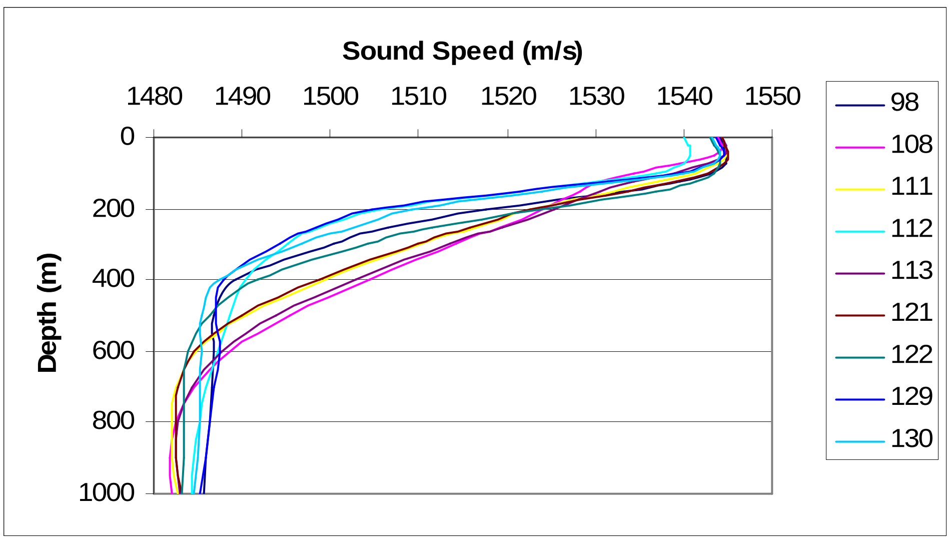


Figure F-1: Summer SVPs in MIRC

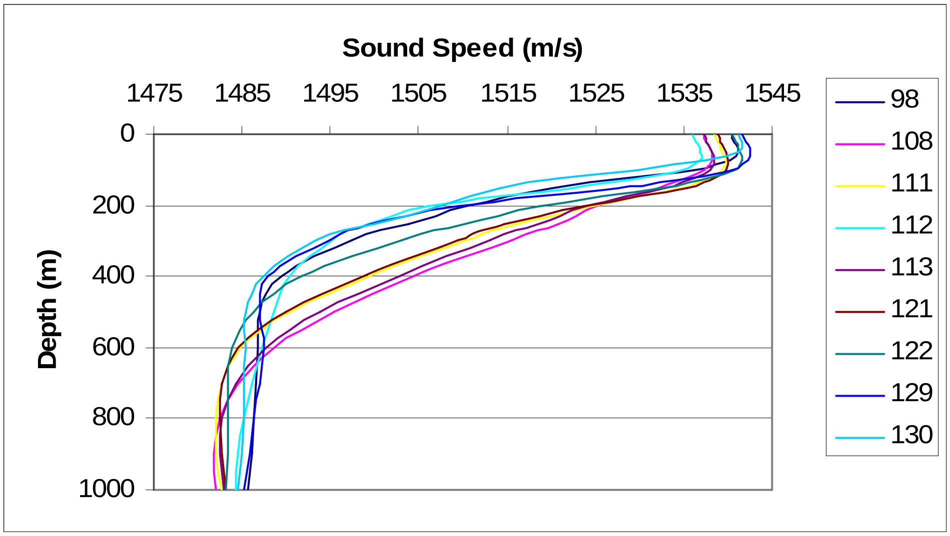


Figure F-2: Winter SVPs in MIRC.

The distribution of the ten SVP provinces across the MIRC is provided in Table F-6.

Table F-6: Distribution of SVP Provinces in MIRC

SVP Province	Frequency of Occurrence
98	22.65 %
108	2.21 %
111	14.50 %
112	0.38 %
113	15.59 %
118	2.56 %
121	3.81 %
122	18.99 %
129	5.80 %
130	13.51 %

The HFBL classes represented in the MIRC primarily range from moderate-loss bottoms (class 4, 5 and 6) to high-loss bottoms (classes 7 or 8). The distribution of HFBL classes summarized in Table F-7 indicates that approximately two-thirds of the MIRC is a high-loss bottom, with most of the remaining 40 percent a moderate-loss bottom.

Table F-7. Distribution of High-Frequency Bottom Loss Classes in MIRC

HFBL Class	Frequency of Occurrence
2	0.25 %
4	11.00 %
5	20.94 %
6	3.75 %
7	13.87 %
8	50.19 %

The logic for consolidating the environmental provinces focuses upon water depth, using the sound speed profile (in deep water) and the HFBL class (in shallow water) as secondary differentiating factors. The first consideration was to ensure that all five bathymetry provinces are represented. Then within each bathymetry province further partitioning of provinces proceeded as follows:

- The three shallowest bathymetry provinces are each represented by one environmental province. In each case, the bathymetry province is dominated by a single, high-loss bottom, so that the secondary differentiating environmental parameter is of no consequence.
- The 2,000-meter bathymetry province consists of two environmental provinces. The vast majority of this bathymetry province consists of high-loss bottoms making the SVP provinces making the more important secondary differentiating environmental parameter. The variance in the sound speed field, which is generally quite small, is represented by two SVP provinces.
- The 5,000-meter bathymetry province is far and away the most prevalent water depth in the MIRC. Although the environmental variability across this bathymetry province is relatively small, its sheer size relative to the other water depths warrants some partitioning to capture some of this variability. This is accomplished by subdividing this bathymetry province into four environmental provinces, one for each of the four most prevalent SVP provinces.

The resulting nine environmental provinces used in the MIRC acoustic modeling are described in Table F-8.

Table F-8: Distribution of Environmental Provinces in the MIRC Study Area

Environmental Province	Water Depth	SVP Province	HFBL Class	LFBL Province	Sediment Thickness	Frequency of Occurrence
1	200 m	122	8	– 98*	0.22 secs	0.23%
2	500 m	122	8	– 98*	0.16 secs	0.64%
3	1,000 m	122	8	62	0.2 secs	1.98%
4	2,000 m	122	8	62	0.19 secs	13.37%
5	2,000 m	111	8	62	0.19 secs	4.32%
6	5,000 m	98	5	13	0.18 secs	26.94%
7	5,000 m	122	8	13	0.1 secs	21.78%
8	5,000 m	111	4	43	0.39 secs	15.47%
9	5,000 m	113	4	43	0.32 secs	15.27%

* Negative province numbers indicate shallow water provinces

The percentages given in Table F-8 indicate the frequency of occurrence of each environmental province across the general operating area in the MIRC. The distributions of the environments within each of the SINKEX sub-areas are, by definition, limited to the two deepest bathymetry provinces as indicated in Table F-9.

Table F-9. Distribution of Environmental Provinces within SINKEX Sub-Areas

Environmental Province	SINKEX East	SINKEX South	SINKEX General
4	1.62%	0.00%	13.07%
5	0.00%	0.11%	2.98%
6	15.32%	99.89%	35.49%
7	83.06%	0.00%	13.68%
8	0.00%	0.00%	17.00%
9	0.00%	0.00%	17.78%

F.4 Impact Volumes and Impact Ranges

Many naval actions include the potential to injure or harass marine animals in the neighboring waters through noise emissions. The number of animals exposed to potential harassment in any such action is dictated by the propagation field and the characteristics of the noise source.

The impact volume associated with a particular activity is defined as the volume of water in which some acoustic metric exceeds a specified threshold. The product of this impact volume with a volumetric animal density yields the expected value of the number of animals exposed to that acoustic metric at a level that exceeds the threshold. The acoustic metric can either be an sound exposure term (sound exposure level, either in a limited frequency band or across the full band) or a pressure term (such as peak pressure or positive impulse). The thresholds associated with each of these metrics define the levels at which half of the animals exposed will experience some degree of harassment (ranging from behavioral change to mortality).

Impact volume is particularly relevant when trying to estimate the effect of repeated source emissions separated in either time or space. Impact range, which is defined as the maximum range at which a particular threshold is exceeded for a single source emission, defines the range to which marine mammal activity is monitored in order to meet mitigation requirements.

With the exception of explosive sources, the sole relevant measure of potential harm to the marine wildlife due to sonar activities is the accumulated (summed over all source emissions) sound exposure level received by the animal over the duration of the activity. Harassment measures for explosive sources include sound exposure level and pressure-related metrics (peak pressure and positive impulse).

Regardless of the type of source, estimating the number of animals that may be injured or otherwise harassed in a particular environment entails the following steps.

- Each source emission is modeled according to the particular operating mode of the sonar. The "effective" energy source level is computed by integrating over the bandwidth of the source, scaling by the pulse length, and adjusting for gains due to source directivity. The location of the source at the time of each emission must also be specified.
- For the relevant environmental acoustic parameters, transmission loss (TL) estimates are computed, sampling the water column over the appropriate depth and range intervals. TL data are sampled at the typical depth(s) of the source and at the nominal center frequency of the

source. If the source is relatively broadband, an average over several frequency samples is required.

- The accumulated energy within the waters that the source is "operating" is sampled over a volumetric grid. At each grid point, the received energy from each source emission is modeled as the effective sound exposure level reduced by the appropriate propagation loss from the location of the source at the time of the emission to that grid point and summed. For the peak pressure or positive impulse, the appropriate metric is similarly modeled for each emission. The maximum value of that metric, over all emissions, is stored at each grid point.
- The impact volume for a given threshold is estimated by summing the incremental volumes represented by each grid point for which the appropriate metric exceeds that threshold.
- Finally, the number of takes is estimated as the "product" (scalar or vector, depending on whether an animal density depth profile is available) of the impact volume and the animal densities.

This section describes in detail the process of computing impact volumes (that is, the first four steps described above). This discussion is presented in two parts: active sonars and explosive sources. The relevant assumptions associated with this approach and the limitations that are implied are also presented. The final step, computing the number of takes is discussed in subsection F.5.

F.4.1 Computing Impact Volumes for Active Sonars

This section provides a detailed description of the approach taken to compute impact volumes for active sonars. Included in this discussion are:

- Identification of the underwater propagation model used to compute transmission loss data, a listing of the source-related inputs to that model, and a description of the output parameters that are passed to the energy accumulation algorithm.
- Definitions of the parameters describing each sonar type.
- Description of the algorithms and sampling rates associated with the energy accumulation algorithm.

F.4.1.1 Transmission Loss Calculations

TL data are pre-computed for each of two seasons in each of the environmental provinces described in the previous subsection using the Gaussian Ray Bundle (GRAB) propagation loss model (Keenan 2000). The TL output consists of a parametric description of each significant eigenray (or propagation path) from source to animal. The description of each eigenray includes the departure angle from the source (used to model the source vertical directivity later in this process), the propagation time from the source to the animal (used to make corrections to absorption loss for minor differences in frequency and to incorporate a surface-image interference correction at low frequencies), and the TL suffered along the eigenray path.

The eigenray data for a single GRAB model run are sampled at uniform increments in range out to a maximum range for a specific "animal" (or "target" in GRAB terminology) depth. Multiple GRAB runs are made to sample the animal depth dependence. The depth and range sampling parameters are summarized in Table F-10. Note that some of the low-power sources do not require TL data to large maximum ranges.

Table F-10: TL Depth and Range Sampling Parameters by Sonar Type

Sonar	Range Step	Maximum Range	Depth Sampling
MK-48	10 m	10 km	0 – 1 km in 5 m steps 1 km – Bottom in 10 m steps
AN/SQS-53	10 m	200 km	0 – 1 km in 5 m steps 1 km – Bottom in 10 m steps
AN/AQS-22	10 m	10 km	0 – 1 km in 5 m steps 1 km – Bottom in 10 m steps
AN/ASQ-62	5 m	5 km	0 – 1 km in 5 m steps 1 km – Bottom in 10 m steps
AN/SQS-56	10 m	50 km	0 – 1 km in 5 m steps 1 km – Bottom in 10 m steps
BQQ-10	20 m	150 km	0 – 1 km in 5 m steps 1 km – Bottom in 10 m steps
AN/SQS-53 Kingfisher Mode	10 m	200 km	0 – 1 km in 5 m steps 1 km – Bottom in 10 m steps
AN/SSQ-125	20 m	100 km	0 – km in 5-m steps 1 km – Bottom in 10-m steps
MK-84 Range Pinger	5 m	10 km	0 – 1 km in 5 m steps 1 km – Bottom in 10 m steps
PUTR Transponders	5 m	10 km	0 – 1 km in 5 m steps 1 km – Bottom in 10 m steps

In a few cases, most notably the AN/SQS-53C for thresholds below approximately 180 dB, TL data may be required by the energy summation algorithm at ranges greater than covered by the pre-computed GRAB data. In these cases, TL is extrapolated to the required range using a simple cylindrical spreading loss law in addition to the appropriate absorption loss. This extrapolation leads to a conservative (or under) estimate of TL at the greater ranges. Modeling is still conducted down to the 120 dB level as in other TAP documents. The 180 dB only refers to the data used in the modeling process. The lower dB level at which there is actual GRAB transmission loss (TL) data available for modeling is 180 dB. From 180 dB to 120 dB the transmission loss must be extrapolated to complete the modeling.

Although GRAB provides the option of including the effect of source directivity in its eigenray output, this capability is not exercised. By preserving data at the eigenray level, this allows source directivity to be applied later in the process and results in fewer TL calculations.

The other important feature that storing eigenray data supports is the ability to model the effects of surface-image interference that persist over range. However, this is primarily important at frequencies lower than those associated with the sonars considered in this subsection. A detailed description of the modeling of surface-image interference is presented in the subsection on explosive sources.

F.4.1.2 Energy Summation

The summation of SEL over multiple pings in a range-independent environment is a trivial exercise for the most part. A volumetric grid that covers the waters in and around the area of sonar operation is initialized. The source then begins its set of pings. For the first ping, the TL from the source to each grid point is determined (summing the appropriate eigenrays after they have been modified by the vertical beam pattern), the "effective" energy source level is reduced by that TL, and the result is added to the accumulated SEL at that grid point. After each grid point has been updated, the accumulated energy at grid points in each depth layer is compared to the specified threshold. If the accumulated energy exceeds that threshold, then the incremental volume represented by that grid point is added to the impact volume for that depth layer. Once all grid points have been processed, the resulting sum of the incremental volumes represents the impact volume for one ping.

The source is then moved along one of the axes in the horizontal plane by the specified ping separation range and the second ping is processed in a similar fashion. Again, once all grid points have been processed, the resulting sum of the incremental volumes represents the impact volume for two pings. This procedure continues until the maximum number of pings specified has been reached.

Defining the volumetric grid over which energy is accumulated is the trickiest aspect of this procedure. The volume must be large enough to contain all volumetric cells for which the accumulated energy is likely to exceed the threshold but not so large as to make the energy accumulation computationally unmanageable.

Determining the size of the volumetric grid begins with an iterative process to determine the lateral extent to be considered. Unless otherwise noted, throughout this process the source is treated as omni directional and the only animal depth that is considered is the TL target depth that is closest to the source depth (placing source and receiver at the same depth is generally an optimal TL geometry).

The first step is to determine the impact range (R_{MAX}) for a single ping. The impact range in this case is the maximum range at which the effective energy source level reduced by the TL is greater than the threshold. Next, the source is moved along a straight-line track and SEL is accumulated at a point that has a CPA range of R_{MAX} at the mid-point of the source track. That total SEL summed over all pings is then compared to the prescribed threshold. If it is greater than the threshold (which, for the first R_{MAX}, it must be) then R_{MAX} is increased by 10 percent, the accumulation process is repeated, and the total energy is again compared to the threshold. This continues until R_{MAX} grows large enough to ensure that the accumulated SEL at that lateral range is less than the threshold. The lateral range dimension of the volumetric grid is then set at twice R_{MAX}, with the grid centered along the source track. In the direction of advance for the source, the volumetric grid extends of the interval from [$-R_{MAX}$, 3 R_{MAX}] with the first source position located at zero in this dimension. Note that the source motion in this direction is limited to the interval [0, 2 R_{MAX}]. Once the source reaches 2 R_{MAX} in this direction, the incremental volume contributions have approximately reached their asymptotic limit and further pings add essentially the same amount. This geometry is demonstrated in Figure F-3.

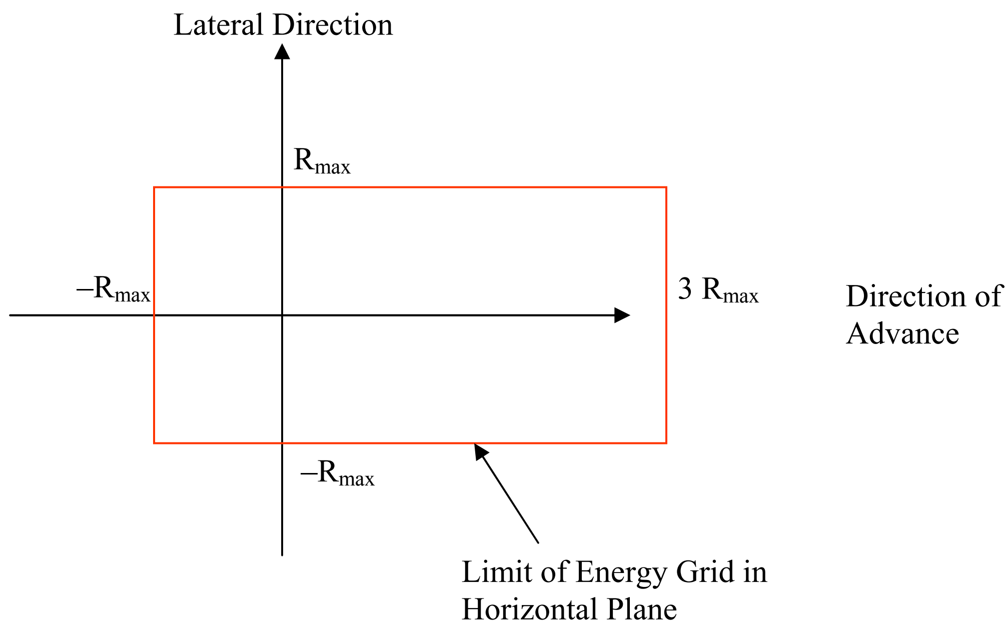


Figure F-3: Horizontal Plane of Volumetric Grid for Omni Directional Source

If the source is directive in the horizontal plane, then the lateral dimension of the grid may be reduced and the position of the source track adjusted accordingly. For example, if the main lobe of the horizontal source beam is limited to the starboard side of the source platform, then the port side of the track is reduced substantially as demonstrated in Figure F-4.

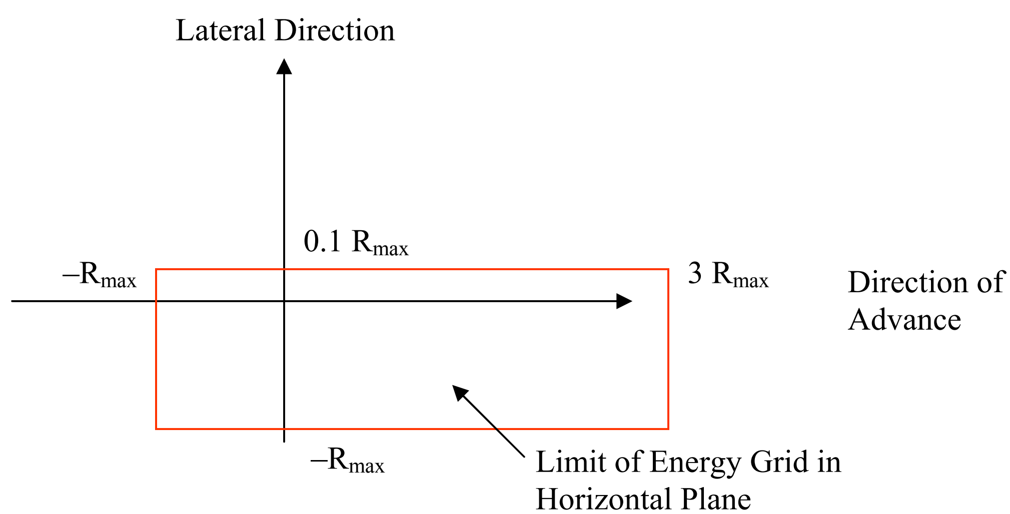


Figure F-4: Horizontal Plane of Volumetric Grid for Starboard Beam Source

Once the extent of the grid is established, the grid sampling can be defined. In both dimensions of the horizontal plane the sampling rate is approximately $R_{MAX}/100$. The round-off error associated with this sampling rate is roughly equivalent to the error in a numerical integration to determine the area of a circle with a radius of R_{MAX} with a partitioning rate of $R_{MAX}/100$ (approximately 1 percent). The depth-sampling rate of the grid is comparable to the sampling rates in the horizontal plane but discretized to match an actual TL sampling depth. The depth-sampling rate is also limited to no more than 10 meters to ensure that significant TL variability over depth is captured.

F.4.1.3 Impact Volume per Hour of Sonar Operation

The impact volume for a sonar moving relative to the animal population increases with each additional ping. The rate at which the impact volume increases varies with a number of parameters but eventually approaches some asymptotic limit. Beyond that point the increase in impact volume becomes essentially linear as depicted in Figure F-5.

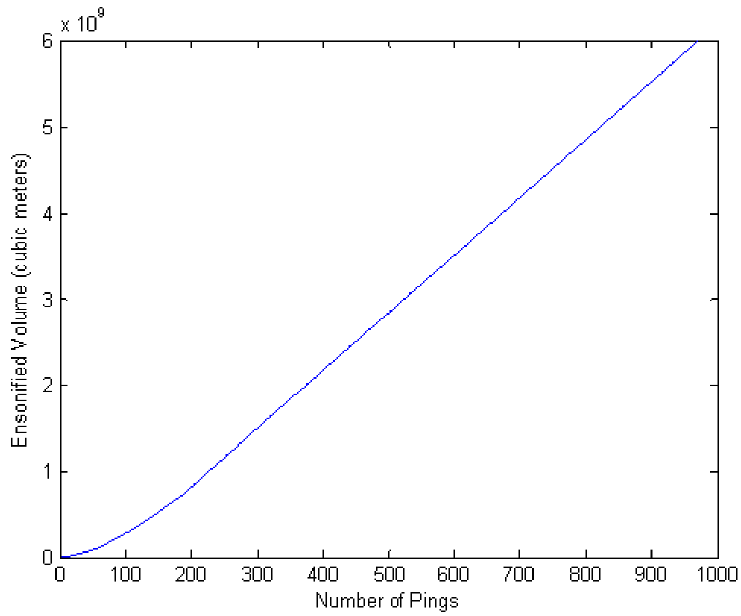


Figure F-5: 53C Impact Volume by Ping

The slope of the asymptotic limit of the impact volume in a given depth is the impact volume added per ping. This number multiplied by the number of pings in an hour gives the hourly impact volume for the given depth increment. Completing this calculation for all depths in a province, for a given source, gives the hourly impact volume vector, v_n, which contains the hourly impact volumes by depth for province n. Figure F-6 provides an example of an hourly impact volume vector for a particular environment.

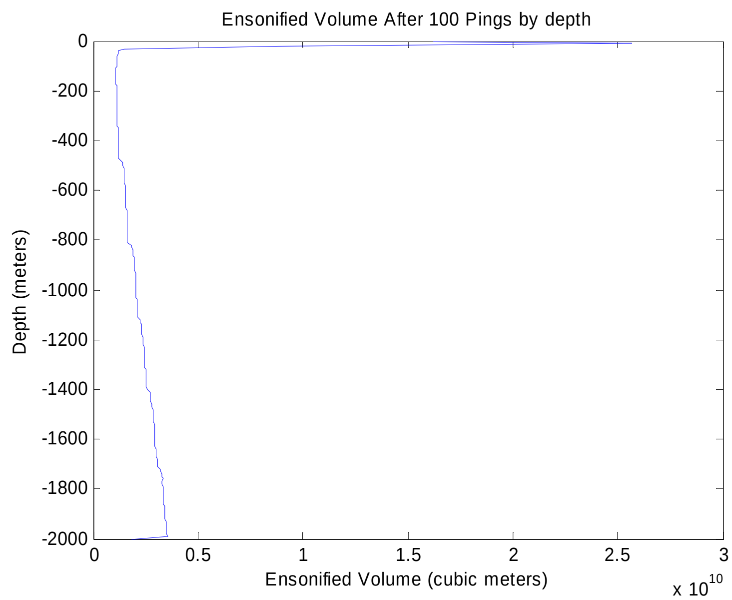


Figure F-6: Example of an Impact Volume Vector

F.4.2 Computing Impact Volumes for Explosive Sources

This section provides the details of the modeling of the explosive sources. This energy summation algorithm is similar to that used for sonars, only differing in details such as the sampling rates and source parameters. These differences are summarized in the following subsections. A more significant difference is that the explosive sources require the modeling of additional pressure metrics: (1) peak pressure, and (2) "modified" positive impulse. The modeling of each of these metrics is described in detail in the subsections of F.4.2.3.

F.4.2.1 Transmission Loss Calculations

Modeling impact volumes for explosive sources span requires the same type of TL data as needed for active sonars. However unlike active sonars, explosive ordnances and the EER source are broadband, contributing significant energy from tens of hertz to tens of kilohertz. To accommodate the broadband nature of these sources, TL data are sampled at seven frequencies from 10 Hz to 40 kHz, spaced every two octaves.

An important propagation consideration at low frequencies is the effect of surface-image interference. As either source or target approach the surface, pairs of paths that differ by a single surface reflection set up an interference pattern that ultimately causes the two paths to cancel each other when the source or target is at the surface. A fully coherent summation of the eigenrays produces such a result but also introduces extreme fluctuations that would have to be highly sampled in range and depth, and then smoothed to give meaningful results. An alternative approach is to implement what is sometimes called a semi-coherent summation. A semi-coherent sum attempts to capture significant effects of surface-image interference (namely the reduction of the field due to destructive interference of reflected paths as the source or target approach the surface) without having to deal with the more rapid fluctuations associated with a fully coherent sum. The semi-coherent sum is formed by a random phase addition of paths that have already been multiplied by the expression:

$$\sin^2 [4\pi f z_s z_a / (c^2 t)]$$

where f is the frequency, z_s is the source depth, z_a is the animal depth, c is the sound speed and t is the travel time from source to animal along the propagation path. For small arguments of the sine function this expression varies directly as the frequency and the two depths. It is this relationship that causes the propagation field to go to zero as the depths approach the surface or the frequency approaches zero

This surface-image interference must be applied across the entire bandwidth of the explosive source. The TL field is sampled at several representative frequencies. However, the image-interference correction given above varies substantially over that frequency spacing. To avoid possible under sampling, the image-interference correction is averaged over each frequency interval.

F.4.2.2 Source Parameters

Unlike active sonars, explosive sources are defined by only two parameters: (1) net explosive weight, and (2) source detonation depth. Values for these source parameters are defined earlier in subsection F.2.2.

The effective energy source level, which is treated as a de facto input for the other sonars, is instead modeled directly for EER and munitions. For both, the energy source level is comparable to the model used for other explosives (Arons 1954; Weston 1960; McGrath 1971; Urick 1983; Christian and Gaspin 1974). The energy source level over a one-third octave band with a center frequency of f for a source with a net explosive weight of w pounds is given by:

$$ESL = 10 \log_{10} (0.26 f) + 10 \log_{10} (2 p_{max}^2 / [1/\theta^2 + 4 \pi f^2]) + 197 \text{ dB}$$

where the peak pressure for the shock wave at 1 meter is defined as

$$p_{max} = 21{,}600 (w^{1/3} / 3.28)^{1.13} \text{ psi} \qquad \text{(F-1)}$$

and the time constant is defined as:

$$\theta = [(0.058) (w^{1/3}) (3.28 / w^{1/3})^{0.22}] / 1{,}000 \text{ msec} \qquad \text{(F-2)}$$

In contrast to munitions that are modeled as omnidirectional sources, the EER source is a continuous line array that produces a directed source. The EER array consists of two explosive strips that are fired simultaneously from the center of the array. Each strip generates a beam pattern with the steer direction of the main lobe determined by the burn rate. The resulting response of the entire array is a bifurcated beam for frequencies above 200 Hz, while at lower frequencies the two beams tend to merge into one.

Since very short ranges are under consideration, the loss of directivity of the array needs to be accounted for in the near field of the array. This is accomplished by modeling the sound pressure level across the field as the coherent sum of contributions of infinitesimal sources along the array that are delayed according to the burn rate. For example, for frequency f the complex pressure contribution at a depth z and horizontal range x from an infinitesimal source located at a distance z' above the center of the array is

$$p(r,z) = e^{i\phi}$$

where

$$\phi = kr' + \alpha z', \text{ and}$$
$$\alpha = 2\pi f / c_b$$

with k the acoustic wave number, c_b the burn rate of the explosive ribbon, and r' the slant range from the infinitesimal source to the field point (x,z).

Beam patterns as function of vertical angle are then sampled at various ranges out to a maximum range that is approximately L^2 / □ where L is the array length and □ is the wavelength. This maximum range is a rule-of-thumb estimate for the end of the near field (Bartberger 1965). Finally, commensurate with the resolution of the TL samples, these beam patterns are averaged over octave bands.

A couple of sample beam patterns are provided in Figure F-7 and Figure F-8. In both cases, the beam response is sampled at various ranges from the source array to demonstrate the variability across the near field. The 80-Hz family of beam patterns presented in Figure F-7 shows the rise of a single main lobe as range increases.

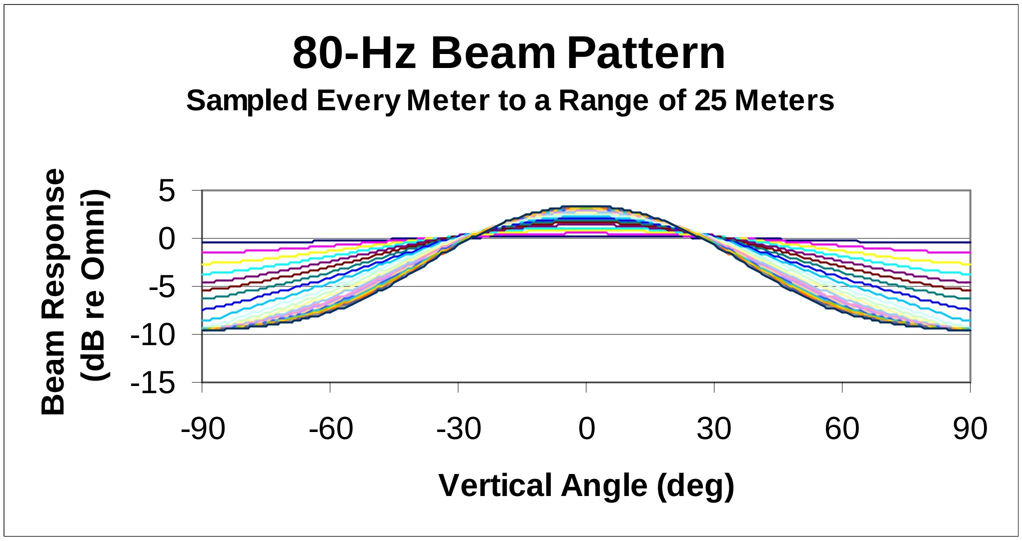


Figure F-7: 80-Hz Beam Patterns across Near Field of EER Source

On the other hand, the 1,250-Hz family of beam patterns depicted in Figure F-8 demonstrates the typical high-frequency bifurcated beam.

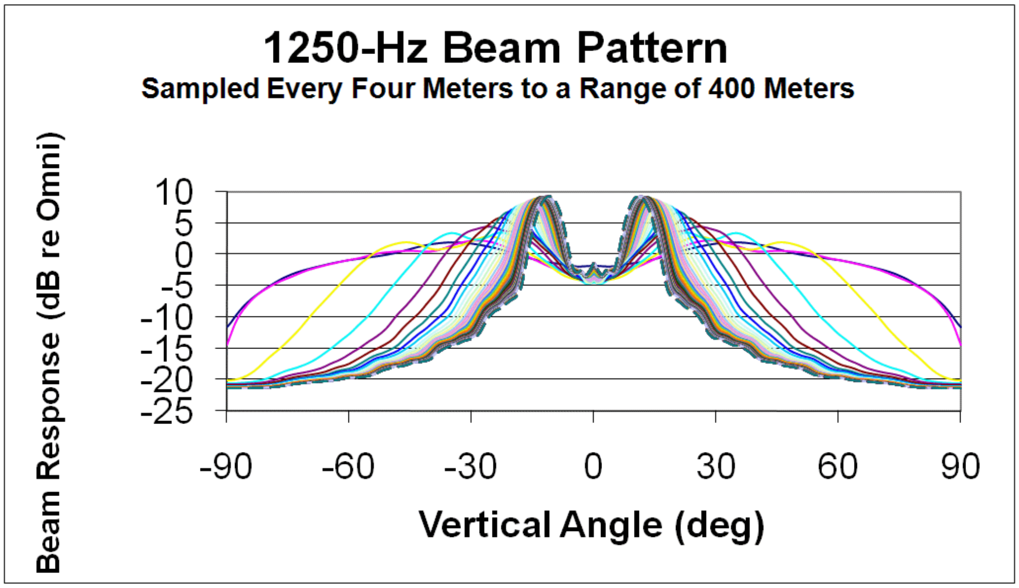


Figure F-8: 1,250-Hz Beam Patterns across Near Field of EER Source

F.4.2.3 Impact Volumes for Various Metrics

The impact of explosive sources on marine wildlife is measured by three different metrics, each with its own thresholds. The energy metric, peak one-third octave, is treated in similar fashion as the energy metric used for the active sonars, including the summation of energy if there are multiple source emissions. The other two, peak pressure and positive impulse, are not accumulated but rather the maximum levels are taken.

F.4.2.3.1 Peak One-Third Octave Energy Metric

The computation of impact volumes for the energy metric follows closely the approach taken to model the energy metric for the active sonars. The only significant difference is that SEL is sampled at several frequencies in one-third-octave bands and only the peak one-third-octave level is accumulated over time.

F.4.2.3.2 Peak Pressure Metric

The peak pressure metric is a simple, straightforward calculation at each range/animal depth combination. First, the transmission ratio, modified by the source level in a one-octave band and the vertical beam pattern, is averaged across frequency on an eigenray-by-eigenray basis. This averaged transmission ratio (normalized by the total broadband source level) is then compared across all eigenrays with the maximum designated as the peak arrival. Peak pressure at that range/animal depth combination is then simply the product of:

- The square root of the averaged transmission ratio of the peak arrival,
- The peak pressure at a range of one meter (given by equation F-1), and
- The similitude correction (given by $r^{-0.13}$, where r is the slant range along the eigenray estimated as tc with t the travel time along the dominant eigenray and c the nominal speed of sound).

If the peak pressure for a given grid point is greater than the specified threshold, then the incremental volume for the grid point is added to the impact volume for that depth layer.

F.4.2.3.3 "Modified" Positive Impulse Metric

The modeling of positive impulse follows the work of Goertner (Goertner 1982). The Goertner model defines a "partial" impulse as

$$\int_0^{T_{min}} p(t)\, dt$$

where p(t) is the pressure wave from the explosive as a function of time t, defined so that p(t) = 0 for t < 0. This pressure wave is modeled as

$$p(t) = p_{max}\, e^{-t/\theta}$$

where p_{max} is the peak pressure at 1 meter (see, equation B-1), and θ is the time constant defined as

$$\theta = 0.058\ w^{1/3}\ (r/w^{1/3})^{0.22}\ \text{seconds}$$

with w the net explosive weight (pounds), and r the slant range between source and animal.

The upper limit of the “partial” impulse integral is

$$T_{min} = \min\ \{T_{cut}, T_{osc}\}$$

where T_{cut} is the time to cutoff and T_{osc} is a function of the animal lung oscillation period. When the upper limit is T_{cut}, the integral is the definition of positive impulse. When the upper limit is defined by T_{osc}, the integral is smaller than the positive impulse and thus is just a “partial” impulse. Switching the integral limit from T_{cut} to T_{osc} accounts for the diminished impact of the positive impulse upon the animals lungs that compress with increasing depth and leads to what is sometimes call a “modified” positive impulse metric.

The time to cutoff is modeled as the difference in travel time between the direct path and the surface-reflected path in an isospeed environment. At a range of r, the time to cutoff for a source depth z_s and an animal depth z_a is

$$T_{cut} = 1/c\ \{\ [r^2 + (z_a + z_s)^2]^{1/2} – [r^2 + (z_a – z_s)^2]^{1/2}\ \}$$

where c is the speed of sound.

The animal lung oscillation period is a function of animal mass M and depth z_a and is modeled as

$$T_{osc} = 1.17\ M^{1/3}\ (1 + z_a/33)^{–5/6}$$

where M is the animal mass (in kg) and z_a is the animal depth (in feet).

The modified positive impulse threshold is unique among the various injury and harassment metrics in that it is a function of depth and the animal weight. So instead of the user specifying the threshold, it is computed as $K\ (M/42)^{1/3}\ (1 + z_a\ /\ 33)^{1/2}$. The coefficient K depends upon the level of exposure. For the onset of slight lung injury, K is 19.7; for the onset of extensive lung hemorrhaging (1 percent mortality), K is 47.

Although the thresholds are a function of depth and animal weight, sometimes they are summarized as their value at the sea surface for a typical dolphin calf (with an average mass of 12.2 kg). For the onset of slight lung injury, the threshold at the surface is approximately 13 psi-msec; for the onset of extensive lung hemorrhaging (1 percent mortality), the threshold at the surface is approximately 31 psi-msec.

As with peak pressure, the “modified” positive impulse at each grid point is compared to the derived threshold. If the impulse is greater than that threshold, then the incremental volume for the grid point is added to the impact volume for that depth layer.

F.4.2.4 Impact Volume per Explosive Detonation

The detonations of explosive sources are generally widely spaced in time and/or space. This implies that the impact volume for multiple firings can be easily derived by scaling the impact volume for a single detonation. Thus the typical impact volume vector for an explosive source is presented on a per-detonation basis.

F.4.3 Impact Volume by Region

The MIRC is described by nine environmental provinces. The hourly impact volume vector for operations involving any particular source is a linear combination of the nine impact volume vectors with the weighting determined by the distribution of those nine environmental provinces within the range. Unique hourly impact volume vectors for winter and summer are calculated for each type of source and each metric/threshold combination.

F.5 Risk Function: Theoretical and Practical Implementation

This section discusses the recent addition of a risk function "threshold" to acoustic effects analysis procedure. This approach includes two parts, a new metric, and a function to map exposure level under the new metric to probability of harassment. What these two parts mean, how they affect exposure calculations, and how they are implemented are the objects of discussion.

Thresholds and Metrics

The term "thresholds" is broadly used to refer to both thresholds and metrics. The difference, and the distinct roles of each in effects analyses, will be the foundation for understanding the risk function approach, putting it in perspective, and showing that, conceptually, it is similar to past approaches.

Sound is a pressure wave, so at a certain point in space, sound is simply rapidly changing pressure. Pressure at a point is a function of time. Define p(t) as pressure (in micropascals) at a given point at time t (in seconds); this function is called a "time series." Figure F-9 gives the time series of the first "hallelujah" in Handel's Hallelujah Chorus.

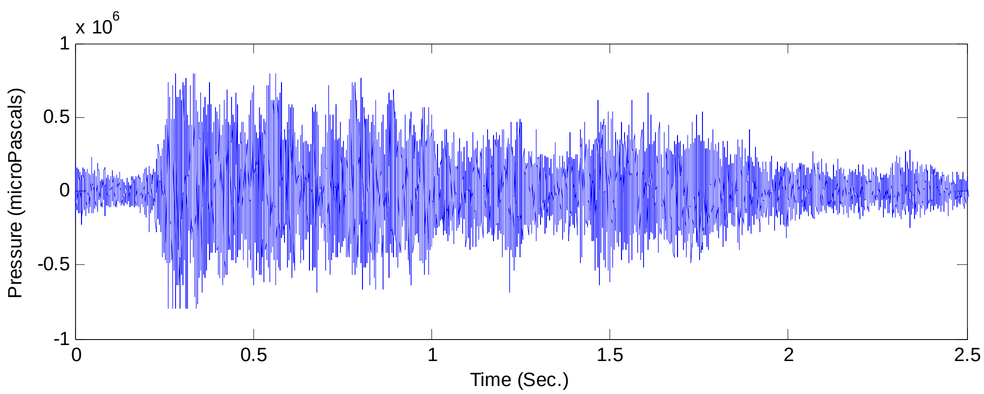


Figure F-9: Time Series

The time-series of a source can be different at different places. Therefore, sound, or pressure, is not only a function of time, but also of location. Let the function p(t), then be expanded to p(t;x,y,z) and denote the time series at point (x,y,z) in space. Thus, the series in Figure F-9 p(t) is for a given point (x,y,z). At a different point in space, it would be different.

Assume that the location of the source is (0,0,0) and this series is recorded at (0,10,-4). The time series above would be p(t;0,10,-4) for 0<t<2.5.

As in Figure F-9, pressure can be positive or negative, but acoustic power, which is proportional to the square of the pressure, is always positive, this makes integration meaningful. Figure F-10 is $p^2(t;0,10,-4)$.

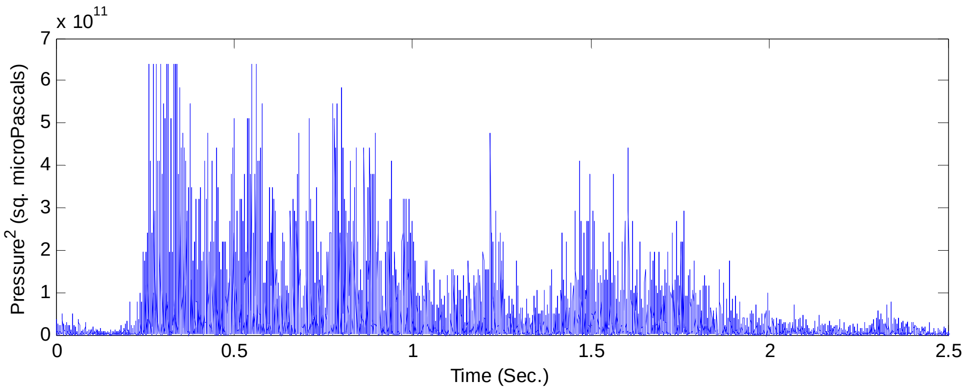


Figure F-10: Time Series Squared

The metric chosen to evaluate the sound field at the end of this first "hallelujah" determines how the time series is summarized from thousands of points, as in Figure F-9, to a single value for each point (x,y,z) in the space. The metric essentially "boils down" the four dimensional p(t,x,y,z) into a three dimensional function m(x,y,z) by dealing with time. There is more than one way to summarize the time component, so there is more than one metric.

Max Sound Pressure Level (SPL)

Because of the large dynamic range of the acoustic power, it is generally represented on a logarithmic scale using SPLs. SPL is actually the ratio of acoustic power density (power/unit area = $\frac{p^2}{Z}$ where Z = ρc is the acoustic impedance). This ratio is presented on a logarithmic scale relative to a reference pressure level, and is defined as:

$$SPL = 10\log_{10}\left(\frac{p^2}{p_{ref}^2}\right) = 20\log_{10}\left(abs\left(\frac{p}{p_{ref}}\right)\right)$$

(Note that SPL is defined in dB re a reference pressure, even though it comes from a ratio of powers)

One way to characterize the power of the time series $p(t;x,y,z)$ with a single number over the 2.5 seconds is to only report the maximum SPL value of the function over time or,

$SPL_{\max} = \max\{10\log_{10}(p^2(t,x,y,z))\}$ (relative to a reference pressure of 1) for 0<t<2.5

The $SPL_{\max}$ for this snippet of the Hallelujah Chorus is:

$$10\log_{10}\left(6.4\times10^{11}\,\mu Pa^2/1\mu Pa^2\right) = 118dB \text{ Re } 1\mu\text{Pa}$$

and occurs at 0.2606 seconds, as shown in Figure F-11.

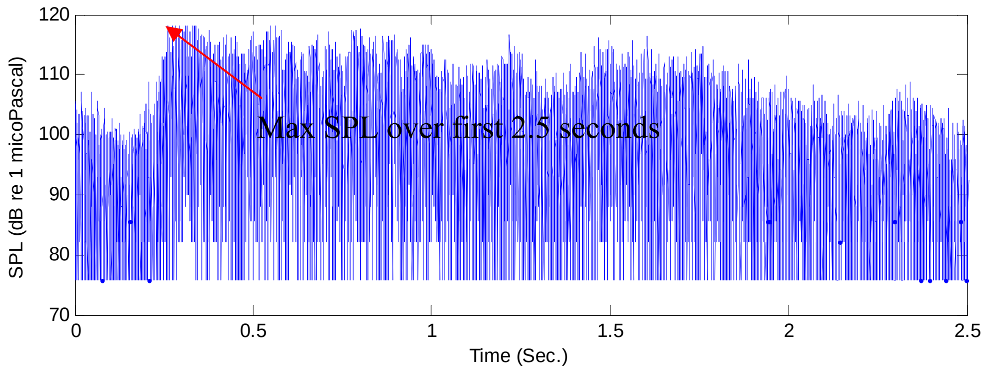


Figure F-11: Max SPL of Time Series Squared

Integration

SPL_{max} is not necessarily influenced by the duration of the sound (2.5 seconds in this case). Integrating the function over time gives the sound exposure level, which does take this duration into account. A simple integration of $p^2(t;x,y,z)$ over t is common and is proportional to the sound exposure level at (x,y,z). Because we will again be dealing in levels (logarithms of ratios), we neglect the impedance and simply measure the square of the pressure:

$$Energy = \int_0^T p^2(t,x,y,z)dt$$, where T is the maximum time of interest in this case 2.5.

The energy for this snippet of the Hallelujah Chorus is $8.47 \times 10^{10}\ \mu Pa^2 \cdot s$. This would more commonly be reported as an SEL:

$$SEL = 10\log_{10}\left(\frac{\int_0^T p^2(t,x,y,z)dt}{1.0\mu Pa^2 s}\right) = 109.3 \text{ dB Re } 1\mu\text{Pa}^2\text{s}$$

Energy is sometimes called "equal energy" because if p(t) is a constant function and the duration is doubled, the effect is the same as doubling the signal amplitude (y value). Thus, the duration and the signal have an "equal" influence on the energy metric.

Mathematically,

$$\int_0^{2T} p(t)^2\,dt = 2\int_0^T p(t)^2\,dt = \int_0^T 2p(t)^2\,dt$$

or a doubling in duration equals a doubling in energy equals a doubling in signal.

Sometimes, the integration metrics are referred to as having a "3 dB exchange rate" because if the duration is doubled, this integral increases by a factor of two, or 10log10(2)=3.01 dB. Thus, equal energy has "a 3 dB exchange rate."

After p(t) is determined (i.e., when the stimulus is over), propagation models can be used to determine p(t;x,y,z) for every point in the vicinity and for a given metric. Define

$$m_a(x, y, z, T) = \text{value of metric "a" at point (x,y,z) after time T}$$

So,

$$m_{energy}(x, y, z; T) = \int_0^T p(t)^2\, dt$$

$$m_{\max SPL}(x, y, z; T) = \max(10 \log_{10}\left(p^2(t)\right))\ over\ [0, T]$$

Since modeling is concerned with the effects of an entire event, T is usually implicitly defined: a number that captures the duration of the event. This means that $m_a(x, y, z)$ is assumed to be measured over the duration of the received signal.

Three Dimensions versus Two Dimensions

To further reduce the calculation burden, it is possible to reduce the domain of $m_a(x, y, z)$ to two dimensions by defining $m_a(x, y) = \max\{m_a(x, y, z)\}$ over all z. This reduction is not used for this analysis, which is exclusively three-dimensional.

Threshold

For a given metric, a threshold is a function that gives the probability of exposure at every value of m_a. This threshold function will be defined as

$$D(m_a(x, y, z)) = \Pr(effect\ at\ m_a(x, y, z))$$

The domain of D is the range of $m_a(x, y, z)$, and its range is the number of thresholds.

An example of threshold functions is the Heavyside (or unit step) function, currently used to determine PTS and TTS in cetaceans. For PTS, the metric is $m_{energy}(x, y, z)$, defined above, and the threshold function is a Heavyside function with a discontinuity at 215 dB, shown in Figure F-12.

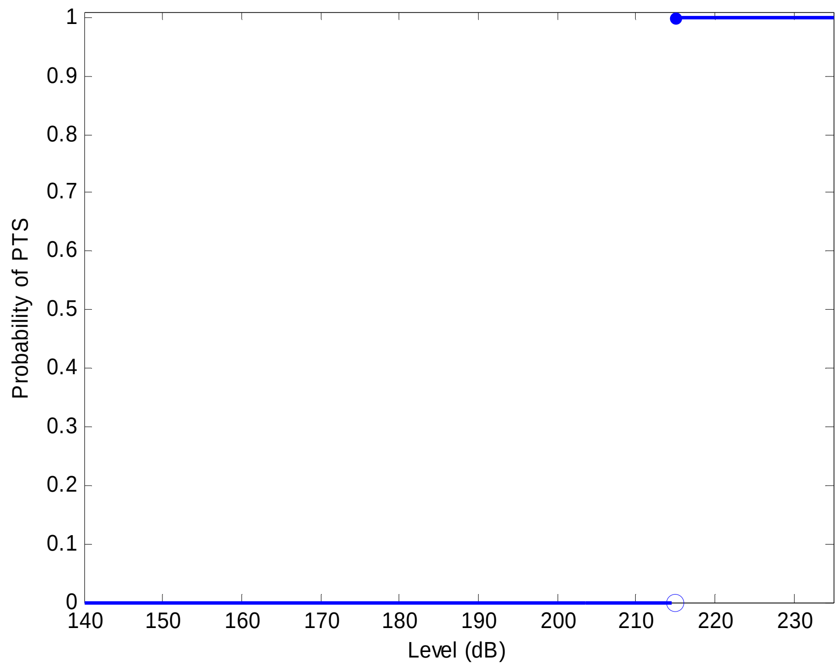


Figure F-12: PTS Heavyside Threshold Function

Mathematically, this D is defined as:

$$D(m_{energy}) = \begin{cases} 0 \;\; for \; m_{energy} < 215 \\ 1 \;\; for \; m_{energy} \geq 215 \end{cases}$$

Any function can be used for D, as long as its range is in [0,1]. The risk functions use normal Feller risk functions (defined below) instead of heavyside functions, and use the max SPL metric instead of the energy metric. While a heavyside function is specified by a single parameter, the discontinuity, a Feller function requires three parameters: the basement cutoff value, the level above the basement for 50 percent effect, and a steepness parameter. Mathematically, these Feller, "risk" functions, D, are defined as

$$D(m_{\max SPL}) = \begin{cases} \dfrac{1}{1+\left(\dfrac{K}{m_{\max SPL} - B}\right)^{A}} \;\; for \; m_{\max SPL} \geq B \\ 0 \;\; for \; m_{\max SPL} < B \end{cases}$$

where B=cutoff (or basement), K=the difference in level (dB) between the basement and the median (50 percent effect) harassment level, and A = the steepness factor. The risk function for odontocetes and pinnipeds uses the parameters:

B = 120 dB,
K = 45 dB, and
A = 10.

The risk function for mysticetes uses:

B = 120 dB,
K = 45 dB, and
A = 8.

Harbor porpoises are a special case. Though the metric for their behavioral harassment is also SPL, their risk function is a heavyside step function with a harassment threshold discontinuity (0 percent to 100 percent) at 120 dB. All other species use the continuous Feller cumulative distribution function (CDF) function for evaluating expected harassment.

Multiple Metrics and Thresholds

It is possible to have more than one metric, and more than one threshold in a given metric. For example, in this document, the criteria to define harassment have two metrics (energy for PTS and TTS, and max SPL for Feller risk function) to define MMPA Level A (PTS) and Level B harassment (TTS and Feller risk function), of which the most conservative is used to determine harassment; and three thresholds (two for energy, one for max SPL). The energy thresholds are heavyside functions, as described above, with discontinuities at 215 and 195 for PTS (Level A) and TTS (Level B), respectively. The max SPL effect is calculated from the Feller risk function (Level B) for odontocetes defined in the previous section.

Calculation of Expected Exposures

Determining the number of expected exposures for disturbance is the object of this analysis.

$$\text{Expected exposures in volume V=} \int_V \rho(V)D(m_a(V))dV$$

For this analysis, $m_a = m_{\max SPL}$, so

$$\int_V \rho(V)D(m_a(V)dV = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \rho(x,y,z)D(m_{\max SPL}(x,y,z))dxdydz$$

In this analysis, the densities are constant over the x/y plane, and the z dimension is always negative, so this reduces to

$$\int_{-\infty}^{0} \rho(z)\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} D(m_{\max SPL}(x,y,z))dxdydz$$

Numeric Implementation

Numeric integration of $\int_{-\infty}^{\infty} \rho(z)\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} D(m_{\max SPL}(x,y,z))dxdydz$ can be involved because, although the bounds are infinite, D is non-negative out to 141 dB, which, depending on the environmental specifics, can drive propagation loss calculations and their numerical integration out to more than 100 km.

The first step in the solution is to separate out the x/y-plane portion of the integral:

$$\text{Define f(z)=} \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} D(m_{\max SPL}(x,y,z))dxdy .$$

Calculation of this integral is the most involved and time consuming part of the calculation. Once it is complete,

$$\int_{-\infty}^{0}\rho(z)\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}D(m_{\max SPL}(x,y,z))dxdydz=\int_{-\infty}^{0}\rho(z)f(z)dz,$$

which, when numerically integrated, is a simple dot product of two vectors.

Thus, the calculation of f(z) requires the majority of the computation resources for the numerical integration. The rest of this section presents a brief outline of the steps to calculate f(z) and preserve the results efficiently.

The concept of numerical integration is, instead of integrating over continuous functions, to sample the functions at small intervals and sum the samples to approximate the integral. The smaller the size of the intervals, the closer the approximation, but the longer the calculation, so a balance between accuracy and time is determined in the decision of step size. For this analysis, z is sampled in 5-meter steps to 1,000 meters in depth and 10-meter steps to 2,000 meters, which is the limit of animal depth in this analysis. The step size for x is 5 meters, and y is sampled with an interval that increases as the distance from the source increases. Mathematically,

$$z\in Z=\{0,5,...1000,1010,...,2000\}$$
$$x\in X=\{0,\pm5,...,\pm5k\}$$
$$y\in Y=\left\{0,\pm5*(1.005)^{0},\pm5*\left[(1.005)^{0}+(1.005)^{1}\right],...,\pm5*\left[\sum_{i=0}^{j}(1.005)^{i}\right]\right\}$$

for integers k, j, which depend on the propagation distance for the source. For this analysis, k = 20,000 and j = 600.

With these steps, $f(z_0)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}D(m_{\max SPL}(x,y,z_0))dxdy$ is approximated as

$$\sum_{z\in Y}\sum_{x\in X}D(m_{\max SPL}(x,y,z_0))\Delta x\Delta y$$

where X,Y are defined as above.

This calculation must be repeated for each $z_0\in Z$, to build the discrete function f(z).

With the calculation of f(z) complete, the integral of its product with $\rho(z)$ must be calculated to complete evaluation of

$$\int_{-\infty}^{\infty}\rho(z)\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}D(m_{\max SPL}(x,y,z))dxdydz=\int_{-\infty}^{0}\rho(z)f(z)dz$$

Since f(z) is discrete, and $\rho(z)$ can be readily made discrete, $\int_{-\infty}^{0}\rho(z)f(z)dz$ is approximated numerically as $\sum_{z\in Z}\rho(z)f(z)$, a dot product.

Preserving Calculations for Future Use

Calculating f(z) is the most time-consuming part of the numerical integration, but the most time-consuming portion of the entire process is calculating $m_{\max SPL}(x,y,z)$ over the area range required for the minimum cutoff value (141 dB). The calculations usually require propagation estimates out to over 100 km, and those estimates, with the beam pattern, are used to construct a sound field that extends 200 km x 200 km (40,000 sq km), with a calculation at the steps for every value of X and Y, defined above. This is repeated for each depth, to a maximum of 2,000 meters.

Saving the entire $m_{\max SPL}$ for each z is unrealistic, requiring great amounts of time and disk space. Instead, the different levels in the range of $m_{\max SPL}$ are sorted into 0.5 dB wide bins; the volume of water at each bin level is taken from $m_{\max SPL}$, and associated with its bin. Saving this, the amount of water ensonified at each level, at 0.5 dB resolution, preserves the ensonification information without using the space and time required to save $m_{\max SPL}$ itself. Practically, this is a histogram of occurrence of level at each depth, with 0.5 dB bins. Mathematically, this is simply defining the discrete functions $V_z(L)$, where $L = \{.5a\}$ for every positive integer a, for all $z \in Z$. These functions, or histograms, are saved for future work. The information lost by saving only the histograms is *where* in space the different levels occur, although *how often* they occur is saved. But the thresholds (risk function curves) are purely a function of level, not location, so this information is sufficient to calculate f(z).

Applying the risk function to the histograms is a dot product:

$$\sum_{\ell \in L_1} D(\ell) V_{z_0}(\ell) \approx \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} D(m_{\max SPL}(x, y, z_0))dxdy$$

So, once the histograms are saved, neither $m_{\max SPL}(x, y, z)$ nor f(z) must be recalculated to generate $\int_{-\infty}^{0} \rho(z) \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} D(m_{\max SPL}(x, y, z))dxdydz$ for a new threshold function.

For the interested reader, the following section includes an in-depth discussion of the method, software, and other details of the f(z) calculation.

Software Detail

The risk function metric uses the cumulative normal probability distribution to determine the probability that an animal is affected by a given SPL. The acoustic quantity of interest is the maximum SPL experienced over multiple pings in a range-independent environment. The procedure for calculating the impact volume at a given depth is relatively simple. In brief, given the SPL of the source and the TL curve, the received SPL is calculated on a volumetric grid. For a given depth, volume associated with each SPL interval is calculated. Then, this volume is multiplied by the probability that an animal will be affected by that SPL. This gives the impact volume for that depth, that can be multiplied by the animal densities at that depth, to obtain the number of animals affected at that depth. The process repeats for each depth to construct the impact volume as a function of depth.

The case of a single emission of sonar energy, one ping, illustrates the computational process in more detail. First, the sound pressure levels are segregated into a sequence of bins that cover the range encountered in the area. The SPL are used to define a volumetric grid of the local sound field. The impact volume for each depth is calculated as follows: for each depth in the volumetric grid, the SPL at each x/y plane grid point is calculated using the SPL of the source, the TL curve, the horizontal beam pattern of the source, and the vertical beam patterns of the source. The sound pressure levels in this grid become the bins in the volume histogram. Figure F-13 shows a volume histogram for a low-power sonar. Level bins are 0.5 dB in width and the depth is 50 meters in an environment with water depth of 100 meters. The oscillatory structure at very low levels is due the flattening of the TL curve at long distances from the source, which magnifies the fluctuations of the TL as a function of range. The "expected" impact volume for a given level at a given depth is calculated by multiplying the volume in each level bin by the risk function probability function at that level. Total expected impact volume for a given depth is the sum of these "expected" volumes. Figure F-14 is an example of the impact volume as a function of depth at a water depth of 100 meters.

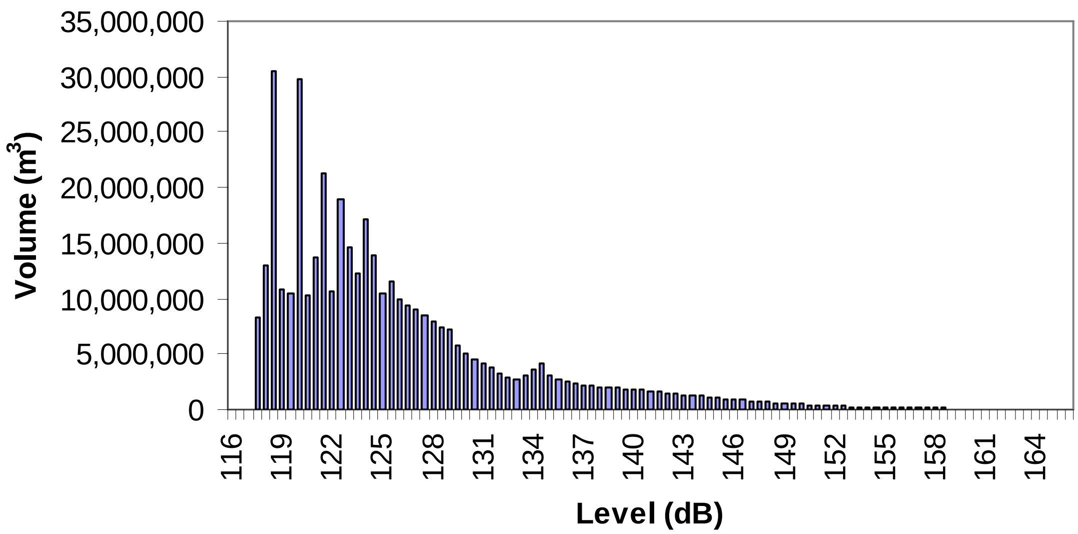


Figure F-13: Example of a Volume Histogram

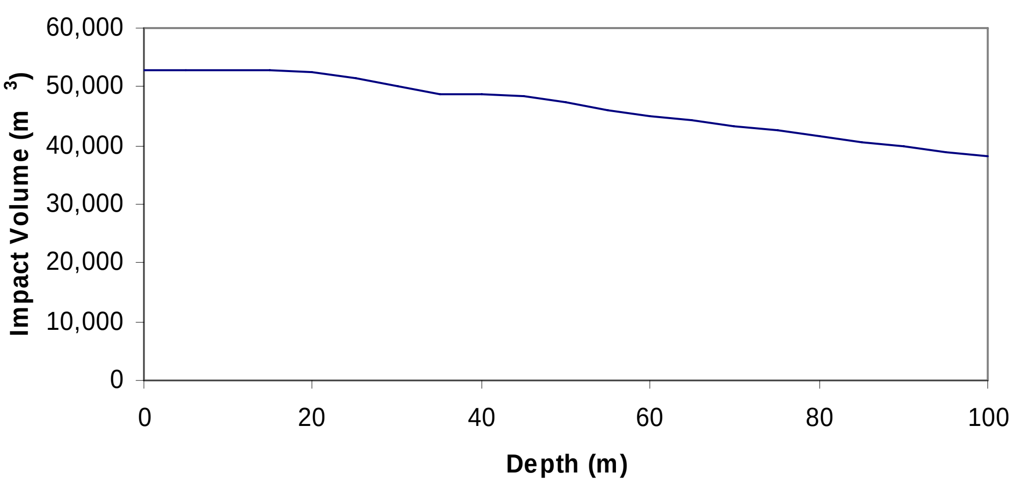


Figure F-14: Example of the Dependence of Impact Volume on Depth

The volumetric grid covers the waters in and around the area of sonar operation. The grid for this analysis has a uniform spacing of 5 meters in the x-coordinate and a slowly expanding spacing in the y-coordinate that starts with 5 meters spacing at the origin. The growth of the grid size along the y-axis is a geometric series. Each successive grid size is obtained from the previous by multiplying it by 1+Ry, where Ry is the y-axis growth factor. The n^{th} grid size is related to the first grid size by multiplying by $(1+Ry)^{(n-1)}$. For an initial grid size of 5 meters and a growth factor of 0.005, the 100^{th} grid increment is 8.19 meters. The constant spacing in the x-coordinate allows greater accuracy as the source moves along the x-axis. The slowly increasing spacing in y reduces computation time, while maintaining accuracy, by taking advantage of the fact that TL changes more slowly at longer distances from the source. The x-and y-coordinates extend from –Rmax to +Rmax, where Rmax is the maximum range used in the TL calculations. The z direction uses a uniform spacing of 5 meters down to 1,000 meters and 10 meters from 1,000 to 2,000 meters. This is the same depth mesh used for the effective energy metric as described above. The depth mesh does not extend below 2,000 meters, on the assumption that animals of interest are not found below this depth.

The next three figures indicate how the accuracy of the calculation of impact volume depends on the parameters used to generate the mesh in the horizontal plane. Figure F-15 shows the relative change of impact volume for one ping as a function of the grid size used for the x-axis. The y-axis grid size is fixed at 5m and the y-axis growth factor is 0, i.e., uniform spacing. The impact volume for a 5 meters grid size is the reference. For grid sizes between 2.5 and 7.5 meters, the change is less than 0.1 percent. A grid size of 5 meters for the x-axis is used in the calculations. Figure F-16 shows the relative change of impact volume for one ping as a function of the grid size used for the y-axis. The x-axis grid size is fixed at 5 meters and the y-axis growth factor is 0. The impact volume for a 5-meter grid size is the reference. This figure is very similar to that for the x-axis grid size. For grid sizes between 2.5 and 7.5 meters, the change is less than 0.1 percent. A grid size of 5 meters is used for the y-axis in our calculations. Figure F-17 shows the relative change of impact volume for one ping as a function of the y-axis growth factor. The x-axis grid size is fixed at 5 meters and the initial y-axis grid size is 5 meters. The impact volume for a growth factor of 0 is the reference. For growth factors from 0 to 0.01, the change is less than 0.1 percent. A growth factor of 0.005 is used in the calculations.

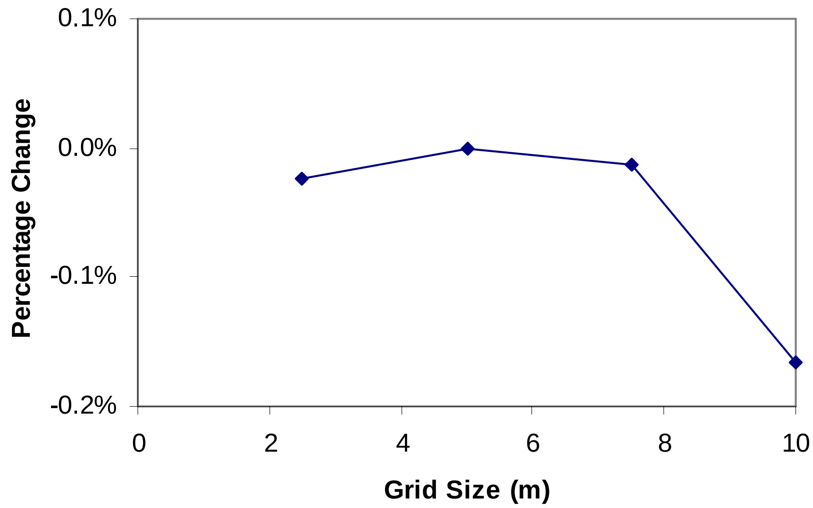


Figure F-15: Change of Impact Volume as a Function of X-Axis Grid Size.

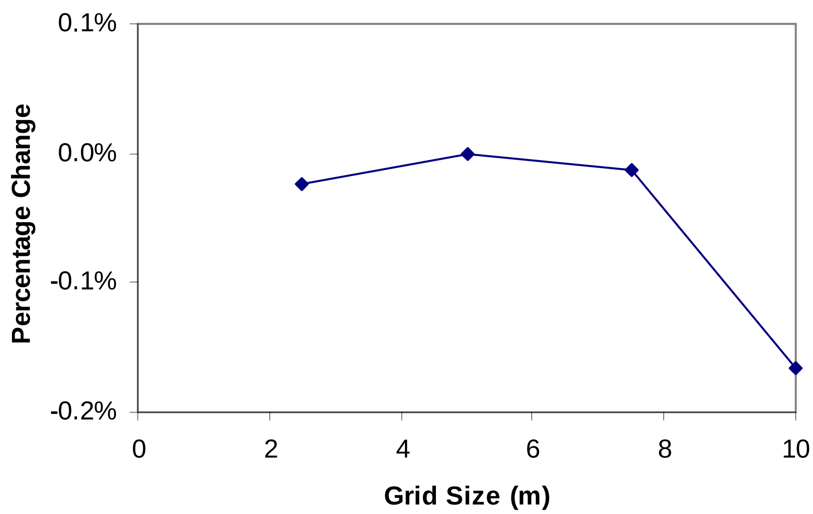


Figure F-16: Change of Impact Volume as a Function of Y-Axis Grid Size

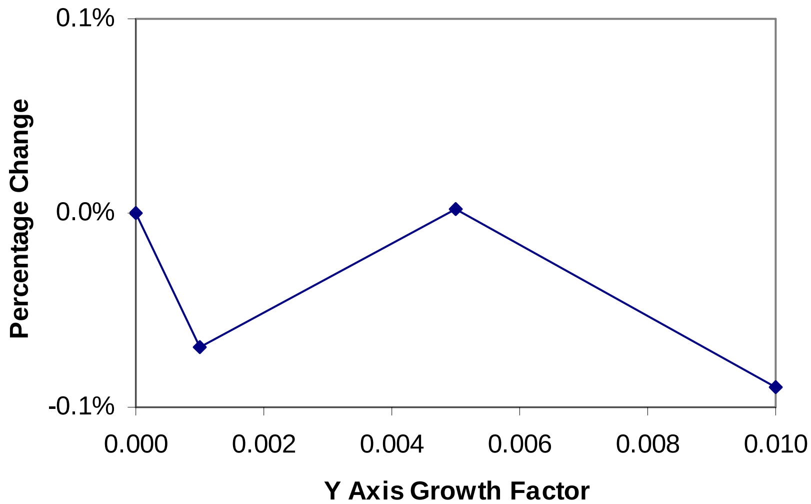


Figure F-17: Change of Impact Volume as a Function of Y-Axis Growth Factor

Another factor influencing the accuracy of the calculation of impact volumes is the size of the bins used for SPL. The SPL bins extend from 100 dB (far lower than required) up to 300 dB (much higher than that expected for any sonar system). Figure F-18 shows the relative change of impact volume for one ping as a function of the bin width. The x-axis grid size is fixed at 5 meters the initial y-axis grid size is 5 meters, and the y-axis growth factor is 0.005. The impact volume for a bin size of 0.5 dB is the reference. For bin widths from 0.25 dB to 1.00 dB, the change is about 0.1 percent. A bin width of 0.5 is used in our calculations.

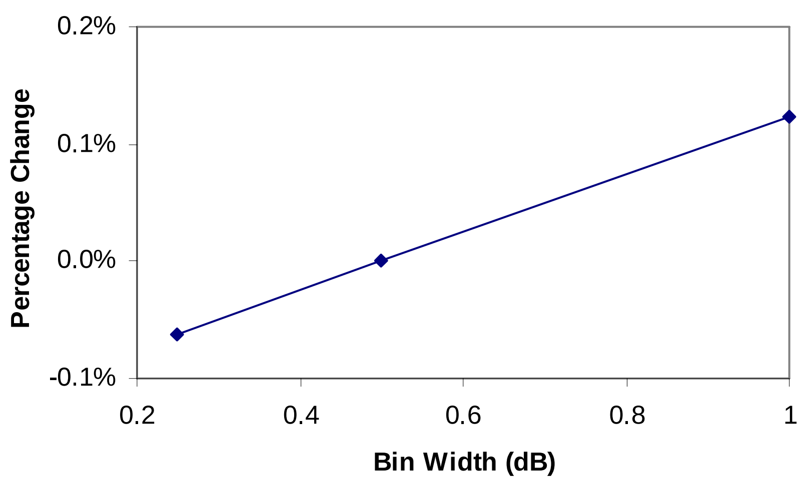


Figure F-18: Change of Impact Volume as a Function of Bin Width

Two other issues for discussion are the maximum range (Rmax) and the spacing in range and depth used for calculating TL. The TL generated for the energy accumulation metric is used for risk function analysis. The same sampling in range and depth is adequate for this metric because it requires a less demanding computation (i.e., maximum value instead of accumulated energy). Using the same value of Rmax needs some discussion since it is not clear that the same value can be used for both metrics. Rmax was set so that the TL at Rmax is more than needed to reach the energy accumulation threshold of 173 dB for 1,000 pings. Since energy is accumulated, the same TL can be used for one ping with the source level increased by 30 dB (10 $\log_{10}$(1,000)). Reducing the source level by 30 dB, to get back to its original value, permits the handling of a sound pressure level threshold down to 143 dB, comparable to the minimum required. Hence, the TL calculated to support energy accumulation for 1,000 pings will also support calculation of impact volumes for the risk function metric.

The process of obtaining the maximum SPL at each grid point in the volumetric grid is straightforward. The active sonar starts at the origin and moves at constant speed along the positive x-axis emitting a burst of energy, a ping, at regularly spaced intervals. For each ping, the distance and horizontal angle connecting the sonar to each grid point is computed. Calculating the TL from the source to a grid point has several steps. The TL is made up of the sum of many eigenrays connecting the source to the grid point. The beam pattern of the source is applied to the eigenrays based on the angle at which they leave the source. After summing the vertically beamformed eigenrays on the range mesh used for the TL calculation, the vertically beamformed TL for the distance from the sonar to the grid point is derived by interpolation. Next, the horizontal beam pattern of the source is applied using the horizontal angle connecting the sonar to the grid point. To avoid problems in extrapolating TL, only grid points with distances less than R_{max} are used. To obtain the SPL at a grid point, the SPL of the source is reduced by that TL. For the first ping, the volumetric grid is populated by the calculated SPL at each grid point. For the second ping and subsequent pings, the source location increments along the x-axis by the spacing between pings and the SPL for each grid point is again calculated for the new source location. Since the risk function metric uses the maximum of the SPLs at each grid point, the newly calculated SPL at each grid point is compared to the SPL stored in the grid. If the new level is larger than the stored level, the value at that grid point is replaced by the new SPL.

For each bin, a volume is determined by summing the ensonified volumes with a maximum SPL in the bin's interval. This forms the volume histogram shown in Figure F-13. Multiplying by the risk function probability function for the level at the center of a bin gives the impact volume for that bin. The result can be seen in Figure F-14, which is an example of the impact volume as a function of depth.

The impact volume for a sonar moving relative to the animal population increases with each additional ping. The rate at which the impact volume increases for the risk function metric is essentially linear with the number of pings. Figure F-19 shows the dependence of impact volume on the number of pings. The function is linear; the slope of the line at a given depth is the impact volume added per ping. This number multiplied by the number of pings in an hour gives the hourly impact volume for the given depth increment. Completing this calculation for all depths in a province, for a given source, gives the hourly impact volume vector which contains the hourly impact volumes by depth for a province. Figure F-20 provides an example of an hourly impact volume vector for a particular environment. Given the speed of the sonar platform, the hourly impact volume vector could be displayed as the impact volume vector per kilometer of track.

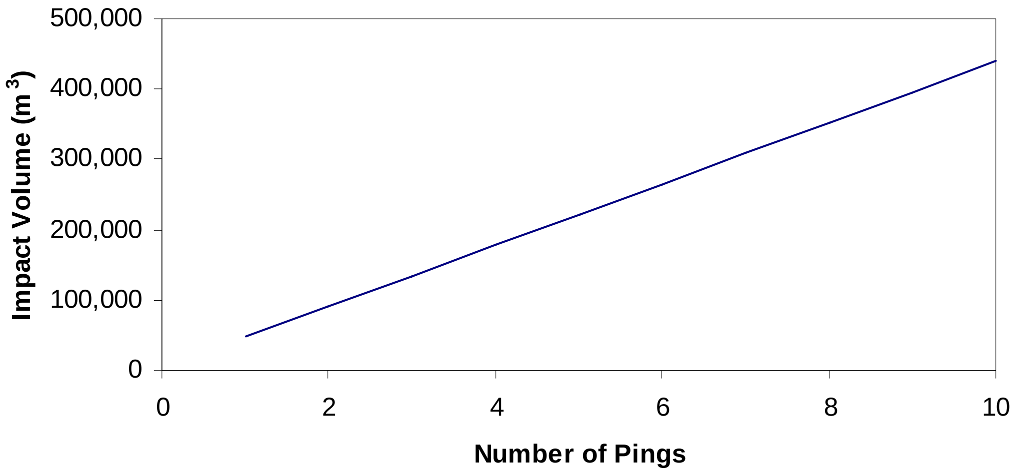


Figure F-19: Dependence of Impact Volume on the Number of Pings

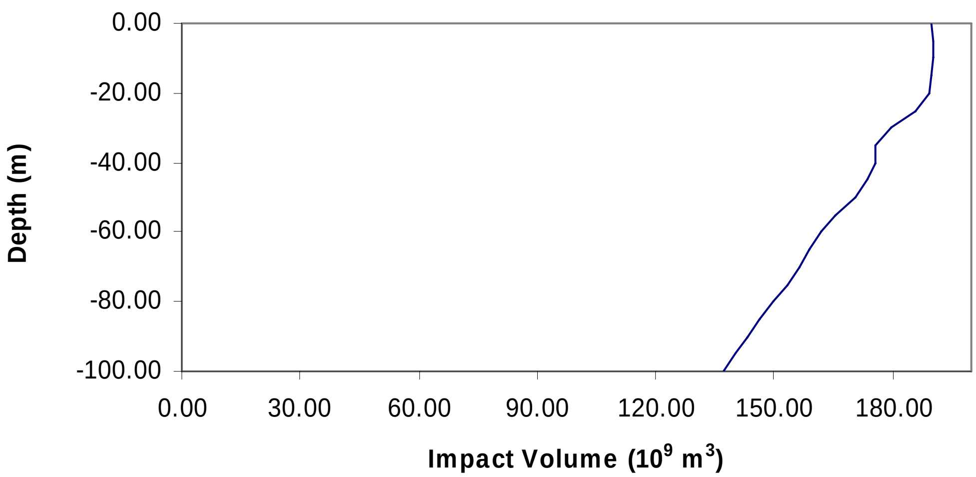


Figure F-20: Example of an Hourly Impact Volume Vector

F.6 Harassments

This section defines the animal densities and their depth distributions for the MIRC. This is followed by a series of tables providing harassment estimates per unit of operation for each source type (active sonars and explosives).

F.6.1 Animal densities

Densities are usually reported by marine biologists as animals per square kilometer, which is an area metric. This gives an estimate of the number of animals below the surface in a certain area, but does not provide any information about their distribution in depth. The impact volume vector (see subsection A.4.3) specifies the volume of water ensonified above the specified threshold in each depth interval. A corresponding animal density for each of those depth intervals is required to compute the expected value of the number of exposures. The two-dimensional area densities do not contain this information, so three-dimensional densities must be constructed by using animal depth distributions to extrapolate the density at each depth. The required depth distributions are presented in the biology subsection.

F.6.2 MMPA Harassment Exposure Estimates

The following sperm whale example demonstrates the methodology used to create a three-dimensional density by merging the area densities with the depth distributions. The sperm whale surface density is 0.0028 whales per square kilometer. From the depth distribution report, "depth distribution for sperm whales based on information in the Amano paper is: 19 percent in 0-2 m, 10 percent in 2-200 m, 11 percent in 201-400 m, 11 percent in 401-600 m, 11 percent in 601-800 m and 38 percent in >800 m." So the sperm whale density at 0-2 m is 0.0028*0.19/0.002 = 0.266 per cubic km, at 2-200 m is 0.0028*0.10/0.198 = 0.001414 per cubic km, and so forth.

In general, the impact volume vector samples depth in finer detail than given by the depth distribution data. When this is the case, the densities are apportioned uniformly over the appropriate intervals. For example, suppose the impact volume vector provides volumes for the intervals 0-2 meters, 2-10 meters, and 10-50 meters. Then for the depth-distributed densities discussed in the preceding paragraph,

- 0.266 whales per cubic km is used for 0-2 meters,
- 0.001414 whales per cubic km is used for the 2-10 meters, and
- 0.001414 whales per square km is used for the 10-50 meters.

Once depth-varying, three-dimensional densities are specified for each species type, with the same depth intervals and the ensonified volume vector, the density calculations are finished. The expected number of ensonified animals within each depth interval is the ensonified volume at that interval multiplied by the volume density at that interval and this can be obtained as the dot product of the ensonified volume and animal density vectors.

Since the ensonified volume vector is the ensonified volume per unit operation (i.e., per hour, per sonobuoy, etc), the final harassment count for each animal is the unit operation harassment count multiplied by the number of units (hours, sonobuoys, etc). The number of unit operations for each source are provided in Table F-1.

F.6.3 Post Acoustic Modeling Analysis

The acoustic modeling results include additional analysis to account for land mass, multiple ships, and number of animals that could be exposed. Specifically, post modeling analysis is designed to consider:

- Acoustic footprints for sonar sources must account for land masses.
- Acoustic footprints for sonar sources should not be added independently, which would result in overlap with other sonar systems used during the same active sonar activity. As a consequence, the area of the total acoustic footprint would be larger than the actual acoustic footprint when multiple ships are operating together.
- Acoustic modeling should account for the maximum number of individuals of a species that could potentially be exposed to sonar within the course of 1 day or a discreet continuous sonar event if less than 24 hours.

When modeling the effect of sound projectors in the water, the ideal task presents modelers with complete *a priori* knowledge of the location of the source(s) and transmission patterns during the times of interest.

In these cases, calculation inputs include the details of source path, proximity of shoreline, high-resolution density estimates, and other details of the scenario. However, in the MIRC, there are sound-producing events for which the source locations, and transmission patterns are unknown, but still require analysis to predict effects. For these cases, a more general modeling approach is required: "We will be operating somewhere in this large area for X minutes. What are the potential effects on average?"

Modeling these general scenarios requires a statistical approach to incorporate the scenario nuances into harassment calculations. For example, one may ask: "If an animal receives 130 decibel (dB) SPL when the source passes at closest point of approach (CPA) on Tuesday morning, how do we know it doesn't receive a higher level on Tuesday afternoon?" This question cannot be answered without knowing the path of the source (and several other facts). Because the path of the source is unknown, the number of an individual's re-exposures cannot be calculated directly. But it can, on average, be accounted for by making appropriate assumptions.

Table F-11 lists unknowns created by uncertainty about the specifics of a future proposed action, the portion of the calculation to which they are relevant, and the assumption that allows the effect to be computed without the detailed information.

The following sections discuss three topics that require action details, and describe how the modeling calculations used the general knowledge and assumptions to overcome the future-action uncertainty with respect to re-exposure of animals, land shadow, and the effect of multiple-ship training events.

Table F-11: Unknowns and Assumptions

Unknowns	Relevance	Assumption
Path of ship (esp. with respect to animals)	Ambiguity of multiple exposures, Local population: upper bound of harassments	Most conservative case: ships are everywhere within Sonar Operating Area
Source(s) locations	Ambiguity of multiple exposures, land shadow	Equal distribution of action in each modeling area
Direction of sonar transmission	Land shadow	Equal probability of pointing any direction
Number of ships	Effect of multiple ships	Average number of ships per training event
Distance between ships	Effect of multiple ships	Average distance between ships

F.6.3.1 Multiple Exposures in General Modeling Scenario

Consider the following hypothetical scenario. A box is painted on the surface of a well-studied ocean environment with well-known sound propagation characteristics. A sonar source and 100 whales are inserted into that box and a curtain is drawn. What will happen? The details of what will happen behind the curtain are unknown, but the existing knowledge, and general assumptions, can allow for a calculation of average effects.

For the first period of time, the source is traveling in a straight line and pinging at a given rate. In this time, it is known how many animals, on average, receive their max SPLs from each ping. As long as the source travels in a straight line, this calculation is valid. However, after an undetermined amount of time, the source will change course to a new and unknown heading.

If the source changes direction 180 degrees and travels back through the same swath of water, all the animals the source passes at closest point of approach (CPA) before the next course change have already been exposed to what will be their maximum SPL, so the population is not "fresh." If the direction does not change, only new animals will receive what will be their maximum SPL from that source (though most have received sound from it), so the population is completely "fresh." Most source headings lead to a population of a mixed "freshness," varying by course direction. Since the route and position of the source over time are unknown, the freshness of the population at CPA with the source is unknown. This ambiguity continues through the remainder of the exercise.

What is known? The source and, in general, the animals remain in the vicinity of the OPAREA. Thus, if the farthest range to a possible effect from the source is X kilometers (km), no animals farther than X km outside of the OPAREA can be harassed. The intersection of this area with a given animal's habitat multiplied by the density of that animal in its habitat represents the maximum number of animals that can be harassed by activity in that OPAREA, which shall be defined as "the local population." Two details: first, this maximum should be adjusted down if a risk function is being used, because not 100% of animals within X km of the OPAREA border will be harassed. Second, it should be adjusted up to account for animal motion in and out of the area.

The ambiguity of population freshness throughout the training event means that multiple exposures cannot be calculated for any individual animal. It must be dealt with generally at the population level.

Solution to the Ambiguity of Multiple Exposures in the General Modeling Scenario

At any given time, each member of the population has received a maximum SPL (possibly zero) that indicates the probability of harassment during the training event. This probability indicates the contribution of that individual to the expected value of the number of harassments. For example, if an animal receives a level that indicates 50 percent probability of harassment, it contributes 0.5 to the sum of the expected number of harassments. If it is passed later with a higher level that indicates a 70 percent chance of harassment, its contribution increases to 0.7. If two animals receive a level that indicates 50 percent probability of harassment, they together contribute 1 to the sum of the expected number of harassments. That is, we statistically expect exactly one of them to be harassed. Let the expected value of harassments at a given time be defined as "the harassed population" and the difference between the local population (as defined above) and the harassed population be defined as "the unharassed population." As the training event progresses, the harassed population will never decrease and the unharassed population will never increase.

The unharassed population represents the number of animals statistically "available" for harassment. Since we do not know where the source is, or where these animals are, we assume an average (uniform) distribution of the unharassed population over the area of interest. The densities of unharassed animals are lower than the total population density because some animals in the local population are in the harassed population.

Density relates linearly to expected harassments. If action A, in an area with a density of 2 animals per square kilometer (km^2) produces 100 expected harassments, then action A in an area with 1 animal per km^2 produces 50 expected harassments. The modeling produces the number of expected harassments per ping starting with 100 percent of the population unharassed. The next ping will produce slightly fewer harassments because the pool of unharassed animals is slightly less.

For example, consider the case where 1 animal is harassed per ping when the local population is 100, 100 percent of which are initially unharassed. After the first ping, 99 animals are unharassed, so the number of animals harassed during the second ping are

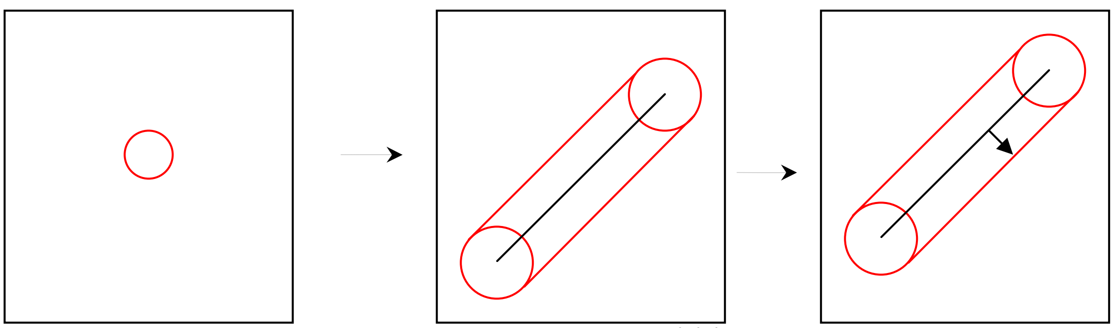
$$10\left(\frac{99}{100}\right) = 1(.99) = 0.99 \text{ animals}$$

and so on for the subsequent pings.

Mathematics

A closed form function for this process can be derived as follows.

Define H = number of animals harassed per ping with 100 percent unharassed population. H is calculated by determining the expected harassment for a source moving in a straight line for the duration of the exercise and dividing by the number of pings in the exercise (Figure F-21).



$$\text{H} = \int\int\int \rho(z) D(L(x,y,z)) dxdydz \,/\text{N\_pings}$$

Figure F-21: Process of Calculating H

The total unharassed population is then calculated by iteration. Each ping affects the unharassed population left after all previous pings:

Define P_n = unharassed population after ping n

P_0 = local population

$$P_1 = P_0 - H$$

$$P_2 = P_1 - H\left(\frac{P_1}{P_0}\right)$$

$$\ldots$$

$$P_n = P_{n-1} - H\left(\frac{P_{n-1}}{P_0}\right)$$

Therefore,

$$P_n = P_{n-1}\left(1-\left(\frac{H}{P_0}\right)\right) = P_{n-2}\left(1-\left(\frac{H}{P_0}\right)\right)^2 = \ldots = P_0\left(1-\left(\frac{H}{P_0}\right)\right)^n$$

Thus, the total number of harassments depends on the per-ping harassment rate in an unharassed population, the local population size, and the number of operation hours.

Local Population: Upper Bound on Harassments

As discussed above, Navy planners have confined periods of sonar use to training areas. The size of the harassed population of animals for an action depends on animal re-exposure, so uncertainty about the precise source path creates variability in the "harassable" population. Confinement of sonar use to a sonar training area allows modelers to compute an upper bound, or worst case, for the number of harassments with respect to location uncertainty. This is done by assuming that every animal which enters the training area at any time in the exercise (and also many outside) is “harassable” and creates an upper bound on the number of harassments for the exercise. Since this is equivalent to assuming that there are sonars transmitting simultaneously from each point in the confined area throughout the action length, this greatly overestimates the take from an exercise.

NMFS has defined a 24-hour "refresh rate," or amount of time in which an individual can be harassed no more than once. The Navy has determined that, in a 24-hour period, all sonar activities in the MIRC transmit for a subset of that time (Table F-12).

Table F-12: Duration of 53C Use During 24-hour Period

Exercise	Longest continuous interval of 53C use in 24-hour period
Multi-Strike Group	12 hours
TRACKEX-TORPEX	8 hours

The most conservative assumption for a single ping is that it harasses the entire population within the range (a gross over-estimate). However, the total harassable population for multiple pings will be even greater, since animal motion over the period in the Table F-12 can bring animals into range that otherwise would be out of the harassable population.

Animal Motion Expansion

Though animals often change course to swim in different directions, straight-line animal motion would bring the more animals into the harassment area than a "random walk" motion model. Since precise and accurate animal motion models exist more as speculation than documented fact and because the modeling requires an undisputable upper bound, calculation of the upper bound for MIRC modeling areas uses a straight-line animal motion assumption. This is a conservative assumption.

For a circular area, the straight-line motion in any direction produces the same increase in harassable population. However, since the ranges are non-circular polygons, choosing the initial fixed direction as perpendicular to the longest diagonal produces greater results than any other direction. Thus, the product of the longest diagonal and the distance the animals move in the period of interest gives an overestimate of the expansion in range modeling areas due to animal motion. The MIRC expansions use this estimate as an absolute upper bound on animal-motion expansion.

Figure F-22 illustrates an example that illustrates the overestimation, which occurs during the second arrow:

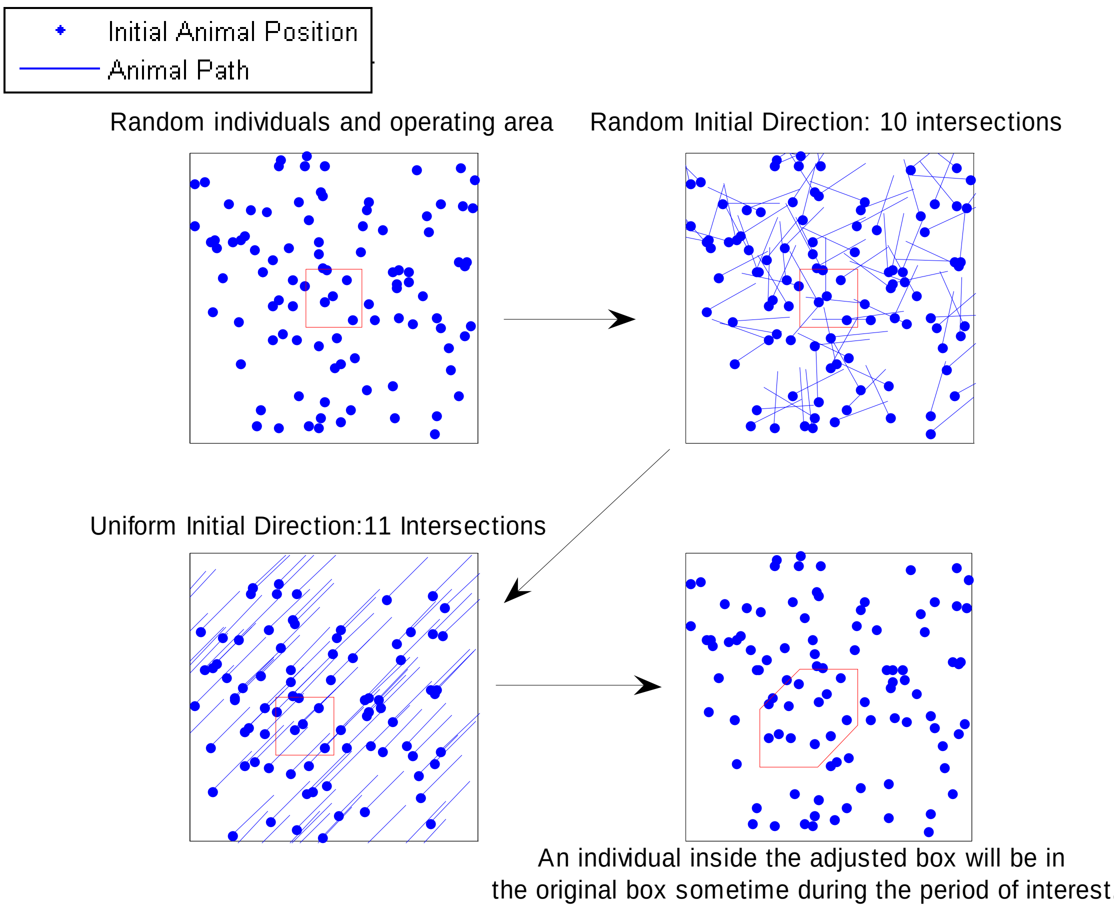


Figure F-22: Process of Setting an Upper Bound on Individuals Present in Area

It is important to recognize that the area used to calculate the harassable population, shown in Figure F-22 will, in general, be much larger than the area that will be within the ZOI of a ship for the duration of its broadcasts. For a source moving faster than the speed of the marine animals, a better (and much smaller) estimate of the harassable population would be that within the straight line ZOI cylinder shown in Figure F-22. Using this smaller population would lead to a greater dilution of the unharassed population per ping and would greatly reduce the estimated harassment.

Risk Function Expansion

The expanded area contains the number of animals that will enter the range over the period of interest. However, an upper bound on harassments must also include animals outside the area that would be affected by a source transmitting from the area's edge. A gross overestimation could simply assume pinging at every point on the range border throughout the exercise and would include all area with levels from a source on the closest border point greater than the risk function basement. In the case of MIRC, this would include all area within approximately 150 km from the edge of the adjusted box. This basic method would give a crude and exaggerated upper bound, since only a tiny fraction of this out-of-range area can be ensonified above threshold for a given ping. A more refined upper bound on harassments can be found by maintaining the assumption that a sonar is transmitting from each point in the adjusted box and calculating the expected ensonified area, which would give all animals inside the area a 100 percent probability of harassment, and those outside the area a varying probability, based on the risk function.

$$\int_{0}^{L^{-1}(120\,dB)} D(L(r))dr \quad ,$$

Where L is the SPL function with domain in range and range in level,
r is the range from the sonar operating area,
L^{-1}(120 dB) is the range at which the received level drops to 120 dB, and
D is the risk function (probability of harassment vs. level).

At the corners of the polygon, additional area can be expressed as

$$\frac{\left[\pi-\theta\right] \int_{0}^{L^{-1}(120\,dB)} D(L(r))rdr}{2\pi}$$

with D, L, and r as above, and
θ the inner angle of the polygon corner, in radians.

For the risk function and transmission loss of the MIRC, this method adds an area equivalent by expanding the boundaries of the adjusted box by four kilometers. The resulting shape, the adjusted box with a boundary expansion of 4 km, does not possess special meaning for the problem. But the number of individuals contained by that shape, is the harassable population and an absolute upper bound on possible harassments for that operation.

Figure F-23 illustrates the growth of area for the sample case above. The shapes of the boxes are unimportant. The area after the final expansion, though, gives an upper bound on the "harassable," or initially unharassed population which could be affected by training activities.

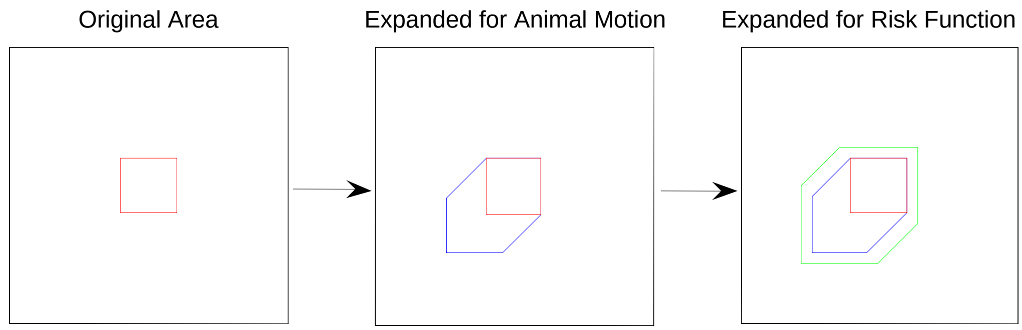


Figure F-23: Process of Expanding Area to Create Upper Bound of Harassments

For the most powerful source, the 53C, the expected winter rate of harassment for pantropical spotted dolphins is approximately 0.133743 harassments per ping. The exercise will transmit sonar pings for 12 hours in a 24 hour period, as given in the action table above, with 120 pings per hour, a total of 120*12=1,440 pings in a 24 hour period.

The MIRC has an area of approximately 1,872,094 square kilometers and a diagonal of 1,940 km. Adjusting this with straight-line (upper bound) animal motion of 5.5 kilometers per hour for 12 hours, animal motion adds 1,940*5.5*12= 128,040 square kilometers to the area. Using the risk function to calculate the expected range outside the MIRC adds another 20,728 square kilometers, bringing the total upper-bound of the affected area to 2,020,862 square km.

For this analysis, pantropical spotted dolphins have an average density of 0.0226 animals per square kilometer, so the upper bound number of pantropical spotted dolphins that can be affected by 53C activity in the MIRC during a 24 hour period is 2,020,862 *0.0226=45,671 dolphins.

In the first ping, 0.133743 pantropical spotted dolphins will be harassed. With the second ping, $0.133743\left(\frac{45671-0.133743}{45671}\right)=0.13374261$ pantropical spotted dolphins will be harassed. Using the formula derived above, after 12 hours of continuous operation, the remaining **unharassed** population is

$$P_{1440}=P_0\left(1-\left(\frac{h}{P_0}\right)\right)^{1440}=45671\left(1-\left(\frac{0.133743}{45671}\right)\right)^{1440}\approx 45478.82$$

So the **harassed** population will be 45671-45478.82 = 192.18 animals.

Contrast this with linear accumulation of harassments without consideration of the local population and the dilution of the unharassed population:

Harassments = 0.133743 *1,440=192.6 animals

The difference in harassments is very small, as a percentage of total harassments, because the size of the MIRC implies a large “harassable” population relative to the harassment per ping of the 53C. In cases where the harassable population is not as large, with respect to the per ping harassments, the difference in harassments between linear accumulation and density dilution is more pronounced. Note that these numbers were calculated without consideration of land-shadow and multiple-ship effects.

F.6.3.2 Land Shadow

The risk function considers the possibility of harassment possible if an animal receives 120 dB SPL, or above. In the open ocean of the MIRC, this can occur as far away as 150 km, so over a large "effect" area, sonar sound could, but does not necessarily, harass an animal. The harassment calculations for a general modeling case must assume that this effect area covers only water fully populated with animals, but in some portions of the MIRC, land partially encroaches on the area, obstructing sound propagation.

As discussed in the introduction of "Additional Modeling Considerations" Navy planners do not know the exact location and transmission direction of the sonars at future times. These factors however, completely determine the interference of the land with the sound, or "land shadow," so a general modeling approach does not have enough information to compute the land shadow effects directly. However, modelers can predict the reduction in harassments at any point due to land shadow for different pointing directions and use expected probability distribution of activity to calculate the average land shadow for operations in each range.

For the ranges, in each alternative, the land shadow is computed over a dense grid in each operations area. Figure F-24 shows the grid for the MIRC.

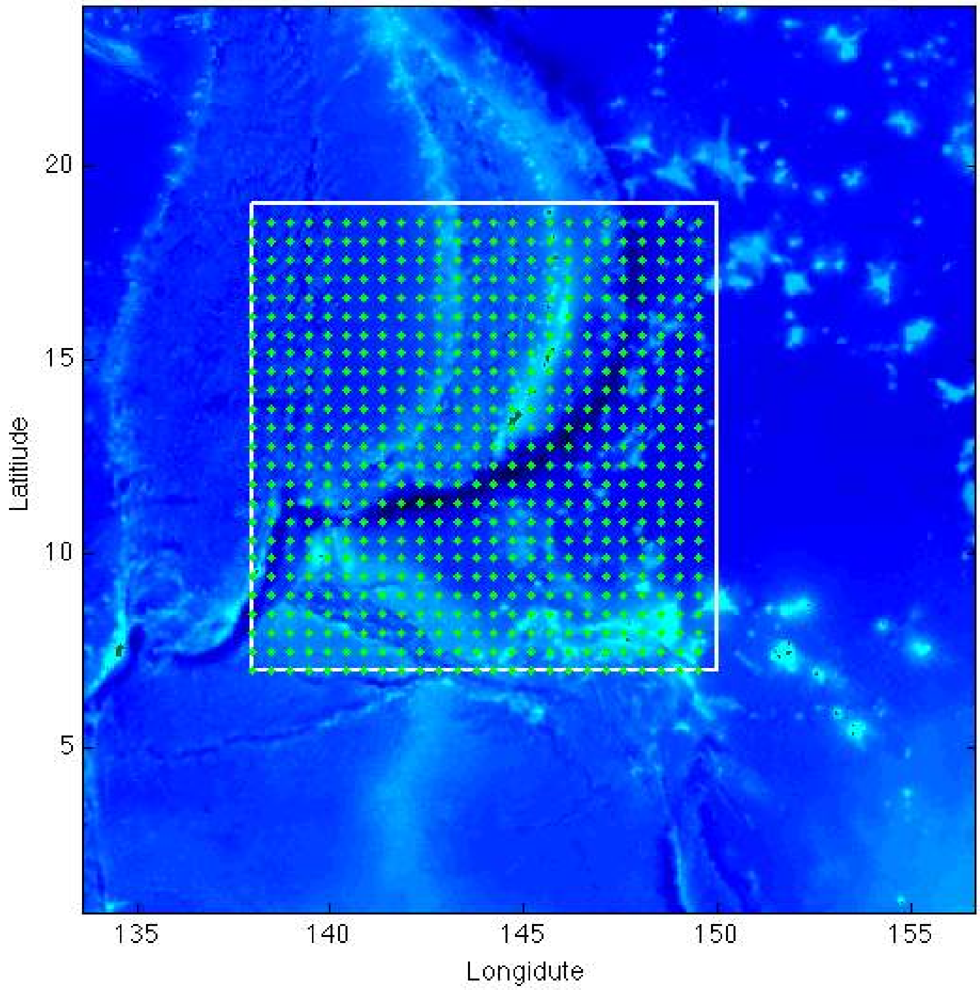


Figure F-24: Illustrative Grid for MIRC Study Area. Each green point represents approximately 100 points on the actual grid used for land shadow calculation, which samples every km.

For each of the coastal points that are within 150 km of the grid, the azimuth and distance is computed. In the computation, only the minimum range at each azimuth is computed. Figure F-25 shows the minimum range compared with azimuth for the sample point.

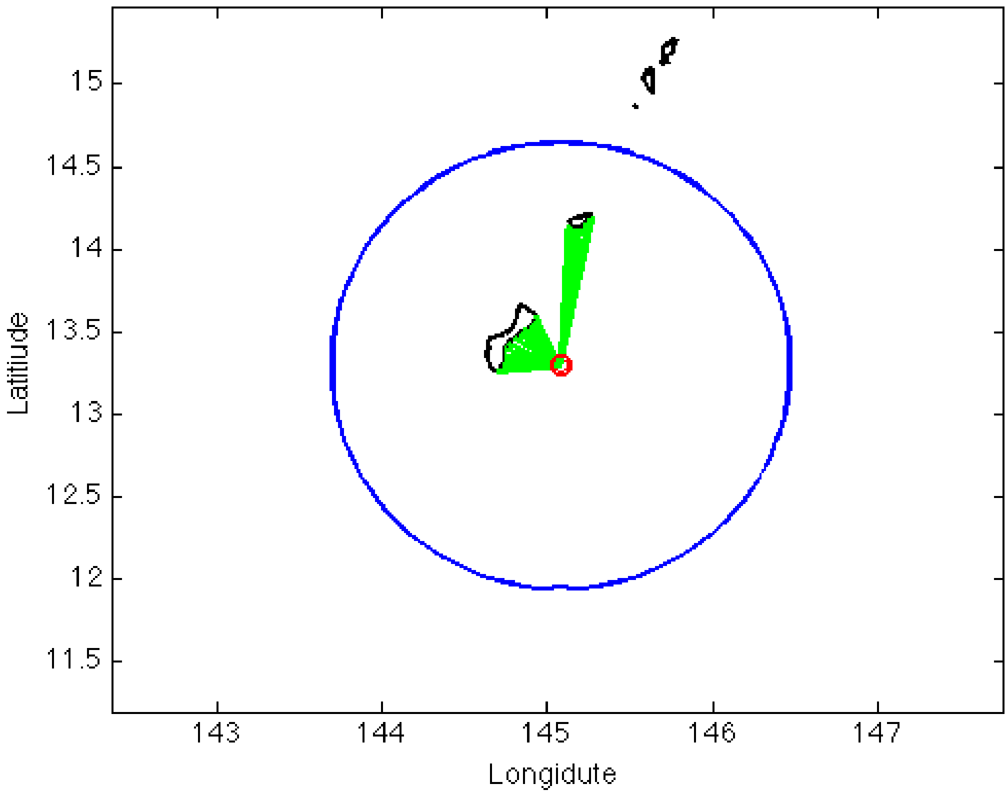


Figure F-25: The nearest point at each azimuth (with 1^{o} spacing) to a sample grid point (red circle) is shown by the green lines.

Now, the average of the distances to shore, along with the angular profile of land is computed (by summing the unique azimuths that intersect the coast) for each grid point. The values are then used to compute the land shadow for the grid points.

Computing the Land Shadow Effect at Each Grid Point

The effect of land shadow is computed by determining the levels, and thus the distances from the sources, that the harassments occur. Table F-13 gives a mathematical extrapolation of the distances and levels at which harassments occur, with average propagation in the MIRC. Figure F-26 provides the percentage of behavioral harassments for every 5-degree band of received level from the 53C/D sonar.

Table F-13: Behavioral Harassments at each Received Level Band from 53C

Received Level (dB SPL)	Distance at which Levels Occur in MIRC	Percent of Behavioral Harassments Occurring at Given Levels
Below 150	15 km - 150 km	< 2%
150>Level>160	6 km – 15 km	18%
160>Level>170	2 km – 6 km	41%
170>Level>180	0.5 km – 2 km	27%
180>Level>190	170 m – 500 m	10%
Above 190 dB	0 m – 170 m	<3%

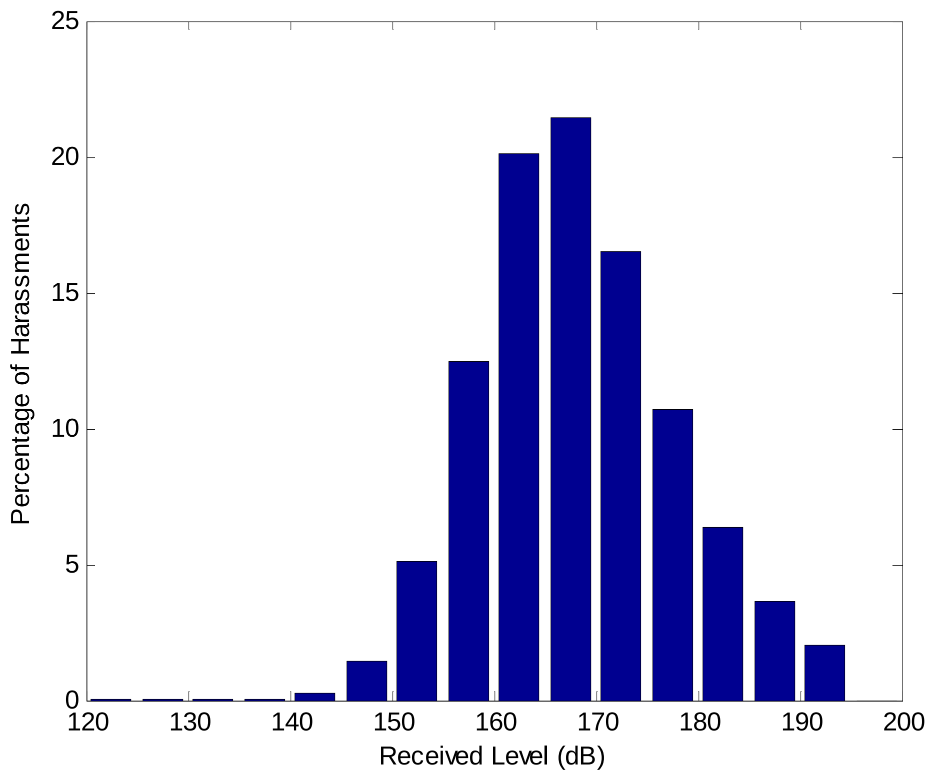


Figure F-26: The approximate percentage of behavioral harassments for every 5 degree band of received level from the 53C

With the data used to produce the previous figure, the average effect reduction across season for a sound path blocked by land can be calculated. For the 53C, since approximately 94 percent of harassments occur within 10 kilometers of the source, a sound path blocked by land at 10 kilometers will, on average, cause approximately 94 percent the effect of an unblocked path, as shown in Figure F-27.

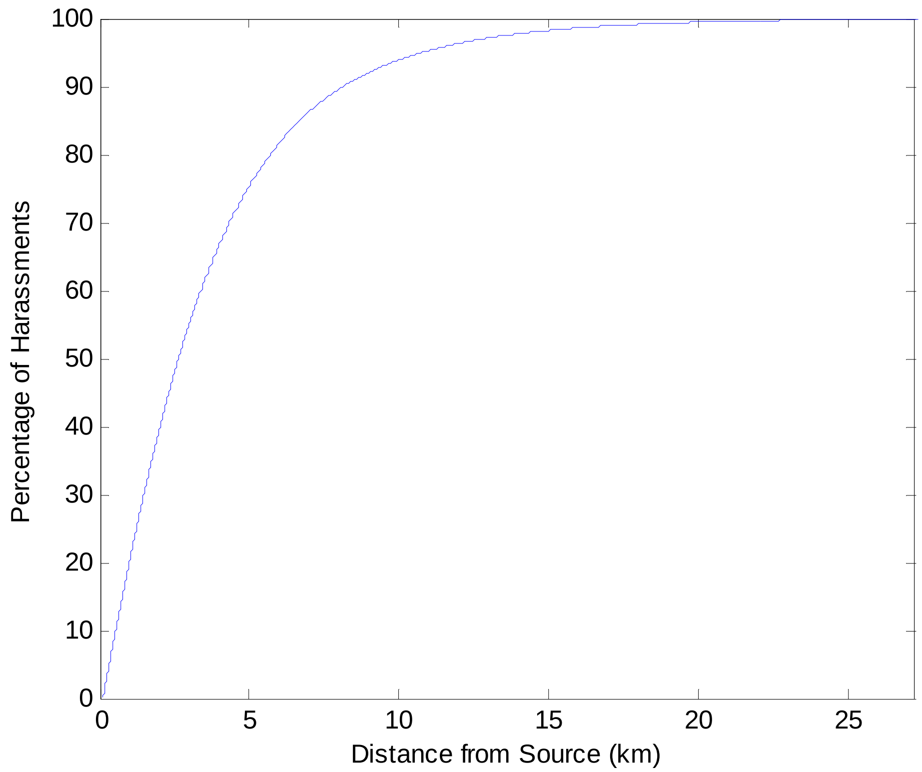


Figure F-27: Average Percentage of Harassments Occurring Within a Given Distance

As described above, the mapping process determines the angular profile of and distance to the coastline(s) from each grid point. The distance, then, determines the reduction due to land shadow when the sonar is pointed in that direction. The angular profile, then, determines the probability that the sonar is pointed at the coast.

Define θ_n = angular profile of coastline at point n in radians

Define r_n = mean distance to shoreline

Define A(r) = average effect adjustment factor for sound blocked at distance r

The land shadow at point n can be approximated by $A(r_n)\theta_n/(2\pi)$. For illustration, the following plots give the land shadow reduction factor at each point in each range area for the 53C. The white portions of the plot indicate the areas outside the range and the blue lines indicate the coastline. The color plots inside the ranges give the land shadow factor at each point. The average land shadow factor for the 53C in the MIRC is 0.9997, or the reduction in effect is 0.03 percent. For the other, lower-power sources, this reduction is lower. The effect of land shadow in the MIRC is also negligible.

F.6.3.3 The Effect of Multiple Ships

Behavioral harassment, under risk function, uses maximum SPL over a 24-hour period as the metric for determining the probability of harassment. An animal that receives sound from two sonars, operating simultaneously, receives its maximum SPL from one of the ships. Thus, the effects of the louder, or closer, sonar determine the probability of harassment, and the more distant sonar does not. If the distant sonar operated by itself, it would create a lesser effect on the animal, but in the presence of a more dominating sound, its effects are cancelled. When two sources are sufficiently close together, their sound fields within the cutoff range will partially overlap and the larger of the two sound fields at each point in that overlap cancel the weaker. If the distance between sources is twice as large as the range to cutoff, there will be no overlap.

Computation of the overlap between sound fields requires the precise locations and number of the source ships. The general modeling scenarios of the MIRC do not have these parameters, so the effect was modeled using an average ship distance, 20 km, and an average number of ships per exercise. The number of ships per exercise varied based on the type of exercise, as given in Table F-14.

Table F-14: Average Number of 53C-Transmitting Ships in the MIRC Exercise Types

Action	Average Number of SQS-53C-Transmitting Ships
Multi-Strike Group	4
TRACKEX-TORPEX	1.5

The formation of ships in any of the above exercise has been determined by Navy planners. The ships are located in a straight line, perpendicular to the direction traveled. Figures F-28 and F-29 show examples with four ships, and their ship tracks.

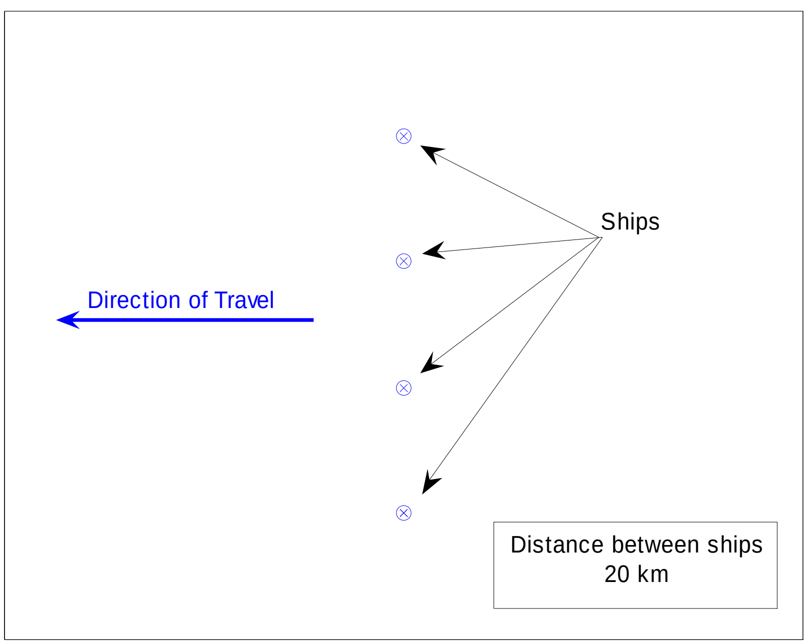


Figure F-28: Formation and Bearing of Ships in Four-Ship Example

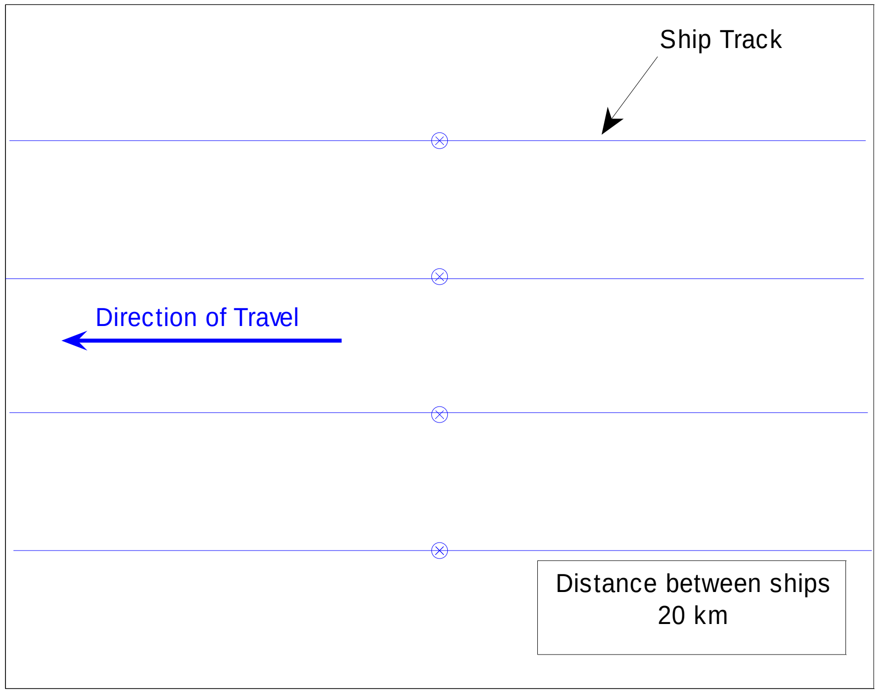


Figure F-29: Ship Tracks of Ships in 4-Ship Example

The sound field created by these ships, which transmit sonar continually as they travel will be uniform in the direction of travel (or the "x" direction), and vary by distance from the ship track in the direction perpendicular to the direction of travel (or the "y" direction) (Figure F-30).

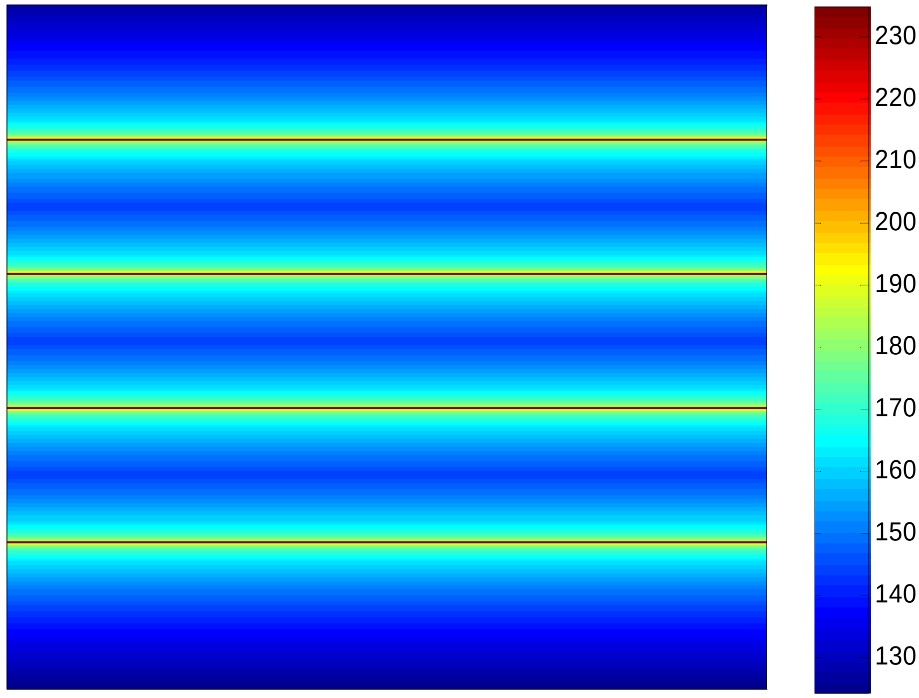


Figure F-30: Sound Field Produced by Multiple Ships

This sound field of the four ships operating together ensonifies less area than four ships operating individually. At the time of modeling, even the average number of ships and mean distances between them were unknown, so a post-calculation correction should be applied.

Referring to the above picture of the sound field around the ship tracks, the portion above the upper-most ship track, and the portion below the lower-most ship track sum to produce exactly the sound field as an individual ship.

Therefore, the remaining portion of the sound field, between the uppermost ship track and the lowermost ship track, is the contribution of the three additional ships (Figure F-31).

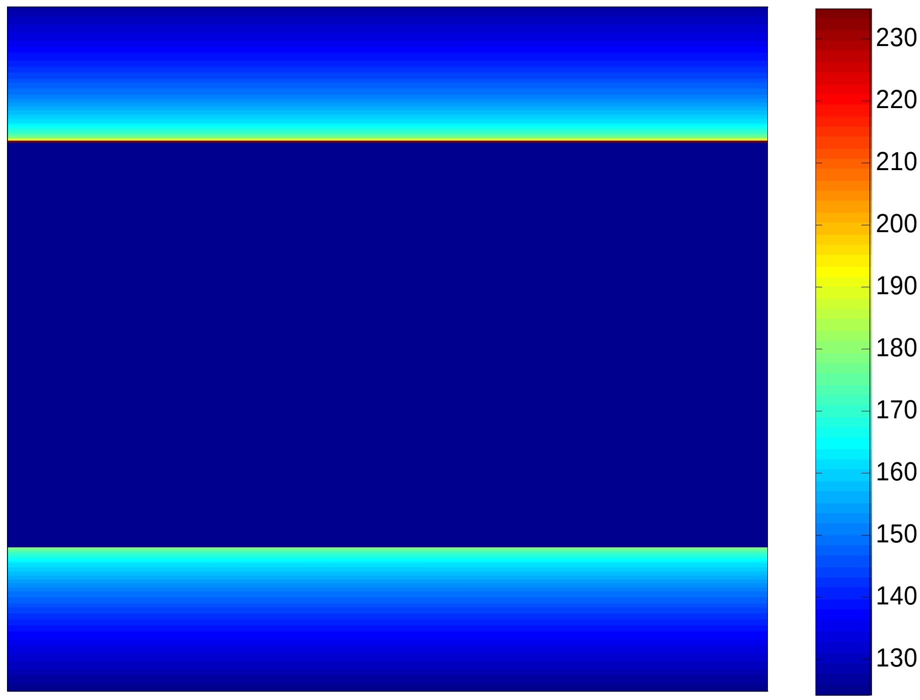


Figure F-31: Upper and Lower Portion of Sound Field

This remaining sound field is made up of three bands (Figure F-32). Each of the three additional ships contributes one band to the sound field. Each band is somewhat less than the contribution of the individual ship because its sound is overcome by the nearer source at the center of the band. Since each ship maintains 20 kilometer distance between it and the next, the height of these bands is 20 km, and the sound from each side projects 10 kilometers before it is overcome by the source on the other side of the band. Thus, the contribution to a sound field for an additional ship is identical to that produced by an individual ship whose sound path is obstructed at 10 kilometers. The work in the previous discussion on land shadow provides a calculation of effect reduction for obstructed sound at each range. An AQS-53C-transmitting ship with obstructed signal at 10 kilometers causes 94 percent of the number of harassments as a ship with an unobstructed signal. Therefore, each additional ship causes 0.94 times the harassments of the individual ship. Applying this factor to the exercise types, an adjustment from the results for a single ship can be applied to predict the effects of multiple ships (Table F-15).

Table F-15: Adjustment Factors for Multiple Ships in MIRC Exercise Types

Action	Average Number of SQS-53C-Transmitting Ships	Adjustment Factor from Individual Ship for Formation and Distance
Multi-Strike Group	4	3.82
TRACKEX-TORPEX	2	1.94

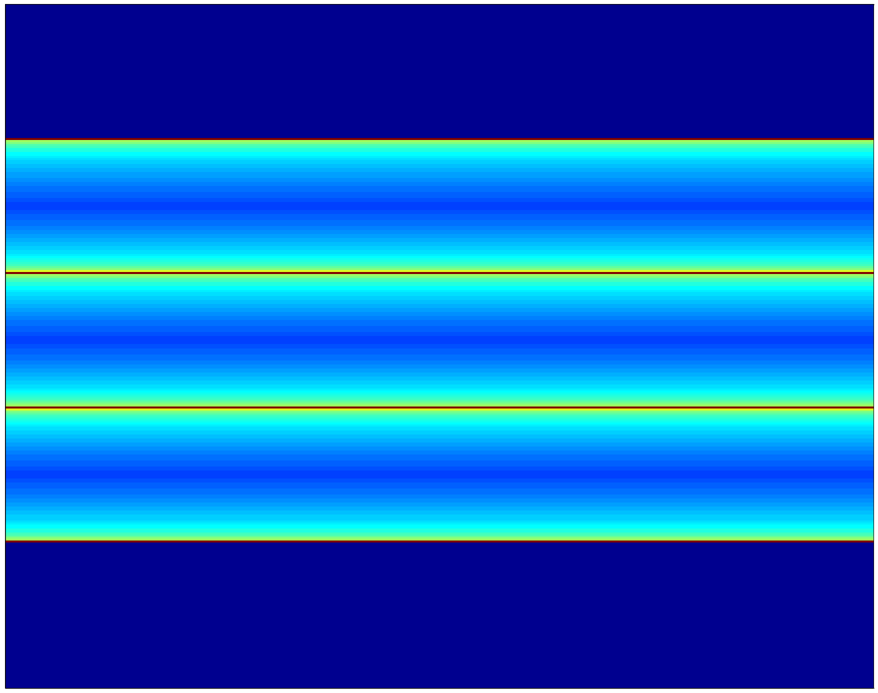


Figure F-32: Central Portion of Sound Field

F.7 References

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APPENDIX G

MARINE MAMMAL DENSITY

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APPENDIX H

CETACEAN STRANDING REPORT

Description of marine mammal strandings and causes

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TABLE OF CONTENTS

CETACEAN STRANDING REPORT

H.1 WHAT IS A STRANDED MARINE MAMMAL?

When a live or dead marine mammal swims or floats onto shore and becomes “beached” or incapable of returning to sea, the event is termed a “stranding” (Geraci *et al.* 1999; Perrin and Geraci 2002; Geraci and Lounsbury 2005; NMFS 2007). The legal definition for a stranding within the United States is that “ (A) a marine mammal is dead and is (i) on a beach or shore of the United States; or (ii) in waters under the jurisdiction of the United States (including any navigable waters); or (B) a marine mammal is alive and is (i) on a beach or shore of the United States and is unable to return to the water; (ii) on a beach or shore of the United States and, although able to return to the water, is in need of apparent medical attention; or (iii) in the waters under the jurisdiction of the United States (including any navigable waters), but is unable to return to its natural habitat under its own power or without assistance.” (16 United States Code [U.S.C.] 1421h).

The majority of animals that strand are dead or moribund (NMFS 2007). For those that are alive, human intervention through medical aid and/or guidance seaward may be required for the animal to return to the sea. If unable to return to sea, rehabilitation at an appropriate facility may be determined as the best opportunity for animal survival.

Three general categories can be used to describe strandings: single, mass, and unusual mortality events. The most frequent type of stranding is a single stranding, which involves only one animal (or a mother/calf pair) (NMFS 2007).

Mass stranding involves two or more marine mammals of the same species other than a mother/calf pair (Wilkinson 1991), and may span one or more days and range over several miles (Simmonds and Lopez-Jurado 1991; Frantzis 1998; Walsh *et al.* 2001; Freitas 2004). In North America, only a few species typically strand in large groups of 15 or more and include sperm whales, pilot whales, false killer whales, Atlantic white-sided dolphins, white-beaked dolphins, and rough-toothed dolphins (Odell 1987, Walsh *et al.* 2001). Some species, such as pilot whales, false-killer whales, and melon-headed whales occasionally strand in groups of 50 to 150 or more (Geraci *et al.* 1999). All of these normally pelagic off-shore species are highly sociable and usually infrequently encountered in coastal waters. Species that commonly strand in smaller numbers include pygmy killer whales, common dolphins, bottlenose dolphins, Pacific white-sided dolphin Frasier’s dolphins, gray whale and humpback whale (West Coast only), harbor porpoise, Cuvier’s beaked whales, California sea lions, and harbor seals (Mazzuca *et al.* 1999; Norman *et al.* 2004; Geraci and Lounsbury 2005).

Unusual mortality events (UMEs) can be a series of single strandings or mass strandings, or unexpected mortalities (i.e., die-offs) that occur under unusual circumstances (Dierauf and Gulland 2001; Harwood 2002; Gulland 2006; NMFS 2007). These events may be interrelated: for instance, at-sea die-offs lead to increased stranding frequency over a short period of time, generally within one to two months. As published by the NMFS, revised criteria for defining a UME include (Hohn *et al.* 2006b):

(1) A marked increase in the magnitude or a marked change in the nature of morbidity, mortality, or strandings when compared with prior records.

(2) A temporal change in morbidity, mortality, or strandings is occurring.

(3) A spatial change in morbidity, mortality, or strandings is occurring.

(4) The species, age, or sex composition of the affected animals is different than that of animals that are normally affected.

(5) Affected animals exhibit similar or unusual pathologic findings, behavior patterns, clinical signs, or general physical condition (e.g., blubber thickness).

(6) Potentially significant morbidity, mortality, or stranding is observed in species, stocks or populations that are particularly vulnerable (e.g., listed as depleted, threatened or endangered or declining). For example, stranding of three or four right whales may be cause for great concern whereas stranding of a similar number of fin whales may not.

(7) Morbidity is observed concurrent with or as part of an unexplained continual decline of a marine mammal population, stock, or species.

Unusual environmental conditions are probably responsible for most UMEs and marine mammal die-offs (Vidal and Gallo-Reynoso 1996; Geraci *et al.* 1999; Walsh *et al.* 2001; Gulland and Hall 2005). Table H-1 provides an overview of documented UMEs attributable to natural causes over the past four decades worldwide.

Table H-1. Marine mammal unusual mortality events attributed to or suspected from natural causes 1978-2005.

Year	Species and number	Location	Cause
1978	Hawaiian monk seals (50)	NW Hawaiian Islands	Ciguatoxin and maitotoxin
1979-80	Harbor seals (400)	Massachusetts	Influenza A
1982	Harbor seals	Massachusetts	Influenza A
1983	Multiple pinniped species	West coast of US, Galapagos	El Nino
1984	California sea lions (226)	California	Leptospirosis
1987	Sea otters (34)	Alaska	Saxitoxin
1987	Humpback whales (14)	Massachusetts	Saxitoxin
1987-88	Bottlenose dolphins (645)	Eastern seaboard (New Jersey to Florida)	Morbillivirus; Brevetoxin
1987-88	Baikal seals (80-100,000)	Lake Baikal, Russia	Canine distemper virus
1988	Harbor seals (approx 18,000)	Northern Europe	Phocine distemper virus
1990	Striped dolphins (550)	Mediterranean Sea	Dolphin morbillivirus
1990	Bottlenose dolphins (146)	Gulf Coast, US	Unknown; unusual skin lesions observed

Year	Species and number	Location	Cause
1994	Bottlenose dolphins (72)	Texas	Morbillivirus
1995	California sea lions (222)	California	Leptospirosis
1996	Florida manatees (149)	West Coast Florida	Brevetoxin
1996	Bottlenose dolphins (30)	Mississippi	Unknown; Coincident with algal bloom
1997	Mediterranean monk seals (150)	Western Sahara, Africa	Harmful algal bloom; Morbillivirus
1997-98	California sea lions (100s)	California	El Nino
1998	California sea lions (70)	California	Domoic acid
1998	Hooker's sea lions (60% of pups)	New Zealand	Unknown, bacteria likely
1999	Harbor porpoises	Maine to North Carolina	Oceanographic factors suggested
2000	Caspian seals (10,000)	Caspian Sea	Canine distemper virus
1999-2000	Bottlenose dolphins (115)	Panhandle of Florida	Brevetoxin
1999-2001	Gray whales (651)	Canada, US West Coast, Mexico	Unknown; starvation involved
2000	California sea lions (178)	California	Leptospirosis
2000	California sea lions (184)	California	Domoic acid
2000	Harbor seals (26)	California	Unknown; Viral pneumonia suspected
2001	Bottlenose dolphins (35)	Florida	Unknown
2001	Harp seals (453)	Maine to Massachusetts	Unknown
2001	Hawaiian monk seals (11)	NW Hawaiian Islands	Malnutrition
2002	Harbor seals (approx. 25,000)	Northern Europe	Phocine distemper virus
2002	Multispecies (common dolphins, California sea lions, sea otters) (approx. 500)	California	Domoic acid
2002	Hooker's sea lions	New Zealand	Pneumonia
2002	Florida manatee	West Coast of Florida	Brevetoxin
2003	Multispecies (common dolphins, California sea lions, sea otters) (approx. 500)	California	Domoic acid
2003	Beluga whales (20)	Alaska	Ecological factors
2003	Sea otters	California	Ecological factors
2003	Large whales (16 humpback, 1 fine, 1 minke, 1 pilot, 2 unknown)	Maine	Unknown; Saxitoxin and domoic acid detected in 2 of 3 humpbacks
2003-2004	Harbor seals, minke whales	Gulf of Maine	Unknown
2003	Florida manatees (96)	West Coast of Florida	Brevetoxin
2004	Bottlenose dolphins (107)	Florida Panhandle	Brevetoxin
2004	Small cetaceans (67)	Virginia	Unknown
2004	Small cetaceans	North Carolina	Unknown
2004	California sea lions (405)	Canada, US West Coast	Leptospirosis

Year	Species and number	Location	Cause
2005	Florida manatees, bottlenose dolphins (ongoing Dec 2005)	West Coast of Florida	Brevetoxin
2005	Harbor porpoises	North Carolina	Unknown
2005	California sea lions; Northern fur seals	California	Domoic acid
2005	Large whales	Eastern North Atlantic	Domoic acid suspected
2005-2006	Bottlenose dolphins	Florida	Brevetoxin suspected

Note: Data from Gulland and Hall (2007): citations for each event contained in Gulland and Hall (2007).

H.2 UNITED STATES STRANDING RESPONSE ORGANIZATION

Stranding events provide scientists and resource manager's information not available from limited at-sea surveys, and may be the only way to learn key biological information about certain species such as distribution, seasonal occurrence, and health (Rankin 1953; Moore *et al.* 2004; Geraci and Lounsbury 2005). Necropsies are useful in attempting to determine a reason for the stranding, and are performed on stranded animals when the situation and resources allow.

In 1992, Congress passed the Marine Mammal Health and Stranding Response Act (MMHSRA) which authorized the Marine Mammal Health and Stranding Response Program (MMHSRP) under authority of the Department of Commerce, National Marine Fisheries Service. The MMHSRP was created because of public concern over marine mammal mortalities. Its objectives are twofold: to formalize the response process and to focus efforts being initiated by numerous local stranding organizations.

Major elements of the MMHSRP include the following (NMFS 2007):

- National Marine Mammal Stranding Network
- Marine Mammal UME Program
- National Marine Mammal Tissue Bank (NMMTB) and Quality Assurance Program
- Marine Mammal Health Biomonitoring, Research, and Development
- Marine Mammal Disentanglement Network
- John H. Prescott Marine Mammal Rescue Assistance Grant Program (a.k.a. the Prescott Grant Program)
- Information Management and Dissemination.

The United States has a well-organized network in coastal states to respond to marine mammal strandings. Overseen by the NMFS, the National Marine Mammal Stranding Network is comprised of smaller organizations manned by professionals and volunteers from nonprofit organizations, aquaria, universities, and state and local governments trained in stranding response. Currently, more than 400 organizations are authorized by NMFS to respond to marine mammal strandings (NMFS 2007).

The following is a list of NMFS Regions and Associated States and Territories:

- NMFS Northeast Region- ME, NH, MA, RI, CT, NY, NJ, PA, DE, MD, VA
- NMFS Southeast Region- NC, SC, GA, FL, AL, MS, LA, TX, PR, VI
- NMFS Southwest Region- CA
- NMFS Northwest Region- OR, WA
- NMFS Alaska Region- AK
- NMFS Pacific Islands Region- HI, Guam, American Samoa, Commonwealth of the Northern Mariana Islands (CNMI)

Stranding reporting and response efforts over time have been inconsistent, although effort and data quality within the United States have been improving within the last 20 years (NMFS 2007). Given the historical inconsistency in response and reporting, however, interpretation of long-term trends in marine mammal stranding is difficult (NMFS 2007). During the past decade (1995 to 2004), approximately 40,000 stranded marine mammals (about 12,400 were cetaceans) have been reported by the regional stranding networks, averaging 3,600 reported strandings per year (Figure H-1; NMFS 2007). The highest number of strandings was reported between the years 1998 and 2003. Detailed regional stranding information including most commonly stranded species can be found in Zimmerman (1991), Geraci and Lounsbury (2005), and NMFS (2007).

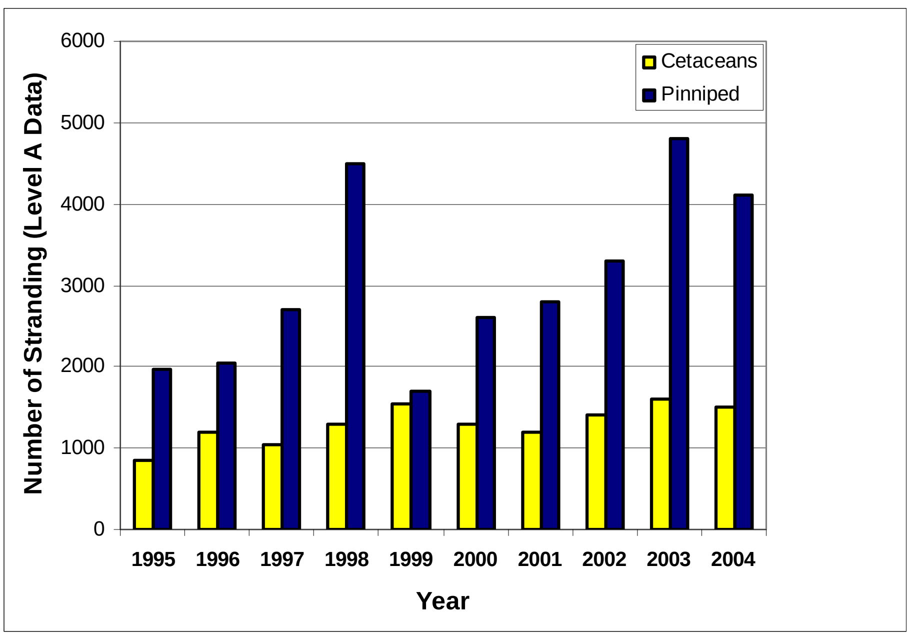

Figure H-1. United States annual cetacean and pinniped stranding events from 1995-2004.
(Source: NMFS 2007)

H.3 THREATS TO MARINE MAMMALS AND POTENTIAL CAUSES FOR STRANDING

Like any wildlife population, there are normal background mortality rates that influence marine mammal population dynamics, including starvation, predation, aging, reproductive success, and disease (Geraci *et al.* 1999; Carretta *et al.* 2007). Strandings may be reflective of this natural cycle or, more recently, may be the result of anthropogenic sources (i.e., human impacts). Current science suggests that multiple factors, both natural and man-made, may be acting alone or in combination to cause a marine mammal to strand (Geraci *et al.* 1999; Culik 2002; Perrin and Geraci 2002; Hoelzel 2003; Geraci and Lounsbury 2005; NRC 2006). While post-stranding data collection and necropsies of dead animals are attempted in an effort to find a possible cause for the stranding, it is often difficult to pinpoint exactly one factor that is responsible for any given stranding. An animal suffering from one ailment becomes susceptible to various other influences because of its weakened condition, making it difficult to determine a primary cause. In many stranding cases, scientists never learn the exact reason for the stranding. Specific threats and potential stranding causes may include the following:

- Natural causes
    - Disease
    - Natural toxins
    - Weather and climatic influences
    - Navigation errors
    - Social cohesion
    - Predation
- Anthropogenic (human influenced) causes
    - Fisheries interaction
    - Vessel strike
    - Pollution and ingestion
    - Noise

H.4 NATURAL THREATS/STRANDING CAUSES

H.4.1 Overview

Significant natural causes of mortality, die-offs, and stranding discussed below include disease and parasitism; marine neurotoxins from algae; navigation errors that lead to inadvertent stranding; and climatic influences that impact the distribution and abundance of potential food resources (i.e., starvation). Other natural mortality not discussed in detail includes predation by other species such as sharks (Cockcroft *et al.* 1989; Heithaus 2001), killer whales (Constantine *et al.* 1998; Guinet *et al.* 2000; Pitman *et al.* 2001), and some species of pinniped (Hiruki *et al.* 1999; Robinson *et al.* 1999).

H.4.2 Disease

Like other mammals, marine mammals frequently suffer from a variety of diseases of viral, bacterial, and fungal origin (Visser *et al.* 1991; Dunn *et al.* 2001; Harwood, 2002). Gulland and Hall (2005, 2007) provide a more detailed summary of individual and population effects of marine mammal diseases.

Microparasites such as bacteria, viruses, and other microorganisms are commonly found in marine mammal habitats and usually pose little threat to a healthy animal (Geraci *et al.* 1999).

For example, long-finned pilot whales that inhabit the waters off of the northeastern coast of the United States are carriers of the morbillivirus, yet have grown resistant to its usually lethal effects (Geraci *et al.* 1999). Since the 1980s, however, virus infections have been strongly associated with marine mammal die-offs (Domingo *et al.* 1992; Geraci and Lounsbury 2005). Morbillivirus is the most significant identified marine mammal virus and suppresses a host's immune system and increases risk of secondary infection (Harwood 2002). The largest bottlenose dolphin die-off associated with morbillivirus occurred in 1987, when hundreds of coastal dolphins succumbed to the virus (Lipscomb *et al.* 1994). A bottlenose dolphin UME in 1993 and 1994 was caused by morbillivirus. Die-offs ranged from northwestern Florida to Texas, with an increased number of deaths as it spread (NMFS 2007). A 2004 UME in Florida was also associated with dolphin morbillivirus (NMFS 2004). Influenza A was responsible for the first reported mass mortality in the U.S., occurring along the coast of New England in 1979-1980 (Geraci *et al.* 1999; Harwood, 2002). Canine distemper virus has been responsible for large scale pinniped mortalities and die-offs (Grachev *et al.* 1989; Kennedy *et al.* 2000; Gulland and Hall 2005), while a bacteria, *Leptospira pomona*, is responsible for periodic die-offs in California sea lions about every four years (Gulland *et al.* 1996; Gulland and Hall 2005). It is difficult to determine whether microparasites commonly act as a primary pathogen, or whether they show up as a secondary infection in an already weakened animal (Geraci *et al.* 1999). Most marine mammal die-offs from infectious disease in the last 25 years, however, have had viruses associated with them (Simmonds and Mayer 1997; Geraci *et al.* 1999; Harwood 2002).

Macroparasites are usually large parasitic organisms and include lungworms, trematodes (parasitic flatworms), and protozoans (Geraci and St.Aubin 1987; Geraci *et al.* 1999). Marine mammals can carry many different types, and have shown a robust tolerance for sizeable infestation unless compromised by illness, injury, or starvation (Morimitsu *et al.* 1987; Dailey *et al.* 1991; Geraci *et al.* 1999). *Nasitrema spp.*, a usually benign trematode found in the head sinuses of cetaceans (Geraci *et al.* 1999), can cause brain damage if it migrates (Ridgway and Dailey 1972). As a result, this worm is one of the few directly linked to stranding in the cetaceans (Dailey and Walker 1978; Geraci *et al.* 1999).

Non-infectious disease, such as congenital bone pathology of the vertebral column (osteomyelitis, spondylosis deformans, and ankylosing spondylitis), has been described in several species of cetacean (Paterson 1984; Alexander *et al.* 1989; Kompanje 1995; Sweeny *et al.* 2005). In humans, bone pathology such as ankylosing spondylitis, can impair mobility and increase vulnerability to further spinal trauma (Resnick and Niwayama 2002). Bone pathology has been found in cases of single strandings (Paterson 1984; Kompanje 1995), and also in cetaceans prone to mass stranding (Sweeny *et al.* 2005), possibly acting as a contributing or causal influence in both types of events.

H.4.3 Naturally Occurring Marine Neurotoxins

Some single cell marine algae common in coastal waters, such as dinoflagellates and diatoms, produce toxic compounds that can accumulate (termed bioaccumulation) in the flesh and organs of fish and invertebrates (Geraci *et al.* 1999; Harwood 2002). Marine mammals become exposed to these compounds when they eat prey contaminated by these naturally produced toxins (Van Dolah 2005). Figure H-2 shows U.S. animal mortalities from 1997-2006 resulting from toxins produced during harmful algal blooms.

In the Gulf of Mexico and mid- to southern Atlantic states, "red tides," a form of harmful algal bloom, are created by a dinoflagellate (*Karenia brevis*). *K. brevis* is found throughout the Gulf of Mexico and sometimes along the Atlantic coast (Van Dolah 2005; NMFS 2007). It produces a neurotoxin known as brevetoxin. Brevetoxin has been associated with several marine mammal UMEs within this area (Geraci 1989; Van Dolah *et al.* 2003; NMFS 2004; Flewelling *et al.*, 2005; Van Dolah, 2005; NMFS, 2007). On the U.S. West Coast and in the northeast Atlantic, several species of diatoms produce a toxin called domoic acid which has also been linked to marine mammal strandings (Geraci *et al.* 1999; Van Dolah *et al.* 2003; Greig *et al.* 2005; Van Dolah 2005; Brodie *et al.* 2006; NMF 2007). Other algal toxins associated with marine mammal strandings include saxitoxins and ciguatoxins and are summarized by Van Dolah (2005).

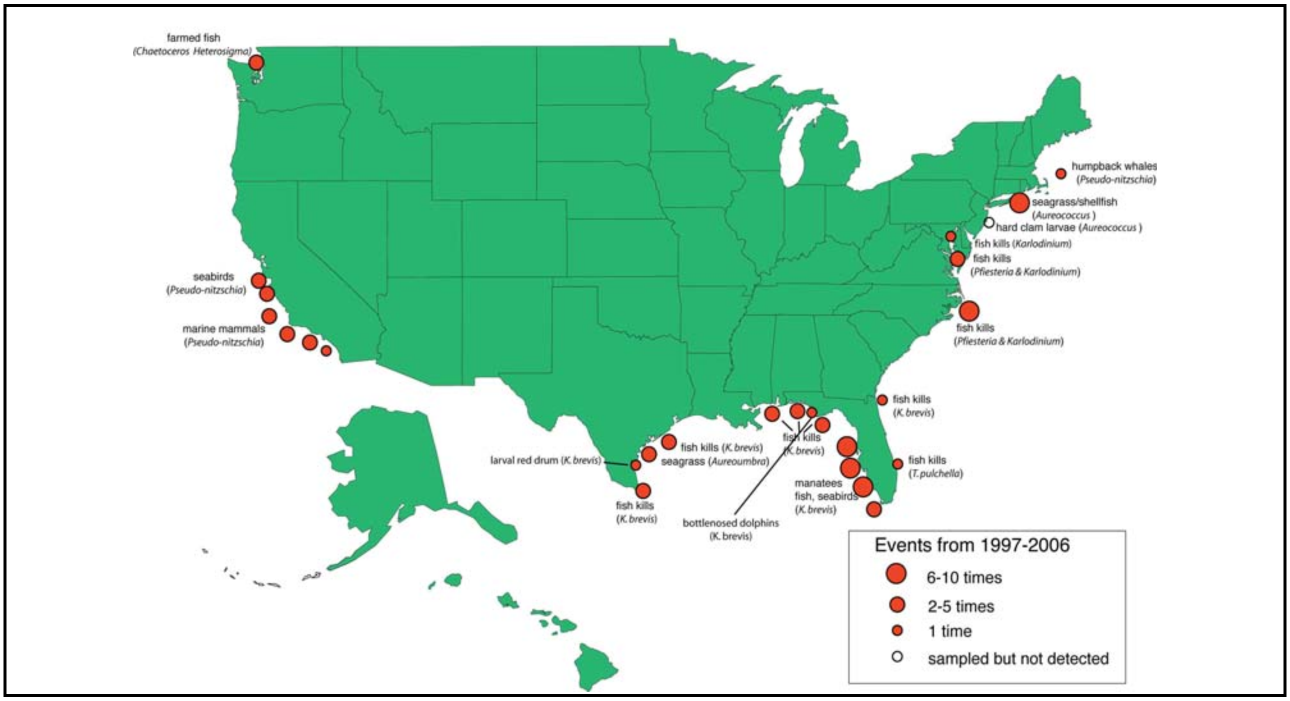

Figure H-2. Animal Mortalities from harmful algal blooms within the United States from 1997-2006.
(Source: Woods Hole Oceanographic Institute (WHO) http://www.whoi.edu/redtide/HABdistribution/HABmap.html)

H.4.4 Weather events and climate influences

Severe storms, hurricanes, typhoons, and prolonged temperature extremes may lead to localized marine mammal strandings (Geraci *et al.* 1999; Walsh *et al.* 2001). Hurricanes may have been responsible for mass strandings of pygmy killer whales in the British Virgin Islands and Gervais' beaked whales in North Carolina (Mignucci-Giannoni *et al.* 2000; Norman and Mead 2001). Storms in 1982-1983 along the California coast led to deaths of 2,000 northern elephant seal pups (Le Boeuf and Reiter 1991). Ice movement along southern Newfoundland has forced groups of blue whales and white-beaked dolphins ashore (Sergeant 1982). Seasonal oceanographic conditions in terms of weather, frontal systems, and local currents may also play a role in stranding (Walker *et al.* 2005).

The effect of large scale climatic changes to the world's oceans and how these changes impact marine mammals and influence strandings is difficult to quantify given the broad spatial and temporal scales involved, and the cryptic movement patterns of marine mammals (Moore 2005; Learmonth *et al.* 2006). The most immediate, although indirect, effect is decreased prey availability during unusual conditions. This, in turn, results in increased search effort required by marine mammals (Crocker *et al.* 2006) and potential starvation if foraging is not successful. Stranding may follow either as a direct result of starvation or as an indirect result of a weakened and stressed state (e.g., succumbing to disease) (Selzer and Payne 1988; Geraci *et al.* 1999; Moore 2005; Learmonth *et al.* 2006; Weise *et al.* 2006).

Two recent papers examined potential influences of climate fluctuation on stranding events in southern Australia, including Tasmania, an area with a history of more than 20 mass strandings since the 1920s (Evans *et al.* 2005; Bradshaw *et al.* 2006). These authors note that patterns in animal migration, survival, fecundity, population size, and strandings will revolve around the availability and distribution of food resources. In southern Australia, movement of nutrient-rich waters pushed closer to shore by periodic meridional winds (occurring about every 12 to 14 years) may be responsible for bringing marine mammals closer to land, thus increasing the probability of stranding (Bradshaw *et al.* 2006). The papers conclude, however, that while an overarching model can be helpful for providing insight into the prediction of strandings, the particular reasons for each one are likely to be quite varied.

H.4.5 Navigational Error

Geomagnetism- It has been hypothesized that, like some land animals, marine mammals may be able to orient to the Earth's magnetic field as a navigational cue, and that areas of local magnetic anomalies may influence strandings (Bauer *et al.* 1985; Klinowska 1985; Kirschvink *et al.* 1986; Klinowska 1986; Walker *et al.* 1992; Wartzok and Ketten 1999). In a plot of live stranding positions in Great Britain with magnetic field maps, Klinowska (1985, 1986) observed an association between live stranding positions and magnetic field levels. In all cases, live strandings occurred at locations where magnetic minima, or lows in the magnetic fields, intersect the coastline. Kirschvink *et al.* (1986) plotted stranding locations on a map of magnetic data for the East Coast, and were able to develop associations between stranding sites and locations where magnetic minima intersected the coast. The authors concluded that there were highly significant tendencies for cetaceans to beach themselves near these magnetic minima and coastal intersections. The results supported the hypothesis that cetaceans may have a magnetic sensory system similar to other migratory animals, and that marine magnetic topography and patterns may influence long-distance movements (Kirschvink *et al.* 1986). Walker *et al.* (1992) examined fin whale swim patterns off the northeastern U.S. continental shelf, and reported that migrating animals aligned with lows in the gradient of magnetic intensity. While a similar pattern between magnetic features and marine mammal strandings at New Zealand stranding sites was not seen (Brabyn and Frew 1994), mass strandings in Hawaii typically were found to occur within a narrow range of magnetic anomalies (Mazzuca *et al.* 1999).

Echolocation Disruption in Shallow Water- Some researchers believe stranding may result from reductions in the effectiveness of echolocation within shallow water, especially with the pelagic species of odontocetes who may be less familiar with coastline (Dudok van Heel 1966; Chambers and James 2005). For an odontocete, echoes from echolocation signals contain important information on the location and identity of underwater objects and the shoreline. The authors postulate that the gradual slope of a beach may present difficulties to the navigational systems of some cetaceans, since it is common for live strandings to occur along beaches with shallow, sandy gradients (Brabyn and McLean 1992; Mazzuca *et al.* 1999; Maldini *et al.* 2005; Walker *et al.* 2005). A contributing factor to echolocation interference in turbulent, shallow water is the presence of microbubbles from the interaction of wind, breaking waves, and currents. Additionally, ocean water near the shoreline can have an increased turbidity (e.g., floating sand or silt, particulate plant matter, etc.) due to the run-off of fresh water into the ocean, either from rainfall or from freshwater outflows (e.g., rivers and creeks). Collectively, these factors can reduce and scatter the sound energy within echolocation signals and reduce the perceptibility of returning echoes of interest.

H.4.6 Social cohesion

Many pelagic species such as sperm whales, pilot whales, melon-head whales, and false killer whales, and some dolphins occur in large groups with strong social bonds between individuals. When one or more animals strand due to any number of causative events, then the entire pod may follow suit out of social cohesion (Geraci *et al.* 1999; Conner 2000; Perrin and Geraci 2002; NMFS 2007).

H.5 ANTHROPOGENIC THREATS/STRANDING CAUSES

H.5.1 Overview

With the exception of historic whaling in the 19th and early part of the 20th century, during the past few decades there has been an increase in marine mammal mortalities associated with a variety of human activities (Geraci *et al.* 1999; NMFS 2007). These include fisheries interactions (bycatch and directed catch), pollution (marine debris, toxic compounds), habitat modification (degradation, prey reduction), vessel strikes (Laist *et al.* 2001), and gunshots. Figure H-3 shows potential worldwide risk to small-toothed cetaceans by source.

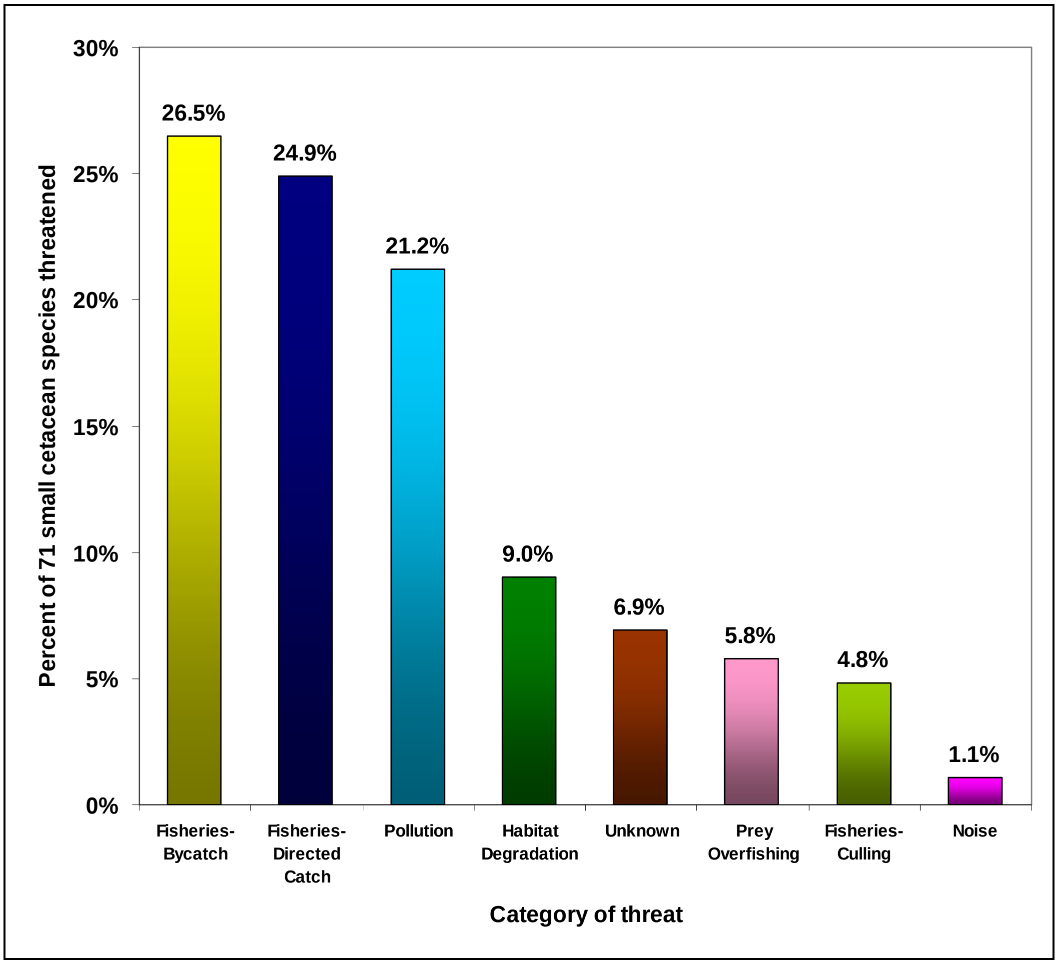

Figure H-3. Human threats to world wide small cetacean populations.
(Source: Culik 2002)

H.5.2 Fisheries Interaction: By-Catch and Entanglement

The incidental catch of marine mammals in commercial fisheries is a significant threat to the survival and recovery of many populations of marine mammals (Geraci *et al.* 1999; Baird 2002; Culik 2002; Carretta *et al.* 2004; Geraci and Lounsbury 2005; NMFS 2007). Interactions with fisheries and entanglement in discarded or lost gear continue to be a major factor in their deaths worldwide (Geraci *et al.* 1999; Nieri *et al.* 1999; Geraci and Lounsbury 2005; Read *et al.* 2006; Zeeber *et al.* 2006).

By-catch- By-catch is the catching of non-target species within a given fishing operation and can include non-commercially used invertebrates, fish, sea turtles, birds, and marine mammals (NRC 2006). Read *et al.* (2006) estimated the magnitude of marine mammal by-catch in U.S. and global fisheries. Data for the United States was obtained from fisheries observer programs, reports of entangled stranded animals, and fishery logbooks. In U.S. fisheries, the mean annual by-catch of marine mammals between 1990 and 1999 was 6,215 animals (SE = +/- 448). Eighty-four percent of cetacean by-catch occurred in gill-net fisheries, with dolphins and porpoises constituting the majority of these. The authors noted a 40 percent decline in marine mammal by-catching the years 1995 through 1999 compared to 1990 through 1994, and suggested that effective conservation measures implemented during the later time period played a significant role.

To estimate annual global by-catch, Read *et al.* (2006) used U.S. vessel by-catch data from 1990-1994 and extrapolated to the world's vessels for the same time period. They calculated an estimate of 653,365 of marine mammals caught annually around the world, again with most occurring in gill-net fisheries. The authors concluded that with global marine mammal by-catch likely to be in the hundreds of thousands every year, by-catch in fisheries will be the single greatest threat to many marine mammal populations around the world.

Entanglement- Active and discarded fishing gear pose a major threat to marine mammals. Entanglement can lead to drowning and/or impairment in activities such as diving, swimming, feeding and breeding. Stranded marine mammals frequently exhibit signs of previous fishery interaction, such as scarring or gear still attached to their bodies, and the cause of death for many stranded marine mammals is often attributed to such interactions (Baird and Gorgone 2005; Geraci *et al.* 1999; Campagna *et al.* 2007). Because marine mammals that die or are injured in fisheries may not wash ashore and not all animals that do wash ashore exhibit clear signs of interactions, stranding data probably underestimate fishery-related mortality and serious injury (NMFS 2005a).

Various accounts of fishery-related stranding deaths have been reported over the last several decades along the U.S. coast. From 1993 through 2003, 1,105 harbor porpoises were reported stranded from Maine to North Carolina, many of which had cuts and body damage suggestive of net entanglement (NMFS 2005d). In 1999, it was possible to determine that the cause of death for 38 of the stranded porpoises was from fishery interactions (NMFS 2005d). An estimated 78 baleen whales were killed annually in the offshore southern California/Oregon drift gillnet fishery during the 1980s (Heyning and Lewis 1990). From 1998-2005, based on observer records, five fin whales (CA/OR/WA stock), 12 humpback whales (ENP stock), and six sperm whales (CA/OR/WA stock) were either seriously injured or killed in fisheries off the mainland U.S. West Coast (California Marine Mammal Stranding Network Database 2006).

H.5.3 Ship Strike

Marine mammals sometimes come into physical contact with oceangoing vessels, which can lead to injury or death and cause subsequent stranding (Laist *et al.* 2001; Geraci and Lounsbury 2005; de Stephanis and Urquiola 2006). These events, termed "ship strikes," occur when an animal at the surface is struck directly by a vessel, when a surfacing animal hits the bottom of a vessel, or when an animal just below the surface is cut by a vessel's propeller. The severity of injuries typically depends on the size and speed of the vessel (Knowlton and Kraus 2001; Laist *et al.* 2001; Vanderlaan and Taggart 2007).

The growth in civilian commercial ports has been accompanied by a large increase in commercial vessel traffic. This has, in turn, expanded the threat of ship strikes to marine mammals in recent decades. The Final Report of the NOAA International Symposium on "Shipping Noise and Marine Mammals: A Forum for Science, Management, and Technology" stated that the worldwide commercial fleet has grown from approximately 30,000 vessels in 1950 to over 85,000 vessels in 1998 (NRC 2003; Southall 2005). From 1985 to 1999, world seaborne trade doubled to 5 billion tons and currently includes 90 percent of the total world trade, with container shipping movements representing the largest volume of seaborne trade. Current statistics support the prediction that the international shipping fleet will continue to grow at current or greater rates. Vessel densities along existing coastal routes are expected to increase both domestically and internationally. New routes are expected to develop as new ports are opened and existing ports are expanded. Vessel propulsion systems are also advancing toward faster ships operating in higher sea states for lower operating costs; and container ships are expected to become larger along certain routes (Southall 2005). Given the expected increase in vessel density and operational capability, a concomitant increase in marine mammal ship strikes can be expected.

H.5.4 Ingestion of Marine Debris and Exposure to Toxins

Debris in the marine environment poses a health hazard for marine mammals. Not only can they become entangled, but animals may ingest plastics and other debris that are indigestible, and which can contribute to illness or death through irritation or blockage of the stomach and intestines (Tarpley and Marwitz 1993, Whitaker *et al.* 1994; Gorzelany 1998; Secchi and Zarzur 1999; Baird and Hooker 2000). There are certain species of cetaceans (e.g. sperm whales) that are more likely to eat trash, especially plastics (Geraci *et al.* 1999; Evans *et al.* 2003; Whitehead 2003).

For example, between 1990 and October 1998, 215 pygmy sperm whales stranded along the U.S. Atlantic coast from New York through the Florida Keys (NMFS 2005a). Remains of plastic bags and other debris were found in the stomachs of 13 of these animals. In 1987, a pair of latex examination gloves was retrieved from the stomach of a stranded dwarf sperm whale (NMFS 2005c). In one pygmy sperm whale found stranded in 2002, red plastic debris was found in the stomach along with squid beaks (NMFS 2005a). Oliveira de Meirelles and Barros (2007) documented mortality to a rough-toothed dolphin in Brazil from plastic debris ingestion.

Chemical contaminants like organochlorines (PCBs, DDT) and heavy metals may pose potential health risks to marine mammals (Das *et al.* 2003; De Guise *et al.* 2003).Despite having been banned for decades, levels of organochlorines are still high in marine mammal tissue samples taken along U.S. coasts (Hickie *et al.* 2007; Krahn *et al.* 2007; NMFS 2007a). These compounds are long-lasting, reside in marine mammal adipose tissues (especially in the blubber), and can be toxic. Contaminant levels in odontocetes (piscivorous animals) have been reported to be one to two orders of magnitude higher compared to mysticetes (planktivorous animals) (Borell 1993; O'Shea and Brownell 1994; O'Hara and Rice 1996; O'Hara *et al.* 1999).

Chronic exposure to PCBs and/or DDT is immunosuppressive, as has been seen in bottlenose dolphins (Lahvis *et al.* 1995) and seals (p. vitulina) (Ross *et al.* 1996). Chronic exposure has been linked to infectious disease mortality in harbor porpoises stranded in the UK (Jepson *et al.* 1999; Jepson *et al.* 2005), carcinoma in California in sea lions (Ylitalo *et al.* 2005), and population reductions of Baltic seals (Bergman *et al.* 2001). High levels of PCBs in immature, pelagic dolphins has been observed (Struntz *et al.* 2004), raising concern about contaminant loads further offshore. Moderate levels of PCBs and chlorinated pesticides (such as DDT, DDE, and dieldrin) have been found in pilot whale blubber with bioaccumulation levels more similar in whales from the same stranding event than from animals of the same age or sex (NMFS 2005b). Accumulation of heavy metals has also been documented in many cetaceans (Frodello and Marchand 2001; Das *et al.* 2003; Wittnich *et al.* 2004), sometimes exceeding levels known to cause neurologic and immune system impairment in other mammals (Nielsen *et al.* 2000; Das *et al.* 2003; De Guise *et al.* 2003).

Other forms of habitat contamination and degradation may also play a role in marine mammal mortality and strandings. Some events caused by humans have direct and obvious effects on marine mammals, such as oil spills (Geraci *et al.* 1999). Oil spills can cause both short- and long-term medical problems for many marine mammal species through ingestion of tainted prey, coating of skin/fur, and adherence to oral and nasal cavities (Moeller 2003). In most cases, the effects of contamination are likely to be indirect in nature; e.g. effects on prey species availability or an increase in disease susceptibility (Geraci *et al.* 1999).

H.5.5 Anthropogenic Sound

There is evidence that underwater man-made sounds, such as explosions, drilling, construction, and certain types of sonar (Southall *et al.* 2006), may be a contributing factor in some stranding events. Marine mammals may respond both behaviorally and physiologically to anthropogenic sound exposure, (e.g., Richardson *et al.* 1995; Finneran *et al.* 2000; Finneran *et al.* 2003; Finneran *et al.* 2005); however, the range and magnitude of the behavioral response of marine mammals to various sound sources is highly variable (Richardson *et al.* 1995) and appears to depend on the species involved, the experience of the animal with the sound source, the motivation of the animal (e.g., feeding, mating), and the context of the exposure.

Exposure to sonar signals has been postulated as being a specific cause of several stranding events. Given that it is likely that the frequency of certain sonar systems is within the range of hearing of many marine mammals, the consideration of sonar as a causative mechanism of stranding is warranted. In the following sections, specific stranding events that have been putatively linked to sonar operations are discussed.

H.6 STRANDING EVENT CASE STUDIES

Over the past two decades, several mass stranding events involving beaked whales have been documented. A review of historical data (mostly anecdotal) maintained by the Marine Mammal Program in the National Museum of Natural History, Smithsonian Institution reports 49 beaked whale mass stranding events between 1838 and 1999. The largest beaked whale mass stranding occurred in the 1870s in New Zealand when 28 Gray's beaked whales (*Mesoplodon grayi*) stranded. Blainsville's beaked whale (*Mesoplodon densirostris*) strandings are rare, and records show that they were involved in one mass stranding in 1989 in the Canary Islands. Cuvier's beaked whales (*Ziphius cavirostris*) are the most frequently reported beaked whale to strand, with at least 19 stranding events from 1804 through 2000 (DoC and DoN 2001; Smithsonian Institution 2000). While beaked whale strandings have occurred since the 1800s (Geraci and Lounsbury 1993; Cox *et al.* 2006; Podesta *et al.* 2006), several mass strandings have been temporally and spatially associated with naval operations utilizing mid-frequency active (MFA) sonar (Simmonds and Lopez-Jurado 1991; Frantzis 1998; Jepson *et al.* 2003; Cox *et al.* 2006).

H.6.1 Beaked Whale Case Studies

In the following sections, specific stranding events that have been putatively linked to potential sonar operations are discussed. These events represent a small overall number of animals over an 11 year period (40 animals) and not all worldwide beaked whale strandings can be linked to naval activity (ICES 2005a,b; Podesta *et al.* 2006). Four of the five events occurred during NATO exercises or events where DON presence was limited (Greece, Portugal, and Spain). One of the five events involved only DON ships (Bahamas). These events are given specific consideration in the case studies that follow.

Beaked whale stranding events associated with naval operations.

1996	May	Greece (NATO/US)
2000	March	Bahamas (US)
2000	May	Portugal, Madeira Islands (NATO/US)
2002	September	Spain, Canary Islands (NATO/US)
2006	January	Spain, Mediterranean Sea coast (NATO/US)

1996 Greece Beaked Whale Mass Stranding (May 12 – 13, 1996)

<u>Description</u>: Twelve Cuvier's beaked whales (*Ziphius cavirostris*) stranded along a 38.2-km (20.6-NM) strand of the coast of the Kyparissiakos Gulf on May 12 and 13, 1996 (Frantzis 1998). From May 11 through May 15, the NATO research vessel Alliance was conducting sonar tests with signals of 600 Hz and 3 kHz and root-mean-squared (rms) sound pressure levels (SPL) of 228 and 226 dB re: 1 µPa, respectively (D'Amico and Verboom 1998; D'Spain *et al.* 2006). The timing and the location of the testing encompassed the time and location of the whale strandings (Frantzis 1998).

<u>Findings</u>: Partial necropsies of eight of the animals were performed, including external assessments and the sampling of stomach contents. No abnormalities attributable to acoustic exposure were observed, but the stomach contents indicated that the whales were feeding on cephalods soon before the stranding event. No unusual environmental events before or during the stranding event could be identified (Frantzis 1998).

<u>Conclusions</u>: The timing and spatial characteristics of this stranding event were atypical of stranding in Cuvier's beaked whale, particularly in this region of the world. No natural phenomenon that might contribute to the stranding event coincided in time with the mass stranding. Because of the rarity of mass strandings in the Greek Ionian Sea, the probability that the sonar tests and stranding coincided in time and location, while being independent of each other, was estimated as being extremely low (Frantzis 1998). However, because information for

the necropsies was incomplete and inconclusive, the cause of the stranding cannot be precisely determined.

2000 Bahamas Marine Mammal Mass Stranding (March 15-16, 2000)

Description: Seventeen marine mammals comprised of nine Cuvier's beaked whales, three Blainville's beaked whales (*Mesoplodon densirostris*), two unidentified beaked whales, two minke whales (*Balaenoptera acutorostrata*), and one spotted dolphin (*Stenella frontalis*), stranded along the Northeast and Northwest Providence Channels of the Bahamas Islands on March 15-16, 2000 (Evans and England 2001). The strandings occurred over a 36-hour period and coincided with DON use of mid-frequency active sonar within the channel. Navy ships were involved in tactical sonar exercises for approximately 16 hours on March 15. The ships, which operated the AN/SQS-53C and AN/SQS-56, moved through the channel while emitting sonar pings approximately every 24 seconds. The timing of pings was staggered between ships and average source levels of pings varied from a nominal 235 dB SPL (AN/SQS-53C) to 223 dB SPL (AN/SQS-56). The center frequency of pings was 3.3 kHz and 6.8 to 8.2 kHz, respectively.

Seven of the animals that stranded died, while ten animals were returned to the water alive. The animals known to have died included five Cuvier's beaked whales, one Blainville's beaked whale, and the single spotted dolphin. Six necropsies were performed and three of the six necropsied whales (one Cuvier's beaked whale, one Blainville's beaked whale, and the spotted dolphin) were fresh enough to permit identification of pathologies by computerized tomography (CT). Tissues from the remaining three animals were in a state of advanced decomposition at the time of inspection.

Findings: All five necropsied beaked whales were in good body condition and did not show any signs of external trauma or disease. In the two best preserved whale specimens, hemorrhage was associated with the brain and hearing structures. Specifically, subarachnoid hemorrhage within the temporal region of the brain and intracochlear hemorrhages were noted. Similar findings of bloody effusions around the ears of two other moderately decomposed whales were consistent with the same observations in the freshest animals. In addition, three of the whales had small hemorrhages in their acoustic fats, which are fat bodies used in sound production and reception (i.e., fats of the lower jaw and the melon). The best-preserved whale demonstrated acute hemorrhage within the kidney, inflammation of the lung and lymph nodes, and congestion and mild hemorrhage in multiple other organs.

Other findings were consistent with stresses and injuries associated with the stranding process. These consisted of external scrapes, pulmonary edema and congestion. The spotted dolphin demonstrated poor body condition and evidence of a systemic debilitating disease. In addition, since the dolphin stranding site was isolated from the acoustic activities of Navy ships, it was determined that the dolphin stranding was unrelated to the presence of Navy active sonar.

Conclusions: The post-mortem analyses of stranded beaked whales led to the conclusion that the immediate cause of death resulted from overheating, cardiovascular collapse and stresses associated with being stranded on land. However, the presence of subarachnoid and intracochlear hemorrhages were believed to have occurred prior to stranding and were hypothesized as being related to an acoustic event. Passive acoustic monitoring records demonstrated that no large scale acoustic activity besides the Navy sonar exercise occurred in the times surrounding the stranding event. The mechanism by which sonar could have caused the observed traumas or caused the animals to strand was undetermined. The spotted dolphin was in overall poor condition for examination, but showed indications of long-term disease. No analysis of baleen whales (minke whale) was conducted.

2000 Madeira Island, Portugal Beaked Whale Strandings (May 10 – 14, 2000)

Description: Three Cuvier's beaked whales stranded on two islands in the Madeira Archipelago, Portugal, from May 10–14, 2000 (Cox *et al.* 2006). A joint NATO amphibious training exercise, named "Linked Seas 2000," which involved participants from 17 countries, took place in Portugal during May 2–15, 2000. The timing and location of the exercises overlapped with that of the stranding incident.

Findings: Two of the three whales were necropsied. Two heads were taken to be examined. One head was intact and examined grossly and by CT; the other was only grossly examined because it was partially flensed and had been seared from an attempt to dispose of the whale by fire (Ketten 2005). No blunt trauma was observed in any of the whales. Consistent with prior CT scans of beaked whales stranded in the Bahamas 2000 incident, one whale demonstrated subarachnoid and peribullar hemorrhage and blood within one of the brain ventricles. Post-cranially, the freshest whale demonstrated renal congestion and hemorrhage, which was also consistent with findings in the freshest specimens in the Bahamas incident.

Conclusions: The pattern of injury to the brain and auditory system were similar to those observed in the Bahamas strandings, as were the kidney lesions and hemorrhage and congestion in the lungs (Ketten 2005). The similarities in pathology and stranding patterns between these two events suggested a similar causative mechanism. Although the details about whether or how sonar was used during "Linked Seas 2000" is unknown, the presence of naval activity within the region at the time of the strandings suggested a possible relationship to Navy activity.

2002 Canary Islands Beaked Whale Mass Stranding (24 September 2002)

Description: On September 24, 2002, 14 beaked whales stranded on Fuerteventura and Lanzaote Islands in the Canary Islands (Jepson *et al.* 2003). Seven of the 14 whales died on the beach and the 7 were returned to the ocean. Four beaked whales were found stranded dead over the next three days either on the coast or floating offshore (Fernández *et al.* 2005). At the time of the strandings, an international naval exercise called Neo-Tapon, involving numerous surface warships and several submarines was being conducted off the coast of the Canary Islands. Tactical mid-frequency active sonar was utilized during the exercises, and strandings began within hours of the onset of the use of mid-frequency sonar (Fernández *et al.* 2005).

Findings: Eight Cuvier's beaked whales, one Blainville's beaked whale, and one Gervais' beaked whale were necropsied; six of them within 12 hours of stranding (Fernández *et al.* 2005). The stomachs of the whales contained fresh and undigested prey contents. No pathogenic bacteria were isolated from the whales, although parasites were found in the kidneys of all of the animals. The head and neck lymph nodes were congested and hemorrhages were noted in multiple tissues and organs, including the kidney, brain, ears, and jaws. Widespread fat emboli were found throughout the carcasses, but no evidence of blunt trauma was observed in the whales. In addition, the parenchyma of several organs contained macroscopic intravascular bubbles and lesions, putatively associated with nitrogen off-gassing.

Conclusions: The association of NATO mid-frequency sonar use close in space and time to the beaked whale strandings, and the similarity between this stranding event and previous beaked whale mass strandings coincident with sonar use, suggests that a similar scenario and causative mechanism of stranding may be shared between the events. Beaked whales stranded in this event demonstrated brain and auditory system injuries, hemorrhages, and congestion in multiple organs, similar to the pathological findings of the Bahamas and Madeira stranding events. In addition, the necropsy results of Canary Islands stranding event lead to the hypothesis that the presence of disseminated and widespread gas bubbles and fat emboli were indicative of nitrogen bubble formation, similar to what might be expected in decompression sickness (Jepson *et al.* 2003; Fernández *et al.* 2005). Whereas gas emboli would develop from the nitrogen gas, fat emboli would enter the blood stream from ruptured fat cells (presumably where nitrogen bubble formation occurs) or through the coalescence of lipid bodies within the blood stream.

The possibility that the gas and fat emboli found by Fernández *et al.* (2005) was due to nitrogen bubble formation has been hypothesized to be related to either direct activation of the bubble by sonar signals or to a behavioral response in which the beaked whales flee to the surface following sonar exposure. The first hypothesis is related to rectified diffusion (Crum and Mao 1996), the process of increasing the size of a bubble by exposing it to a sound field. This process is facilitated if the environment in which the ensonified bubbles exist is supersaturated with gas. Repetitive diving by marine mammals can cause the blood and some tissues to accumulate gas to a greater degree than is supported by the surrounding environmental pressure (Ridgway and Howard 1979). Deeper and longer dives of some marine mammals, such as those conducted by beaked whales, are theoretically predicted to induce greater levels of supersaturation (Houser *et al.* 2001). If rectified diffusion were possible in marine mammals exposed to high-level sound, conditions of tissue supersaturation could theoretically speed the rate and increase the size of bubble growth. Subsequent effects due to tissue trauma and emboli would presumably mirror those observed in humans suffering from decompression sickness.

It is unlikely that the short duration of sonar pings would be long enough to drive bubble growth to any substantial size, if such a phenomenon occurs. However, an alternative but related hypothesis has also been suggested: stable bubbles could be destabilized by high-level sound exposures such that bubble growth then occurs through static diffusion of gas out of the tissues. In such a scenario the marine mammal would need to be in a gas-supersaturated state for a long enough period of time for bubbles to become of a problematic size. The second hypothesis speculates that rapid ascent to the surface following exposure to a startling sound might produce tissue gas saturation sufficient for the evolution of nitrogen bubbles (Jepson *et al.* 2003; Fernández *et al.* 2005). In this scenario, the rate of ascent would need to be sufficiently rapid to compromise behavioral or physiological protections against nitrogen bubble formation.

Although theoretical predictions suggest the possibility for acoustically mediated bubble growth, there is considerable disagreement among scientists as to its likelihood (Piantadosi and Thalmann 2004). Sound exposure levels predicted to cause in vivo bubble formation within diving cetaceans have not been evaluated and are suspected as needing to be very high (Evans 2002; Crum *et al.* 2005). Further, although it has been argued that traumas from recent beaked whale strandings are consistent with gas emboli and bubble-induced tissue separations (Jepson *et al.* 2003), there is no conclusive evidence supporting this hypothesis and there is concern that at least some of the pathological findings (e.g., bubble emboli) are artifacts of the necropsy. Currently, stranding networks in the United States have created a set of necropsy guidelines to determine, in part, the possibility and frequency with which bubble emboli can be introduced into marine mammals during necropsy procedures (Arruda *et al.* 2007).

2006 Spain, Gulf of Vera Beaked Whale Mass Stranding (26-27 January 2006)

Description: The Spanish Cetacean Society reported an atypical mass stranding of four beaked whales that occurred January 26, 2006, on the southeast coast of Spain near Mojacar (Gulf of Vera) in the Western Mediterranean Sea. According to the report, two of the whales were discovered the evening of January 26 and were found to be still alive. Two other whales were discovered during the day on January 27, but had already died. A following report stated that the first three animals were located near the town of Mojacar and were examined by a team from the University of Las Palmas de Gran Canarias, with the help of the stranding network of Ecologistas en Acción Almería-PROMAR and others from the Spanish Cetacean Society. The fourth animal was found dead on the afternoon of May 27, a few kilometers north of the first three animals.

From January 25-26, 2006, a NATO surface ship group (seven ships including one U.S. ship under NATO operational command) conducted active sonar training against a Spanish submarine within 93 km (50 NM) of the stranding site.

Findings: Veterinary pathologists necropsied the two male and two female beaked whales (*Z. cavirostris*).

Conclusions: According to the pathologists, a likely cause of this type of beaked whale mass stranding event may have been anthropogenic acoustic activities. However, no detailed pathological results confirming this supposition have been published to date, and no positive acoustic link was established as a direct cause of the stranding.

Even though no causal link can be made between the stranding event and naval exercises, certain conditions may have existed in the exercise area that, in their aggregate, may have contributed to the marine mammal strandings (Freitas 2004):

- Operations were conducted in areas of at least 1,000 m (3,281 ft) in depth near a shoreline where there is a rapid change in bathymetry on the order of 1,000 to 6,000 m (3,281 to 19,685 ft) occurring a cross a relatively short horizontal distance (Freitas 2004).
- Multiple ships, in this instance, five MFA sonar equipped vessels, were operating in the same area over extended periods of time (20 hours) in close proximity.
- Exercises took place in an area surrounded by landmasses, or in an embayment. Operations involving multiple ships employing mid-frequency active sonar near land may produce sound directed towards a channel or embayment that may cut off the lines of egress for marine mammals (Freitas 2004).

H.7 OTHER GLOBAL STRANDING DISCUSSIONS

In the following sections, stranding events that have been putatively linked to DON activity in popular press are presented. As detailed in the individual case study conclusions, the DON believes that there is enough to evidence available to refute allegations of impacts from mid-frequency sonar.

Stranding Events Case Studies

2003 Washington State Harbor Porpoise Strandings (May 2 – June 2, 2003)

Description: At 10:40 a.m. on May 5, 2003, the USS Shoup began the use of mid-frequency tactical active sonar as part of a naval exercise. At 2:20 p.m., the USS Shoup entered the Haro Strait and terminated active sonar use at 2:38 p.m., thus limiting active sonar use within the strait to less than 20 minutes. Between May 2 and June 2, 2003, approximately 16 strandings involving 15 harbor porpoises (*Phocoena phocoena*) and one Dall's porpoise (*Phocoenoides dalli*) were reported to the Northwest Marine Mammal Stranding Network. A comprehensive review of all strandings and the events involving USS Shoup on May 5, 2003, were presented in DON (2004). Given that the USS Shoup was known to have operated sonar in the strait on May 5, and that supposed behavioral reactions of killer whales (*Orcinus orca*) had been putatively linked to these sonar operations (NMFS Office of Protected Resources 2005), NMFS undertook an analysis of whether sonar caused the strandings of the harbor porpoises.

Whole carcasses of ten of harbor porpoises and the head of an additional porpoise were collected for analysis. Necropsies were performed on ten of the harbor porpoises and six whole carcasses and two heads were selected for CT imaging. Gross examination, histopathology, age determination, blubber analysis, and various other analyses were conducted on each of the carcasses (Norman *et al.* 2004).

Findings: Post-mortem findings and analysis details are found in Norman *et al.* (2004). All of the carcasses suffered from some degree of freeze-thaw artifact that hampered gross and histological evaluations. At the time of necropsy, three of the porpoises were moderately fresh, whereas the remainder of the carcasses was considered to have moderate to advanced decomposition. None of the 11 harbor porpoises demonstrated signs of acoustic trauma. In contrast, a putative cause of death was determined for five of the porpoises; two animals had blunt trauma injuries and three animals had indication of disease processes (fibrous peritonitis, salmonellosis, and necrotizing pneumonia). A cause of death could not be determined in the remaining animals, which is consistent with expected percentage of marine mammal necropsies conducted within the northwest region.

Conclusions: NMFS concluded from a retrospective analysis of stranding events that the number of harbor porpoise stranding events in the approximate month surrounding the USS Shoup use of sonar was higher than expected based on annual strandings of harbor porpoises (Norman *et al.* 2004). It is important to note that the number of strandings in the May-June timeframe in 2003 was also higher for the outer coast, indicating a much wider phenemona than use of sonar by USS Shoup in Puget Sound for one day in May. The conclusion by NMFS that the number of strandings in 2003 was higher is also different from that of The Whale Museum, which has documented and responded to harbor porpoise strandings since 1980 (Osborne 2003). According to The Whale Museum, the number of strandings as of May 15, 2003, was consistent with what was expected based on historical stranding records and was less than that occurring in certain years. For example, since 1992 the San Juan Stranding Network has documented an average of 5.8 porpoise strandings per year. In 1997, there were 12 strandings in the San Juan Islands with more than 30 strandings throughout the general Puget Sound area. Disregarding the discrepancy in the historical rate of porpoise strandings and its relation to the USS Shoup, NMFS acknowledged that the intense level of media attention focused on the strandings likely resulted in an increased reporting effort by the public over that which is normally observed (Norman *et al.* 2004). NMFS also noted in its report that the "sample size is too small and biased to infer a specific relationship with respect to sonar usage and subsequent strandings."

Seven of the porpoises collected and analyzed died prior to Shoup departing to sea on May 5, 2003. Of these seven, one, discovered on May 5, 2003, was in a state of moderate decomposition, indicating it died before May 5; the cause of death was determined to be due, most likely, to salmonella septicemia. Another porpoise, discovered at Port Angeles on May 6, 2003, was in a state of moderate decomposition, indicating that this porpoise also died prior to May 5. One stranded harbor porpoise discovered fresh on May 6 is the only animal that could potentially be linked in time to the USS Shoup's May 5 active sonar use. Necropsy results for this porpoise found no evidence of acoustic trauma. The remaining eight strandings were discovered one to three weeks after the USS Shoup's May 5 transit of the Haro Strait, making it difficult to causally link the sonar activities of the USS Shoup to the timing of the strandings. Two of the eight porpoises died from blunt trauma injury and a third suffered from parasitic infestation, which possibly contributed to its death (Norman *et al.* 2004). For the remaining five porpoises, NMFS was unable to identify the causes of death.

The speculative association of the harbor porpoise strandings to the use of sonar by the USS Shoup is inconsistent with prior stranding events linked to the use of mid-frequency sonar. Specifically, in prior events, the stranding of whales occurred over a short period of time (less than 36 hours), stranded individuals were spatially co-located, traumas in stranded animals were consistent between events, and active sonar was known or suspected to be in use. Although mid-frequency active sonar was used by the USS Shoup, the distribution of harbor porpoise strandings by location and with respect to time surrounding the event do not support the suggestion that mid-frequency active sonar was a cause of harbor porpoise strandings. Rather, a complete lack of evidence of any acoustic trauma within the harbor porpoises, and the identification of probable causes of stranding or death in several animals, further supports the conclusion that harbor porpoise strandings were unrelated to the sonar activities of the USS Shoup (DON 2004).

2004 Hawai'i Melon-Headed Whale Mass Stranding (July 3-4, 2004)

Description: The majority of the following information is taken from the NMFS report on the stranding event (Southall *et al.* 2006). On the morning of July 3, 2004, 150 to 200 melon-headed whales (*Peponocephala electra*) entered Hanalei Bay, Kauai. Individuals attending a canoe blessing ceremony observed the animals entering the bay at approximately 7 a.m. The whales were reported entering the bay in a "wave as if they were chasing fish" (Braun 2005). At 6:45 a.m. on July 3, 2004, approximately 46.3 km (25 NM) north of Hanalei Bay, active sonar was tested briefly prior to the start of an anti-submarine warfare exercise.

The whales stopped in the southwest portion of the bay, grouping tightly, and displayed spy-hopping and tail-slapping behavior. As people went into the water among the whales, the pod separated into as many as four groups, with individual animals moving among the clusters. This continued through most of the day, with the animals slowly moving south and then southeast within the bay. By about 3 p.m., police arrived and kept people from interacting with the animals. At 4:45 p.m. on July 3, 2004, the RIMPAC Battle Watch Captain received a call from a National Marine Fisheries representative in Honolulu, Hawaii, reporting the sighting of as many as 200 melon-headed whales in Hanalei Bay. At 4:47 p.m. the Battle Watch Captain directed all ships in the area to cease active sonar transmissions.

At 7:20 p.m. on July 3, 2004, the whales were observed in a tight single pod 68.6 m (75 yards) from the southeast side of the bay. The pod was circling in a group and displayed frequent tail slapping and whistle vocalizations and some spy hopping. No predators were observed in the bay and no animals were reported as having fresh injuries. The pod stayed in the bay through the night of July 3, 2004.

On the morning of July 4, 2004, the whales were observed to still be in the bay and collected in a tight group. A decision was made at that time to attempt to herd the animals out of the bay. A 213 to 244-m (700- to 800-ft) rope was constructed by weaving together beach morning glory vines. This vine rope was tied between two canoes and with the assistance of 30 to 40 kayaks, was used to herd the animals out of the bay. By approximately 11:30 a.m. on July 4, 2004, the pod was coaxed out of the bay.

A single neonate melon-headed whale was observed in the bay on the afternoon of July 4, after the whale pod had left the bay. The following morning on July 5, 2004, the neonate was found stranded on Lumahai Beach. It was pushed back into the water but was found stranded dead between 9 and 10 a.m. near the Hanalei pier. NMFS collected the carcass and had it shipped to California for necropsy, tissue collection, and diagnostic imaging.

Following the stranding event, NMFS undertook an investigation of possible causative factors of the stranding. This analysis included available information on environmental factors, biological factors, and an analysis of the potential for sonar involvement. The latter analysis included vessels that utilized mid-frequency active sonar on the afternoon and evening of July 2. These vessels were to the southeast of Kauai, on the opposite side of the island from Hanalei Bay.

<u>Findings</u>: NMFS concluded from the acoustic analysis that the melon-headed whales would have had to have been on the southeast side of Kauai on July 2 to have been exposed to sonar from naval vessels on that day (Southall *et al.* 2006). There was no indication whether the animals were in that region or whether they were elsewhere on July 2. NMFS concluded that the animals would have had to swim from 1.4 to 4.0 m/s (3 to 9 mi/hr) for 6.5 to 17.5 hours after sonar transmissions ceased to reach Hanalei Bay by 7 a.m. on July 3. Sound transmissions by ships to the north of Hanalei Bay on July 3 were produced as part of exercises between 6:45 a.m. and 4:47 p.m. Propagation analysis conducted by the 3rd Fleet estimated that the level of sound from these transmissions at the mouth of Hanalei Bay could have ranged from 138 to 149 dB re: 1 µPa.

NMFS was unable to determine any environmental factors (e.g., harmful algal blooms, weather conditions) that may have contributed to the stranding. However, additional analysis by Navy investigators found that a full moon occurred the evening before the stranding and was coupled with a squid run (Mobley *et al.* 2007). In addition, a group of 500 to 700 melon-headed whales were observed to come close to shore and interact with humans in Sasanhaya Bay, Rota, on the same morning as the whales entered Hanalei Bay (Jefferson *et al.* 2006). Previous records further indicated that, though the entrance of melon-headed whales into the shallows is rare, it is not unprecedented. A pod of melon-headed whales entered Hilo Bay in the 1870s in a manner similar to that which occurred at Hanalei Bay in 2004.

The necropsy of the melon-headed whale calf suggested that the animal died from a lack of nutrition, likely following separation from its mother. The calf was estimated to be approximately one week old. Although the calf appeared not to have eaten for some time, it was not possible to determine whether the calf had ever nursed after it was born. The calf showed no signs of blunt trauma or viral disease and had no indications of acoustic injury.

Conclusions: Although it is not impossible, it is unlikely that the sound level from the sonar caused the melon-headed whales to enter Hanalei Bay. This conclusion is based on a number of factors:

1. The speculation that the whales may have been exposed to sonar the day before and then fled to the Hanalei Bay is not supported by reasonable expectation of animal behavior and swim speeds. The flight response of the animals would have had to persist for many hours following the cessation of sonar transmissions. Such responses have not been observed in marine mammals and no documentation of such persistent flight response after the cessation of a frightening stimulus has been observed in other mammals. The swim speeds, though feasible for the species, are highly unlikely to be maintained for the durations proposed, particularly since the pod was a mixed group containing both adults and neonates. Whereas Southall *et al.* (2006) suggest that the animals would have had to swim from 1.4 to 4.0 m/s (3 to 9 mi/hr) for 6.5 to 17.5 hours, it is improbable that a neonate could achieve the same for a period of many hours.

2. The area between the islands of Oahu and Kauai and the Pacific Missile Range Facility (PMRF) training range have been used in RIMPAC exercises for more than 20 years, and are used year-round for ASW training using mid frequency active sonar. Melon-headed whales inhabiting the waters around Kauai are likely not naive to the sound of sonar and there has never been another stranding event associated in time with ASW training at Kauai or in the Hawaiian Islands. Similarly, the waters surrounding Hawaii contain an abundance of marine mammals, many of which would have been exposed to the same sonar operations that were speculated to have affected the melon-headed whales. No other strandings were reported coincident with the RIMPAC exercises. This leaves it uncertain as to why melon-headed whales, and no other species of marine mammal, would respond to the sonar exposure by stranding.

3. At the nominal swim speed for melon-headed whales, the whales had to be within 2.8 and 3.7 km (1.5 and 2 NM) of Hanalei Bay before sonar was activated on July 3. The whales were not in their open ocean habitat but had to be close to shore at 6:45 a.m. when the sonar was activated to have been observed inside Hanalei Bay from the beach by 7 a.m. (Hanalei Bay is very large area). This observation suggests that other potential factors could be causative of the stranding event (see below).

4. The simultaneous movement of 500 to 700 melon-headed whales and Risso's dolphins into Sasanhaya Bay, Rota, in the Northern Marianas Islands on the same morning as the

2004 Hanalei stranding (Jefferson *et al.* 2006) suggests that there may be a common factor which prompted the melon-headed whales to approach the shoreline. A full moon occurred the evening before the stranding and a run of squid was reported concomitant with the lunar activity (Mobley *et al.* 2007). Thus, it is possible that the melon-headed whales were capitalizing on a lunar event that provided an opportunity for relatively easy prey capture. A report of a pod entering Hilo Bay in the 1870s indicates that on at least one other occasion, melon-headed whales entered a bay in a manner similar to the occurrence at Hanalei Bay in July 2004. Thus, although melon-headed whales entering shallow embayments may be an infrequent event, and every such event might be considered anomalous, there is precedent for the occurrence.

5. The received noise sound levels at the bay were estimated to range from roughly 95 to 149 dB re: 1 μPa. Received levels as a function of time of day have not been reported, so it is not possible to determine when the presumed highest levels would have occurred and for how long. However, received levels in the upper range would have been audible by human participants in the bay. The statement by one interviewee that he heard "pings" that lasted an hour and that they were loud enough to hurt his ears is unreliable. Received levels necessary to cause pain over the duration stated would have been observed by most individuals in the water with the animals. No other such reports were obtained from people interacting with the animals in the water.

Although NMFS concluded that sonar use was a "plausible, if not likely, contributing factor in what may have been a confluence of events (Southall *et al.* 2006)," this conclusion was based primarily on the basis that there was an absence of any other compelling explanation. The authors of the NMFS report on the incident were unaware, at the time of publication, of the simultaneous event in Rota. In light of the simultaneous Rota event, the Hanalei stranding does not appear as anomalous as initially presented and the speculation that sonar was a causative factor is weakened. The Hanalei Bay incident does not share the characteristics observed with other mass strandings of whales coincident with sonar activity (e.g., specific traumas, species composition, etc.). In addition, the inability to conclusively link or exclude the impact of other environmental factors makes a causal link between sonar and the melon-headed whale strandings highly speculative at best.

1980- 2004 Beaked Whale Strandings in Japan (Brownell *et al.* 2004)

Description: Brownell *et al.* (2004) compared the historical occurrence of beaked whale strandings in Japan (where there are U.S. naval bases) with strandings in New Zealand (which lacks a U.S. naval base) and concluded the higher number of strandings in Japan may be related to the presence of U.S. Navy vessels using mid-frequency sonar. While the dates for the strandings were well documented, the authors of the study did not attempt to correlate the dates of any Navy activities or exercises with the dates of the strandings.

To fully investigate the allegation made by Brownell *et al.* (2004), the Center for Naval Analysis (CNA) looked at the past U.S. Naval exercise schedules from 1980 to 2004 for the water around Japan in comparison to the dates for the strandings provided by Brownell *et al.* (2004). None of the strandings occurred during or within weeks after any DON exercises. While the CNA analysis began by investigating the probabilistic nature of any co-occurrences, the results were a 100 percent probability that the strandings and sonar use were not correlated by time. Given there was no instance of co-occurrence in over 20 years of stranding data, it can be reasonably postulated that sonar use in Japanese waters by DON vessels did not lead to any of the strandings documented by Brownell *et al.* (2004).

2004 Alaska Beaked Whale Strandings (June 17 to July 19, 2004)

Description: Between June 17 and July 19, 2004, five beaked whales were discovered at various locations along 2,575 km (1,389.4 NM) of the Alaskan coastline, and one was found floating (dead) at sea. Because the DON exercise Alaska Shield/Northern Edge 2004 occurred within the approximate timeframe of these strandings, it has been alleged that sonar may have been the probable cause of these strandings.

The Alaska Shield/Northern Edge 2004 exercise consisted of a vessel-tracking event followed by a vessel-boarding search-and-seizure event. There was no ASW component to the exercise, no use of mid-frequency sonar, and no use of explosives in the water. There were no events in the Alaska Shield/Northern Edge exercise that could have caused any of the strandings over this 33 day period.

2005 North Carolina Marine Mammal Mass Stranding Event (January 15-16, 2005)

Description: On January 15 and 16, 2005, 36 marine mammals consisting of 33 short-finned pilot whales, one minke whale, and two dwarf sperm whales stranded alive on the beaches of North Carolina (Hohn *et al.* 2006a). The animals were scattered across a 111-km (59.9-NM) area from Cape Hatteras northward. Because of the live stranding of multiple species, the event was classified as a UME (Unusual Mortality Event). It is the only stranding on record for the region in which multiple offshore species were observed to strand within a two- to three-day period.

The DON indicated that from January 12 to 14, some unit level training with mid-frequency active sonar was conducted by vessels that were 93 to 185 km (50.2 to 99.8 NM) from Oregon Inlet. An expeditionary strike group was also conducting exercises to the southeast, but the closest point of active sonar transmission to the inlet was 650 km (350.7 NM) away. The unit level operations were not unusual for the area or time of year and the vessels were not involved in antisubmarine warfare exercises. Marine mammal observers on board the vessels did not detect any marine mammals during the period of unit level training. No sonar transmissions were made on January 15-16.

The National Weather Service reported that a severe weather event moved through North Carolina on January 13 and 14 (Figure H-4). The event was caused by an intense cold front that moved into an unusually warm and moist air mass that had been persisting across the eastern United States for about a week. The weather caused flooding in the western part of the state, considerable wind damage in central regions of the state, and at least three tornadoes that were reported in the north central part of the state. Severe, sustained (one to four days) winter storms are common for this region.

Over a two-day period (January 16-17), two dwarf sperm whales, 27 pilot whales, and one minke whale were necropsied and tissue samples collected. Twenty-five of the stranded cetacean heads were examined; two pilot whale heads and the heads of the dwarf sperm whales were analyzed by CT.

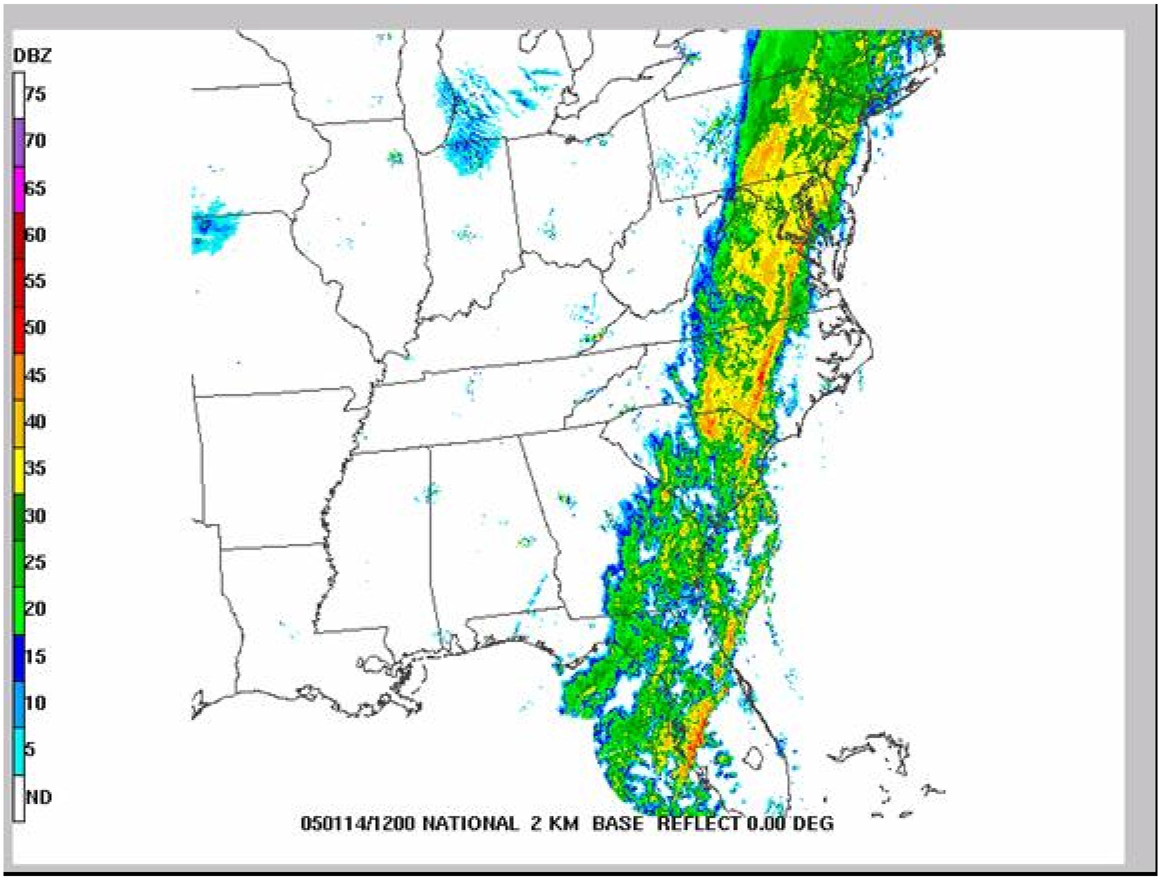

Figure H-4. Regional radar imagery for the East Coast (including North Carolina) on July 14. The time of the image is approximately 7 a.m.

Findings: The pilot whales and dwarf sperm whale were not emaciated, but the minke whale, which was believed to be a dependent calf, was emaciated. Many of the animals were on the beach for an extended period of time prior to necropsy and sampling, and many of the biochemical abnormalities noted in the animals were suspected of being related to the stranding and prolonged time on land. Lesions were observed in all of the organs, but there was no consistency across species. Musculoskeletal disease was observed in two pilot whales and cardiovascular disease was observed in one dwarf sperm whale and one pilot whale. Parasites were a common finding in the pilot whales and dwarf sperm whales but were considered consistent with the expected parasite load for wild odontocetes. None of the animals exhibited traumas similar to those observed in prior stranding events associated with mid-frequency sonar activity. Specifically, there was an absence of auditory system trauma and no evidence of distributed and widespread bubble lesions or fat emboli, as was previously observed (Fernández *et al.* 2005).

Sonar transmissions prior to the strandings were limited in nature and did not share the concentration identified in previous events associated with mid-frequency active sonar use (Evans and England 2001). The operational/environmental conditions were also dissimilar (e.g., no constrictive channel and a limited number of ships and sonar transmissions). NMFS noted that environmental conditions were favorable for a shift from up-welling to down-welling conditions, which could have contributed to the event. However, other severe storm conditions existed in the days surrounding the strandings and the impact of these weather conditions on at-sea conditions is unknown. No harmful algal blooms were noted along the coastline.

Conclusions: All of the species involved in this stranding event are known to strand in this region. Although the cause of the stranding could not be determined, several whales had preexisting conditions that could have contributed to the stranding. Cause of death for many of the whales was likely due to the physiological stresses associated with being stranded. A consistent suite of injuries across species, which was consistent with prior strandings where sonar exposure is expected to be a causative mechanism, was not observed.

NMFS was unable to determine any causative role that sonar may have played in the stranding event. The acoustic modeling performed, as in the Hanalei Bay incident, was hampered by uncertainty regarding the location of the animals at the time of sonar transmissions. However, as in the Hanalei Bay incident, the response of the animals following the cessation of transmissions would imply a flight response that persisted for many hours after the sound source was no longer operational. In contrast, the presence of a severe weather event passing through North Carolina during January 13 and 14 is a possible contributing factor to the North Carolina UME of January 15.

H.8 STRANDING SECTION CONCLUSIONS

Marine mammal strandings have been a historic and ongoing occurrence attributed to a variety of causes. Over the last fifty years, increased awareness and reporting has lead to more information about species effected and raised concerns about anthropogenic sources of stranding. While there has been some marine mammal mortalities potentially associated with mid-frequency sonar effects to a small number of species (primarily limited numbers of certain species of beaked whales), the significance and actual causative reason for any impacts is still subject to continued investigation. ICES (2005a) noted, that taken in context of marine mammal populations in general, sonar is not a major threat, nor a significant contributor to the overall ocean noise budget. However, continued research based on sound scientific principles is needed in order to avoid speculation as to stranding causes, and to further our understanding of potential effects or lack of effects from military mid-frequency sonar (Bradshaw *et al.* 2006; ICES 2005b; Barlow and Gisiner 2006; Cox *et al.* 2006).

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APPENDIX I

BAIN COMMENT RESPONSES

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Appendix I – Responses to Bain Letter

CRITIQUE OF THE RISK ASSESSMENT MODEL EMPLOYED TO CALCULATE TAKES IN THE HAWAII RANGE COMPLEX SUPPLEMENTAL DRAFT ENVIRONMENTAL IMPACT STATEMENT

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Abstract

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1

In reviewing whether the parameters employed were based upon the best available science, the implications in the uncertainty in the values, and biases and limitations in the risk function criteria, The commenter asserted that data were incorrectly interpreted by NMFS when calculating parameter values, resulting in a model that underestimates takes. NMFS, in its regulatory capacity for the MMPA, chose the data sets, interpreted the data, and set parameters for the risk function analysis to quantify exposures to mid-frequency sound sources NMFS may classify as Level B takes for military readiness activities. Of primary importance to the commenter was that the risk function curves specified by NMFS do not account for a wide range of frequencies from a variety of sources (e.g., motor boats, seismic survey activities, "banging on pipes"). In fact, all of the commenter's comments concerning "data sets not considered" by NMFS relate to sound sources that are either higher or lower in frequency than MFA sonar, are contextually different (such those presented in whale watch vessel disturbances or oil industry activities), or are relatively continuous in nature as compared to intermittent sonar pings. These sounds from data sets not considered have no relation to the frequency or duration of a typical Navy MFA sonar as described in the Draft EIS/OEIS.

As discussed above and in the Draft EIS/OEIS, NMFS selected data sets that were relevant to MFA sonar sources and selected parameters accordingly. In order to satisfy The commenter's concern that a risk function must be inherently precautionary, NMFS could have selected data sets and developed parameters derived from a wide variety of sources across the entire spectrum of sound frequencies in addition to or as substitutes for those that best represent the Navy's MFA sonar. The net result, however, would have been a risk function that captures a host of behavioral responses beyond those that are biologically significant as contemplated by the definition of Level B harassment under the MMPA applicable to military readiness activities. The commenter's specific comments and the Navy's responses are provided below.

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This page a duplicate of above

2 Given the results of the modeling for MIRC, having a lower basement value would not result in any significant number of additional takes. This was demonstrated in the Final EIS/OEIS (Table 3.7-6 and Figure 3.7-10) showing that less than 1% of the predicted number of takes resulted from exposures below 140 dB. The commenter further suggests that the criteria used to establish the risk function parameters should reflect the biological basement where any reaction is detectable. The MMPA was not intended to regulate any and all marine mammal behavioral reactions. Congress amended the MMPA to make clear its intention with the amendment to the MMPA for military readiness activities as enumerated in the following National Defense Authorization Act clarification - (i) any act that injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild [Level A Harassment]; or (ii) 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. NMFS, in its regulatory capacity for the MMPA, chose the data sets and parameters for use in the risk function analysis to regulate military readiness activities. Congress, by amending the MMPA, specifically is not regulating any and all behavioral reactions.

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3 NMFS, as a cooperating agency and in its role as the MMPA regulator, reviewed all available applicable data and determined that there were specific data from three data sets that should be used to develop the criteria. NMFS then applied the risk function to predict exposures that resulted in exposures that NMFS may classify as harassment. (This is described in the Final EIS/OEIS at Section 3.7.3.1.14). NMFS developed two risk curves based on the Feller adaptive risk function, one for odontocetes and one for mysticetes, with input parameters of B=120 dB, K=45, 99% point = 195 dB, 50% point = 165 dB.

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This page a duplicate of above

4 The risk function methodology assumes variations in responses within the species and was chosen specifically to account for uncertainties and the limitations in available data. NMFS considered all available data sets and determined it to be the best data currently available. While the data sets have limitations, they constitute the best available science.

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This page a duplicate of above

5

The commenter was concerned that if one animal is "taken" and leaves an area then the whole pod would likely follow. As explained in Appendix F of the Draft EIS/OEIS, the model does not operate on the basis of an individual animal but quantifies exposures NMFS may classify as takes based on the summation of fractional marine mammal densities. Because the model does not consider the many mitigation measures that the Navy utilizes when it is using MFA sonar, to include MFA sonar power down and power off requirements should mammals be spotted within certain distances of the ship, if anything, it over estimates the amount of takes given that large pods of animals should be easier to detect than individual animals.

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This page a duplicate of above

6 Modeling accounts for exposures NMFS may classify as takes at distances up to 125 km as described in the Final EIS/OEIS (Table 3.7-6). As discussed in Appendix F of both the Final and Draft EIS/OEIS, the MIRC contains a total of 9 distinct environmental provinces with specific sound propagation characteristics. These represent the various combinations of five bathymetry provinces, ten Sound Velocity Profile province, and six high frequency bottom loss classes. Based on these different provinces, the Navy identified different representative sonar modeling areas to fully encompass sound attenuation within the MIRC. Within these provinces, sound attenuated down to 140 dB at distances out to about 125 km (Table 3.7-6). Using these sound propagation characteristics, the risk function modeling for the MIRC resulted in less than 1% of the exposures that NMFS may classify as a take occurring between 120 dB and 140 dB (Table 3.7-6). The area encompassed by this sound propagation, as determined by NMFS for exposures that may constitute harassment, avoids a bias towards underestimation because the risk function parameters were designed with this in mind.

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This page a duplicate of above

7

Section 5.2 of the Draft EIS/OEIS evaluated alternative and/or additional mitigations, specifically, as it relates to potential mitigation approaches. The examples of the fundamentally different approaches noted in the comment were addressed in this section of the Draft EIS/OEIS. In addition, NMFS has identified general goals of mitigation measures. These goals include avoidance or minimization of injury or death, a reduction in the number of marine mammals exposed to received levels when these are expected to result in takes, a reduction in the number of times marine mammals are exposed when these are expected to result in takes, a reduction in the intensity of exposures that are expected to result in takes, and reduction in adverse effects to marine mammal habitat.

In this regard, NMFS and Navy have identified mitigation measures that are practicable and reasonably effective. For example, the safety zones reduce the likelihood of physiological harm, the number of marine mammals exposed, and the intensity of those exposures.

NMFS and Navy have determined that mitigation measures in conjunction with our understanding of decades of sonar use has resulted in only negligible impacts in the MIRC Section 3.7.3). Mitigation measures that are practicable involve those that reduce direct physiological effects within the TTS and PTS thresholds.

Introduction

The Navy distinguishes two types of takes: Level A, in which there is immediate injury or death; and Level B, in which there is no immediate injury, but cumulative exposure may lead to harm at the population level. However, in certain contexts, Level B harassment may lead to Level A takes through indirect mechanisms.

The population effects of Level A takes on populations are relatively easy to assess, as individuals that are killed are obviously removed from the population, and those that are injured are more likely to die whenever the population is next exposed to stress.

Calculating the population effects of Level B takes is a topic of contemporary research (Trites and Bain 2000). For example, Bain (2002a) explored using energetic consequences of behavior change in conjunction with population dynamics models to estimate population effects of Level B takes. Stress concurrent with Level B harassment would have additional population consequences. Stress may occur in the absence of behavioral change, or the absence of change in significant behavioral patterns such as foraging or nursing, or exclusion from optimal habitat. Lusseau et al. (2006) concluded disturbance caused a decline in and posed a significant threat to the survival of the bottlenose dolphin population in Doubtful Sound, New Zealand. While they noted vessel strikes were occurring (Level A takes), cumulative behavioral effects (Level B takes) were believed to be the primary threat to the population.

Models relating acoustic exposure to takes thus are not sufficient by themselves to interpret the effects of noise on populations. It is likely that different magnitudes of effect, whether physical harm, behavioral change that leads to physical harm, disruption of significant behavioral activities, or behavioral changes that pose negligible risk to populations when they occur only rarely but can become significant when exposure is prolonged or repeated, will have different relationships to noise. The different magnitudes of takes will have different population consequences. Thus it will be challenging to synthesize results of multiple studies, as different measured endpoints may belong on different curves relating them to noise, and different endpoints will have different population consequences. Further, the population consequences can depend on the health of the population (Bain 2002a). All these factors need to be considered when evaluating the environmental consequences of exposing marine mammals to noise.

Unconditional effects

Temporary Threshold Shifts in captive marine mammals are commonly used as an index of physical harm (e.g., Nachtigall et al. 2003, Finneran et al. 2002 and 2005, Kastak et al. 2005). Limiting experimental noise exposure to levels that cause temporary effects alleviates ethical concerns about deliberately causing permanent injury. However, repeated exposure to noise that causes temporary threshold shifts can lead to permanent hearing loss. In fact, chronic exposure to levels of noise too low to cause temporary threshold shifts can cause permanent hearing loss. Animal models (e.g., rats, cats,

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8 Navy agrees with the comment and notes that there is no documented decrease in many populations of endangered and non-endangered species in MIRC, where decades of sonar use, training, and RDT&E have occurred, would suggest that there is an absence of Level A effects from those activities.

9 This issue was recognized and discussed as presented in the Draft EIS/OEIS (Section 3.7.2.4.4, page 3.7-44). Based on prior National Oceanic and Atmospheric Administration rulings, NMFS established that exposures resulting in Level A and B harassment cannot be considered to overlap in an analysis of impacts, otherwise the regulatory distinction between the two criteria would be lost and the take quantification required would be ambiguous. To facilitate the regulatory process, a clear and distinct division between Level A and Level B harassments was maintained as required by NMFS in its role as the regulator and a cooperating agency in the Draft EIS/OEIS.

monkeys, chinchillas) have been used for tests of noise causing permanent physical harm (Henderson et al. 1991, Gao et al. 1992, Blakeslee et al. 1978, Clark 1991). Damage to hearing from noise exposure is an example of unconditional injury from noise. OSHA (2007) requires limiting human exposure to noise at 115 dB above threshold (equivalent to 145 dB re 1 μPa for killer whales, Szymanski et al. 1999) to 15 minutes.

Stress reactions are another available index (e.g., Romano et al. 2004). Ayres (personal communication) found evidence suggesting that whale watching results in increased levels of stress hormones in wild killer whales.

Conditional effects

Changes in behavior resulting from noise exposure could result in indirect injury in the wild. A variety of mechanisms for Level B harassment to potentially lead to Level A takes have been identified.

Gas bubble lesions have been observed in beaked whales (Jepson et al. 2003, Fernandez et al. 2005, Cox et al. 2006). A variety of mechanisms have been proposed for this. While some have proposed these may be due to acoustically mediated bubble growth, and hence are an unconditional consequence of noise exposure (Crum and Mao 1996), it is more likely that these result from decompression sickness. That is, changes in dive behavior may prevent clearance of nitrogen gas from the body, resulting in larger bubbles than would occur in undisturbed dive patterns. One possible change is that beaked whales may remain submerged for an unusually long period of time, and then rapidly ascend. The rapid ascent is a change in behavior that prevents nitrogen from remaining in solution in the blood. Zimmer and Tyack (2007) questioned whether the rapid ascent mechanism would actually result in lesions, and proposed another behavior change that might occur is interruption of deep dives. Deep dives allow the lungs to collapse, preventing nitrogen from reaching the body. Further, a series of rapid breaths at the surface can be used to clear nitrogen absorbed under pressure. Interruption of the normal surface interval can allow nitrogen to build up over time. Changes in depths of dives are of more concern than rapid ascents as this mechanism would be applicable to a wide range of species, while if the rapid ascent mechanism is involved, it would be primarily a concern for deep diving species (Zimmer and Tyack 2007).

While failure to flee may lead to injury in beaked whales, flight may lead to injury in other species. Minke whales have been found stranded after sonar exercises (NOAA and Navy 2001). A minke whale was observed traveling at high speed during exposure to mid-frequency sonar in Haro Strait in 2003. It is easy to see how such behavior would lead to stranding when a beach is located in front of the whale, as minke whales lack echolocation and visibility is limited underwater. Exhaustion from rapid flight leading to heart or other muscle damage (Williams and Thorne 1996) could also account for increased mortality such as was observed in harbor porpoises following sonar exercises in Juan de Fuca and Haro Straits in April and May of 2003. Harbor porpoises, in contrast to

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9 This issue was recognized and discussed as presented in the Draft EIS/OIES (Section 3.7.3.1.10, page 3.7-67). Based on prior National Oceanic and Atmospheric Administration rulings, NMFS established that exposures resulting in Level A and B harassment cannot be considered to overlap in an analysis of impacts, otherwise the regulatory distinction between the two criteria would be lost and the take quantification required would be ambiguous. To facilitate the regulatory process, a clear and distinct division between Level A and Level B harassments was maintained as required by NMFS in its role as the regulator and a cooperating agency in the Draft EIS/OEIS.

Dall's porpoises, rarely engage in sustained high energy activities such as rapid swimming or bow riding, and hence are less adapted to long distance flight responses.

Even successful flight may have negative survival consequences. In the absence of disturbance, individuals will tend to occupy optimal habitat. Displacement from optimal habitat will have consequences that will depend on the duration of the displacement, the quality of the alternate habitat, and the condition of the individuals at the time of displacement.

Separation of individuals from social units is another consequence of noise exposure that may lead to mortality. In 2003 in Haro Strait, some killer whales responded to mid-frequency sonar by seeking shelter behind a reef. Others chose to flee, resulting in splitting of a pod that historically spent all of its time together as a single unit. While no deaths resulted from this particular incident, other killer whales have been observed separated from their social units resulting in death prior to reunion or requiring human intervention to restore the individual to its social unit (Schroeder et al. 2007).

Temporary threshold shifts may conditionally lead to harm. Impaired hearing ability increases vulnerability to ship strike. In 2003, blunt force trauma was identified as a cause of death in the investigation of harbor porpoise mortalities following exposure to mid-frequency sonar in Washington State. A minke whale was nearly struck by a research vessel in the area where one had been observed fleeing mid-frequency sonar exposure. These species are familiar with boats in that area, and normally avoid them by a wide margin when they can hear them coming.

Impaired auditory ability may also increase predation risk. For example, Dahlheim and Towell (1994) reported an attack by killer whales on white-sided dolphins. The approach by the whales went undetected due to the noise of the research vessel. Further, impaired hearing may impair foraging ability and communication (Bain and Dahlheim 1994).

The Risk Function Model

The risk function uses three parameters. B is the received level at which the most sensitive individuals start to respond with changes in significant behaviors such as foraging. K is the difference in received level between the level at which half of individuals respond and the level at which the most sensitive individuals respond. That is, B+K is the level at which 50% of individuals respond. A is a shape parameter that attempts to capture the variability in responsiveness of the population. That is, are essentially all the individuals the same and the bulk of them become responsive when the received level is near B+K, in which case a simple threshold model would provide a good approximation, or is there a lot of variation in the population, in which case many individuals become responsive when received levels are near B?

The model is based on the hypothesis that some individuals start to respond at lower levels than others. It anticipates that some individuals will hold out until very high levels before responding. The model includes parameters that allow it to be applied appropriately to species with differing noise tolerance. However, the Navy used one set of parameter values to predict the responses of all species. This paper reviews the accuracy of the choice of parameter values, the implications of using the wrong parameter values, and whether the model makes unbiased predictions when uncertainty in the parameter values exists.

Limitations

Like many models, the risk model has limitations. It fails to take into account social interactions. For example, the model anticipates that individuals may move away from a source at different exposure levels, but fails to recognize that this would result in individuals becoming separated from the group. This is likely to lead to the curve becoming asymmetrical, with the "holdouts" responding to the behavior of their schoolmates rather than the sound. As the area exposed to lower levels of noise is larger than the area exposed to higher levels of noise, this would result in more individuals being affected than the model predicts for social species.

The model does not account for multiple sources. Kruse (1991), Williams and Ashe (2007) and Bain et al. (2006) noted that killer whale responses to vessels varied with the number of vessels present. The magnitude of certain responses increased on the order of 10% per source, although Williams and Ashe (2007) noted that large numbers of sources could result in changes in the opposite direction of small numbers of sources, potentially canceling out the effect. That is, rather than a risk function that simply identifies how likely a response is to occur, one that takes into account the magnitude of the response would be ideal.

Pingers have been used to reduce entanglement in gillnets. Kraus et al. (1997) were able to reduce entanglement of harbor porpoises by 90%. Gearin et al. (1996, 2000) used more pingers, and were able to reduce entanglement by 95%. While this could be accounted for by the fact that more pingers increase the minimum sound level at the net (Bain 2002b), Laake et al. (1997, 1998, 1999) found porpoises typically remained much farther from the net than the spacing between pingers, even after the avoidance response declined due to habituation. Thus, the effect of multiple sources seems larger than the effect of fewer sources. Pingers have also been successful in protecting other species from nets (Barlow and Cameron, 1999; Cameron 1999, Stone et al. 1997).

In addition to quantitative changes in response to multiple sources, there may be a qualitative change in the response. For example, noise is used in drive fisheries of many odontocete species to cause stranding or near strandings. That is, multiple sources were used to displace individuals in a particular direction, and the consequences (stranding) were more serious than displacement from the source alone as would result from exposure to a single source.

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The risk to the population of qualitatively different responses varies not only with the type of response, but the circumstances. If the response is going ashore, fatalities are highly likely to result. If the response is slowly moving away for a short period of time, no fatalities are likely to result. However, if the response is to slowly move away from a prime feeding area for an extended period of time, and the population is food limited, fatalities may result, and the number is likely to be related directly to the duration of exclusion from the feeding area, and only indirectly to the cumulative sound energy received.

Finally, the model assumes that marine mammals behave independently from each other. This is not likely to be the case. Even species that are normally solitary, like harbor seals, have been observed to school in response to high energy noise (personal observation). To remain a member of a group, individuals must remain in geographic proximity to each other. As more sensitive individuals move away, others who are not sufficiently disturbed by the sound itself would need to move as well to remain members of the group. The result is likely to be a step function at moderate exposure levels rather than the gradual increase in risk predicted by the model. The result would be that risk is underestimated. The proportion of individuals necessary to lead all individuals to respond in a similar manner to noise is likely to vary among species, and propensity to mass strand may be a good predictor of the importance of this effect.

Datasets

The Navy chose to rely upon three datasets.

Captive cetaceans

Studies of captive marine mammals provide an excellent setting for identifying direct effects of sound. E.g., one of the datasets employed by the Navy consists of studies relating short-term exposure of bottlenose dolphins and belugas to high levels of noise to Temporary Threshold Shifts. The Navy (Dept. Navy 2008b, p 3-7) noted aggressive behavior toward the test apparatus, suggesting stress was another consequence of the test (see also Romano et al. 2004). Such effects would be unconditional results of noise exposure.

However, extrapolation of the level at which aggression was observed to the level at which behaviorally mediated effects might occur in the wild is problematic, as this depends on how well trained the subjects were. For example, the Navy has been a leader in training dolphins and other marine mammals to cooperate with husbandry procedures. Tasks like taking blood, stomach lavage, endoscopic examination, collection of feces, urine, milk, semen and skin samples, etc. once required removing individuals from the water and using several people to restrain them. With training, painful and uncomfortable procedures can be accomplished without restraint and with a reduction in stress that has significantly extended lifespans of captive marine mammals (Bain1988).

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This was specifically addressed in the Draft EIS/OEIS (Section 3.7.3.1.14) and considered
as part of this decision making process. Additional data sets from wild animals were
incorporated into development of the risk function parameters specifically to address this
10 concern and these were presented in Section 3.7.3.1.14of the Draft EIS/OEIS. Additionally,
as discussed in Domjan 1998, and as cited in the Draft EIS/OEIS, animals in captivity can
be more or less sensitive than those found in the wild. It does not follow, therefore, that the
risk function modeling underestimates takes.

That is, the absence of avoidance or aggressive behavior does not imply an absence of physical harm, much less the absence of potential for behavior changes that may lead to indirect harm.

Physical harm may occur in the wild without avoidance responses as well. Yano and Dahlheim (1995) found killer whales continued to predate on longlines despite being physically injured by deterrents such as gunshots. Reeves et al. (1996) reviewed other examples from fishery interactions of injurious approaches to deterrence failing.

If belugas and bottlenose dolphins are like killer whales, and the 50% risk level is about 15 dB below the 50% risk level for behavioral change in trained animals (see below), this would put their value around 170 dB re 1 μPa. Even this is likely to be an overestimate, as boat motors with a source level of 165 dB re 1 μPa can cause behavioral changes in bottlenose dolphins (Nowacek et al. 2001.) This new value, 170 dB re 1 μPa, averaged with the other Navy datasets, would drop the average 50% risk level to 160 dB re 1 μPa.

Killer whales

The second dataset is killer whales exposed to mid-frequency sonar from the USS Shoup in Haro Strait, Washington, in May, 2003. The level quoted in the HRC SDEIS (Dept. Navy 2008b) is an estimate of the received levels experienced when mid-frequency sonar was transmitted from about 3 km away. This level caused major behavioral changes in 100% of exposed whales (Risk=1 for Level B takes of a magnitude that in other contexts or species could lead indirectly to physical harm), but was not to believed to have caused Level A takes (the whales did not strand, and received levels were estimated to be too low to have caused threshold shifts, NMFS OPR 2005) in any individuals (Risk = 0). However, much more data are available from the May, 2003 Shoup incident. Behavioral changes were first observed at 47 km (where the received level was estimated to be 121 dB). The behavioral response was tail slapping by about 25% of the individuals observed, which is consistent with observed responses to vessel noise at a similar level. At a distance greater than 22 km, the direction of travel changed away from a feeding area, and hence foraging behavior was disrupted. At this distance, the received level may have increased to the neighborhood of 135 dB re 1 μPa with about 6 dB of reduced spreading loss and 6 dB reduced absorption. This would be comparable to a vessel traveling at low speed approaching to within 10 m, which is very difficult to accomplish without causing whales to turn away. 100% of killer whales responded by abandoning their feeding ground and moving away from the noise source at this received level. While vessels cause diversion from straight-line paths, they have not been observed to displace killer whales from feeding areas (vessels have been observed to displace killer whales from resting areas, but this is likely mediated by presence rather than noise, as the effect is observed in the presence of silent vessels, Trites et al. 1995). Thus it is not surprising that a qualitatively different behavioral response was exhibited. The peak exposure level was estimated to be 175 dB re 1 μPa (HRC SDEIS, although NMFS noted that estimated levels tended to overestimate measured levels by 1-10 dB [NMFS OPR 2005], so the peak exposure level may have been only 165 dB). In addition to changing travel patterns, the pod split, with approximately 50% of the pod continuing to shelter in an acoustic shadow zone, and the other 50% fleeing at high speed. Such behavior has not been observed in the presence of vessels alone. It should be emphasized that 100% of killer whales exhibited a disruption of a significant life process, foraging, at a level that may have been less than 135 dB re 1 μPa, in contrast to the value used in the SDEIS, 169.3 dB re 1 μPa for a 50% response.

Additional datasets are available for killer whale responses to noise. E.g., in Bain and Dahlheim's (1994) study of captive killer whales exposed to band-limited white noise in a band similar to that of mid-frequency sonar at a received level of 135 dB re 1 μPa, abnormal behavior was observed in 50% of the individuals. This is far lower than the level observed in bottlenose dolphins. In addition, Bain (1995) observed that 100% of wild killer whales appeared to avoid noise produced by banging on pipes (fundamental at 300 Hz with higher harmonics) to the 135 dB re 1 μPa contour. This indicates the difference between wild and captive killer whales (non-zero risk in captive marine mammals might correspond to 100% risk in wild individuals of the same species), as well as implying that risk of 100% may occur by 135 dB re 1 μPa for this genus in the wild.

Further, killer whales begin responding to vessel traffic at around 105-110 dB re 1 μPa with minor behavioral changes. By 135 dB re 1 μPa, disruption of foraging may approach 100%. Received level appears to be more important than proximity (Bain 2001). For risk to increase from near 0 at 105 dB re 1 μPa to near 100% by 135 dB re 1 μPa, with A=10, the 50% risk level would need to be about 120 dB re 1 μPa. Substituting 120 for 169 dB re 1 μPa reduces the average level for 50% risk by about 16 dB to 144 dB re 1 μPa. Substituting 135 dB re 1 μPa would reduce the average by 8 dB to 157 dB re 1 μPa.

Finally, the Navy's characterization of the killer whale dataset is incorrect. They indicate the effects observed in the presence of mid-frequency sonar in Haro Strait were confounded by the presence of vessels. However, the effects of vessels on killer whales have been extensively studied (e.g., Kruse 1991, Williams et al. 2002ab, Bain et al. 2006). Behavioral responses attributed to mid-frequency sonar are qualitatively different than those observed to vessels alone. While the observations are anecdotal, they were not inconsistent. The sonar signal was blocked from reaching the whales with full intensity by shallow banks or land masses during three segments of the observation period. The "inconsistencies" can be attributed to differences in behavior depending on whether there was a direct sound path from the Shoup to the whales. It should be noted there was extensive study of this population prior to exposure (see Bigg et al. 1990 and Olesiuk et al. 1990 for a description of typical research protocols), as well as extensive post-exposure monitoring (e.g., Bain et al. 2006).

Right whales

Similarly, the right whale data relied upon are of limited value. While they clearly illustrate that the value at which 50% of animals are influenced is below 135 dB re 1 μPa

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and are therefore helpful in determining the upper limits of the B+K value, they lack sufficient low level exposures needed to fit the low end of the curve. As with killer whales, the Navy misused the data. They averaged values which resulted in 100% response. Thus the average value exceeds the level resulting in a 50% risk.

Right whales exposed to alerting devices consistently responded when received levels were above 135 dB re 1 μPa. Due to the small sample size (six individuals), it is unclear whether this is close to the 50% risk, the 100% risk level, or both. These data do not allow identification of B, as lower exposure levels were not tested. In mysticetes exposed to a variety of sounds associated with the oil industry, typically 50% exhibited responses at 120 dB re 1 μPa. Thus right whales may be similar to killer whales.

The consequences of using incorrect values can be seen by comparing the observed results of the right whale exposures to alert signals (Nowacek et al. 2004) with those predicted by the Navy model. Using the values of B=120, K=45, and A=10 in the HRC SDEIS (Dept. Navy 2008b), the probability of responses for the exposed whales are shown in column two of Table 1. The formula underestimated the number of takes by a factor of over 500. The Navy proposed using A=8 for mysticetes in recognition of this, and the results are shown in column 3. While improved, the model still underestimated takes by a factor of 183. One could try B=105 and K=15. Using A=10 provides a reasonable approximation, overestimating takes by 20% (column 4). A better approximation is provided by A=2, which predicts the number of takes within 2% (column 5). While the probability of all four right whales exposed to the highest alert signals responding is much less than one in a billion based on the Navy model and allows one to unequivocally reject the Navy's choice of parameter values as applying to that species, numerous other combinations of parameter values would fit the data as well as the values shown in the table here. Substituting 120 dB re 1 μPa for 139 dB re 1 μPa results in an average 6 dB lower at 159 dB re 1 μPa.

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11 It is noted that an apparent factual inaccuracy with regard to the only citation provided for the repeated assertion that 50% of marine mammals will react to 120 db re 1uPa. Malme et al., (1983, 1984) indicated that for migrating whales, a 0.5 probability of response occurred at 170 dB.

Table 1. Risk for right whales (model vs. observed)

Received Level (dB re 1 μPa)	RISK B=120,K=45,A=10	RISK B=120,K=45,A=8	RISK B=105,K=15,A=10	RISK B=105,K=15,A=2
Responded				
148	0.008647	0.022021	0.999973	0.891548
143	0.001217	0.004641	0.999908	0.86521
137	5.92E-05	0.000415	0.999488	0.819864
135	1.7E-05	0.000153	0.999026	0.800039
133	4.06E-06	4.86E-05	0.998059	0.777052
No Response				
134	8.52E-06	8.79E-05	0.998633	0.788974
Error Factor	502	183	0.83	1.01

Datasets not considered

The Navy incorrectly concludes that additional datasets are unavailable. In addition to the other killer whale datasets mentioned above, data illustrating the use of acoustic harassment and acoustic deterrent devices on harbor porpoises illustrate exclusion from foraging habitat (Laake et al. 1997, 1998 and 1999, Olesiuk et al. 2002). Data are also available showing exclusion of killer whales from foraging habitat (Morton and Symonds 2002), although additional analysis would be required to assess received levels involved. The devices which excluded both killer whales and harbor porpoises had a source level of 195 dB re 1 μPa, a fundamental frequency of 10 kHz, and were pulsed repeatedly for a period of about 2.5 seconds, followed by a period of silence of similar duration, before being repeated. Devices used only with harbor porpoises had a source level of 120-145 dB re 1 μPa, fundamental frequency of10 kHz, a duration on the order of 300 msec, and were repeated every few seconds. Harbor porpoises, which the Navy treats as having a B+K value of 120 dB re 1 μPa (with A large enough to yield a step function) in the AFAST DEIS (Dept.Navy 2008a), 45 dB lower than the average value used in the HRC SDEIS, may be representative of how the majority of cetacean species, which are shy around vessels and hence poorly known, would respond to mid-frequency sonar. Even if harbor porpoises were given equal weight with the three species used to calculate B+K, including them in the average would put the average value at 154 dB re 1 μPa instead of 165 dB re 1 μPa.

Harbor porpoise responses to various acoustic devices have been documented in captivity and the wild. Pingers with a source level of 130 dB re 1 μPa displace wild harbor porpoises to a distance of at least 100-1000 m, where the received level was likely in the

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The data sources the commenter presents as needing consideration involve contexts that are not applicable to the proposed actions or the sound exposures resulting from those actions. For instance, the commenter's citation to Lusseau et al. (2006) involve disturbance over a three year period to a small pod of dolphins exposed to "8,500 boat tours per year", which is nothing like the type or frequency of action that is proposed by the Navy for SOCAL. In a similar manner, the example from noise used in drive fisheries are not applicable to Navy training. Navy training involving the use of active sonar typically situations ships where the ships are located miles apart, the sound is intermittent, and the training does not involve surrounding the marine mammals at close proximity. Further, suggestions that effects from acoustic harassment devices and acoustic deterrent devices which are relatively continuous sound sources (unlike MFA sonar) and are specifically designed to exclude marine mammals from habitat, are also fundamentally different from the proposed actions and the use of MFA sonar. Finally, reactions to airguns used in seismic research or other activities associated with the oil industry are also not applicable to MFA sonar since the sound/noise sources, their frequency, source levels, and manner of use are fundamentally different.

neighborhood of 80-90 dB re 1 μPa. Studies of harbor porpoises in captivity also found responses to acoustic deterrent devices, but could not be tested at such distances due to limitations in facility size (Kastelein et al. 1997, 2001). This is another example of how studies with captive cetaceans can produce misleading results. Airmar devices with a source level of 195 dB re 1 μPa displaced an estimated 95% of harbor porpoises to a distance of 3 km. While received levels were not measured, they could have been in the neighborhood of 120-130 dB re 1 μPa. These findings are well modeled with a B value of 70 dB re 1 μPa, a K value of 25, and an A value of 4.

Many species are poorly known, due in part to difficulties approaching them from boats and in part because they do not fare well in captivity. Species that may exhibit vulnerability to noise comparable harbor porpoises include many species of Stenella (e.g., striped dolphins), beaked whales, sperm whales (which are best studied from sailboats rather than motorized vessels, and show disruption of foraging at levels below 130 dB re 1 μPa, Jochens et al. 2006), and numerous poorly known species. In contrast, Dall's porpoises are known to bow ride, and appear far less easily disturbed by noise from airguns than harbor porpoises (Calambokidis et al. 1998). They may be an example of a relatively noise tolerant species like the bottlenose dolphins included in the SDEIS.

There are also data that are based on other noise sources. E.g., effects of vessel traffic on whale and dolphin behavior could be interpreted in terms of received levels. While engine noise tends to be continuous rather than intermittent like sonar, in a reverberant environment, mid-frequency sonar may be received as a nearly continuous sound (personal observation).

Likewise, records of marine mammal responses to broadband noise sources like airguns are also likely to be informative. While it may be difficult to extrapolate levels resulting in takes due to potential differences in perception of broadband and narrowband signals, and pulses rather than continuous sounds, they can give an idea of the range of intra-specific and inter-specific variation in B and K values and be applicable to determining the A parameter.

E.g., Calambokidis et al. (1998) found harbor seal responses to airguns typically consisted of visually orienting at received levels from 143 to 158 dB re 1 μPa and moving away at received levels from 158 dB to 185 dB re 1 μPa. However, one harbor seal oriented at 163 dB re 1 μPa rather than moving away. The highest measured received levels for Dall's porpoises were about 170 dB re 1 μPa, but only about 142 dB re 1 μPa for harbor porpoises. Similarly, the highest received levels measured for California sea lions were about 180 dB re 1 μPa, but only about 160 dB re 1 μPa for Steller sea lions. The highest measured received level was also 160 dB re 1 μPa for gray whales. That is, closely related species pairs may differ in their responsiveness to noise by over 20 dB, and taxonomically diverse species pairs may exhibit similar responsiveness.

TTS data similar to those available for cetaceans have been collected from harbor and elephant seals, and California and Steller sea lions (Kastak et al. 1999, 2005). As with cetaceans, field data suggest the Navy parameter values will underestimate takes of some pinniped species, though they may provide a reasonable approximation for harbor seals and California sea lions (e.g., the data described above). Pinniped hearing in species studied to date is less sensitive than in cetaceans (e.g., California sea lions, Schusterman et al. 1972; Steller sea lions, Kastelein et al. 2005; harbor seals, Møhl 1968; northern fur seals, Moore et al. 1987; odontocetes, Au 1993), and it is commonly assumed they are less vulnerable to noise as a result. However, comparisons of Steller sea lions with Dall's porpoises and gray whales exposed to airgun noise indicates this is not always the case. A detailed consideration of pinnipeds is beyond the scope of this paper.

Using the datasets discussed above, 50% risk levels based on trained cetaceans may be 165 dB re 1 μPa, 120 dB re 1 μPa for killer and right whales, and 95 dB re 1 μPa for harbor porpoises. The average of 95, 120, 120 and 165 is 125 dB, 40 dB lower than the 50% risk value of 165 dB used in the Navy model. Even if one uses more stringent criteria for what constitutes takes (120 dB for harbor porpoises, 135 dB for killer and right whales, and 170 dB for bottlenose dolphins), the average would be 140 dB, which is 25 dB lower than the Navy model. Setting B to 100, K to 40, and A to 10 would result in roughly 40 times the number of takes than the model predicts using the Navy's parameter values.

Parameter values

The use of default values for model parameters is problematic. The available data are likely to be biased toward noise tolerant species. That is, species that are intolerant of noise are difficult to approach closely enough to study. They tend to fare poorly in captivity. E.g., spinner dolphins and harbor porpoises showed very poor survivorship in captivity, in contrast to bottlenose dolphins (Bain 1988). Thus averages based on available data are likely to underestimate effects on species for which data are not available.

While the Navy has proposed assuming noise tolerance is predictable along taxonomic lines, which correlate with hearing ability, empirical data do not support this assumption (Bain and Williams 2006). Likewise, there is interspecific variation in noise tolerance in fish (Kastelein 2008).

B Value

The basement value should be set low enough that the risk function predicts takes at the lowest of the level resulting in unconditional injuries, the level at which behaviorally mediated injuries are possible, and the level resulting in minor behavioral changes or stress that can have population level effects with sustained or repeated exposure.

An important property of the model is that the biologically observed basement value is different than the mathematical basement value. The Navy proposes using 120 dB re 1 μPa as the basement value. They indicate the selection of this value is because it was commonly found in noise exposure studies. However, 120 dB re 1 μPa has broadly been

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13 It is noted that an apparent factual inaccuracy with regard to the only citation provided for the repeated assertion that 50% of marine mammals will react to 120 db re 1uPa. Malme et al., (1983, 1984) indicated that for migrating whales, a 0.5 probability of response occurred at 170 dB.

found as the value at which 50% of individuals responded to noise, not a small percentage. Further, a mathematical B of 120 dB corresponds to a risk of less than 2% at 150 dB (with K=45 and A=10), which would be difficult to detect in empirical studies. That is, the studies should be re-evaluated to determine the level at which a small percentage of individuals responded, and then a further correction for the difference between mathematical B and the empirically determined biological B would be needed.

However, further consideration should be given to the nature of the responses used in those studies to determine whether they represent significant behavioral changes or are only likely to have a population scale effect with sustained or repeated exposure.

For example, many looked at changes in migration routes resulting from noise exposure, and found that 50% of migrating whales changed course to remain outside the 120 dB re 1 µPa contour (Malme et al. 1983, 1984). These results might be interpreted in several ways. They could be seen as minor changes in behavior resulting in a slight increase in energy expenditure. Under this interpretation, they would not qualify as changes in a significant behavior, and are irrelevant to setting the basement value. They could be interpreted as interfering with migration, even though the whales did not stop and turn around, and hence 120 dB would make an appropriate B+K value rather than B value. Third, the change in course could have been accompanied by a stress response, in which case the received level at which the course change was initiated rather than the highest level received (120 dB re 1 µPa) could be taken as the biological basement value.

As discussed above, sensitive species like harbor porpoises may be significantly affected by levels below 100 dB re 1 µPa (Kastelein et al. 1997, 2000, 2001). Foraging behavior of killer whales can be disrupted by levels on the order of 105-110 dB re 1 µPa or less (Williams et al. 2002ab, data in Bain et al. 2006). These are far below the 120 dB re 1 µPa level proposed, and as mentioned above, the mathematical B value needed to predict detectable changes at 110 dB would be far lower than 110 dB. For example, B=80, K=45, and A=10 predicts a risk of less than 2% at 110 dB.

K Value

The K value reflects the difference between the mathematical B value and the level at which 50% of individuals respond. Since determining the B value has problems of its own, this critique will focus on determining the B+K value. The 50% risk level is relatively easy to determine, and has been commonly reported in the literature, as noted in the SDEIS. However, the most common value was 120 dB re 1 µPa, as noted in the SDEIS, yet these studies were not used to calculate B+K. Instead, other datasets were used, and the numbers derived were not the 50% risk levels. As mentioned above, there are problems with extrapolation of responses in trained animals to wild animals, and the right and killer whale values were based on levels that resulted in nearly 100% risk, not 50% risk. (It may not be possible to determine a level at which 50% risk occurred in killer whales, but perhaps collaboration among killer whale researchers, whale watch operators, and the Navy might identify the B+K level for that event).

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(See response to #13 above)

The 50% risk level is the median level at which individuals begin to respond, not the mean as calculated in the SDEIS. While there are data suggesting risk of threshold shift is related to duration of exposure, and hence the consequences of exposure to continuous noise sources would be different than exposure to intermittent sources, there are no such data for behaviorally mediated effects. Many species strongly avoid motorized vessels, and hence are more vulnerable to noise than the average of the species considered above. Such species are likely to include those in the sperm and beaked whale families, Pacific right whales, blue whales, melon-headed and pygmy killer whales, right whale dolphins, and Clymene, striped and rough-toothed dolphins. A smaller number of species, like Dall's porpoises, are more tolerant of noise sources than the average of the species considered above. Thus it is unlikely that the average value of B+K across cetacean species would be above 120 dB re 1 μPa, although the value would vary across species.

A value

While the A value is described as relating to the sharpness of the risk function, it also influences the symmetry of the function. As A increases, risk is redistributed from low noise levels to higher noise levels. The relative risk to the population, as opposed to risk to individuals, can be described as the risk to individuals at a given received level times the relative number of individuals receiving that level. As the sound spreads to larger areas, more individuals are exposed to lower levels of noise. The shape of the risk function and the spreading loss model determine the received level that poses the most risk to the population. At high received levels, the risk to the population may be small, because although the risk to individuals is high, the number of individuals likely to be exposed is small. At low levels, the risk to the population may be again small, because although the number of individuals exposed is high, the risk to those individuals is low. At intermediate values, the population experiences the most risk. When A is low, the risk to the population peaks near B, and at high A values, the risk is concentrated near B+K.

The choice of A value appears arbitrary. The Navy indicated they wanted to allow for more response at low levels, and adjusted the A value to accomplish this. However, this would have been better accomplished by lowering the B and B+K values as suggested above.

The significance of an A value underestimating the number of individuals responding to low levels of noise and overestimating the number of individuals responding to high levels of noise is that the area exposed to low levels of noise is larger than the area exposed to high levels of noise, so the calculation would lead to an underestimate of takes.

Calambokidis et al. (1998) employed an appropriate methodology for obtaining data for calculating A values of marine mammals exposed to airguns. They used a small vessel which moved toward and away from the seismic survey vessel, and hence were able to observe behavior and measure received values at distances of over 70 km as well as close

14

to the seismic survey vessel. Thus they were able to observe normal behavior in the presence of low levels of noise, as well as identify levels above which 100% of individuals exhibited behavioral change, and note inter-specific variation in response curves.

Interaction of Terms

It appears that B+K is a stronger predictor of the number of takes than either factor separately. As a result, similar risk curves can be generated for many different pairs of B and K as long as the sum is held constant. K and A together determine the range over which risk rises from 5% to 95%. Similarly, pairs of K and A over a range of values can generate similar risk curves.

With B=120, K=45, and A=10, the risk function predicts risk is near zero at received levels near 120, and that over 99.9% of takes will occur above 138 dB re 1 µPa. Even with A = 8, 99.9% of takes occur at levels above 135 dB. With A values this large, B is better described as the level at which the risk function is undefined (it requires dividing by 0) rather than the level at which risk becomes negligible. That is, the mathematical basement value and the biological basement value are different. The level at which data from marine mammals show barely detectable risk will be far above the mathematical basement value when K is 45 and A is 8 or 10. When K or A are small, the mathematical and biological B values become similar.

Another way of looking at the difference between the mathematical and biological basement value is to ask how much risk is detectable. In field studies, it will be difficult to distinguish responses that occur in only 5% of individuals from baseline behavior. Even if a study were sensitive enough to detect this, the received level to cause 5% risk is more than 30 dB above the mathematical B value for B=120, K =45 and A=8 or 10. That is, if risk becomes biologically detectable at 120 dB, the B value used in the equation for risk should be far lower. When the model uses the biological B value as the mathematical B value, it does not accurately predict the observed pattern of takes.

Long range effects

The Navy expressed uncertainty over whether there would be long distance effects, even when sound levels were received that are known to cause effects at close range. While I am not aware of observations at 65 nautical miles, responses at over 20 miles have been observed in killer whales to mid-frequency sonar, as well as at over 15 miles to mid-frequency sonar in Dall's porpoises, and harbor porpoises appeared to respond to airguns at over 40 nm (personal observation). The porpoises were responding at distances greater than they would respond to natural predators (killer whales), which are not believed to be detectable at those ranges.

15

Further evidence of long range responses to noise can be seen in differences in detection rates of some species using acoustic means and ship-based observations. Such studies indicate that species like Pacific right whales and blue whales avoid motorized vessels at distances which place them over the horizon (Wade et al. 2006, Širović 2006).

Uncertainty and Bias

To assess the effects of uncertainty in the parameter values (B, K, and A) on bias in the estimated number of takes, the following method was used. Two spreading loss models were used. A spherical spreading loss model was used, although this was likely to underestimate received levels, particularly at long distances. The other was spherical spreading at close range followed by a cylindrical spreading loss at longer distances model. An accurate model would depend on actual conditions, which would vary from one sonar exercise to another, both as bottom topography varies from place to place and the structure of the water column varies from time to time. The two models chosen should bracket actual conditions, and will serve for purposes of illustration at this stage. In both models, absorption at 3.5 kHz was used to correct for excess attenuation (Richardson et al. 1995). A source level of 235 dB re 1 μPa was assumed for purposes of illustration.

Individuals were assumed to be distributed uniformly with distance from the source, although in practice, action areas will be large enough that density could reasonably be expected to vary. The action area was divided into concentric rings 10 meters across. As the diameter of the ring increased, the area within the ring increased:

$$A = \pi r_o^2 - \pi r_i^2$$

where r_o is the outer diameter and r_i is the inner diameter of the ring.

The risk was calculated for individuals within the ring using the Navy equation, and the relative number of individuals experiencing that risk level was based on the area of the ring. As in the equation for the individuals, the cumulative impact on the population was normalized to 1 based on the Navy default parameters. The effects of uncertainty were observed by allowing the parameters to vary above and below the default values.

Using this model, the contributions of the innermost rings were small, due to their small area, and the contribution of the outermost rings were small, due to the low risk experienced by individuals in those ring. Figures 1-20 show the shape of the risk function and the relative numbers of takes that would occur as a function of received level for a variety of parameter value combinations.

Selected values of B, K and A were used to calculate relative effects, and the results are shown in Table 2 for a spherical spreading model, and Table 3 for a model that assumes spherical spreading for the first 2 km and then cylindrical spreading after that. The default values are shown in bold. Take numbers are based on Alternative 3 in the Hawaii

16

Range Complex SDEIS (Dept. Navy 2008b), which in turn is based on the No Action Alternative, Table 3.3.1-1. Where the number of takes approaches the size of the population, the actual number of takes will be smaller than shown in the table. However, individuals will be taken multiple times and the duration of takes will be longer than if the calculated number of takes were small. Presumably, longer and more frequent takes of individuals will have more impact on the population than takes due to single exposures.

Table 2. Sensitivity Analysis based on a spherical spreading model

B	K	A	Spreading Model	Relative Effect	Humpback takes	Striped Dolphin takes	Basis
80	45	10	Inv. Square	185.29	2,826,414	867,898	Vary B
90	45	10	Inv. square	75.25	1,147,864	352,471	Vary B
100	45	10	Inv. square	23.92	364,876	112,041	Vary B
110	45	10	Inv. square	5.68	86,643	26,605	Vary B
120	**45**	**10**	**Inv. square**	**1.00**	**15,254**	**4,684**	**SDEIS**
130	45	10	Inv. square	0.14	2,136	656	Vary B
140	45	10	Inv. square	0.02	305	94	Vary B
120	5	10	Inv. Square	167.18	2,550,164	783,071	Vary K
120	15	10	Inv. square	62.22	949,104	291,439	Vary K
120	25	10	Inv. square	18.33	279,606	85,858	Vary K
120	35	10	Inv. square	4.47	68,185	20,937	Vary K
120	**45**	**10**	**Inv. square**	**1.00**	**15,254**	**4,684**	**SDEIS**
120	55	10	Inv. square	0.23	3508	1077	Vary K
120	65	10	Inv. square	0.06	915	281	Vary K
120	75	10	Inv. square	0.01	153	47	Vary K
120	45	1	Inv. square	42.40	646,770	198,602	Vary A
120	45	5	Inv. square	3.27	49,881	15,317	Vary A
120	45	8	Inv. square	1.40	21,356	6,558	Vary A
120	**45**	**10**	**Inv. square**	**1.00**	**15,254**	**4,684**	**SDEIS**
120	45	12	Inv. Square	0.80	12,203	3,747	Vary A
120	45	20	Inv. Square	0.52	7,932	2,436	Vary A
120	45	100	Inv. Square	0.39	5,949	1,827	Vary A
120	**45**	**10**	**Inv. square**	**1.00**	**15,254**	**4,684**	**SDEIS**
105	15	10	Inv. square	251.39	3,834,703	1,177,511	*Orcinus*
105	15	8	Inv. square	250.96	3,828,144	1,175,497	
70	25	10	Inv. square	1070.25	16,325,594	5,013,051	*Phocoena*
70	25	8	Inv. square	1067.49	16,283,492	5,000,123	*Phocoena*

17

14 The values suggested as parameters, the results of which are presented in the above mentioned tables, are not reasonable given the environmental conditions in MIRC have ambient noise (naturally occurring background noise) levels at or above those suggested by the commenter as behavioral harassment "B" basement values. The use of these results for examination of potential uncertainty and bias in the risk function as presented in the Draft EIS/OEIS is, therefore, not informative or applicable in the MIRC context.

Table 3. Sensitivity analysis based on a model with spherical spreading for 2 km followed by cylindrical spreading.

B	K	A	Spreading Model	Relative Effect	Humpback takes	Striped Dolphin takes	Basis
80	45	10	Hybrid	132.20	2,016,579	619,225	Vary B
90	45	10	Hybrid	65.31	996,239	305,912	Vary B
100	45	10	Hybrid	25.30	385,926	118,505	Vary B
110	45	10	Hybrid	6.67	101,744	31,242	Vary B
120	**45**	**10**	**Hybrid**	**1.00**	**15,254**	**4,684**	**SDEIS**
130	45	10	Hybrid	0.08	1,220	325	Vary B
140	45	10	Hybrid	.005	76	23	Vary B
120	5	10	Hybrid	127.23	1,940,771	595,947	Vary K
120	15	10	Hybrid	59.67	910,213	279,496	Vary K
120	25	10	Hybrid	21.39	326,238	100,177	Vary K
120	35	10	Hybrid	5.37	81,901	25,149	Vary K
120	**45**	**10**	**Hybrid**	**1.00**	**15,254**	**4,684**	**SDEIS**
120	55	10	Hybrid	0.18	2,724	836	Vary K
120	65	10	Hybrid	0.04	570	175	Vary K
120	75	10	Hybrid	0.01	143	44	Vary K
120	45	1	Hybrid	34.16	521,077	160,005	Vary A
120	45	5	Hybrid	3.65	55,665	17,093	Vary A
120	45	8	Hybrid	1.51	23,016	7,067	Vary A
120	**45**	**10**	**Hybrid**	**1.00**	**15,254**	**4,684**	**SDEIS**
120	45	12	Hybrid	0.73	11,103	3,409	Vary A
120	45	20	Hybrid	0.35	5,353	1,644	Vary A
120	45	100	Hybrid	0.17	2,593	796	Vary A
120	**45**	**10**	**Hybrid**	**1.00**	**15,254**	**4,684**	**SDEIS**
105	15	10	Hybrid	171.9	2,622,166	805,181	*Orcinus*
105	15	8	Hybrid	171.3	2,612,718	802,279	
70	25	10	Hybrid	516.41	7,877,318	2,418,864	*Phocoena*
70	25	8	Hybrid	514.46	7,847,573	2,409,731	*Phocoena*
80	45	10	Hybrid	132.20	2,016,579	619,225	"Average"species
100	40	10	Hybrid	40.88	623,525	191,464	Stringent criteria
120	45	10	Social75	1.004	15,315	4,703	75% step
120	45	10	Social50	1.06	16,169	4,965	50% step
120	45	10	Social25	1.49	22,728	6,979	25% step
120	45	10	Social10	3.02	46,067	14,146	10% step

18

15 (See response to #14 above)

An interesting characteristic of the Navy model is that uncertainty causes it to be biased to underestimate risk. The reason for this bias is that the area receiving higher than the level of sound associated with a 50% risk based on default values is smaller than the area receiving lower levels. Thus if a species is 10 dB more sensitive than predicted (the B value), the cumulative risk is underestimated by a factor of 5.68, while if it is overestimated by 10 dB the correction is 0.14. Similarly, if the error is 20 dB, the correction factors are 23.92 and 0.02, respectively. However, the values average to 6.15, not 1 as would be the case if the default values provided an unbiased estimate. Errors in K show a similar pattern.

Likewise, if the default value of A is too low, it makes little difference in the estimated number of takes. However, if the default value of A is higher than the actual value, the effect on the population can be seriously underestimated when default values are used.

It should also be noted that the bias increases with increasing uncertainty.

Another source of uncertainty is propagation. As noted above, there is uncertainty over propagation that depends on the structure of the water column. Expectations can be based on historical measurements, and actual conditions can be measured to allow re-running propagation models with actual conditions. However, when received levels as a function of distance are higher than predicted, the result is asymmetrical relative to an error of the same magnitude in the opposite direction, as is the case for errors in the receiver parameters. E.g., when a sound channel forms, the area receiving enough noise to cause takes will dramatically increase.

Finally, the magnitude of the difference between parameter values based on reanalysis of the datasets used by the Navy (with harbor porpoises added, a species included in the AFAST Draft DEIS, Dept. Navy 2008a), and the Navy analysis should be emphasized. The number of takes predicted for an average species differs by a factor of more than 100. For humpbacks, this suggests individuals would be taken an average of about 250 times. Of course, when refresh times are taken into account, the number of retakes would be below this number, but the duration of takes would go up as a result. The cumulative effect on the population is likely to be far higher with the increased number and duration of takes predicted when more realistic parameters are used than when the Navy parameters are used.

SEL vs. SPL

Studies with captive marine mammals suggest that SEL provides a good predictor of Temporary Threshold Shift. That is, there is a tight relationship among signal strength, duration, and TTS. However, for behaviorally mediated effects, this relationship is likely to be different. SPL is likely to qualitatively determine the response for signals longer than 1 ms in duration. As long as signals are produced sufficiently often, the duration from the first signal to the last is likely to be more important than the SEL. That is, for

19

low received levels, one second signals produced every 40 seconds for 120 minutes are likely to have more impact than a continuous signal that lasts 10 minutes, even though the latter contains far more sound energy (600 seconds versus 180 seconds), as a behavioral response will be sustained for hours rather than minutes.

When attempting to predict effects of takes on the population, a take table with multiple columns should be developed. One based on SEL could be used to characterize direct effects such as threshold shifts. The next two should be based on SPL. The first of these should be analyzed to evaluate the total number of individuals that would change their behavior as a result of noise exposure, with particular attention paid to exposure in high risk areas (canyons, near shore, near shipping lanes) for potential indirect injuries. The third analysis would consider duration of exposure (in hours of exercise rather than in the SEL sense) to determine whether factors such as stress, displacement from preferred habitat, changes in foraging success and predation risk, etc., would result in cumulative effects that would alter population growth in a manner equivalent to lethal removals (Bain 2002a).

Summary

In summary, development of a function that recognizes individual variation is a step in the right direction. However, the selected equation is likely to produce underestimates of takes. This is due both to social factors increasing the likelihood of a response at low exposure levels, and asymmetries in the number of individuals affected when parameters are underestimated and overestimated due to uncertainty. Thus it will be important to use the risk function in a precautionary manner.

The sensitivity analysis reveals the importance of using as many datasets as possible. First, for historical reasons, there has been an emphasis on high energy noise sources and the species tolerant enough of noise to be observed near them. Exclusion of the rarer datasets demonstrating responses to low levels of noise biases the average parameter values, and hence underestimates effects on sensitive species. In particular, exclusion of the Navy's own interpretation of harbor porpoise data resulted in an increase of B+K by 11 dB, and a reduction in estimated takes by a factor of about 5. Second, uncertainty is correlated with bias. That is, even if a representative set of noise exposure-response data are used to calculate parameter values, the statistical uncertainty resulting from small samples results in biased parameter estimates that lead to underestimation of effects. Thus when estimating takes, it will be important to correct for bias. When estimating population effects on poorly known species, it will be important to be precautionary.

An important error in the selection of parameter values was in interpretation of existing data. Extrapolating behavioral changes in beluga and killer whales and bottlenose dolphins trained to tolerate physical harm that is in their long-term best interest to the threshold for onset of any physical harm in wild individuals is problematic. A similar mistake was made with the right whale data. The level at which 100% of individuals responded was used as the value at which 50% of individuals responded (B+K).

Likewise, the level at which 100% of killer whales responded to mid-frequency sonar is less than the value derived for B+K in the HRC SDEIS (Dept. Navy 2008b).

The "broad overview" of studies reported responses to received levels of 120 dB re 1 μPa by 50% of individuals. That is, 120 dB re 1 μPa should be taken as a "default" value for B+K, not B. Studies which looked at the level at which statistically significant changes were observed, rather than the level at which 50% of individuals responded found lower levels for B. As a result, B is overestimated, and B+K (the level at which risk is 50%) is as well. The use of data from trained dolphins and white whales biased the average B+K value upward. The exclusion of the effects of AHD's and ADD's on harbor porpoises further biases these values, though the sensitivity analysis suggests that using average values to extrapolate takes is unlikely to be accurate due to the broad range of inter-specific variation.

It is likely that biological B values should be in the range from just detectable above ambient noise to120 dB re 1 μPa. The resulting mathematical B value could be tens of dB lower, not the 120 dB re 1 μPa proposed. For many species, risk may approach 100% in the range from 120-135 dB re 1 μPa, putting K in the 15-45 dB range. A values do not seem well supported by data, and in any case, are likely to be misleading in social species as the risk function is likely to be asymmetrical with a disproportionate number of individuals responding at low noise levels. Re-evaluating the datasets identified by the Navy and including harbor porpoises, an average B+K value of 125 dB was found, and the over-representation of species that fare well in captivity likely biases the average above what it would be for all species. Rather than one equation fitting all species well, parameters are likely to be species typical. As realistic parameter values are lower than those employed in the HRC SDEIS (Dept. Navy 2008b), AFAST DEIS (Dept. Navy 2008a) and related DEIS's, take numbers should be recalculated to reflect the larger numbers of individuals likely to be taken. The difference between the parameter values estimated here and those used in the SDEIS suggests takes were underestimated by two orders of magnitude.

The large number of takes predicted when more sensitive species are used as sources of the parameters indicates that many individuals are likely to be taken many times, and the potential for population scale effects to result from small behavioral changes becomes significant.

Assuming spherical spreading out to 2 km followed by cylindrical spreading, B=120, K=45 and A=10 (the Navy values), most takes occur where the received level is greater than 157 dB re 1 μPa and the distance is less than 13 km. With stringent criteria for what constitutes a take derived in the reanalysis (B=120, K=20, A=10), most takes would occur where the received level is below 145 db re 1 μPa and the distance is over 43 km. With the average values calculated here (B=80, K=45, and assuming A=10), most takes would occur where the received level is below 135 dB re 1 μPa and the distance is over 80 km. These values predict over 100 times more takes as the Navy values, as well as the need for very different approaches to mitigation.

21

The Navy recognizes that the occurrence of conditional effects is important to assessing the impact of noise exposure. As such effects are the result of both received levels and environmental conditions, permit conditions will be important in determining these. The potential for conditional harm suggests using mitigation to limit the potential for actual harm. E.g., the risk of causing stranding can be minimized by restricting exercises to areas far from shore. Limiting the duration of exposure can limit the consequences of long-term displacement, risk of injury from prolonged flight, and limit cumulative effects. The risk of causing gas bubble lesions can be minimized by restricting use near canyons, for extended periods of time, and limiting the number of sources. The absolute effects can be minimized by conducting exercises in areas where population density is low, or at times of year when species of concern are absent.

Finally, it will be important to assess the cumulative effects of noise combined with other factors and population status (Wade and Angliss 1997) to assess the likely effects of sonar exercises on marine mammal populations.

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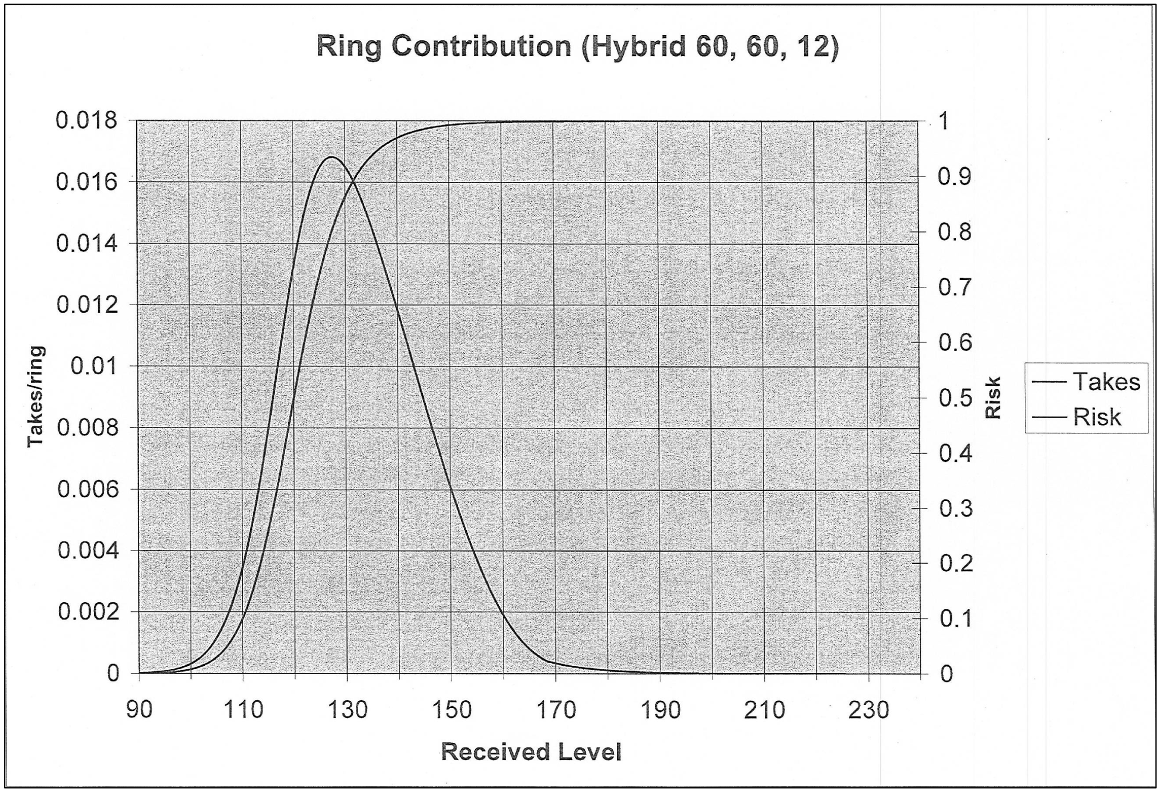
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Takes/ring
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0.016
0.014
0.012
0.01
0.008
0.006
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0.002
0
Risk
1
0.9
0.8
0.7
0.6
0.5
0.4
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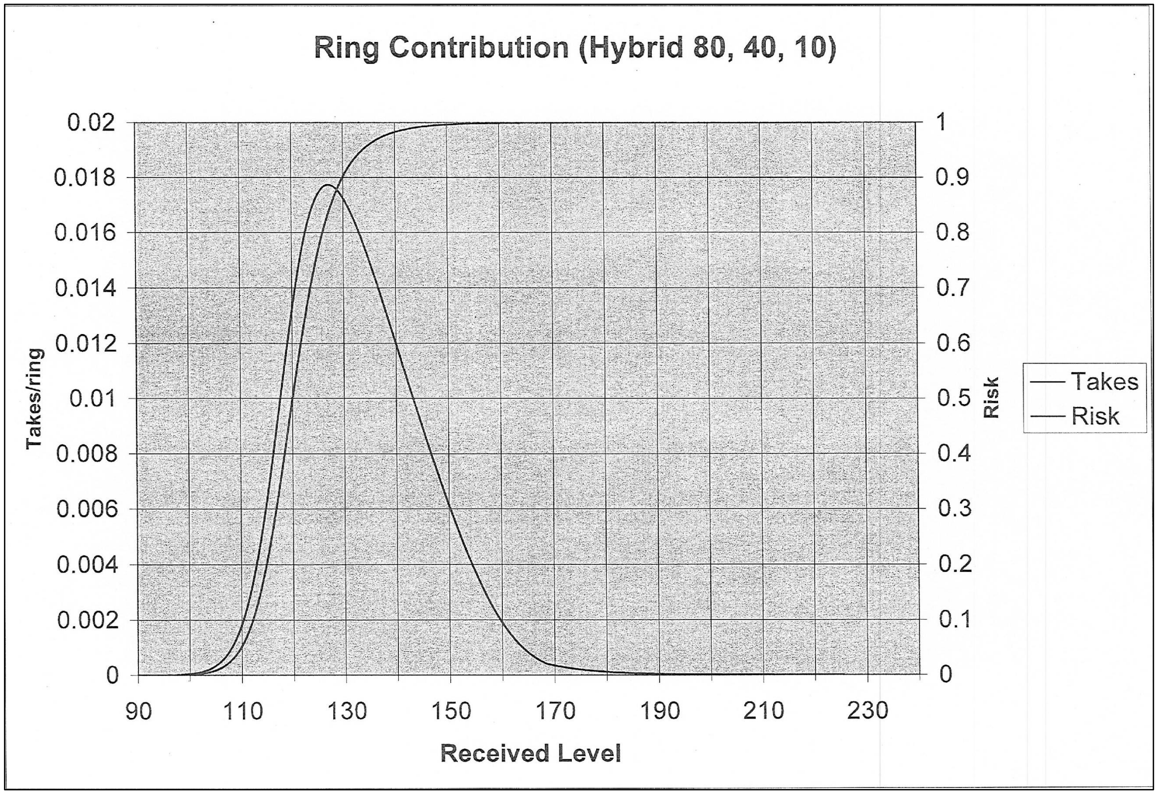
0.1
0
90
110
130
150
170
190
210
230
Received Level
Takes
Risk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0.008
0.006
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0.002
0
Takes/ring
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0.9
0.8
0.7
0.6
0.5
0.4
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Risk
Takes
Risk
90
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190
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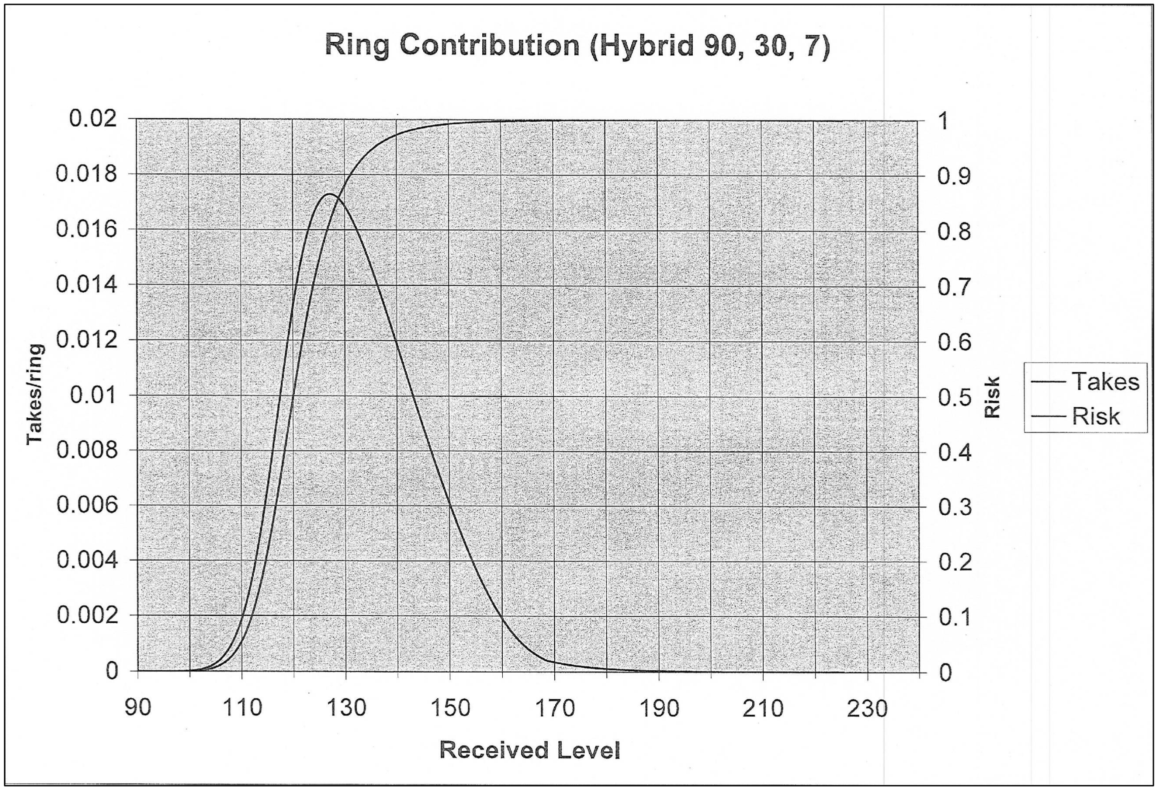
Received Level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0.01
0.008
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0.004
0.002
0
Risk
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0.8
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0.6
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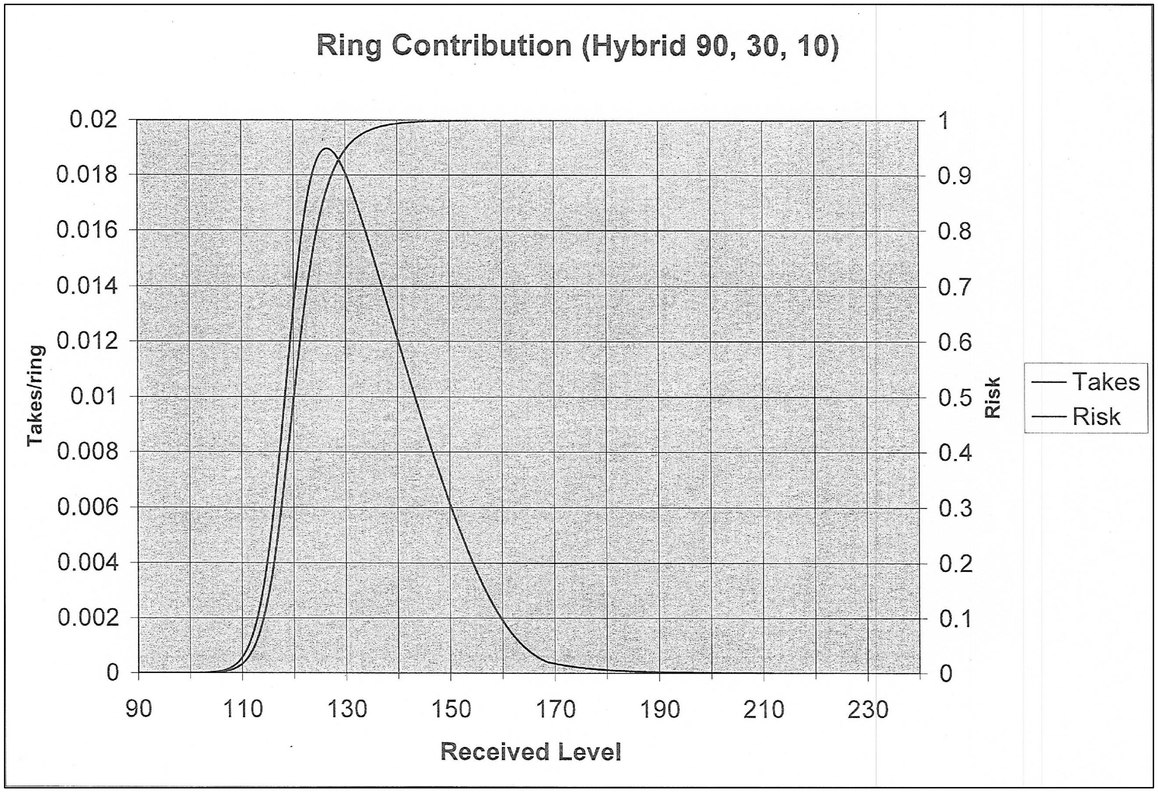
Received Level
Takes
Risk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0.004
0.002
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Risk
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0.8
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170
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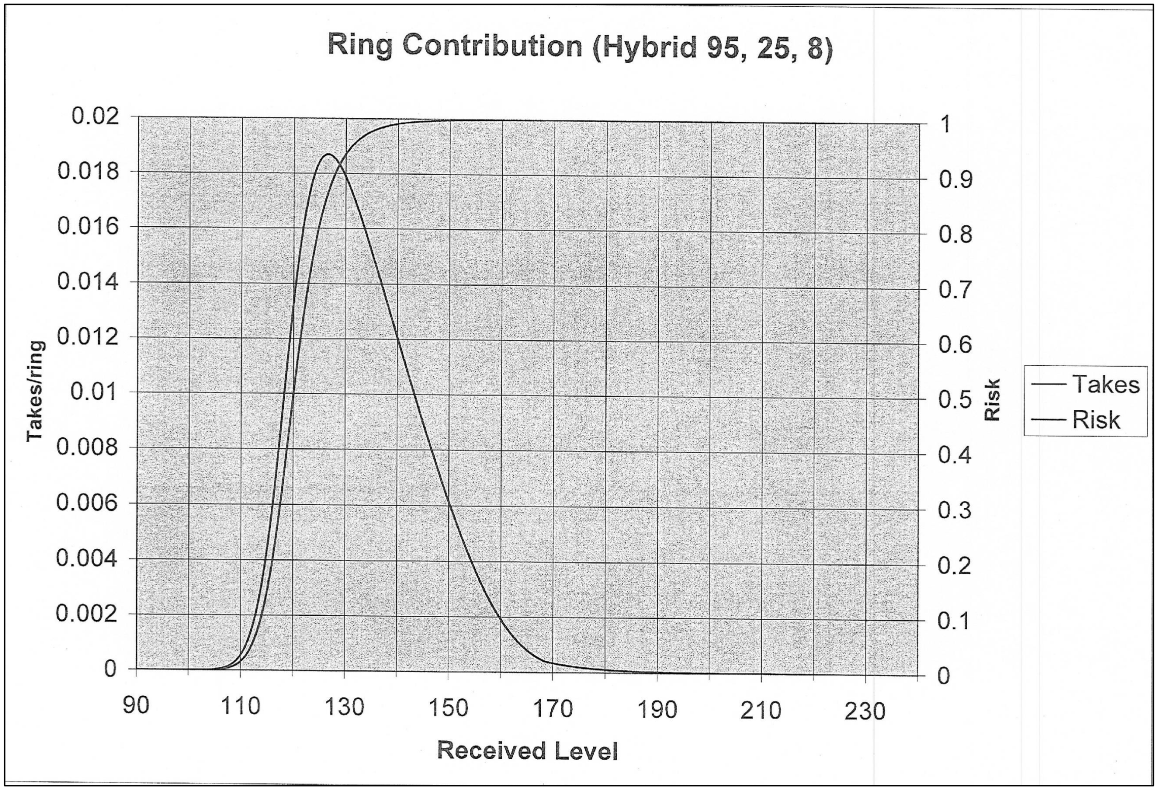
230
Received Level
Takes
Risk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Received Level
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0.006
0.004
0.002
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1
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0.8
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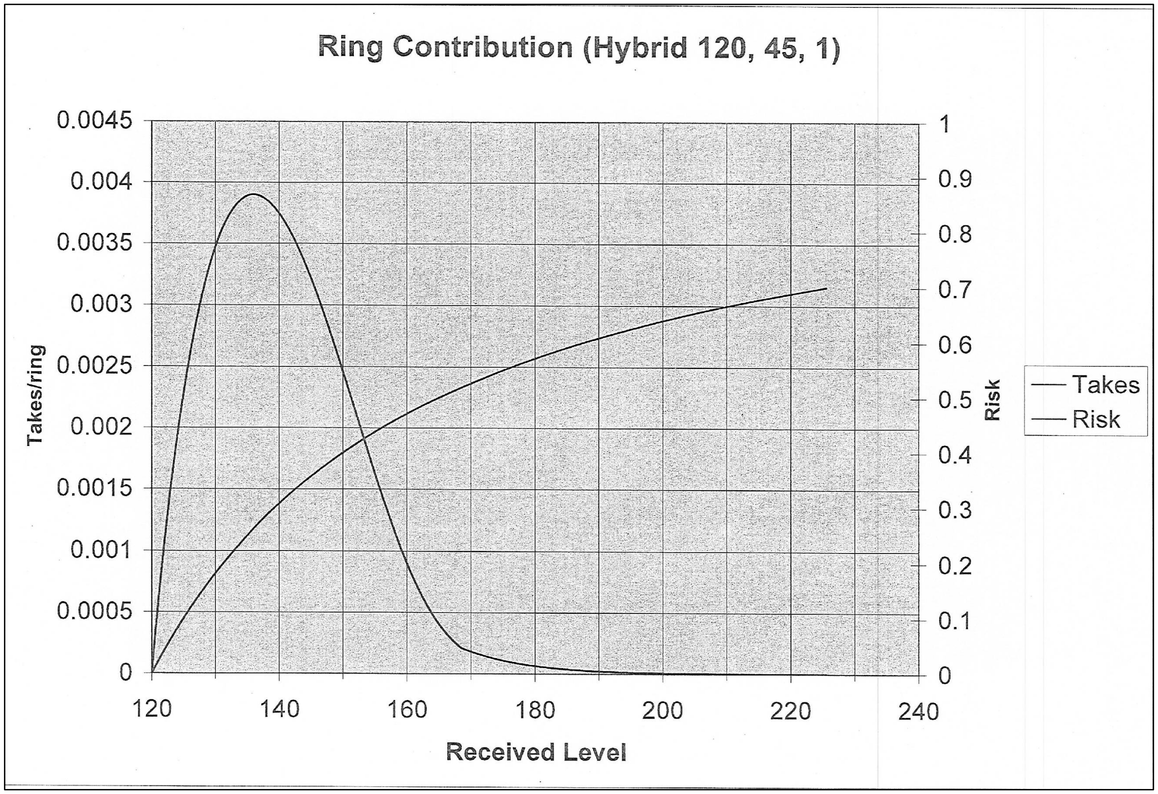
Takes
Risk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0.001
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0
Takes/ring
1
0.9
0.8
0.7
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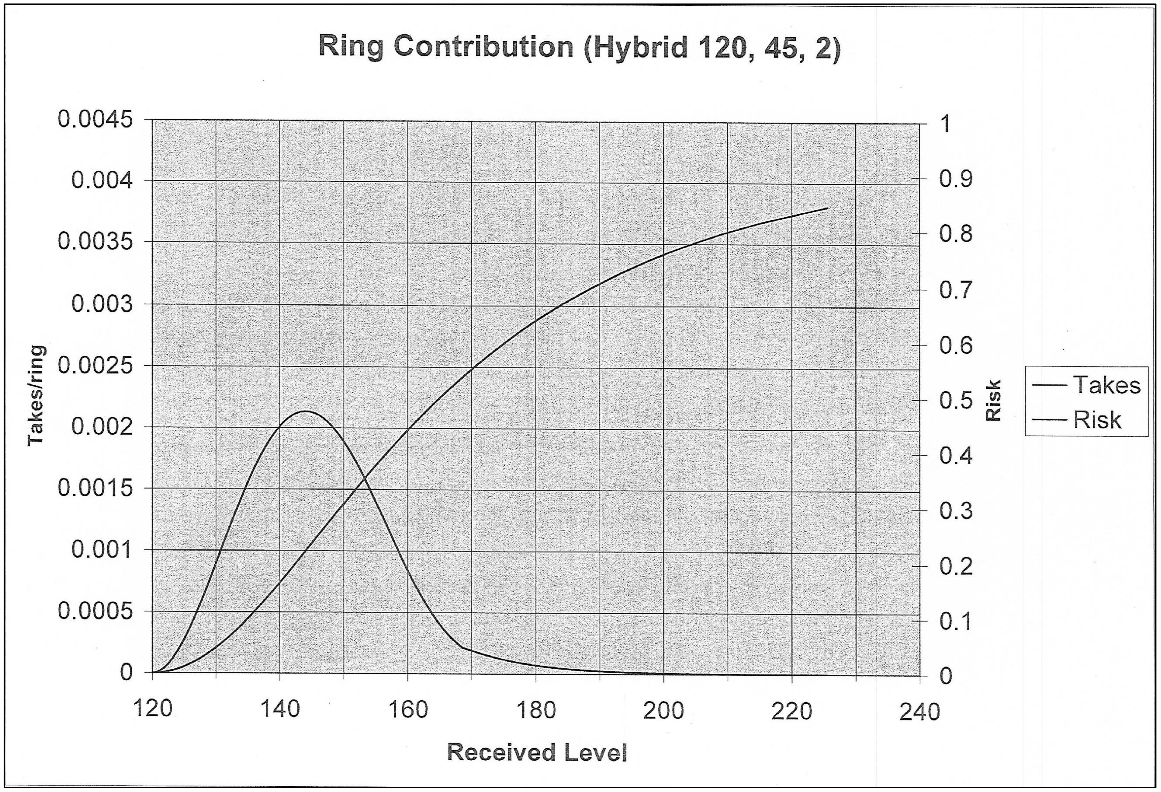
0.1
0
Risk
120
140
160
180
200
220
240
Received Level
Takes
Risk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0.0005
0
Risk
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0.9
0.8
0.7
0.6
0.5
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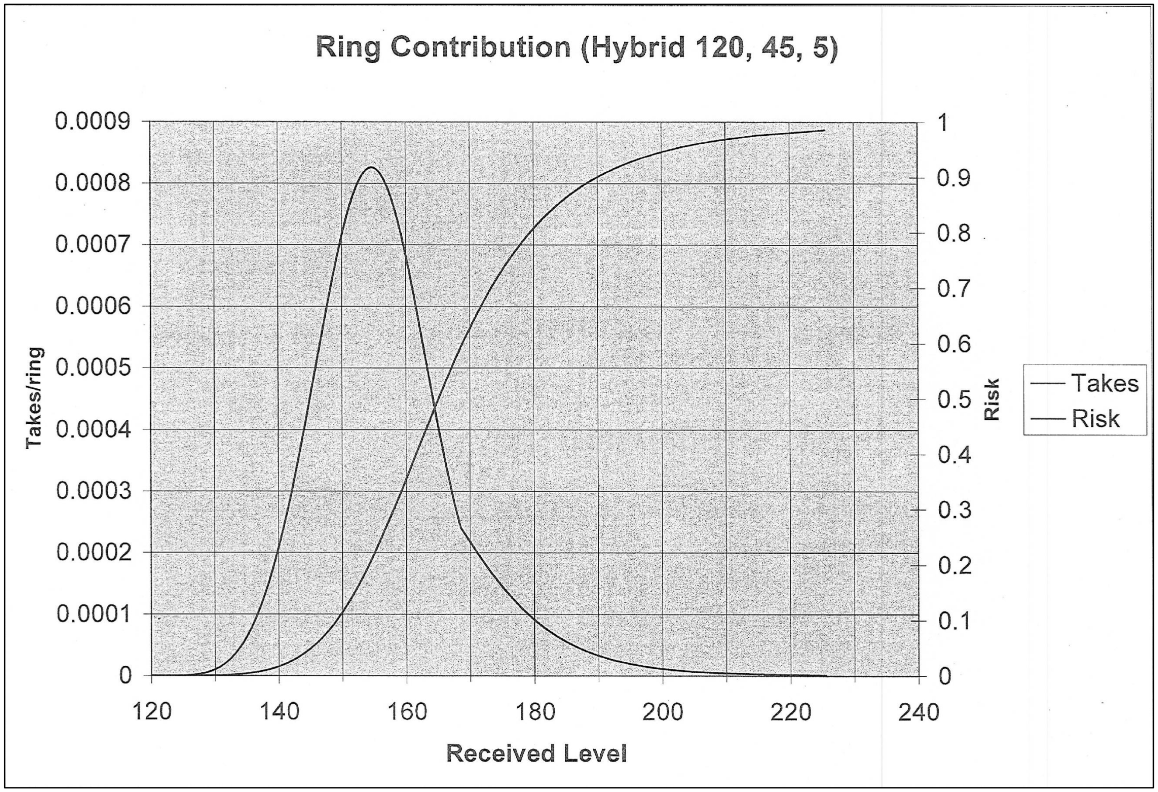
140
160
180
200
220
240
Received Level
Takes
Risk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0.0004
0.0003
0.0002
0.0001
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140
160
180
200
220
240
Received Level
Risk
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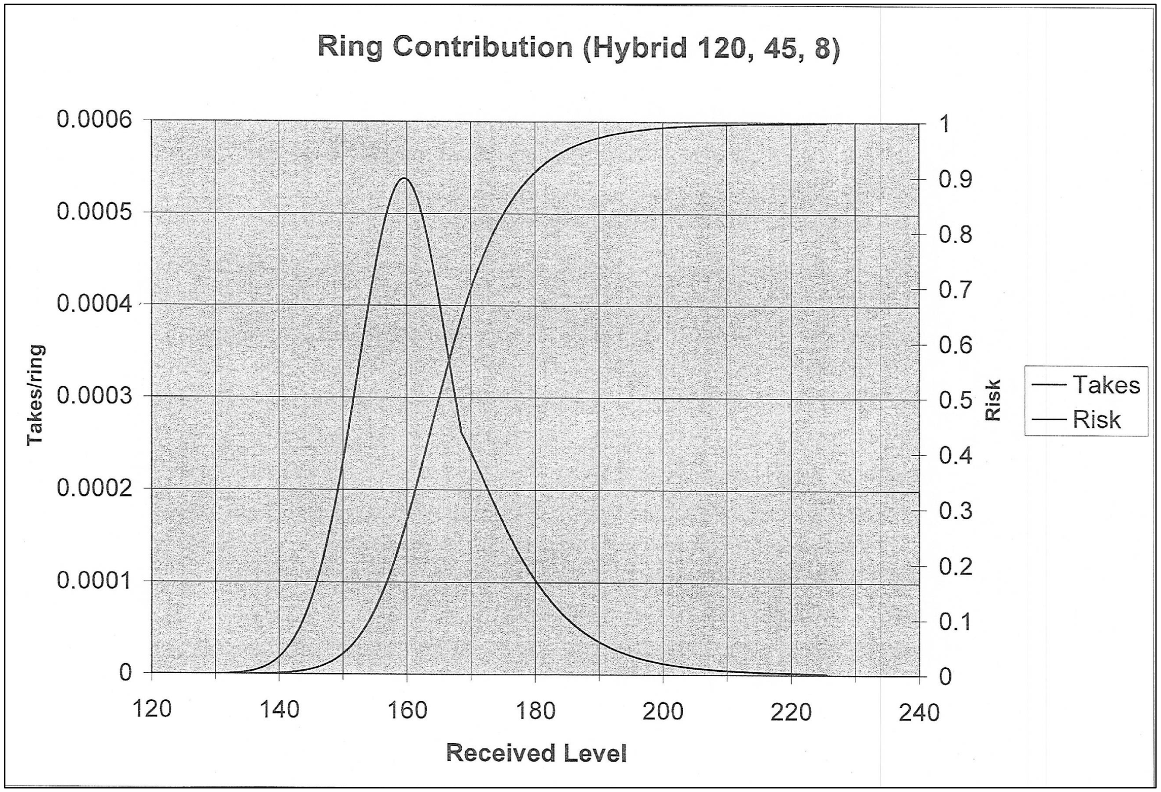
0
Takes
Risk



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0.0003
0.0002
0.0001
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200
220
240
Received Level
Risk
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0.8
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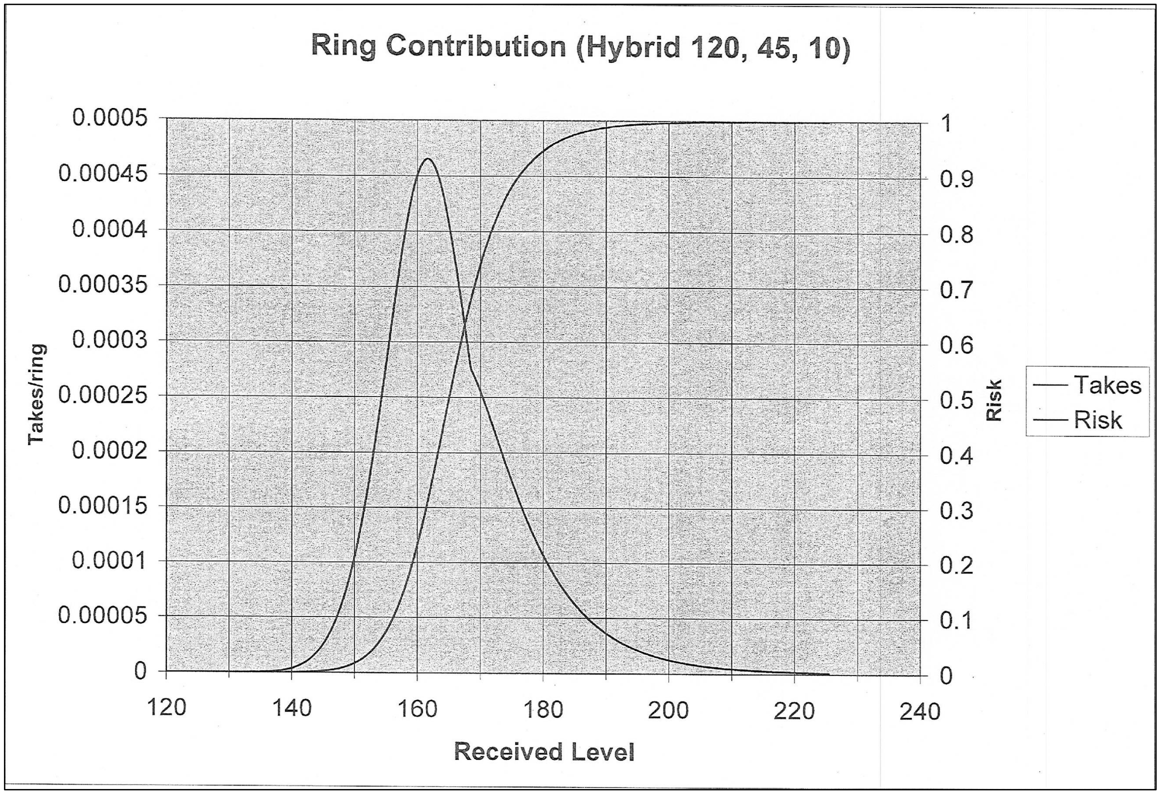
0.6
0.5
0.4
0.3
0.2
0.1
0
Takes
Risk



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0.00035
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0.00025
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0.00015
0.0001
0.00005
0
Risk
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0.9
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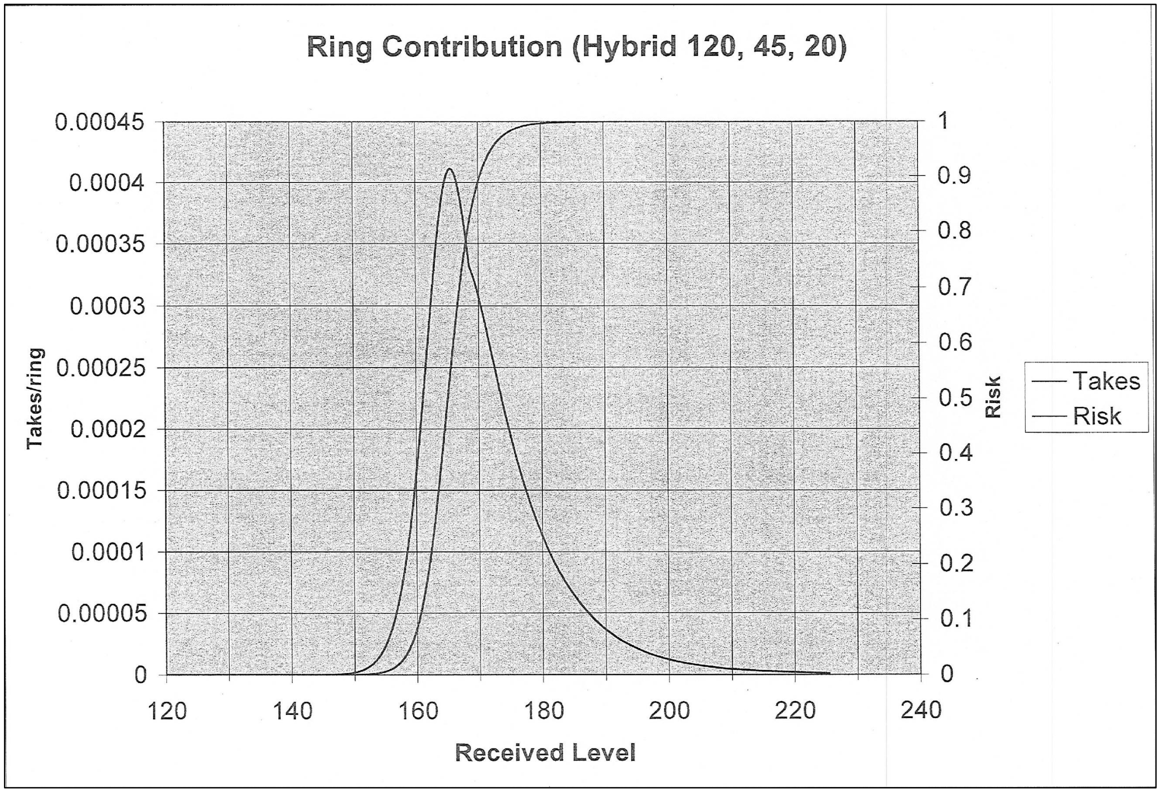
Received Level
Takes
Risk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0.00025
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0.0001
0.00005
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Risk
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0.8
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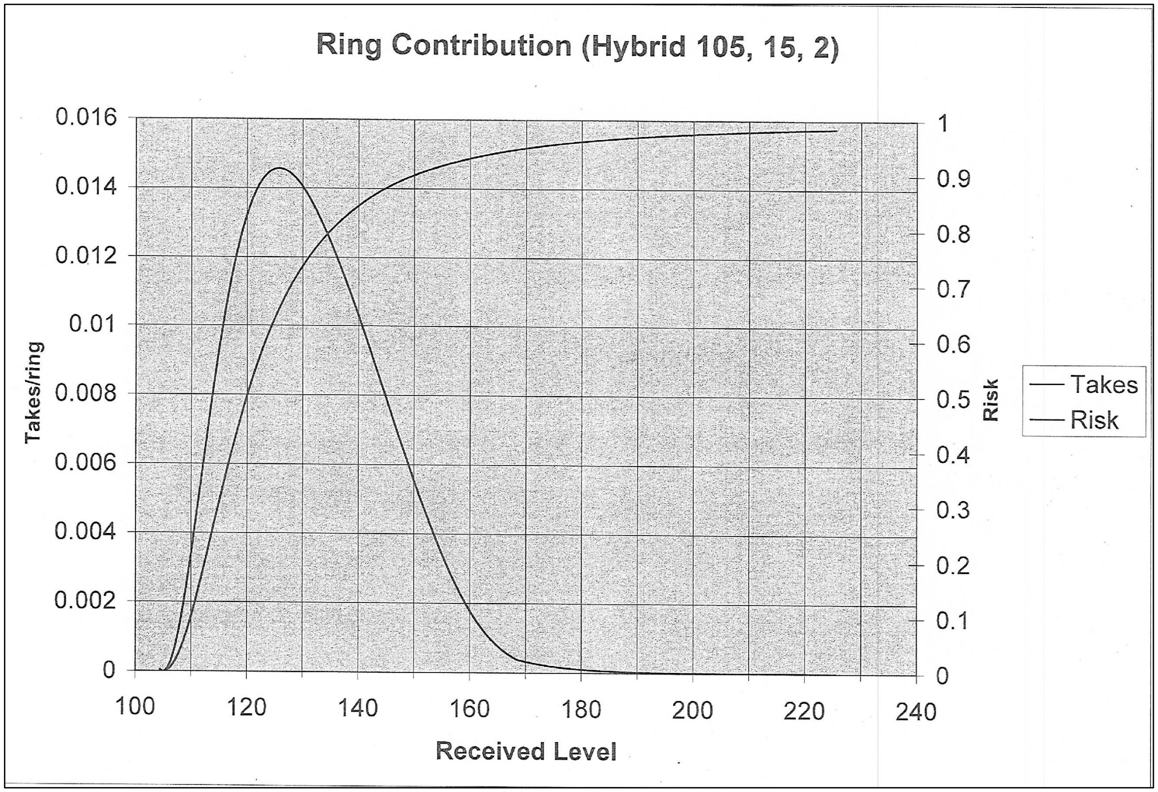
Received Level
Takes
Risk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Takes/ring
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0.012
0.01
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0.006
0.004
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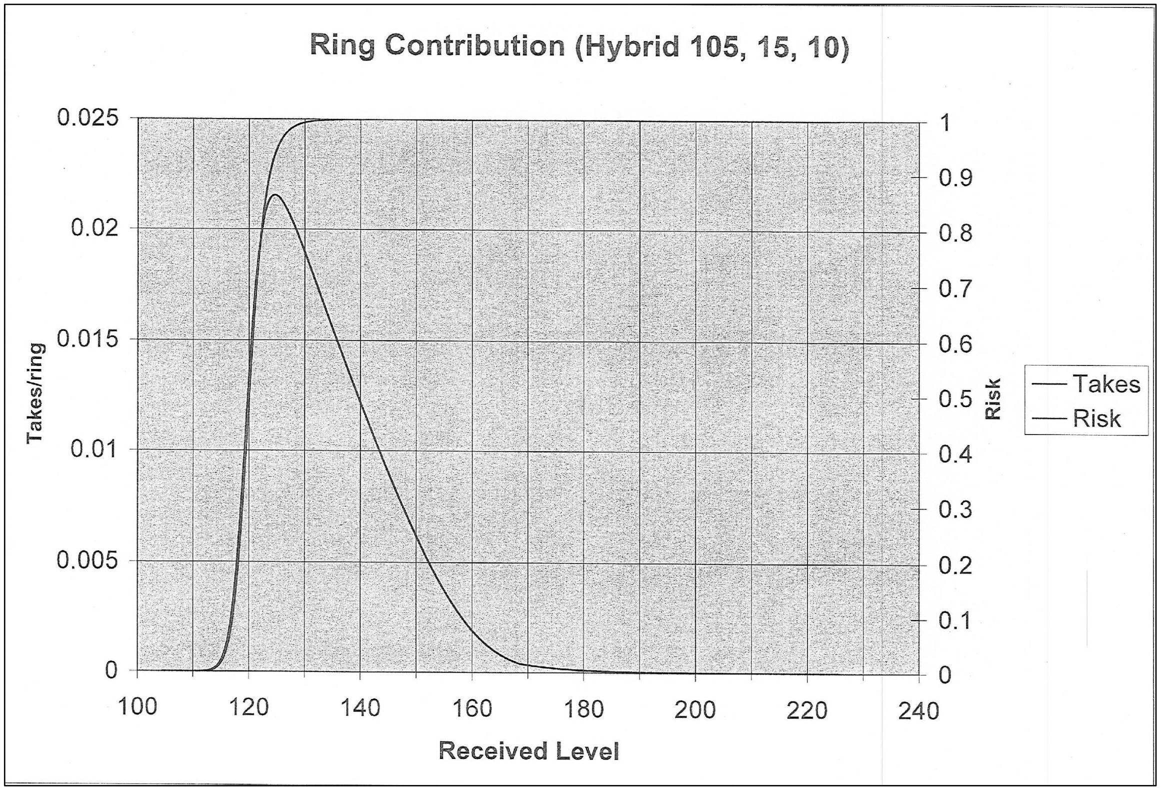
Received Level
Takes
Risk



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Takes/ring
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Risk
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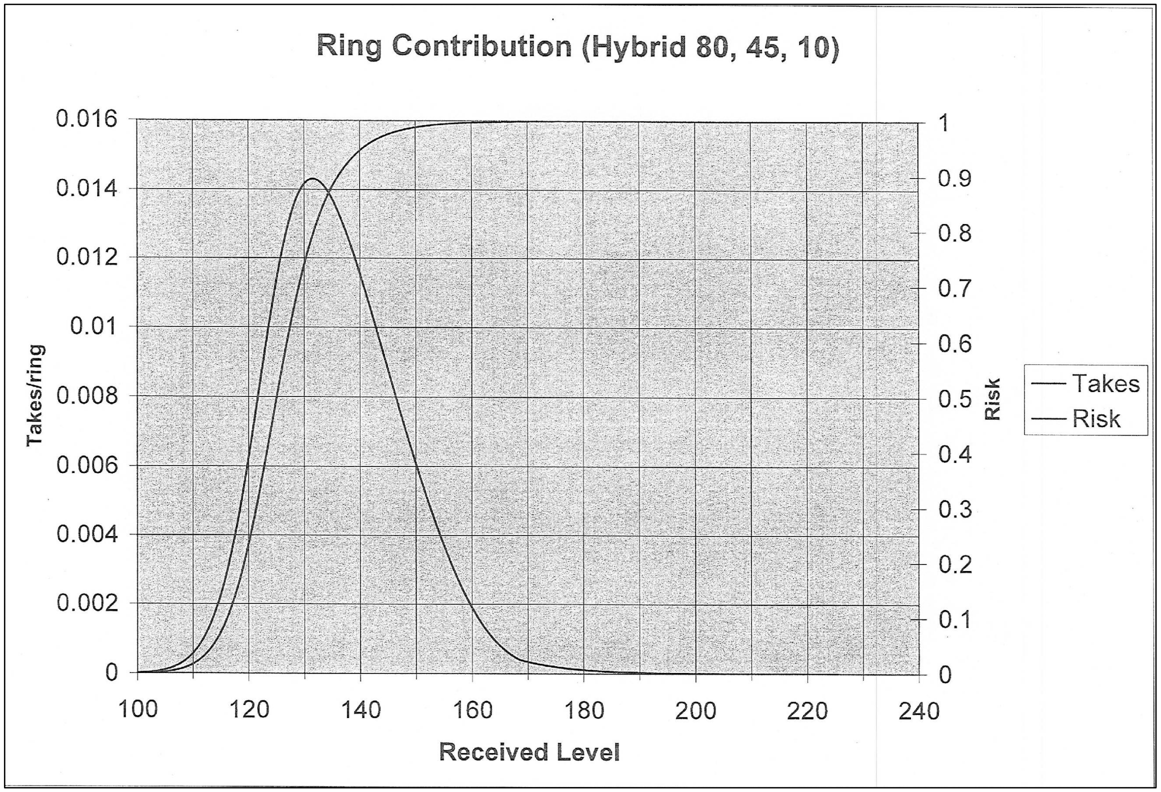
Received Level
Takes
Risk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Received Level
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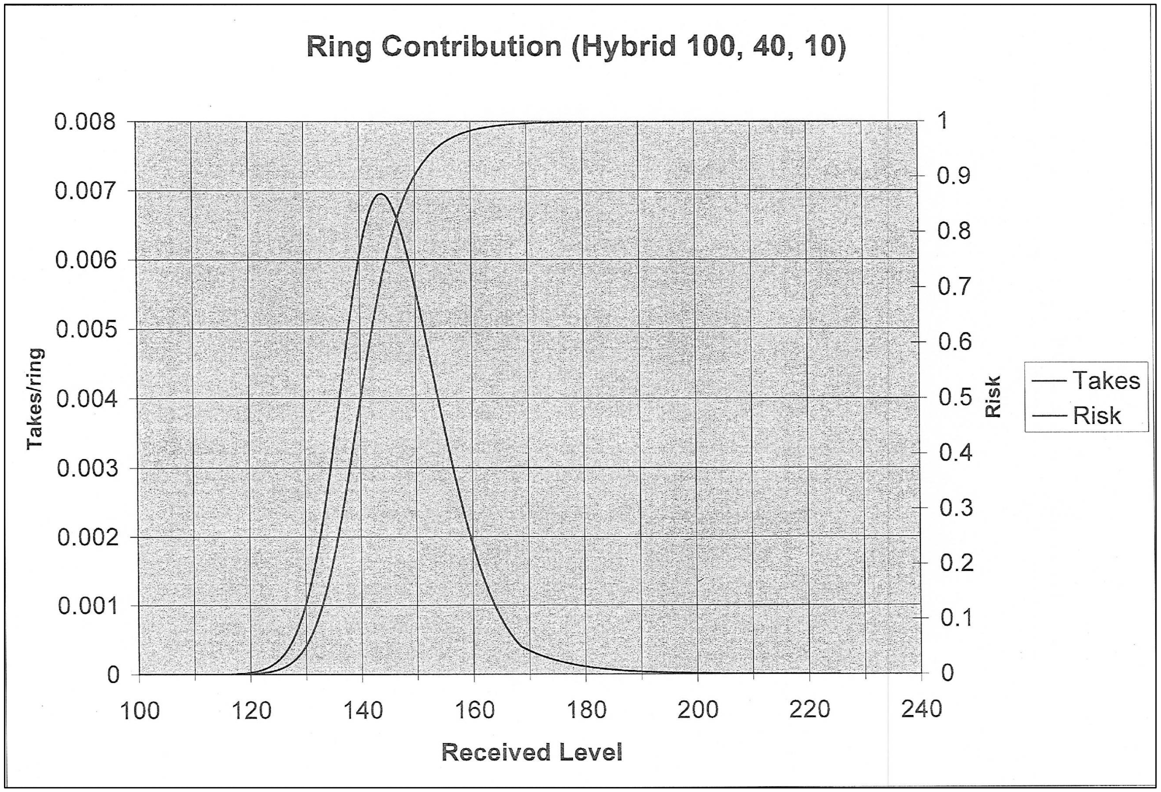
Takes
Risk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0
Risk
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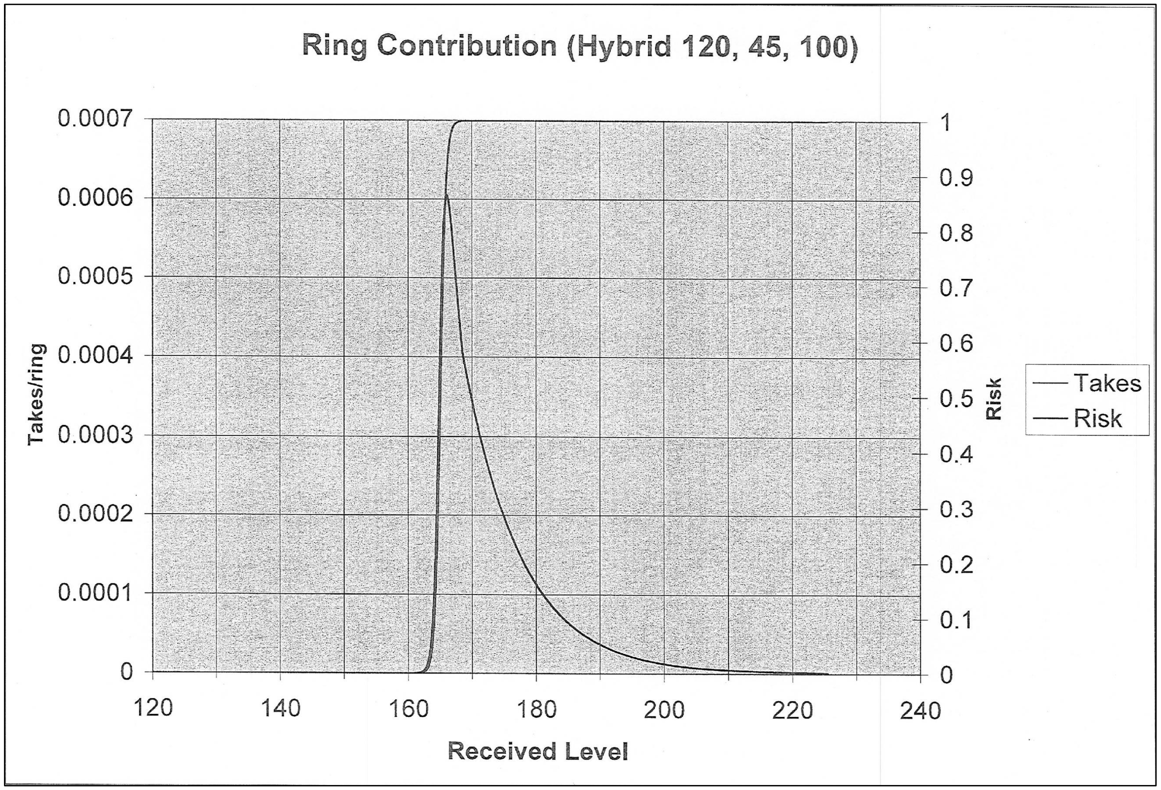
Received Level
Takes
Risk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Takes/ring
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0.0002
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Received Level
Risk
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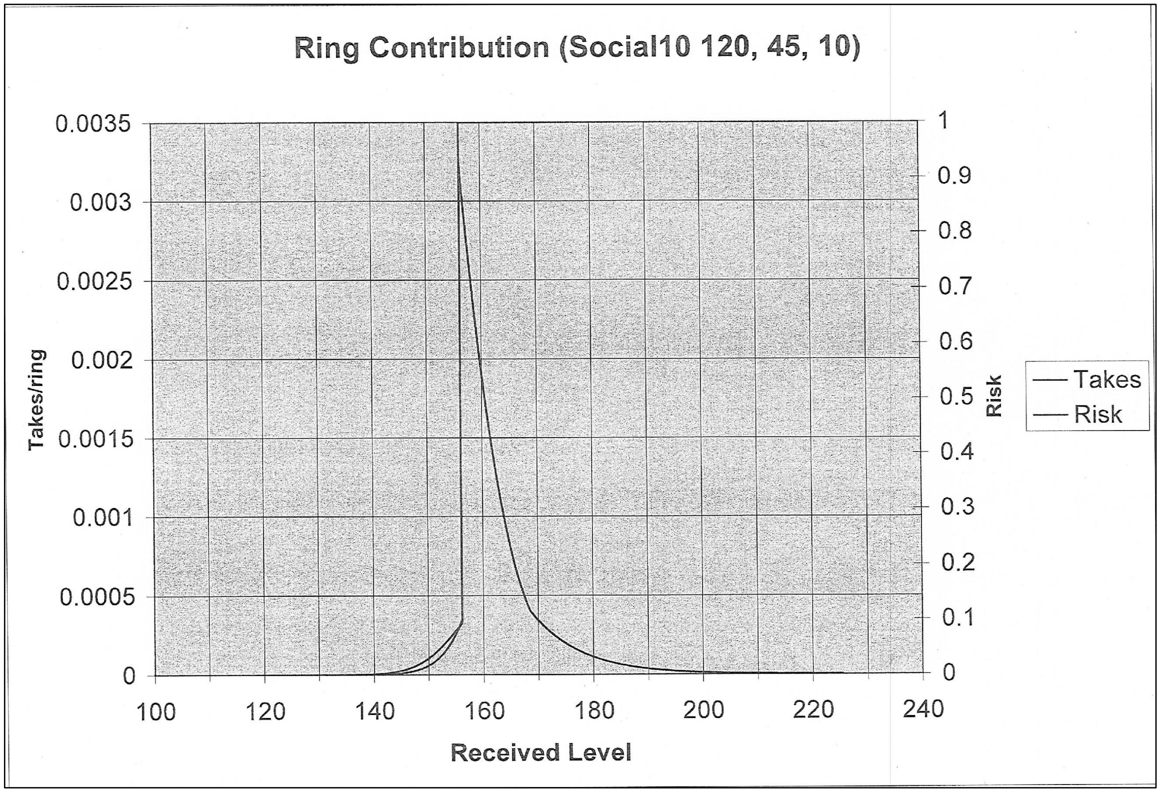
Takes
Risk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0.001
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1
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0.8
0.7
0.6
0.5
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Risk
Takes
Risk
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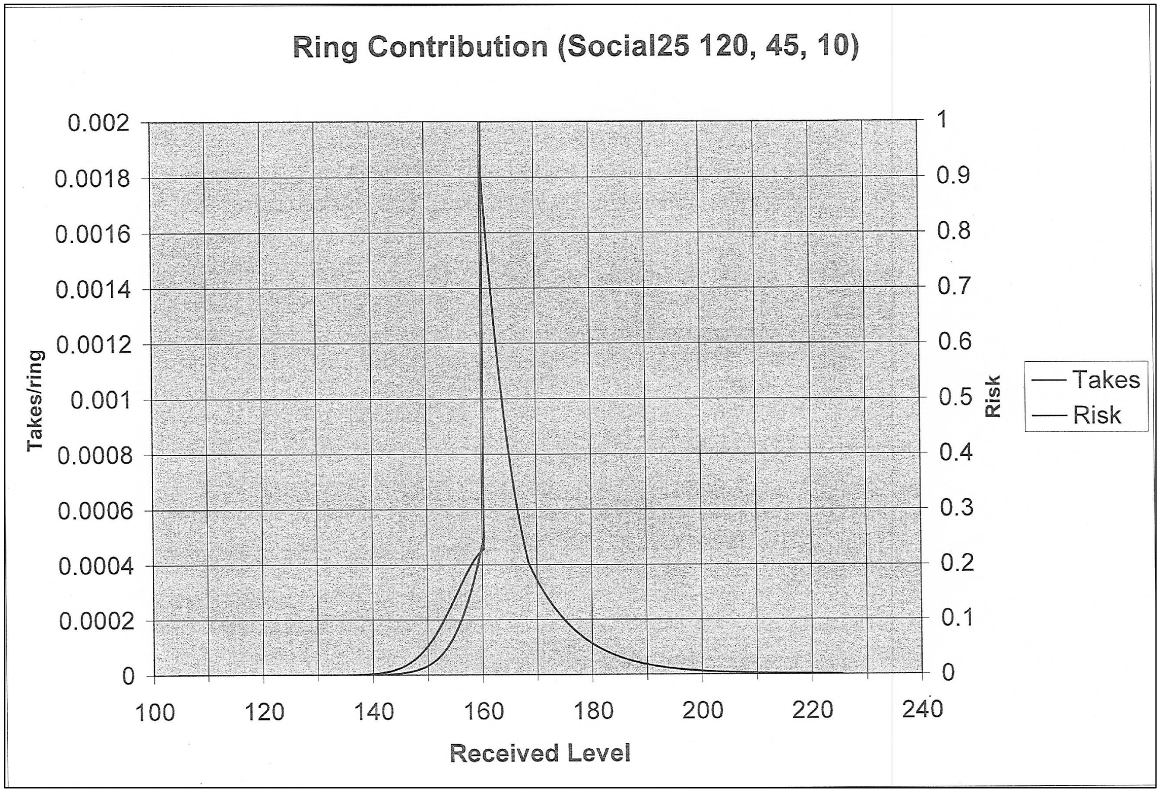
Received Level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0.0018
0.0016
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0.0012
0.001
0.0008
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0.0004
0.0002
0
Risk
1
0.9
0.8
0.7
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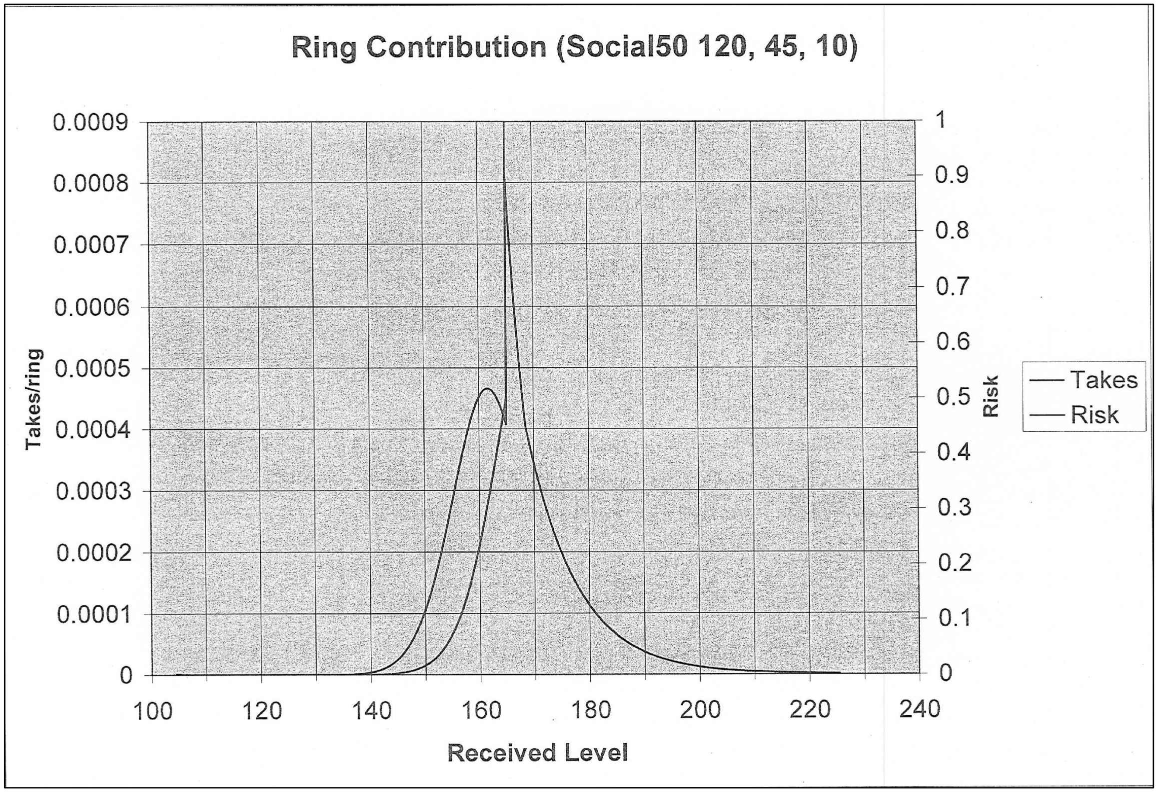
Received Level
Takes
Risk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Risk
Takes
Risk
100
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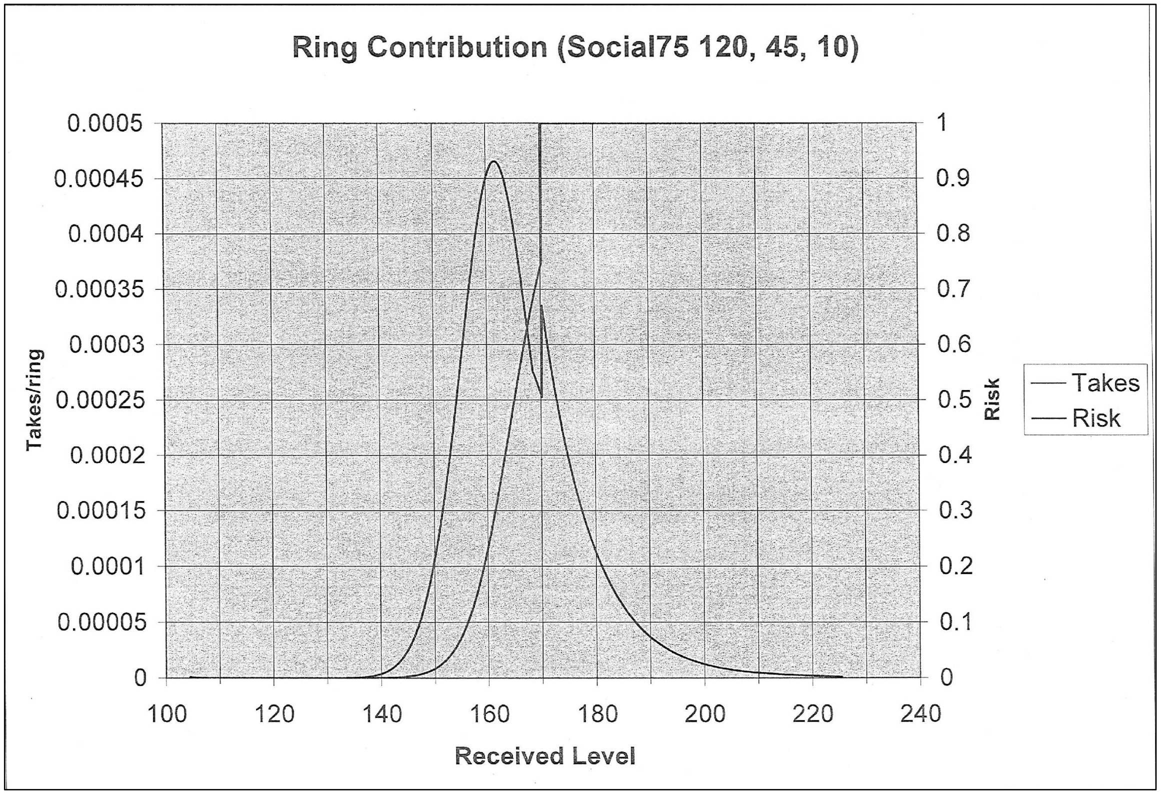
240
Received Level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100
120
140
160
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220
240
Received Level
Takes
Risk

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APPENDIX J

ESSENTIAL FISH HABITAT AND CORAL REEF ASSESSMENT FOR THE MARIANA ISLANDS RANGE COMPLEX EIS/OEIS

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ESSENTIAL FISH HABITAT AND CORAL REEF ASSESSMENT FOR THE MARIANA ISLANDS RANGE COMPLEX EIS/OEIS

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TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

APPENDICES

ACRONYMS AND ABBREVIATIONS

°	Degree
°C	degrees Celsius
AAV	Amphibious Assault Vehicle
AAW	Anti-Air Warfare
ACM	Air Combat Maneuver
AGL	Above Ground Level
AIW	Antarctic Intermediate Water
AMW	Amphibious Warfare
ASUW	Anti-Surface Warfare
ASW	Antisubmarine Warfare
AT	Anti-Terrorism
ATCAA	Air Traffic Control Assigned Airspace
BMUS	bottomfish management unit species
BOMBEX	Bombing Exercise
C2	Command and Control
cm	centimeter
CCD	carbonate compensation depth
CDW	Circumpolar Deep Water
CHCRT	Currently Harvested Coral Reef Taxa
CIWS	Close In Weapon System
CMUS	crustacean management unit species
CNMI	Commonwealth of the Northern Mariana Islands
COMNAVMARIANAS	U.S. Naval Forces Marianas
COTS	crown-of-thorns starfish
CPX	Command Post Exercise
CRED	Coral Reef Ecosystem Division
CRE	coral reef ecosystem
CRRC	combat rubber raiding craft
CSAR	Combat Search and Rescue
DAWR	Division of Aquatic and Wildlife Resources
dB	decibel
DoD	Department of Defense
DoD REP	DoD Representative Guam, CNMI, FSM, and Republic of Palau
DoN	Department of Navy
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EIS/OEIS	Environmental Impact Statement/Overseas Environmental Impact Statement
EMATT	Expendable Mobile Training Targets
EMUA	Exclusive Military Use Area
ENSO	El Niño Southern Oscillation
EO	Executive Order
EOD	Explosive Ordnance Disposal
EPA	Environmental Protection Agency
ERA	Ecological Reserve Area
ESG	Expeditionary Strike Group
EXTORP	Exercise Torpedo
FAD	Fish Aggregating Devices
FAST	Floating At Sea Target
FDM	Farallon de Medinilla
FIREX	Fire Support
FMP	Fishery Management Plan
FP	Force Protection
FSM	Federated States of Micronesia
FTX	Field Training Exercise
ha	hectare
HAPC	Habitats Areas of Particular Concern
ft	foot/feet
ft^2	square foot
ft^3	cubic foot
g	gram
GEPA	Guam Environmental Protection Agency
GUNEX	Gunnery Exercise
Hz	Hertz
IAH	Inner Apra Harbor
JFCOM	Joint Forces Command
lbs.	pounds
kHz	kilohertz
km	kilometer
km^2	square kilometer
kph	km per hour
LAV	light armored vehicle
LBA	leaseback area
LCAC	Landing Craft Air Cushioned
LCPW	Lower Circumpolar Water
LFA	Low Frequency Active
m	meter
m^2	square meter
m^3	cubic meter
mg	milligram
m/sec	meters per second
µm	micron
µPa	micro pascal
ml/l	milliliters per liter
mm	millimeters
MCMEX	Mine Exercise
MFA	medium-frequency active sonar
MIRC	Mariana Islands Range Complex
MIW	Mine Warfare
MMU	minimum mapping unit
MRA	Marine Resources Assessment
MOUT	Military Operations in Urban Terrain
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
MSS	Mobile Security Squadrons
MUS	management unit species
NCA	National Command Authority
NCCOS	National Centers for Coastal Ocean Science
NEC	North Equatorial Current
NEO	Non-Combatant Evacuation Order
NEW	net explosive weight
nm	nautical mile
nm^2	square nautical mile
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPDW	North Pacific Deep Water
NPEC	North Pacific Equatorial Current
NPSG	North Pacific Subtropical Gyre

NSW	Naval Special Warfare
OAH	Outer Apra Harbor
OPAREA	Operations Area
OTB	Over the Beach
PDO	Pacific Decadal Oscillation
Potentially	PHCRT Harvested Coral Reef Taxa
PMUS	pelagic management unit species
ppt	parts per thousand
PTS	permanent threshold shift
PUTR	Portable Undersea Tracking Range
RCMP	Range Complex Management Plan
RDT&E	Research, Development, Test, and Evaluation
re 1 µPa-m	referenced to 1 micropascal at 1 meter
REXTORP	Recoverable Exercise Torpedo
RHIB	Rigid Hull Inflatable Boat
S&R	Surveillance and Reconnaissance
SAR	search and rescue
SCD	silicate compensation depth
SFA	Sustainable Fisheries Act
SHAREM	Ship ASW Readiness and Evaluation Measuring
SINKEX	Sinking Exercise
SLP	sea level pressure
SST	sea surface temperature
STOM	Ship to Objective Maneuver
STW	Strike Warfare
SURTASS	Surveillance Towed Array Sensor System
SUW	Surface Warfare
TRACKEX	Tracking Exercise
TORPEX	Torpedo Exercise
TTS	temporary threshold shift
UAV	Unmanned Aerial Vehicles
UJTL	Universal Joint Task List
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USWEX	Undersea Warfare Exercise
UUV	unmanned underwater vehicles
UXO	Unexploded Ordnance
VBSS	Visit Board Search and Seizure
WPRFMC	Western Pacific Regional Fishery Management Council

EXECUTIVE SUMMARY

The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) set forth new mandates for the National Marine Fisheries Service (NMFS), eight regional fishery management councils (Councils), and other federal agencies to identify and protect important marine and anadromous fish habitat. The Councils (with assistance from NMFS) are required to delineate Essential Fish Habitat (EFH) for all managed species. Federal agencies which fund, permit, or carry out activities that may adversely impact EFH are required to consult with NMFS regarding potential impacts on EFH, and respond in writing to NMFS recommendations.

The MSFCMA defines EFH as those waters and substrates necessary (required to support a sustainable fishery and the managed species) to fish for spawning, breeding, feeding, or growth to maturity (i.e., full life cycle) (16 U.S.C. Section 1802). These waters include aquatic areas and their associated physical, chemical, and biological properties used by fish, and may include areas historically used by fish. Substrate types include sediment, hardbottom, structures underlying the waters, and associated biological communities.

Since coral reefs are considered EFH, this EFH Assessment also includes a Coral Reef Assessment in accordance with Executive Order (EO) 13089 Coral Reef Protection and subsequent guidance documents from the Department of Defense (DoD) and the Navy. EO 13089 on Coral Reef Protection (63 FR 32701) 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." It is DoD policy to protect the U.S. and International coral reefs and to avoid impacting coral reefs to the maximum extent possible.

Military activities in the Mariana Islands Range Complex (MIRC) occur on the ocean surface, under the ocean surface, in the air, and on land, extending from the waters south of Guam to north of Pagan (CNMI), and from the Pacific Ocean east of the Mariana Islands to the Philippine Sea to the west; encompassing 450,187 square nautical miles (nm^2) of open ocean and littorals. The area is used to conduct training activities, training, and evaluation of military hardware, personnel, tactics, munitions, explosives, and electronic combat systems.

EFH species within the MIRC 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/Habitats Areas of Particular Concern (HAPC) designations are provided.

Taking an ecosystem-based management approach, the proposed training activities in the MIRC have the potential to result in direct and indirect impacts to EFH and managed species, such as physical disruption of open ocean habitat, physical destruction or adverse modification of benthic habitats, alteration of water or sediment quality from expended materials or discharge, and cumulative impacts. The ecosystem-based EFH assessment focuses on activities and impacts common to training activities, but also discusses individual exercises/training activities that have unique aspects such as MISSILEX, BOMBEX, Expeditionary Assault, TORPEX, and SINKEX.

Potential ecosystem impacts from expended material (e.g., flares, chaff, dye, torpedo accessories, sunken targets and vessels) could result from exposure to toxic chemicals, through contact with or ingestion of expended materials, and from entanglement. However, the small quantity of material expended (ranging from 0.8 pounds per nm^2 for the No Action Alternative to 1.3 pounds per nm^2 for Alternative 2), the rapid dilution of dissolved constituents, the relatively non-toxic nature of the expended materials, and its eventual encrustation and incorporation into the sediments would minimize impacts to resident marine communities. From an ecosystem-based management perspective, bioaccumulation of toxic metals and organic compounds to higher-order food chain species is not expected. Expended material would not significantly disturb the sea floor or compromise habitat components that support critical ecosystem functions such as feeding, resting, sheltering, reproduction, or migration of managed species.

With respect to ecosystem structure and function, underwater detonations and weapons firing could disrupt habitats, release hazardous chemical by-products, kill or injure marine life, affect hearing organs, modify behavior, mask biologically-relevant sounds, induce stress, and have indirect effects on prey species and other components of the food web. Initial concentrations of explosion by-products are not hazardous to marine life and would not accumulate because training exercises are widely dispersed over time and space. A small number of fish would be killed by shock waves from explosions or would be injured and could subsequently die or suffer greater rates of predation. Beyond the range of direct, lethal or sub-lethal impacts to fish, minor, short-term behavioral reactions would not be ecologically significant or substantially impact ecosystem structure or function with respect to survival, growth, or reproduction. No lasting adverse effect as a result of underwater detonations or weapons training on prey availability or on the food web is expected.

Most bombs and missiles used in MIRC exercises would not have explosive warheads. The shock force from dummy bombs and missiles hitting the sea surface could result in a limited number of fish kills or injuries, and minor acoustic displacement, but would not substantially affect local species and habitats or ecosystem structure and function. Although few fish would be directly struck by Naval gun fire, explosive 5-inch gunnery rounds could kill or injure a small proportion of any nearby assemblage. Behavioral reactions of fish would extend over a larger area. However, adverse regional ecosystem-based management consequences are not anticipated.

With respect to ecosystem structure and function, most fish species would be able to detect mid frequency sonar at the lower end of its range. Short-term behavioral responses such as startle and avoidance may occur, but are not likely to adversely affect indigenous fish communities. Auditory damage from sonar signals is not expected and there is no indication that non-impulsive acoustic sources result in fish mortality.

Under Alternatives 1 and 2, in addition to accommodating the No Action Alternative will be the addition of increased training activities and capability requirements for personnel and platforms, to an overall increase in the number and types of activities such as major exercises and development of new Portable Undersea Tracking Range (PUTR) capabilities. Due to the temporal and spatial variation of major range events which would include multiple training activities over a large area, and avoidance of HAPCs, they are not expected to result in long-term adverse impacts to EFH. Although some individual activities could affect EFH or managed species at the individual level due to localized impacts, these impacts are not additive when considering major range events or the increase in tempo. Therefore, no long-term adverse impacts to EFH would be expected from major range events or increased tempo.

The assessment concludes that based on the limited extent, duration, and magnitude of potential impacts from MIRC training and testing, there would not be adverse impacts to ecosystem structure and function or critical ecosystem services relative to EFH or managed species. From an ecosystem-based management perspective, range training activities would not adversely contribute to cumulative impacts on present or future uses of the area.

1.0 BACKGROUND

1.1 ESSENTIAL FISH HABITAT ASSESSMENT

The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) set forth new mandates for the National Marine Fisheries Service (NMFS), eight regional fishery management councils (Councils), and other federal agencies to identify and protect important marine and anadromous fish habitat. The Councils (with assistance from NMFS) are required to delineate Essential Fish Habitat (EFH) for all managed species. Federal agencies which fund, permit, or carry out activities that may adversely impact EFH are required to consult with NMFS regarding potential impacts on EFH, and respond in writing to NMFS recommendations.

The MSFCMA defines EFH as those waters and substrates necessary (required to support a sustainable fishery and the managed species) to fish for spawning, breeding, feeding, or growth to maturity (i.e., full life cycle) (16 U.S.C. Section 1802). These waters include aquatic areas and their associated physical, chemical, and biological properties used by fish, and may include areas historically used by fish. Substrate types include sediment, hardbottom, structures underlying the waters, and associated biological communities.

Since coral reefs are considered EFH, this EFH Assessment also includes a Coral Reef Assessment in accordance with Executive Order (EO) 13089 Coral Reef Protection and subsequent guidance documents from the Department of Defense (DoD) and the Navy. EO 13089 on Coral Reef Protection (63 FR 32701) 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.” It is DoD policy to protect the U.S. and International coral reefs and to avoid impacting coral reefs to the maximum extent possible.

The Navy adopts an ecosystems management strategy on land and sea; a strategy based on the application of appropriate scientific methodologies focused on levels of biological organization which encompass the essential processes, functions and interactions among organisms and their environment. "Ecosystem" means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit. Therefore, the Navy recognizes that impacts to particular resource areas analyzed in the Environmental Impact Statement/Overseas Envirnmental Impact Statement (EIS/OEIS) can affect other resource areas within the ecosystem, and this EFH assessment incorporates and relies on the analysis conducted for other resource sections wherever possible. The ecosystem-based management approach employed in this document also recognizes that humans, with their cultural diversity, are an integral component of ecosystems, and human impacts, like natural disturbances, affect ecosystems on global, regional and local scales.

EFH can consist of both the water column and the underlying surface (e.g. seafloor) of a particular area. Areas designated as EFH contain habitat essential to the long-term survival and health of our nation’s fisheries. Certain properties of the water column such as temperature, nutrients, or salinity are essential to various species. Some species may require certain bottom types such as sandy or rocky bottoms, vegetation such as seagrasses or kelp, or structurally complex coral or oyster reefs.

EFH includes those habitats that support the different life stages of each managed species. A single species may use many different habitats throughout its life to support breeding, spawning, nursery, feeding, and protection functions. EFH encompasses those habitats necessary to ensure healthy fisheries now and in the future.

Habitat Areas of Particular Concern (HAPC) are discrete subsets of EFH that provide extremely important ecological functions or are especially vulnerable to degradation. Councils may designate a specific habitat area as an HAPC based on one or more of the following reasons:

- Importance of the ecological function provided by the habitat
- Extent to which the habitat is sensitive to human-induced environmental degradation
- Whether, and to what extent, development activities are, or will be, stressing the habitat type
- Rarity of the habitat type

The HAPC designation does not confer additional protection or restrictions upon an area, but can help prioritize conservation efforts. Healthy populations of fish require not only the relatively small habitats identified as HAPCs, but also other areas that provide suitable habitat functions. HAPCs alone will not suffice in supporting the larger numbers of fish needed to maintain sustainable fisheries and a healthy ecosystem.

Since coral reefs are considered EFH, this EFH Assessment also includes a Coral Reef Assessment in accordance with Executive Order (EO) 13089 Coral Reef Protection and subsequent guidance documents from the Department of Defense (DoD) and the Navy. EO 13089 on Coral Reef Protection (63 FR 32701) 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.” It is DoD policy to protect the U.S. and International coral reefs and to avoid impacting coral reefs to the maximum extent possible. No concise definition of coral reefs has been promulgated, with regard to regulatory compliance of EO 13089. In general, coral reefs shall consist of tropical reef building Scleractinian and Hydrozoan corals, as well as calcified Octocorals in the families Tubiporidae and Helioporidae, non-calcified Octocorals (soft corals) and Gorgonian corals, all growing in the 0 to 300 foot depth range. Deep water (300 to 3,000 foot [ft] depth range) precious corals and other deep water coral communities will only be considered in the case of a SINKEX, where the vessel might ultimately land on a deep water coral community.

2.0 PROPOSED ACTION

The Department of Defense (DoD) Representative Guam, Commonwealth of the Northern Mariana Islands (CNMI), Federated States of Micronesia (FSM) and Republic of Palau (DoD REP) proposes to improve training activities in the Mariana Islands Range Complex (MIRC) by selectively improving critical facilities, capabilities, and training capacities. The Proposed Action would result in focused critical enhancements and increases in training that are necessary to maintain a state of military readiness commensurate with the national defense mission. The Proposed Action includes minor repairs and upgrades to facilities and capabilities but does not include any military construction requirements. This is part of the periodically scheduled reviews of facilities and capabilities within the MIRC.

The U.S. Military Services (Services) need to implement actions within the MIRC to support current, emerging, and future training and Research, Development, Test, and Evaluation (RDT&E) activities. Training and RDT&E activities do not include combat operations, operations in direct support of combat, or other activities conducted primarily for purposes other than training. These actions will be evaluated in this Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS) and include:

- Maintaining baseline training and RDT&E activities at mandated levels;
- Increasing training activities and exercises from current levels;
- Accommodating increased readiness activities associated with the force structure changes (human resources, new platforms, additional weapons systems, including undersea tracking capabilities and training activities to support Intelligence, Surveillance, and Reconnaissance[ISR]/Strike); and
- Implementing range complex investment strategies that sustain, upgrade, modernize, and transform the MIRC to accommodate increased use and more realistic training scenarios.

This chapter is divided into the following major subsections: Subsection 2.1 provides a detailed description of the MIRC. Subsections 2.2 to 2.5 describe the major elements of the Proposed Action and Alternatives to the Proposed Action. Subsections 2.4 and 2.5 describe Alternative 1 and Alternative 2.

2.1 DESCRIPTION OF THE MIRC[1]

Military activities in MIRC occur (1) on the ocean surface, (2) under the ocean surface, (3) in the air, and (4) on land. Summaries of the land, air, sea, undersea space addressed in this EIS/OEIS are provided in Tables 2-1, 2-2, 2-3, 2-4, and 2-5. To aid in the description of the training areas covered in the MIRC EIS/OEIS, the range complex is divided into major geographic and functional areas. Each of the individual training areas fall into one of three major MIRC training areas:

- The Surface/Subsurface Area consists of all sea and undersea training areas in the MIRC.
- The Airspace Area includes all Special Use Airspace (SUA) in the MIRC.
- The Land Area includes all land training area in the MIRC.

Summaries of the land, air, sea, undersea space addressed in the EIS/OEIS are provided in Appendix A.

1 For the purposes of this EIS, the MIRC and the Study Area are the same geographical areas. The complex consists of the ranges and the ocean areas surrounding the ranges that make up the Study Area. The Study Area does not include the sovereign territory (including waters out to 12 nm) of the Federated States of Micronesia (FSM).

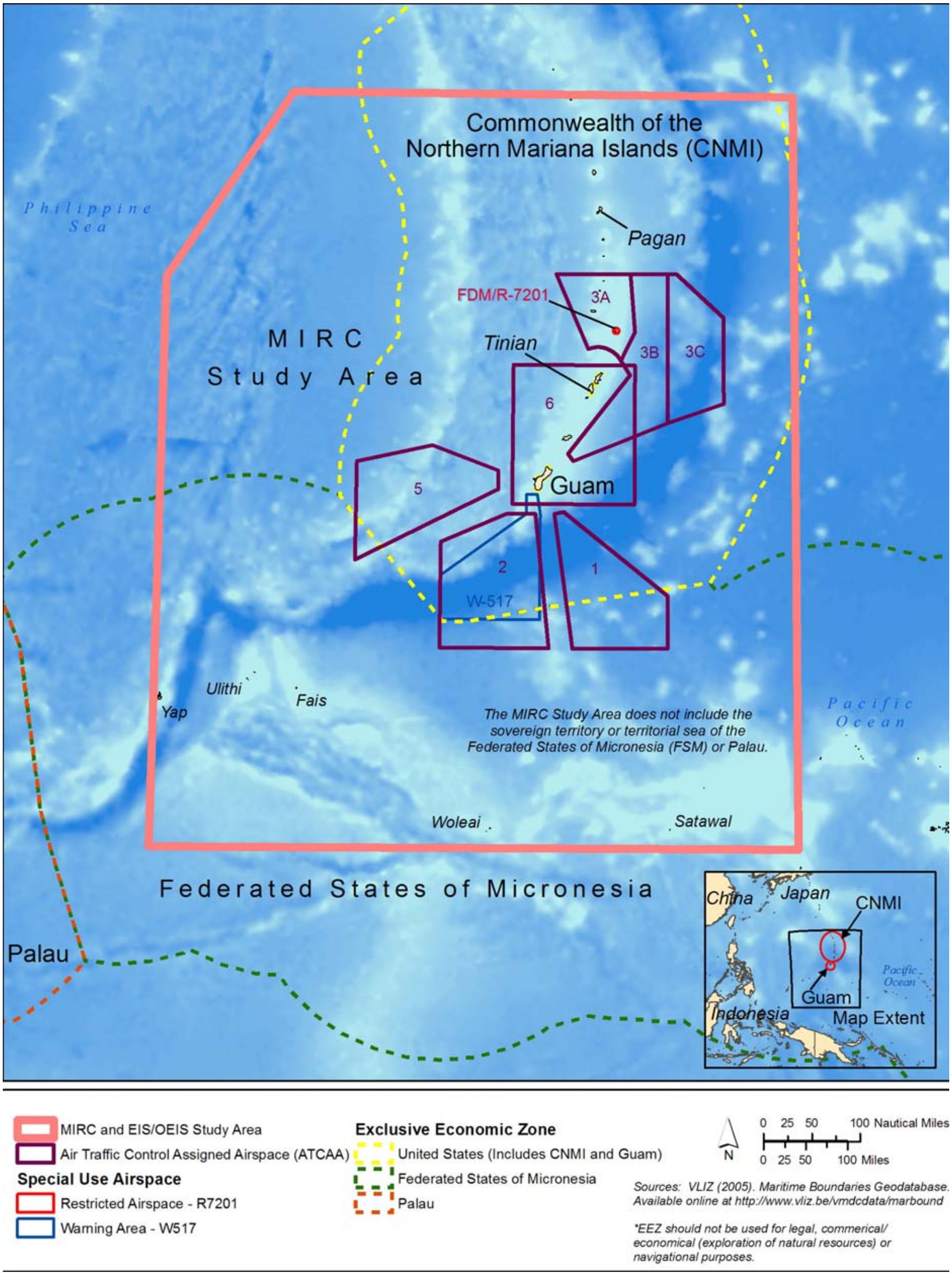

Figure 2-1. Mariana Islands Range Complex and EIS/OEIS Study Area.

2.2 NO ACTION ALTERNATIVE–CURRENT TRAINING WITHIN THE MIRC

The No Action Alternative is the continuation of training activities, RDT&E activities, and continuing base activities. This includes all multi-Service training activities on DoD training areas, including either a joint expeditionary warfare exercise or a joint multi-strike group exercise. The current military training in the MIRC was initially analyzed in the 1999 *Final Environmental Impact Statement Military Training in the Marianas* (DoD 1999) and in several EAs (*e.g*., OEA Notification for Air/Surface International Warning Areas (DoD 2002) and Valiant Shield OEA [DoN 2007]) for more specific training events or platforms. As such, evaluation of the No Action Alternative in this EIS/OEIS provides a baseline for assessing environmental impacts of Alternative 1 (Preferred Alternative), and Alternative 2, as described in the following subsections.

While the No Action Alternative meets a portion of the Service's requirements, it does not meet the purpose and need. This Alternative does not provide for training capabilities for ISR/Strike, undersea warfare improvements, or increased training activities within the MIRC. With reference to the criteria identified in Section 2.2.1, the No Action Alternative does not satisfy criteria 7, 8, and 9 (relating to support for the full spectrum of training requirements).

2.2.1 DESCRIPTION OF CURRENT TRAINING ACTIVITIES WITHIN THE MIRC

Each military training activity described in this EIS/OEIS meets a requirement that can be traced ultimately to requirements from the National Command Authority (NCA) composed of the President of the United States and the Secretary of Defense. Based upon NCA requirements, the Joint Staff develops a set of high-level strategic warfighting missions, called the Universal Joint Task List (UJTL). The Joint Forces Command (JFCOM) and each military Service uses the UJTL to develop specific statements of required tactical tasks. Each Service derives its tactical tasks from the UJTLs. These Service-level tactical task lists are in turn applied to training requirements that the MIRC is to support with range and training area capabilities. Service tactical tasks that encompass the current training activities within the MIRC are listed in Table 2-8, are briefly described below in Service-specific groupings, and are described in greater detail in Appendix D. The source for these lists is the MIRC Range Complex Management Plan (RCMP) (DoN 2006). A complete description, including tempo and ordnance expended for each activity for the No Action Alternative, Alternative 1, and Alternative 2 is provided in Appendix A.

2.3 ALTERNATIVE 1— CURRENT TRAINING, INCREASED TRAINING SUPPORTED BY MODERIZATION AND UPGRADES/MODIFICATIONS TO EXISTING CAPABILITIES, TRAINING ASSOCIATED WITH ISR/STRIKE, AND MULTI-NATIONAL AND/OR JOINT EXERCISES (PREFERRED ALTERNATIVE)

Alternative 1 is a proposal designed to meet the Services' current and foreseeable training requirements. If Alternative 1 were to be selected, in addition to accommodating the No Action Alternative, it would include increased training as a result of upgrades and modernization of existing capabilities, and include establishment of a danger zone and restricted area around FDM (a 10-nm zone around FDM to be established in accordance with C.F.R. Title 33 Part 334; see Figure 2-3). Alternative 1 also includes training associated with ISR/Strike and other

Andersen AFB initiatives. Training will also increase as a result of the acquisition and development of new Portable Underwater Tracking Range (PUTR) capabilities. PUTR trains personnel in undersea warfare including conducting TRACKEX and TORPEX activities. Helicopter, ship, and submarine sonar systems will use this capability. Small arms range capability improvements and MOUT training facility improvements would also increase training activities. Training activities will increase as a result of the development of a laser certified range area in W-517. This laser range capability will aid in the training of aircrews in the delivery of air-to-surface missiles against surface vessel targets. Primarily conducted in W-517, the weapon systems commonly used in this training activity are the laser guided HELLFIRE missile or an inert captive air training missile (CATM). The CATM is a missile shape that contains electronics only, and it remains attached to the aircraft weapon mounting points. The MISSILEX involves in-flight laser designation and guidance, and arming and releasing of the air to surface weapon by aircraft, typically against a small stationary, towed, or maneuvering target; however a CATM Exercise (CATMEX) may be conducted against any laser reflective target mounted on or towed by a target support vessel. Table 2-8 of the EIS/OEIS summarizes these increases in training activities. These increased capabilities will result in increased multi-national and/or joint exercises.

Major Exercise—Training would increase to include additional major exercises involving multiple strike groups and expeditionary task forces (see EIS/OEIS Table 2-7). Major exercises provide multi-Service and multi-national participation in realistic maritime and expeditionary training that is designed to replicate the types of operations and challenges that could be faced during real-world contingency operations. Major exercises provide training for command elements, submarine, ship, aircraft, expeditionary, and special warfare forces in tactics, techniques, and procedures.

(Note: the *Guam and CNMI Military Relocation EIS/OEIS* is being prepared for the relocation of Marine Corps forces from Okinawa to Guam. The Military Relocation EIS/OEIS examines the potential impact from activities associated with the Marine Corps units' relocation, including training activities and infrastructure changes on and off DoD lands. Since the MIRC EIS/OEIS covers DoD training on existing DoD land and training areas in and around Guam and the CNMI, there will be overlap between the two EIS/OEISs in the area of land usage. These documents are being closely coordinated to ensure consistency.)

ISR/Strike—The Air Force has established the ISR/Strike program at Andersen AFB, Guam. ISR/Strike will be implemented in phases over a planning horizon of FY2007–FY2016. ISR/Strike force structure consists of up to 24 fighter, 12 aerial refueling, six bomber, and four unmanned aircraft with associated support personnel and infrastructure. Aircraft operations and training out of Andersen AFB ultimately will increase by 45 percent over the current level (FY2006). Environmental impacts associated with ISR/Strike have been analyzed in the *2006 Establishment and Operation of an Intelligence, Surveillance and Reconnaissance/Strike, Andersen Air Force Base, EIS (USAF 2006a)*. The anticipated 45 percent increase in aircraft operations and training out of and into Andersen AFB requires improved range infrastructure to accommodate this increased training tempo, newer aircraft, and weapon systems commensurate with ISR/Strike force structure. There will be increased activity on all the current training areas supporting Air Force training activities: W-517, ATCAAs, and FDM/R-7201. The ISR/Strike EIS analyzed environmental impacts related to the infrastructure improvements required (USAF 2006a). This EIS/OEIS analyzes the impacts of the increased training resulting from the ISR/Strike implementation.

FDM— As usage of FDM increases under implementation of either Alternative 1 or Alternative 2, a 10-nm danger zone would be established to restrict all private and commercial vessels from entering the area during the conduct of hazardous training activity. Development of a 10-nm danger zone would be supplemented by temporary advisory notices as required. FDM and the near shore waters are leased to the United States for military purposes specifically for use as a live fire naval gunfire and air warfare air strike training range. As such FDM and its near shore area have always been an off-limits area to all personnel both civilian and military due to unexploded ordnance concerns. The lease agreement between CNMI and the United States, states in pertinent part, at Article 12 of the lease: "c. **Farallon de Medinilla:**. Public access to Farallon de Medinilla Island and the waters of the Commonwealth immediately adjacent thereto shall be permanently restricted for safety reasons." This restriction will continue and FDM and near shore areas including the fringing reef and other near shore formations remain a restricted area which prohibits the entry of all personnel, civilian and military from the island without specific permission from Commander US Naval Forces, Marianas. The creation of the proposed danger zone does not affect the continued implementation of restricted access as indicated in the lease agreement; and, therefore no trespassing is permitted on the island or near shore waters and reef at any time.

The proposed danger zone would designate a surface safety zone of 10 nm radius surrounding FDM. Public access to FDM will remain strictly prohibited and there are no commercial or recreational activities on or near the island. Aircraft and marine vessels continue to be restricted in accordance with the lease agreement. Notice to Mariners (NOTMAR) and Notice to Airmen (NOTAM) will continue to be issued at least 72 hours in advance of potentially hazardous FDM range events and may advise restrictions for certain training events. These temporary advisory restrictions are used to maintain the safety of the military and the public during training sessions by providing public notice of potentially hazardous training activity and associated danger zones and restriction areas.

As usage of FDM increases, a danger zone would be established to restrict all private and commercial vessels from entering the area during the conduct of hazardous training activity. Development of a 10-nm danger zone would continue to be supplemented by temporary advisory notices as required. Scheduled training will be communicated to the stakeholders (e.g., local mayors, resource agencies, fishermen) using a telephone tree and e-mail (developed by COMNAVMAR with stakeholders' input) to send, facsimiles to mayors and fishermen, and notices on the NOAA and local cable channels, and emergency management offices. This safety zone provides an additional measure of safety for the public during hazardous training activities involving the island. The Surface Danger Zone is propose as a surface safety exclusion area to be established in accordance with 33 CFR § 334.1. The ACOE may promulgate regulations restricting commercial public and private vessels from entering the restricted safety zone to minimize danger from the hazardous activity in the area.

Modernization and Upgrades of Training Areas

Anti-Submarine Warfare (ASW)—ASW describes the entire spectrum of platforms, tactics, and weapon systems used to neutralize and defeat hostile submarine threats to combatant and non-combatant maritime forces. A critical component of ASW training is the Portable Underwater Tracking Range (PUTR). This is an instrumented range that allows near real-time tracking and feedback to all participants. The tracking range should provide for both a shallow water and deep water operating environment, with a variety of bottom slope and sound velocity profiles similar to potential contingency operating areas. Guam-homeported submarine crews, as well as crews of transient submarines, require ASW training events to maintain qualifications. A MIRC instrumented ASW PUTR, target support services, and assigned torpedo retriever craft would meet support requirements for TORPEX and TRACKEX activities in the MIRC in support of submarines and other deployed ASW forces.

Military Operations in Urban Terrain (MOUT)—MOUT training is conducted within a facility that replicates an urban area, to the extent practicable. The urban area includes a central urban infrastructure of buildings, blocks, and streets; an outlying suburban residential area; and outlying facilities. Suburban area structures should represent a local noncombatant populace and infrastructure. The existing MOUT facilities will be maintained and remodeled as necessary to support training requirements of units stationed at or deployed to the MIRC. In addition modular and temporary facilities may be assembled to support MOUT exercises.

MISSILEX [A-S] and BOMBEX [A-S] in W-517—MISSILEX is authorized in W-517, however in support of HSC-25 a permanent Laser Hazard Area and Missile Hazard Area is required to support HELLFIRE Missile Exercise unit level training requirements. The HELLFIRE laser range location and schedule will be established and coordinated with the Guam FAA. BOMBEX [A-S] is authorized in W-517, however in support of USAF requirements for live fire BOMBEX, Area Training and USAF have developed range safety and mitigation procedures for support of Joint Direct Attack Munitions (JDAM) in W-517. JDAM is capable of over-the-horizon release and GPS guidance to target aimpoint.

A complete description, including tempo and ordnance expended for each activity for the No Action Alternative, Alternative 1, and Alternative 2 is provided in Appendix A.

2.4 ALTERNATIVE 2— CURRENT TRAINING, INCREASED TRAINING SUPPORTED BY MODERIZATION AND UPGRADES/MODIFICATIONS TO EXISTING CAPABILITIES, TRAINING ASSOCIATED WITH ISR/STRIKE, INCREASED MULTI-NATIONAL AND/OR JOINT EXERCISES; INCLUDING ADDITIONAL NAVAL EXERCISES

Implementation of Alternative 2 would include all the actions proposed for MIRC in Alternative 1 and increased training activity associated with major at-sea exercises (see Appendix A Tables A-7 and A-8). Additional major at-sea exercises would provide additional ships and personnel maritime training including additional use of sonar that would improve the level of joint operating skill and teamwork between the Navy, Joint Forces, and Partner Nations. Submarine, ship, and aircraft crews train in tactics, techniques, and procedures required in carrying out the primary mission areas of maritime forces. The additional maritime exercises would take place within the MIRC and would focus on carrier strike group training and ASW activities similar to training conducted in other Seventh Fleet locations, including a Fleet Strike Group Exercise, an Integrated ASW Exercise, and a Ship Squadron ASW Exercise.

Additional Major Exercises proposed for Alternative 2:

The **Fleet Strike Group Exercise** and an additional **Integrated ASW Exercise** would be conducted in the MIRC by forward-deployed Navy Strike Groups to sustain or assess their proficiency in conducting tasking within the Seventh Fleet. Training would be focused on conducting Strike Warfare or ASW in the most realistic environment, against the level of threat expected in order to effect changes to both training and capabilities (e.g., equipment, tactics, and changes to size and composition) of the Navy Strike Group. Although these exercises would emphasize Strike or ASW, there is significant training value inherent in all at-sea exercises and the opportunity to exercise other mission areas. Each exercise would last a week or less.

The **Ship Squadron ASW Exercise** overall objective is to sustain and assess surface ship ASW readiness and effectiveness. The exercise typically involves multiple ships, submarines, and aircraft in several coordinated events over a period of a week or less. Maximizing opportunities to collect high-quality data to support quantitative analysis and assessment of training activities is an additional goal of this training.

A complete description, including tempo and ordnance expended for each activity for the No Action Alternative, Alternative 1, and Alternative 2 is provided in Appendix A.

Table 2-1. Description of Training Activities in the MIRC for No Action Alternative, Alternative 1, and Alternative 2

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION
NO ACTION ALTERNATIVE			
ARMY TRAINING			
	Surveillance and Reconnaissance (S&R)	Finegayan House, Barrigada House, Tinian-Exclusive Military Use Area, and the Lease Back Area	S&R are conducted to evaluate the battlefield and enemy forces, and to gather intelligence. For training of assault forces, opposition forces (OPFOR) units may be positioned ahead of the assault force and permitted a period of time to conduct S&R and prepare defenses against an assaulting force. S&R training has occurred at urban training facilities at Finegayan and Barrigada on Guam, and both the Exclusive Military Use Area (EMUA) and the Lease Back Area (LBA) on Tinian.
	Field Training Exercise (FTX)	Polaris Point Field, Orote Point Airfield/Runway, NLNA, Andersen Air Force Base Northwest Field, and Andersen South Housing Area, and on Tinian at the EMUA	An FTX is an exercise wherein the battalion and its combat and combat service support units deploy to field locations to conduct tactical training activities under simulated combat conditions. A company or smaller-sized element of the Army Reserve, GUARNG, or Guam Air National Guard (GUANG) will typically accomplish an FTX within the MIRC, due to the constrained environment for land forces. The headquarters and staff elements may simultaneously participate in a Command Post Exercise (CPX) mode.
	Live Fire	Pati Pt. CATM Range	Live-fire training is conducted to provide direct fire in support of combat forces.
	Parachute Insertions and Air Assault	Orote Point Triple Spot, Polaris Point Field, and the Ordnance Annex Breacher House. Additionally, Orote Point Airfield/Runway supports personnel, equipment, and Container Delivery System (CDS) airborne parachute insertions.	These air training activities are conducted to insert troops and equipment by parachute and/or by fixed or rotary wing aircraft to a specified objective area.

Table 2-1. Description of Training Activities in the MIRC for No Action Alternative, Alternative 1, and Alternative 2 (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION
NO ACTION ALTERNATIVE			
ARMY TRAINING			
	Military Operations in Urban Terrain (MOUT)	OPCQC House, Ordnance Annex Breacher House, Barrigada Housing, and Andersen South Housing Area. Additionally, the OPCQC supports "raid" type MOUT training on a limited basis	MOUT training activities encompass advanced offensive close quarter battle techniques used on urban terrain conducted by units trained to a higher level than conventional infantry. Techniques include advanced breaching, selected target engagement, and dynamic assault techniques using organizational equipment and assets. MOUT is primarily an offensive operation, where noncombatants are or may be present and collateral damage must be kept to a minimum. MOUT training involves clearing buildings; room-by-room, stairwell-by-stairwell, and keeping them clear. It is manpower intensive, requiring close fire and maneuver coordination and extensive training.
MARINE CORPS TRAINING			
	Ship to Objective Maneuver (STOM)	EMUA on Tinian	STOM is conducted to gain a tactical advantage over the enemy in terms of both time and space. The maneuver is not aimed at the seizure of a beach, but builds upon the foundations of expanding the battlespace.
	Operational Maneuver	Northern and Southern Land Navigation Area	This training exercise supports forces achieving a position of advantage over the enemy for accomplishing operational or strategic objectives.
	Non-Combatant Evacuation Order (NEO)	EMUA on Tinian	NEO training activities are conducted when directed by the Department of State, the DoD, or other appropriate authority whereby noncombatants are evacuated from foreign countries to safe havens or to the United States, when their lives are endangered by war, civil unrest, or natural disaster.
	Assault Support (AS)	Polaris Point Field, Orote Point KD Range, and EMUA on Tinian	AS exercises provide helicopter support for C2, assault escort, troop lift/logistics, reconnaissance, search and rescue (SAR), medical evacuation (MEDEVAC), reconnaissance team insertion/extract and Helicopter Coordinator (Airborne) duties. Assault support provides the mobility to focus and sustain combat power at decisive places and times. It provides the capability to take advantage of fleeting battlespace opportunities.

Table 2-1. Description of Training Activities in the MIRC for No Action Alternative, Alternative 1, and Alternative 2 (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION
NO ACTION ALTERNATIVE			
MARINE CORPS TRAINING			
	Reconnaissance and Surveillance (R & S)	EMUA on Tinian	R&S is conducted to evaluate the battlefield, enemy forces, and gather intelligence. For training of assault forces, OPFOR units may be positioned ahead of the assault force and permitted a period of time to conduct R&S and prepare defenses to the assaulting force.
	Military Operations in Urban Terrain (MOUT)	Ordnance Annex Breacher House	Marine Corps MOUT training is similar in nature and intent to Army MOUT training.
	Direct Fire	FDM and ATCAA 3A airspace	Direct Fire, similar in nature and content to Navy Marksmanship exercises, is used to train personnel in the use of all small arms weapons for the purpose of defense and security. Direct Fire training activities are strictly controlled and regulated by specific individual weapon qualification standards. These training activities have occurred at FDM and OPKDR. Another form of Marine Corps Direct Fire exercises involves the use of aircraft acting as forward observers for Naval Surface Fire Support (NSFS). During this training, Marine aircraft will act as spotters for the ships and relay targeting and battle hit assessments information.
	Exercise Command and Control (C2)	Andersen AFB	This type of exercise provides primary communications training for command, control, and intelligence, providing critical interpretability and situation awareness information.
	Protect and Secure Area of Operations (Protect the Force)	Northwest Field on Andersen Air Force Base	Force protection training activities increase the physical security of military personnel in the region to reduce their vulnerability to attacks. Force protection training includes moving forces and building barriers, detection, and assessment of threats, delay, or denial of access of the adversary to their target, appropriate response to threats and attack, and mitigation of effects of attack. Force protection includes employment of offensive as well as defensive measures.

Table 2-1. Description of Training Activities in the MIRC for No Action Alternative, Alternative 1, and Alternative 2 (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION
NO ACTION ALTERNATIVE			
NAVY TRAINING			
Anti-Submarine Warfare (ASW)	Antisubmarine Warfare Tracking Exercise	MIRC Offshore Areas, W-517	ASW TRACKEX trains aircraft, ship, and submarine crews in tactics, techniques, and procedures for search, detection, localization, and tracking of submarines. The use of sonobuoys is generally limited to areas greater than 100 fathoms, or 600 feet, in depth.
Anti-Submarine Warfare (ASW)	Antisubmarine Warfare Torpedo Exercise	MIRC Offshore Areas, W-517	ASW TORPEX training activities train crews in tracking and attack of submerged targets, using active or passive acoustic systems, and firing one or two Exercise Torpedoes (EXTORPs) or Recoverable Exercise Torpedoes (REXTORPs). TORPEX targets used in the Offshore Areas include live submarines, MK-30 ASW training targets, and MK-39 Expendable Mobile ASW Training Targets (EMATT).
Anti-Air Warfare (AAW)	Missile Firing Exercises (MISSILEX)	MIRC Offshore Areas, W-517, ATCAA 1/2/3/5	MISSILEX is an operation in which missiles are fired from either aircraft or ships against aerial targets. Air-to-Air exercises involve a fighter or fighter/attack aircraft firing a missile at an aerial target. Aerial targets are typically launched. In the MIRC this event refers to training activities in which air-to-air missiles are fired from aircraft against unmanned aerial target drones, gliders, or flares. The missiles fired are not recovered.
Anti-Air Warfare (AAW)	Chaff Exercise (CHAFFEX)	MIRC Offshore Areas, W-517, ATCAA 1/2	A CHAFFEX trains aircraft and shipboard personnel in the use of chaff to counter antiship missile threats. Chaff is a radar confusion reflector, consisting of thin, narrow metallic strips of various lengths and frequency responses, which are used to reflect echoes to deceive radars.
Anti-Air Warfare (AAW)	Flare Exercise	MIRC Offshore Areas, W-517	A flare exercise is an aircraft defensive operation in which the aircrew attempts to cause an infrared (IR) or radar energy source to break lock with the aircraft.

Table 2-1. Description of Training Activities in the MIRC for No Action Alternative, Alternative 1, and Alternative 2 (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION
NO ACTION ALTERNATIVE			
NAVY TRAINING			
Anti-Surface Warfare (ASUW)	Surface-to-Surface Gunnery Exercise (GUNEX)	MIRC Offshore Areas, W-517	Surface-To-Surface GUNEX take place in the open ocean to provide gunnery practice for Navy and Coast Guard ships utilizing shipboard gun systems and small craft crews supporting NSW, EOD, and Mobile Security Squadrons (MSS) utilizing small arms. GUNEX training activities conducted in W-517 involve only surface stationary targets such as a MK-42 Floating At Sea Target (FAST), MK-58 marker (smoke) buoys, or 55 gallon drums. The systems employed against surface targets include the 5-inch, 76mm, 25mm chain gun, 20mm Close In Weapon System (CIWS), .50 caliber machine gun, 7.62mm machine gun, small arms, and 40mm grenade.
Anti-Surface Warfare (ASUW)	Air-to-Surface Gunnery Exercise (GUNEX)	MIRC Offshore Areas, W-517	Air-to-Surface GUNEX training activities are conducted by rotary-wing aircraft against stationary targets (FAST and smoke buoy). Rotary-wing aircraft involved in this operation would use either 7.62mm or .50 caliber door-mounted machine guns. GUNEX training occurs frequently in the MIRC Offshore Areas other than W-517, but exact data on this open ocean training evolution outside of W-517 is not recorded or tracked.
Anti-Surface Warfare (ASUW)	Visit Board Search and Seizure (VBSS)	MIRC Offshore Areas, W-517, Outer Apra Harbor	These exercises involve the interception of a suspect surface ship by a Navy ship and are designed to train personnel to board a ship, other vessel or transport to inspect and examine the vessel's papers or examine it for compliance with applicable laws and regulations. Seizure is the confiscating or taking legal possession of the vessel and contraband (goods or people) found in violation of laws or regulations. A VBSS can be conducted both by ship personnel trained in VBSS or by Naval Special Warfare (NSW) SEAL teams trained to conduct VBSS on uncooperative vessels. Employment onto the vessel designated for inspection is usually done by small boat or by helicopter.

Table 2-1. Description of Training Activities in the MIRC for No Action Alternative, Alternative 1, and Alternative 2 (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION
NO ACTION ALTERNATIVE			
NAVY TRAINING			
Anti-Surface Warfare (ASUW)	Sink Exercise (SINKEX)	MIRC Offshore Areas, W-517	A SINKEX provides training to ship and aircraft crews in delivering live ordnance on a real target. Each SINKEX uses an excess vessel hulk as a target that is eventually sunk during the course of the exercise. The target is an empty, cleaned, and environmentally remediated ship hull that is towed to a designated location where various platforms would use multiple types of weapons to fire shots at the hulk.
Strike Warfare (STW)	Air to Ground Bombing Exercises (Land) (BOMBEX-Land)	FDM, ATCAA 3	BOMBEX (Land) allows aircrews to train in the delivery of bombs and munitions against ground targets. The weapons commonly used in this training are inert training munitions (e.g., MK-76, BDU-45, BDU-48, BDU-56 and MK-80-series bombs), and live MK-80-series bombs and precision guided munitions (Laser Guided Bombs [LGBs] or Laser Guided Training Round [LGTRs]). BOMBEX exercises can involve a single aircraft, a flight of two, four, or multiple aircraft.
Strike Warfare (STW)	Air to Ground Missile Exercises (MISSILEX)	FDM, ATCAA 1/2/3/5	Air-to-ground Missile Exercise trains aircraft crews in the use of air-to-ground missiles. It is conducted mainly by H-60 Aircraft using Hellfire missiles and occasionally by fixed wing aircraft using Maverick missiles. A basic air-to-ground attack involves one or two H-60 aircraft. Typically, the aircraft will approach the target, acquire the target, and launch the missile. The missile is launched in forward flight or at hover at an altitude of 300 feet Above Ground Level (AGL).
Naval Special Warfare (NSW)	Naval Special Warfare Operations (NSW OPS)	Various	NSW personnel perform special activities using tactics that are applicable to the specific tactical situations where the NSW personnel are employed.
Naval Special Warfare (NSW)	Airfield Seizure	Northwest Field on Andersen Air Force Base	Airfield Seizure training activities are used to secure key facilities in order to support follow-on forces, or enable the introduction of follow-on forces. An airfield seizure consists of a raid/seizure force from over the horizon assaulting across a hostile territory in a combination of helicopters, vertical takeoff and landing (VTOL aircraft), and other landing craft with the purpose of securing an airfield or a port.

Table 2-1. Description of Training Activities in the MIRC for No Action Alternative, Alternative 1, and Alternative 2 (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION
NO ACTION ALTERNATIVE			
NAVY TRAINING			
Naval Special Warfare (NSW)	Breaching	OPCQC House, Ordnance Annex Breacher House (OABH)..	Breaching training teaches personnel to employ any means available to break through or secure a passage through an enemy defense, obstacle, minefield, or fortification. This enables a force to maintain its mobility by removing or reducing natural and man-made obstacles. In the NSW sense, breacher training activities are designed to provide personnel experience knocking down doors to enter a building or structure. During the conduct of a normal breach activity, battering rams or less than 1.2 pounds net explosive weight (NEW) is used to knock down doors.
Naval Special Warfare (NSW)	Direct Action	Gab Gab Beach to Apra Harbor and Orote Point training areas, FDM	NSW Direct Action is either covert or overt directed against an enemy force to seize, damage, or destroy a target and/or capture or recover personnel or material. Training activities are small-scale offensive actions including raids; ambushes; standoff attacks by firing from ground, air, or maritime platforms; designate or illuminate targets for precision-guided munitions; support for cover and deception operations; and sabotage inside enemy-held territory. Units involved are typically at the squad or platoon level staged on ships at sea. They arrive in the area of operations by helicopter or CRRC across a beach. NSW teams are capable of using small craft to island hop from Guam to Rota, Rota to Tinian, Tinian to Saipan, and Saipan to FDM; however, this is not a frequent event. Once at FDM, small arms, grenades, and crew-served weapons (weapons that require a crew of several individuals to operate) are employed in direct action against targets on the island. Participation in Tactical Air Control Party/Forward Air Control (TACP/FAC) training in conjunction with a BOMBEX-Land also occurs.

Table 2-1. Description of Training Activities in the MIRC for No Action Alternative, Alternative 1, and Alternative 2 (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION
NO ACTION ALTERNATIVE			
NAVY TRAINING			
Naval Special Warfare (NSW)	Insertion/Extraction	Outer Apra Harbor, Inner Apra Harbor, Gab Gab Beach (western half), Reserve Craft Beach, and Polaris Point Field.	Insertion/extraction activities train forces, both Navy (primarily Special Forces and EOD) and Marine Corps, to deliver and extract personnel and equipment. These activities include, but are not limited to, parachute, fast rope, rappel, Special Purpose Insertion/Extraction (SPIE), CRRC, and lock-in/lock-out from underwater vehicles. Additionally, parachute, fast rope, and rappel training have been conducted at Orote Point Airfield/Runway, Orote Point Triple Spot, OPCQC House, Dan Dan Drop Zone, OPKD Range, and the Ordnance Annex Breacher House.
Naval Special Warfare (NSW)	Military Operations in Urban Terrain (MOUT)	Ordnance Annex Breacher House. Additionally, the OPCQC supports "raid" type MOUT training on a limited basis.	NSW MOUT training is similar in nature and intent to Army and Marine Corps MOUT training, but typically on a smaller scale.
Naval Special Warfare (NSW)	Over the Beach (OTB)	Various	NSW personnel use different methods of moving forces from the sea across a beach onto land areas in order to get closer to a tactical assembly area or target depending on threat force capabilities. A typical OTB exercise would involve a squad (8 personnel) to a platoon (16 personnel) or more of NSW personnel being covertly inserted into the water off of a beach area of hostile territory. However, the insertion could be accomplished by other means, such as fixed-winged aircraft, helicopter, submarine, or surface ship. From the insertion point several miles at sea, the SEALs may use a CRRC, Rigid Hull Inflatable Boat (RHIB), SEAL Delivery Vehicle (SDV), Advanced SEAL Delivery System (ASDS), or swim to reach the beach, where they will move into the next phase of the exercise and on to the objective target area and mission of that phase of the exercise.

Table 2-1. Description of Training Activities in the MIRC for No Action Alternative, Alternative 1, and Alternative 2 (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION
NO ACTION ALTERNATIVE			
NAVY TRAINING			
Amphibious Warfare (AMW)	Naval Surface Fire Support (FIREX Land)	FDM	FIREX (Land) on FDM consists of the shore bombardment of an Impact Area by Navy guns as part of the training of both the gunners and Shore Fire Control Parties (SFCP). A SFCP consists of spotters who act as the eyes of a Navy ship when gunners cannot see the intended target. From positions on the ground or air, spotters provide the target coordinates at which the ship's crew directs its fire. The spotter provides adjustments to the fall of shot, as necessary, until the target is destroyed. On FDM, spotting may be conducted from the special use "no fire" zone or provided from a helicopter platform. No one may land on the island without the express permission of COMNAVMAR (COMNAVMARINST 3502.1).
Amphibious Warfare (AMW)	Marksmanship	Orote Point and Finegayan small arms ranges, and Orote Point KD range	Marksmanship exercises are used to train personnel in the use of small arms weapons for the purpose of ship self defense and security. Basic marksmanship training activities are strictly controlled and regulated by specific individual weapon qualification standards. Small arms include but are not limited to 9mm pistol, 12-gauge shotgun, and 7.62mm rifles.
Amphibious Warfare (AMW)	Expeditionary Raid	Reserve Craft Beach	An Expeditionary Raid (Assault) is an attack involving swift incursion into hostile territory for a specified purpose. The attack is then followed by a planned withdrawal of the raid forces. A raid force can consist of varying numbers of aviation, infantry, engineering, and fire support forces. Expeditionary Raids conducted in support to movement of operational forces are normally directed against objectives requiring specific outcomes not possible by other means. A key influence in every raid is the ability to insert, complete the assigned mission, and extract without providing the enemy force with opportunity to reinforce their forces or plan for counter measures. The expeditionary raid is the foundation for all MEU SOC operational missions and is structured based upon mission requirements, situational settings, and force structure. Reserve Craft Beach is capable of supporting a small Expeditionary Raid training event followed by a brief administrative buildup of forces ashore.

Table 2-1. Description of Training Activities in the MIRC for No Action Alternative, Alternative 1, and Alternative 2 (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION
NO ACTION ALTERNATIVE			
NAVY TRAINING			
Amphibious Warfare (AMW)	Hydrographic Surveys	FDM, Outer Apra Harbor, Tinian EMUA, and Tipalao Cove	Hydrographic Reconnaissance is conducted to survey underwater terrain conditions and report findings to provide precise analysis typically in support of amphibious landings and precise ship and small craft movement through cleared routes (Q-Routes). Exercises involve the methodical reconnoitering of beaches and surf conditions during the day and night to find and clear underwater obstacles and to determine the feasibility of landing an amphibious force on a particular beach.
Mine Warfare (MIW)	Land Demolition	Inner Apra Harbor, Gab Gab Beach, Reserve Craft Beach, Polaris Point Field, Orote Point Airfield/Runway, OPCQC House, Ordnance Annex Breacher House, Ordnance Annex Emergency Detonation Site, NLNA, SLNA, and Barrigada Housing.	Training activities using land demolition training are designed to develop and hone EOD detachment mission proficiency in location, excavation, identification, and neutralization of buried land mines. During the training, teams transit to the training site in trucks or other light-wheeled vehicles. A search is conducted to locate inert (nonexplosively filled) land mines or Improvised Explosive Devices (IEDs) and then designate the target for destruction. Buried land mines and Unexploded Ordnance (UXO) require the detachment to employ probing techniques and metal detectors for location phase. Use of hand tools and digging equipment is required to excavate. Once exposed and/or properly identified, the detachment neutralizes threats using simulated or live explosives. Land demolition training is actively conducted throughout the MIRC. Explosive Ordnance Disposal Mobile Unit (EODMU)-5 is stationed at Main Base and EOD Detachment, Marianas (DET MARIANAS) is a small unit of EOD personnel who are permanently attached to COMNAVBASE MARIANAS and are actively involved in disposing of old munitions and UXO found throughout the MIRC.

Table 2-1. Description of Training Activities in the MIRC for No Action Alternative, Alternative 1, and Alternative 2 (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION
NO ACTION ALTERNATIVE			
NAVY TRAINING			
Mine Warfare (MIW)	Underwater Demolition	Outer Apra Harbor, Piti and Agat Bay Floating Mine Neutralization	Underwater demolitions are designed to train personnel in the destruction of mines, obstacles, or other structures in an area to prevent interference with friendly or neutral forces and noncombatants. It provides NSW and EOD teams experience detonating underwater explosives. Outer Apra Harbor supports this training near the Glass Breakwater at a depth of 125 feet and with up to a 10-pound net explosive weight (NEW) charge. Piti and Agat Bay Floating Mine Neutralization areas also support this type of training, with up to a 20-pound NEW charge.
Logistics and Combat Services Support	Combat Mission Area Training	Orote Point Airfield/Runway	Special Forces and EOD units conduct mission area training that supports their own and other services combat service needs in both the water and on land. At Orote Point Airfield/Runway, this task includes providing patrolling, scouting, observation, imagery, and air control services and training.
Logistics and Combat Services Support	Command and Control (C2)	Reserve Craft Beach	C2 training activities provide primary communications for command, control, and intelligence, providing critical interpretability and situation awareness information. EOD personnel have provided USMC C2 support at Reserve Craft Beach.
Combat Search and Rescue (CSAR)	CSAR Training activities	North Field on Tinian	CSAR activities train rescue forces personnel in the tasks needed to be performed to affect the recovery of distressed personnel during war or military operations other than war. These training activities could include aircraft, surface ships, submarines, ground forces (NSW and USMC), and their associated personnel in the execution of training events.

Table 2-1. Description of Training Activities in the MIRC for No Action Alternative, Alternative 1, and Alternative 2 (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION
NO ACTION ALTERNATIVE			
NAVY TRAINING			
Protect and Secure Area of Operations	Embassy Reinforcement (Force Protection)	Main Base, Inner Apra Harbor, Kilo Wharf, Reserve Craft Beach, Orote Point Airfield/Runway, Orote Point Close Quarters Combat House, Orote Point Radio Tower, and Orote Point Triple Spot	Force protection training increases the physical security of military personnel in the region to reduce their vulnerability to attacks. Force protection training includes moving forces and building barriers; detection and assessment of threats; delay or denial of access of the adversary to their target; appropriate response to threats and attack; and mitigation of effects of attack. Force protection includes employment of offensive as well as defensive measures. Base Naval Security Forces and Marine Support Squadrons frequently conduct force protection training throughout the Main Base, but all forces will participate in force protection training to some degree in multiple locations throughout the MIRC.
Logistics and Combat Services Support	Command and Control (C2)	Reserve Craft Beach	C2 training activities provide primary communications for command, control, and intelligence, providing critical interpretability and situation awareness information. EOD personnel have provided USMC C2 support at Reserve Craft Beach.
Combat Search and Rescue (CSAR)	CSAR Training activities	North Field on Tinian	CSAR activities train rescue forces personnel in the tasks needed to be performed to affect the recovery of distressed personnel during war or military operations other than war. These training activities could include aircraft, surface ships, submarines, ground forces (NSW and USMC), and their associated personnel in the execution of training events.
Protect and Secure Area of Operations	Embassy Reinforcement (Force Protection)	Main Base, Inner Apra Harbor, Kilo Wharf, Reserve Craft Beach, Orote Point Airfield/Runway, Orote Point Close Quarters Combat House, Orote Point Radio Tower, and Orote Point Triple Spot	Force protection training increases the physical security of military personnel in the region to reduce their vulnerability to attacks. Force protection training includes moving forces and building barriers; detection and assessment of threats; delay or denial of access of the adversary to their target; appropriate response to threats and attack; and mitigation of effects of attack. Force protection includes employment of offensive as well as defensive measures. Base Naval Security Forces and Marine Support Squadrons frequently conduct force protection training throughout the Main Base, but all forces will participate in force protection training to some degree in multiple locations throughout the MIRC.

Table 2-1. Description of Training Activities in the MIRC for No Action Alternative, Alternative 1, and Alternative 2 (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION
NO ACTION ALTERNATIVE			
NAVY TRAINING			
Protect and Secure Area of Operations	Anti-Terrorism (AT)	Inner Apra Harbor, Polaris Point Site III, Ordnance Annex Breacher House, and Orote Annex Detonation Range, Northwest Field	AT training activities concentrate on the deterrence of terrorism through active and passive measures, including the collection and dissemination of timely threat information, conducting information awareness programs, coordinated security plans, and personal training. The goal is to develop protective plans and procedures based upon likely threats and strike with a reasonable balance between physical protection, mission requirements, critical assets and facilities, and available resources to include manpower. AT training activities may involve units of Marines dedicated to defending both U.S. Navy and Marine Corps assets from terrorist attack. The units are designated as the Fleet Anti-Terrorism Security Team, or FAST. FAST Company Marines augment, assist, and train installation security when a threat condition is elevated beyond the ability of resident and auxiliary security forces. They are not designed to provide a permanent security force for the installation. They also ensure nuclear material on submarines is not compromised when vessels are docked. FAST Companies deploy only upon approval of the Chief of Naval Operations (CNO). USMC Security Force FAST Platoons stationed in Yokuska, Japan have conducted AT training with Base Naval Security, NSW, and EOD support in multiple locations within the MIRC.
Major Exercises	Joint Exercise/USPACOM; USMC-Navy STOM/USMC-Navy; USMC Urban Ops/USMC	Various	Multiple Strike Group Exercises (Primarily Offshore; annual event, but may include nearshore, Guam, FDM, and CNMI) and Amphibious Assault Group Exercise – No Action Alternative would be one of the two exercises. Alt 1 and Alt 2 consist of one Multiple Strike Group Exercise, and one Amphibious Assault Exercise Expeditionary Warfare Exercise (Offshore/Nearshore/ Tinian/Guam/Saipan/Rota/FDM) Urban Warfare Exercise (Sustainment) (Primarily on Guam; semi-annually, 3-4 weeks per event; may include STOM and Tinian/Saipan/Rota)

Table 2-1. Description of Training Activities in the MIRC for No Action Alternative, Alternative 1, and Alternative 2 (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION
NO ACTION ALTERNATIVE			
AIR FORCE TRAINING			
	Counter Land	FDM, ATCAA 3	Counter Land is similar in nature and content to the Navy's BOMBEX (Land) operation.
	Counter Air	W-517 and ATCAA 1 & 2	Counter air is single to multiple aircraft engaged in advanced, simulated radar, infrared (IR), or visual air-to-air training. During this training, aircraft may dispense chaff and flares as part of missile defense training. Flares are high incendiary devices meant to decoy IR missiles. Burn time for flares usually lasts from 3 to 5 seconds. Chaff exercises train aircraft and/or shipboard personnel in the use of chaff to counter anti-ship and anti-aircraft missile threats. Chaff is a radar confusion reflector, consisting of thin, narrow metallic strips of various lengths and frequency responses, which are used to reflect echoes to deceive radars. During a chaff exercise, the chaff layer combines aircraft maneuvering with deployment of multiple rounds of chaff to confuse incoming missile threats. In an integrated Chaff Exercise scenario, ships/helicopters/fixed wing craft will deploy ship- and air-launched, rapid bloom offboard chaff in preestablished patterns designed to enhance missile defense.
	Airlift	Northwest Field, Andersen Air Force Base	Airlift training activities provide airlift support to combat forces.
	Air Expeditionary	Northwest Field, Andersen Air Force Base	This type of training provides air expeditionary support to forward deployed forces.
	Force Protection	Northwest Field, Tarague Beach Small Arms Range, Main, Andersen Air Force Base	This type of training is to provide Force Protection to individuals, buildings, and specific areas of interest.

Table 2-1. Description of Training Activities in the MIRC for No Action Alternative, Alternative 1, and Alternative 2 (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION
ALTERNATIVE 1— INCREASE OPERATIONAL TRAINING, MODERNIZATION AND UPGRADES			
Major Exercises	Joint Exercise/USPACOM; USMC-Navy STOM/USMC-Navy; USMC Urban Ops/USMC	Various	Training activities would be increased to include training in major exercises, multi-Service and Joint exercises involving multiple strike groups and task forces.
ISR/Strike		Andersen AFB	The Air Force has established the ISR/Strike program at Andersen AFB, Guam. ISR/Strike will be implemented in phases over a planning horizon of FY2007–FY2016. ISR/Strike force structure consists of up to 48 fighter, 12 aerial refueling, six bomber, and six unmanned aircraft with associated support personnel and infrastructure. Aircraft operations and training out of Andersen AFB ultimately will increase by 45 percent over the current level (FY2006).
Modernization and Upgrades of Training Areas	Anti-Submarine Warfare (ASW)	No Undersea Tracking Range site has been identified for the Mariana Islands.	A critical component of ASW training is the Underwater Tracking Range (UTR). This is an instrumented range that allows near real-time tracking and feedback to all participants. The tracking range should provide for both a shallow water and deep water operating environment, with a variety of bottom slope and sound velocity profiles similar to potential contingency operating areas. Guam-homeported submarine crews, as well as crews of transient submarines, require ASW training events to maintain qualifications. A MIRC instrumented ASW PUTR, target support services, and assigned torpedo retriever craft would meet support requirements for TORPEX and TRACKEX activities in the MIRC in support of Fast Attack Submarine (SSN) and Ballistic Missile Submarine (SSBN) and other deployed forces.
	Military Operations in Urban Terrain (MOUT)		The MIRC will need to acquire range space, design, and develop a MOUT facility that will support the training requirements of the Army, Marine Corps, and special warfare units stationed at or deployed into the MIRC.

Table 2-1. Description of Training Activities in the MIRC for No Action Alternative, Alternative 1, and Alternative 2 (cont'd)

ALTERNATIVE 2— NEW DEDICATED CAPABILITIES ON EXISTING DoD RANGES AND TRAINING AREAS			
MISSION AREA	**EVENT**	**ACTIVITY AREA**	**BRIEF DESCRIPTION**
Increase Major At Sea Exercises and Training	Major At Sea Exercises	Various	Additional major at sea exercises would provide additional ships and personnel maritime training including additional use of sonar that would improve the level of joint operating skill and teamwork between the Navy, Joint Forces, and Partner Nations. Submarine, ship, and aircraft crews train in tactics, techniques, and procedures required in carrying out the primary mission areas of maritime forces. The additional maritime exercises would take place within the MIRC and would focus on carrier strike group training and ASW activities similar to training conducted in other Seventh Fleet locations, including a Fleet Strike Group Exercise, an Integrated ASW Exercise, and a Ship Squadron ASW Exercise.

3.0 EXISTING HABITAT CONDITIONS

The existing habitat information and citations provided below come from the *Marine Resources Assessment (MRA) for the Marianas Operating Area* (DoN 2005b), with additional technical information incorporated throughout this section. The 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, which is collectively known as the Marianas MRA study area. The MRA does not discuss nearshore areas where training does not occur. The MIRC study area is larger and overlaps the MRA study area; however, the primary difference is open ocean habitat, which would not affect the analysis, as the regional descriptions for open ocean habitat within the MRA study area would apply to the MIRC study area.

3.1 PHYSICAL ENVIRONMENT AND HABITATS

The islands of the Mariana archipelago lie between latitude 13 degrees (°) N and 20°N and are approximately 5,800 kilometer (km) west of Hawaii, 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 MIRC study area extends from the high tide shore line along the islands of Guam, Tinian, Farallon De Medinilla (FDM) to over 11,000 m of water depth in the Marianas Trench. The MIRC study area includes several dominant physiographic features including the Marianas Trench, seamounts, and active submarine volcanoes.

3.1.1 CLIMATE AND WEATHER

The tropical climate of the MIRC 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 MIRC 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 MIRC 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.

3.1.1.1 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 MIRC 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 MIRC 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 MIRC study area during the rainy season.

Tropical cyclones commonly traverse the MIRC 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 (DoN 2005b).

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 (DoN 2005b).

3.1.1.2 El Niño/Southern Oscillation (ENSO), 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 sea surface temperature (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 MIRC 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 MIRC 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).

3.1.1.3 Pacific Decadal Oscillation (PDO)

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).

3.2 MARINE GEOLOGY

The MIRC 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 3-1). 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 MIRC 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 3-1). 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 3-2). 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; DoN 2005). 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).

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).

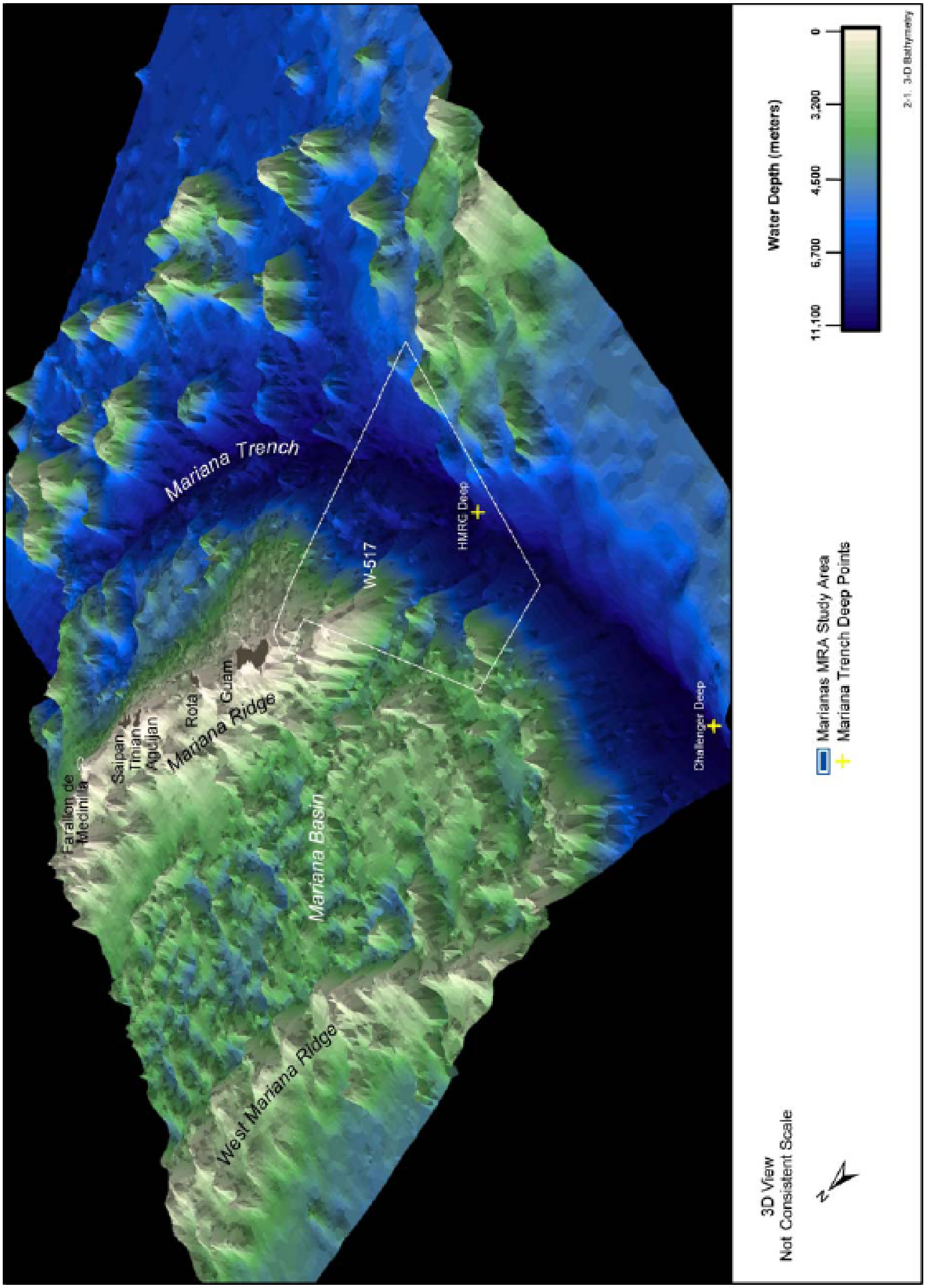

Figure 3-1. Three-dimensional bathymetry and major physiographic features of the MIRC study area. Source Data: Fryer et al. (2003) and Sandwell et al. (2004).

The MIRC 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 3-2). Further, the subduction of the Pacific Plate under the Philippine Plate causes abundant seismic activity in the MIRC 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 MIRC 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 MIRC study area is Ruby Volcano (15°37'N, 145°32'E) last believed to erupt in May 1995 (Smithsonian Institute 1995, Figure 3-3). 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).

3.3 MARINE ENVIRONMENT

3.3.1 OCEANIC WATERS

Oceanic waters in this document refers to the portion of the MIRC 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).

3.3.1.1 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 the MIRC 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 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 MIRC study area can be divided into three main areas: the Mariana Trough, the Mariana Ridge, and the Mariana Trench.

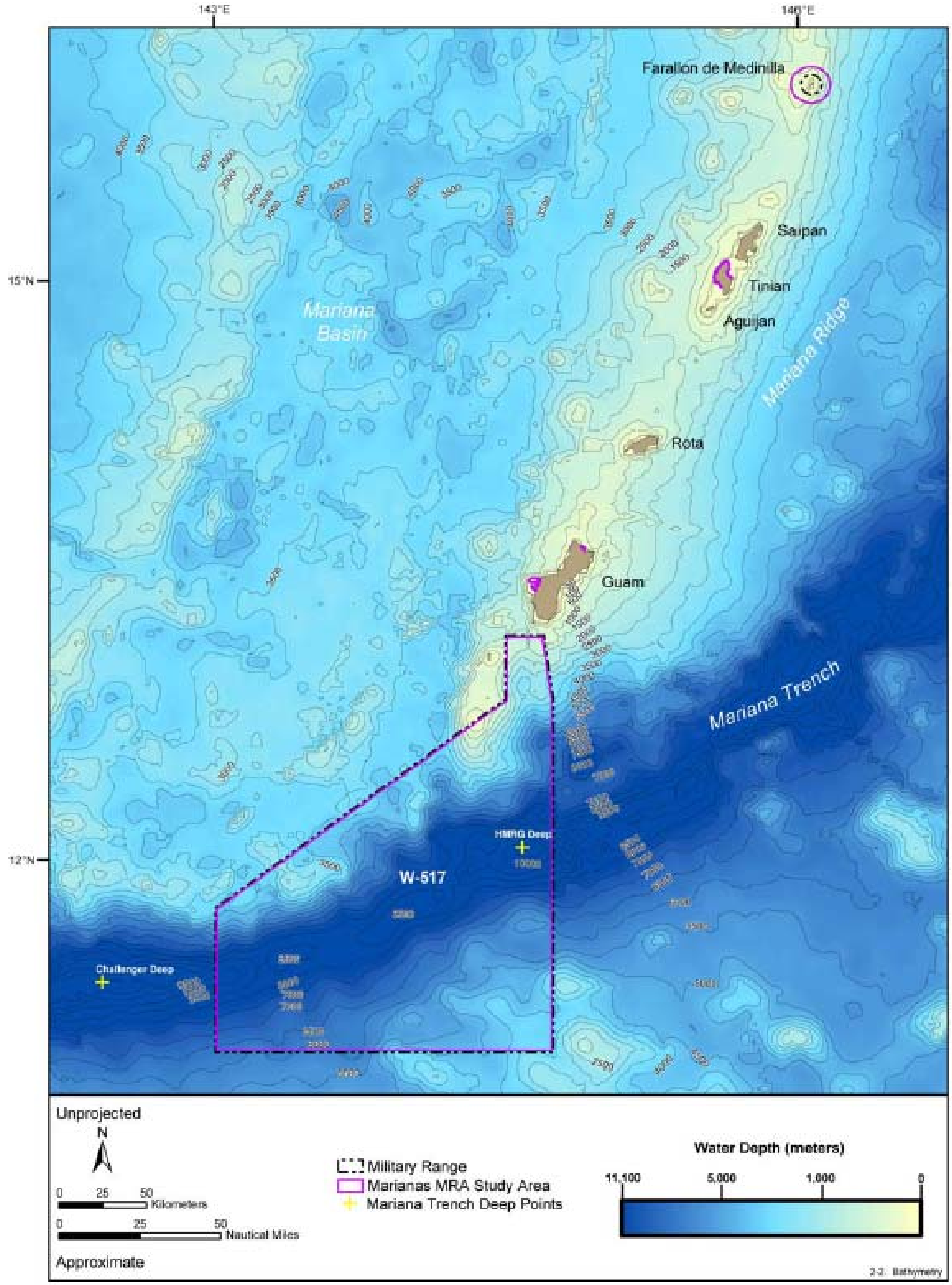

Figure 3-2. Bathymetry of the MIRC study area. Source data: Fryer et al. (2003) and Sandwell et al. (2004).

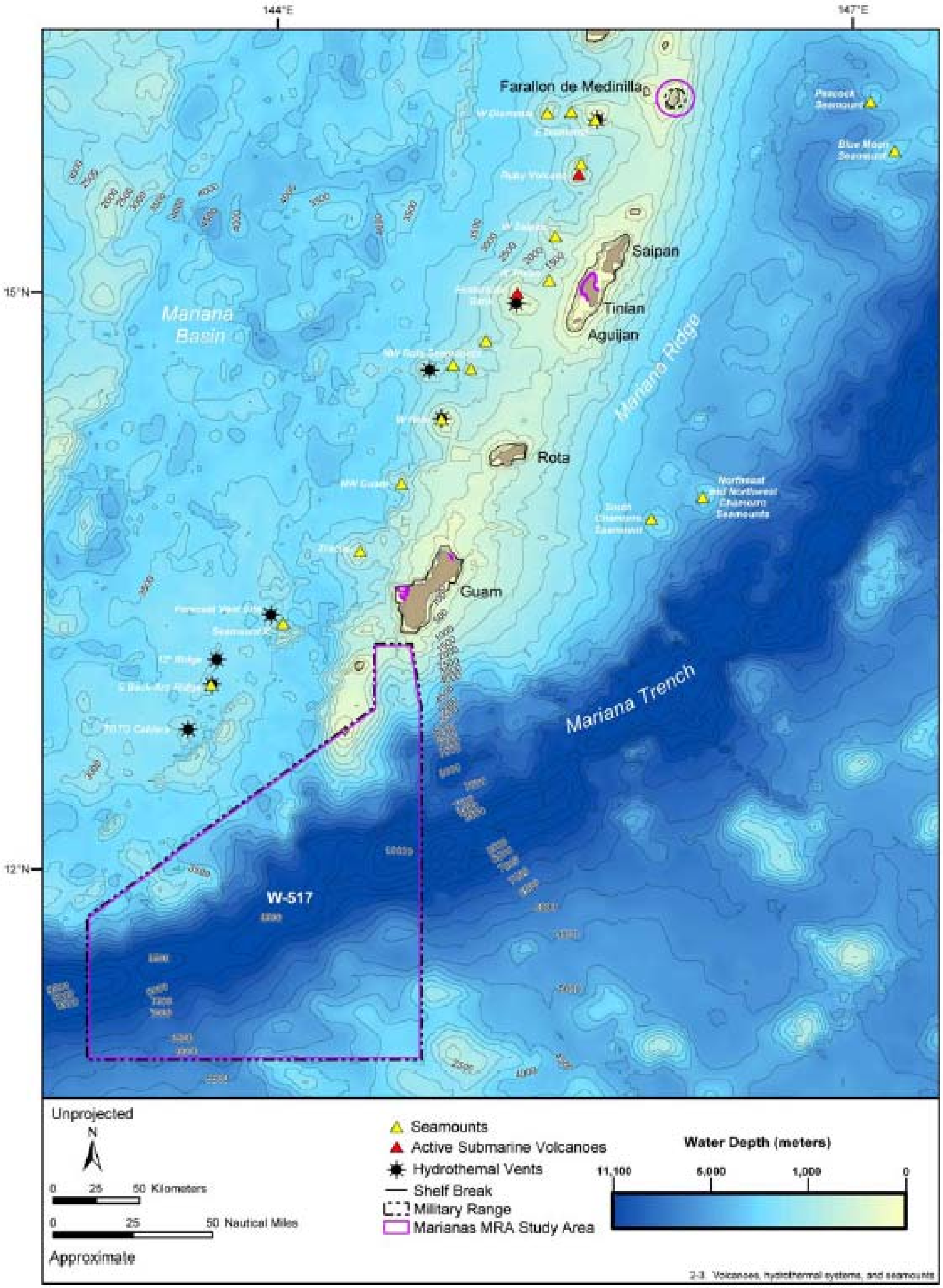

Figure 3-3. Seamounts, active submarine volcanoes, and hydrothermal vents located in the MIRC study area. Source data: Kojima (2002), Fryer et al. (2003), Embley et al. (2004), Mottl et al. (2004), and Sandwell et al. (2004).

Mariana Trough - The Mariana Trough (or Basin) spans the region to the west of the Mariana Ridge (Figure 3-2). 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 3-2). 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 MIRC 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 3-1 and 3-2). 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 3-1 and 3-2). 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 3-1 and 3-2). 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).

3.3.1.2 Bottom Substrate

The bottom substrate covering the seafloor in the MIRC 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).

3.4 PHYSICAL OCEANOGRAPHY

3.4.1 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 MIRC 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, 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).

3.4.1.1 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 3-4a). The North Equatorial Current (NEC) is driven by the trade winds along the equator (Figure 3-4b). 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 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 MIRC study area.

The large mass of the islands within the MIRC 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, 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 MIRC 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).

3.4.1.2 Deepwater Currents/Water Masses

The colder, mid-depth and bottom waters of the MIRC study area do not originate in local waters. Rather, some of the water travels a great distance, 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).

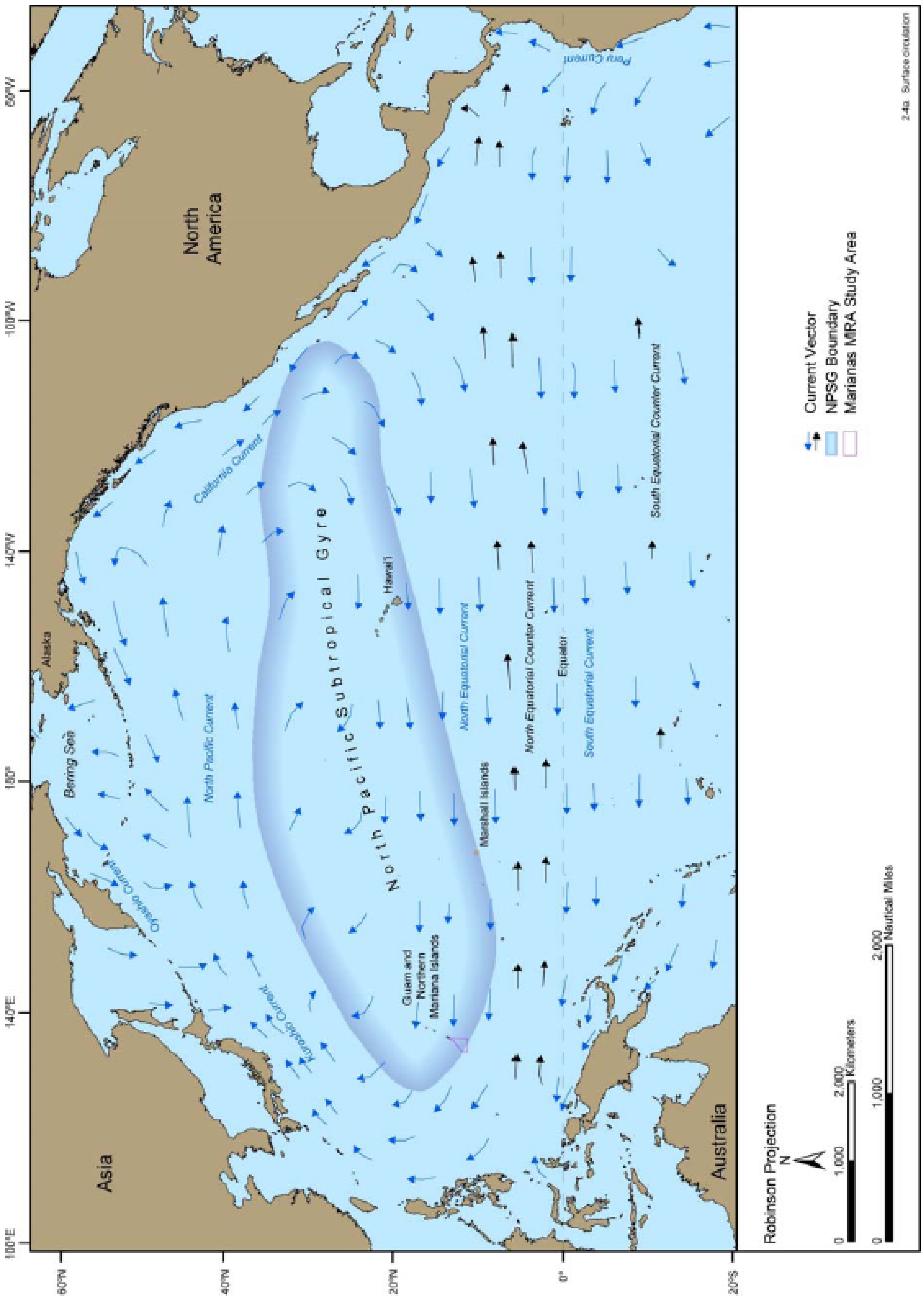

Figure 3-4a. Surface circulation of the Pacific Ocean and outline of the North Pacific Subtropical Gyre. Source Information: Pickard and Emery (1982) and Karl (1999).

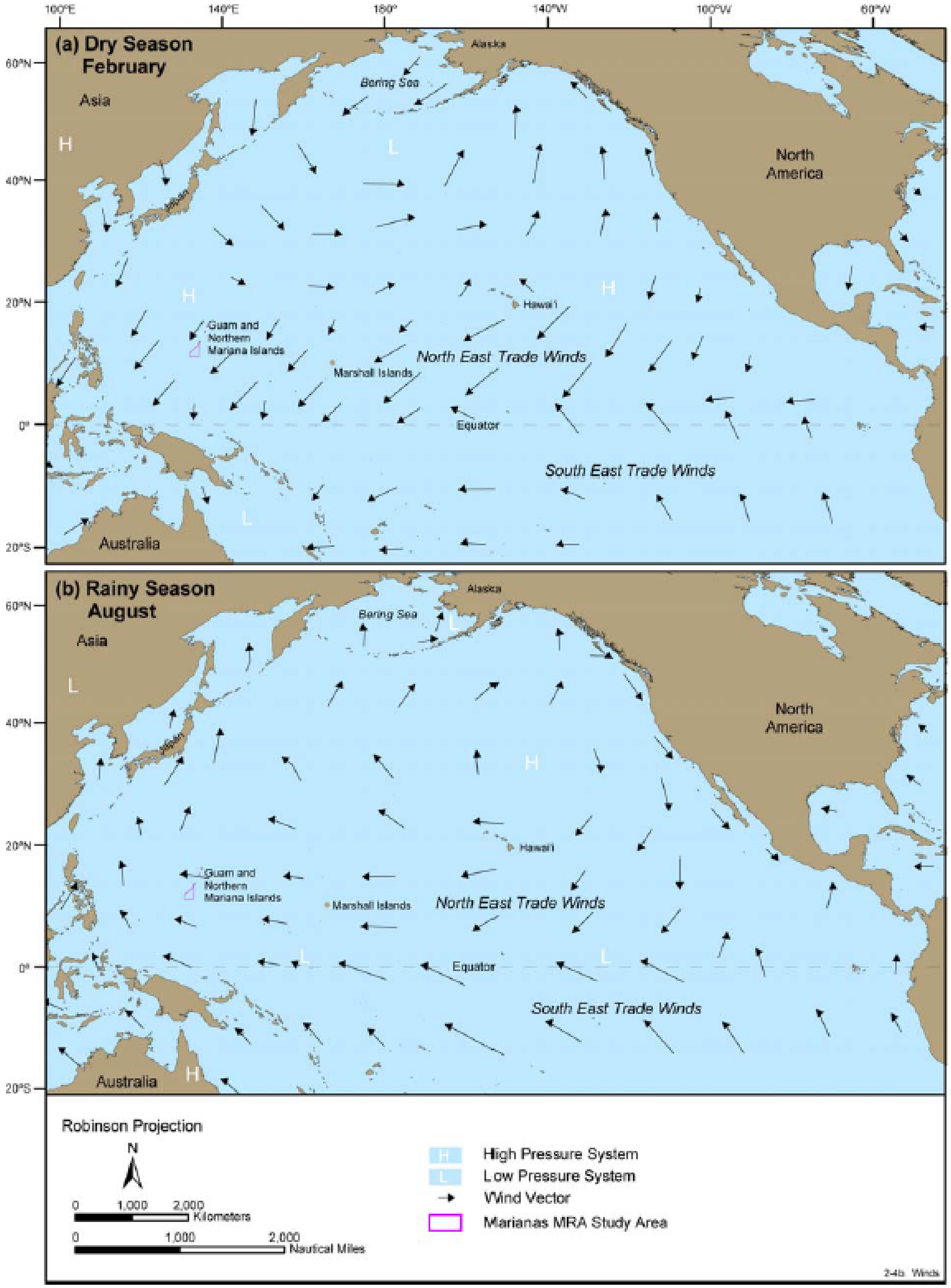

Figure 3-4b. Winds and mean atmospheric highs and lows of the northern Pacific Ocean during the (a) dry season and (b) rainy season. Source information: Pickard and Emery (1982).

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).

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).

3.4.1.3 North Pacific Subtropical Gyre (NPSG)

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 MIRC 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 107 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 (107 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).

3.4.2 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 MIRC study area.

Sea Surface Temperature (SST) - The waters of the MIRC 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 3-5). 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.

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 MIRC study area (Harvell et al. 1999; Paulay and Benayahu 1999; Richmond et al. 2002).

Thermocline - The water column in the MIRC 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 MIRC 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 MIRC 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).

3.5 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 Mariana Islands OPAREA 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 MIRC study area may be found in subsequent chapters.

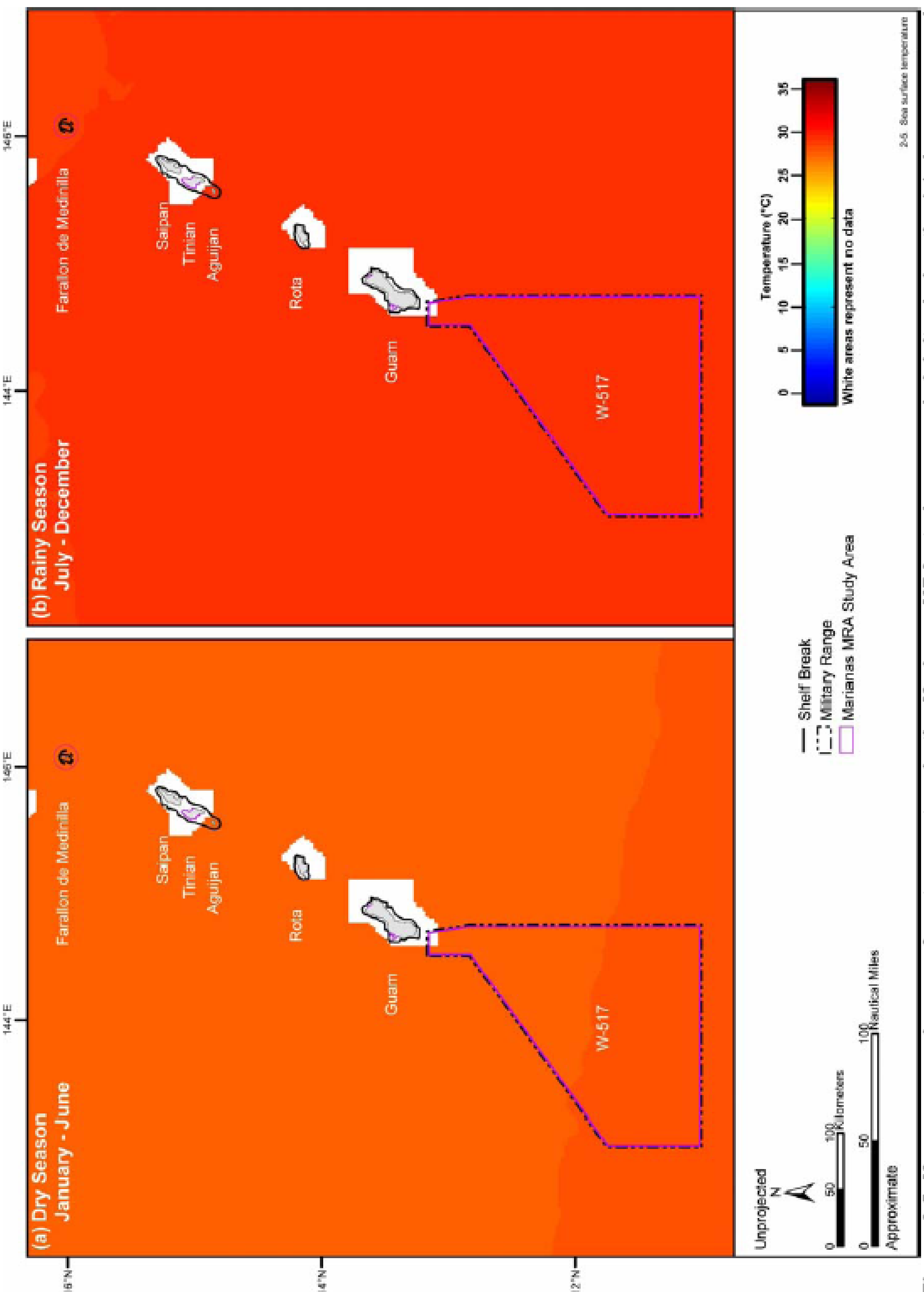

Figure 3-5. Mean seasonal sea surface temperature in the Marianas MIRC study area during the (a) dry season and (b) rainy season. The white areas surrounding Guam and the CNMI islands are areas where sea surface temperature data were unavailable. Source data: NASA (2000).

3.5.1 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 MIRC study area.

3.5.1.1 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 MIRC study area, can be considered an oligotrophic region. The water column surrounding the MIRC 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 MIRC study area (less than 0.1 mg per cubic meter [m^3]) (NASA 1998, Figure 3-6). 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 MIRC 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 percent 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 MIRC study area off the southwest coast of Guam and in the region surrounding the islands of Tinian and Saipan (Figure 3-6). 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 Hawaii (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 3-6). 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 MIRC study area experiences chl a levels below 0.045 mg/m^3 throughout the year (NASA 1998; Figure 3-6). ENSO appears to have little, if any, effect on primary production in the western tropical Pacific (Mackey et al. 1997, Higgins and Mackey 2000).

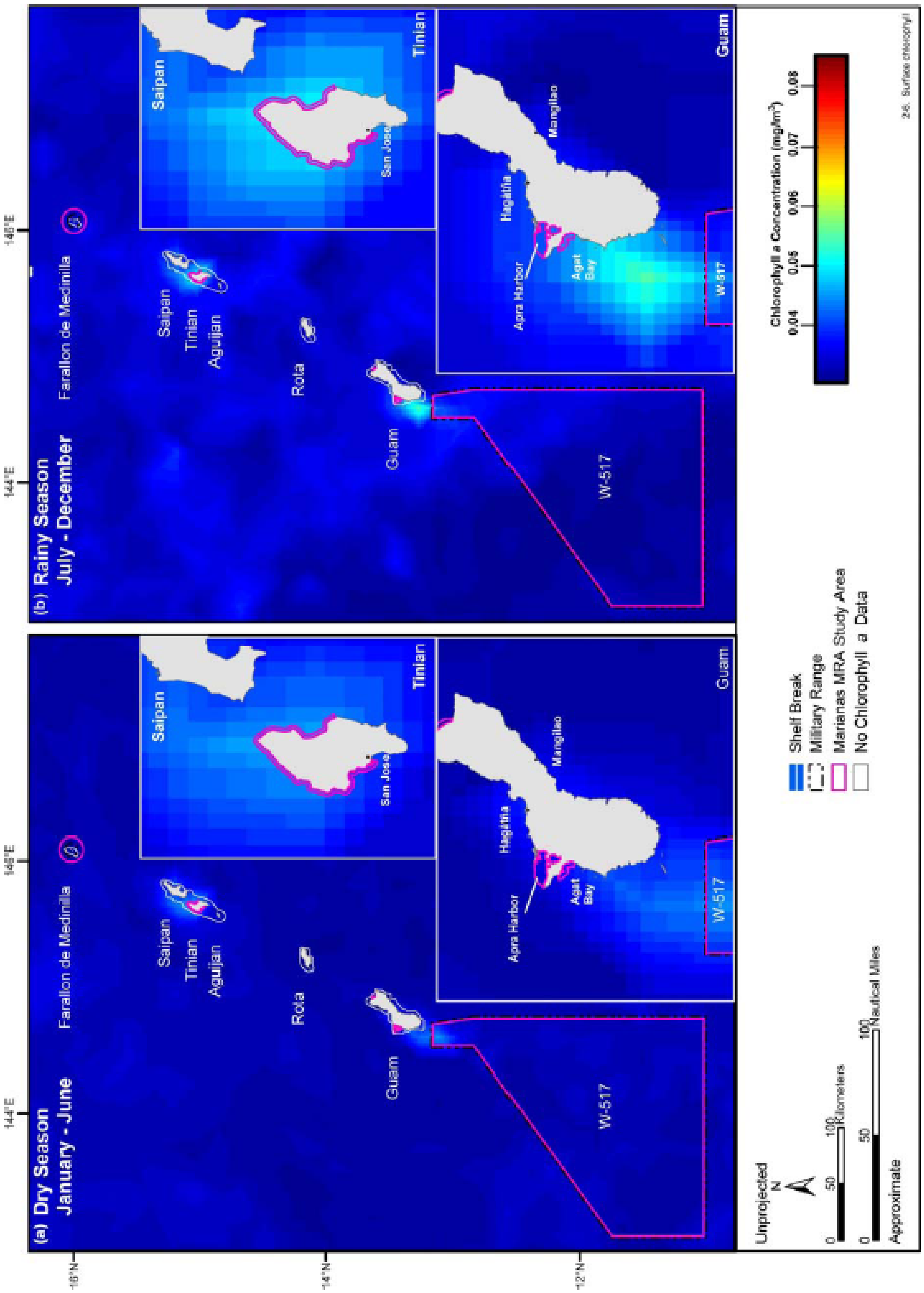

Figure 3-6. Mean seasonal surface chlorophyll a concentrations in the MIRC study area during the (a) dry season and (b) rainy season. Source data: NASA (1998).data were unavailable. Source data: NASA (2000).

3.5.1.2 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 MIRC study area (Embley et al. 2004) and locations are described in further detail in subsequent sections.

3.5.2 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. 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).

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 MIRC study area is practically nonexistent (Uchida 1983). Rather, data gathered in waters surrounding the MIRC 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 MIRC 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 (freeswimming 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).

3.6 OFFSHORE 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 MIRC 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).

3.6.1 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 MIRC 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).

3.6.2 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 MIRC study area (Figure 3-3). 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 MIRC 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 3-3). 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).

3.6.3 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 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).

3.7 COASTAL HABITATS

Coastal habitats of the MIRC 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 MIRC 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).

3.7.1 INTERTIDAL ZONE

Within the intertidal zone, the shoreline can be divided into three subzones: the high-tide zone, the midtide 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 MIRC 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 are rocky in nature (Rock 1999), and are generally lined with rocky intertidal areas, steep cliffs and headlands, and the occasional sandy beach or mudflat (Eldredge 1983). Water erosion of rocky coastlines 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).

3.7.2 CORAL COMMUNITIES AND REEFS

Islands within the MIRC 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). The reefs of the Marianas are within the Indo-Pacific biogeographic region, which supports the world's most diverse coral fauna. While the Marianas exhibit less diversity than some other portions of the Indo-Pacific, such as Malaysia, Indonesia and Palau, they are nearly ten times as diverse as the Caribbean or Hawaiian Islands. There are 377 scleractinian species in Marianas (Randall 2003) versus 60 in Hawaii (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, 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC study area. The depiction of benthic habitats (including reefs) of Guam, Tinian, and FDM presented in Figures 3-7 through 3-9 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, it was approximated using NCCOS/NOAA (2005).

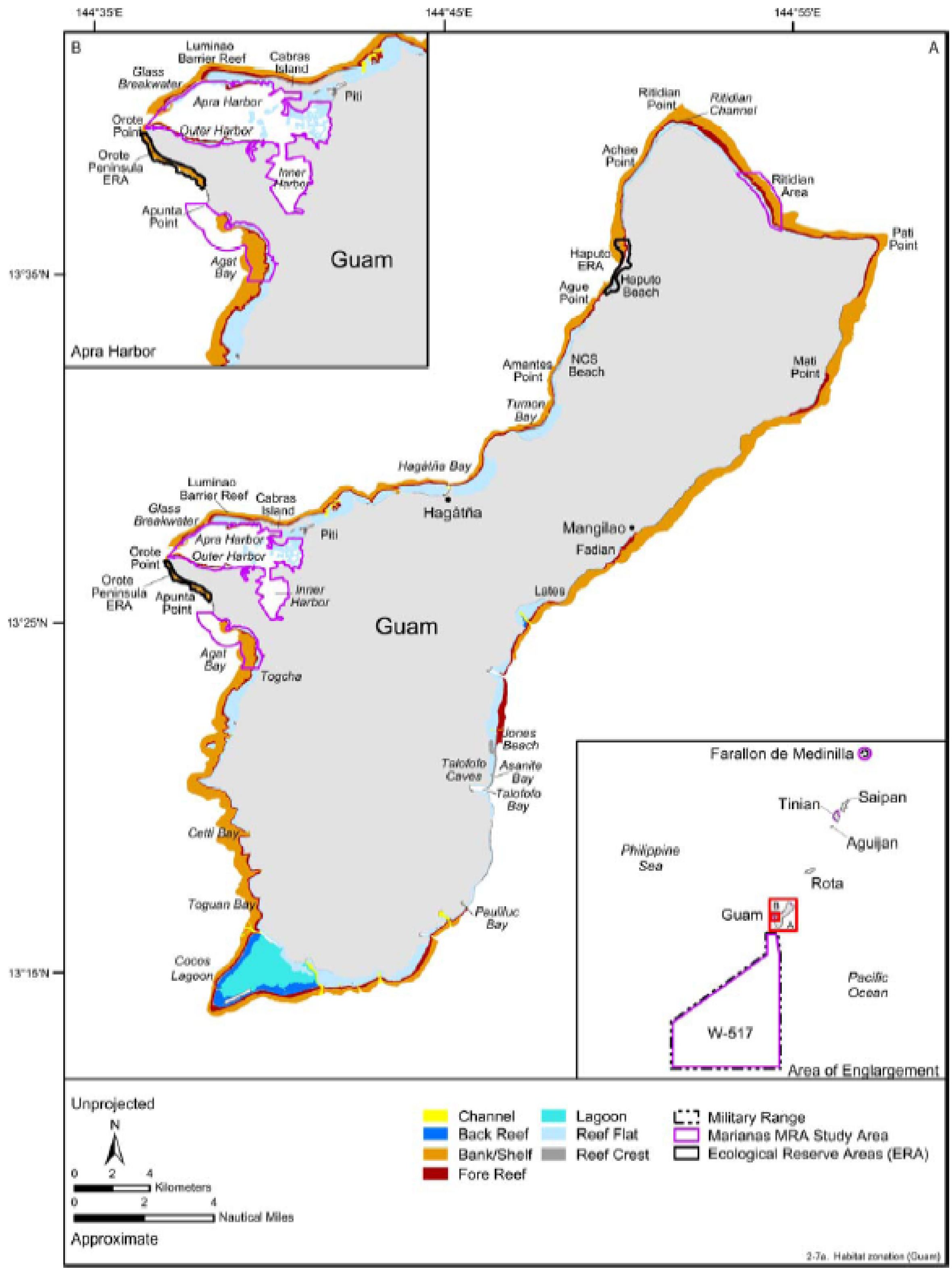

Figure 3-7a. Nearshore benthic habitats of the MIRC study area, Guam: Habitat zonation. Source data: NCCOS/NOAA (2005).

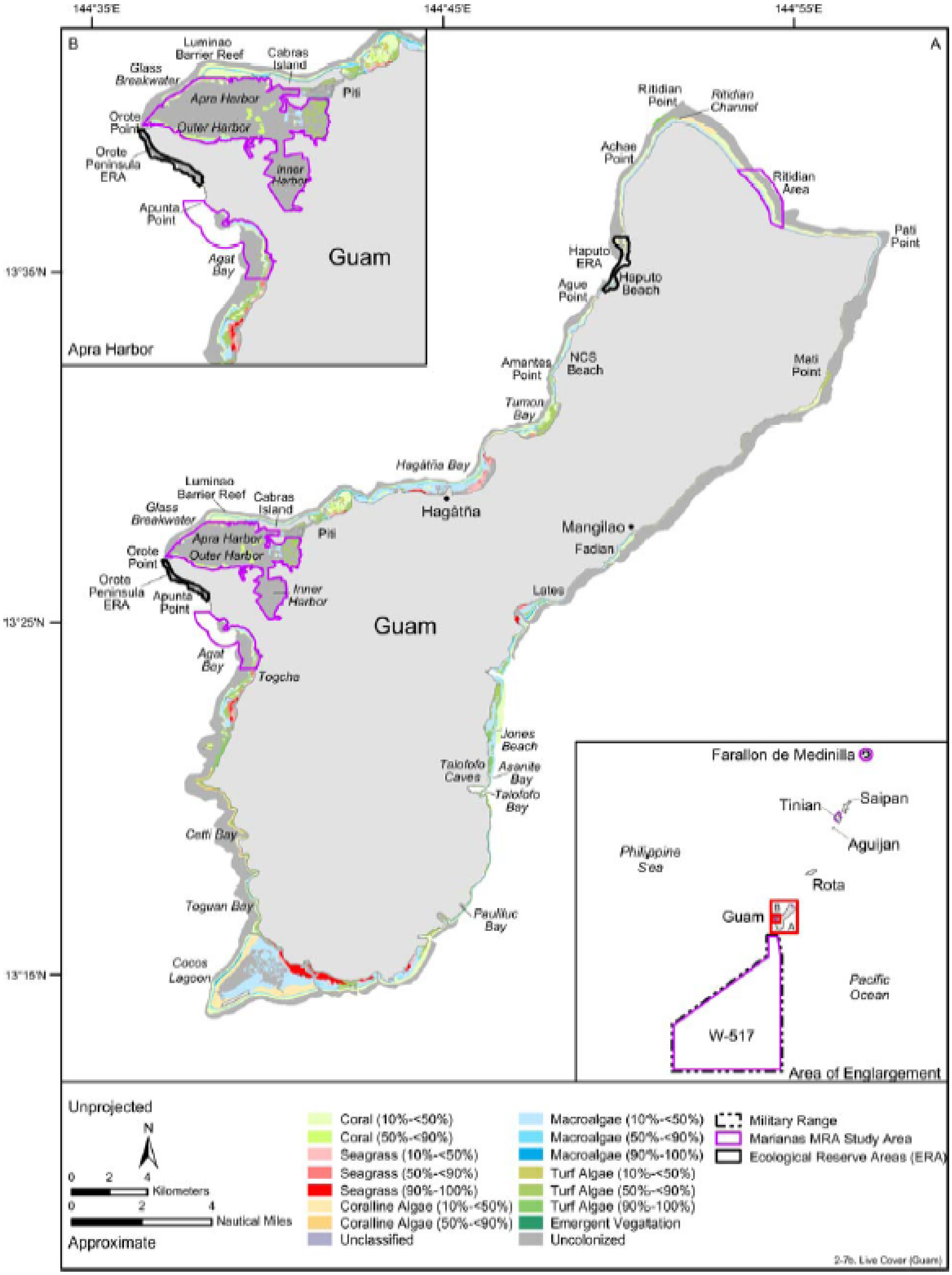

Figure 3-7b. Nearshore benthic habitats of the MIRC study area, Guam: Live cover. Source data: NCCOS/NOAA (2005).

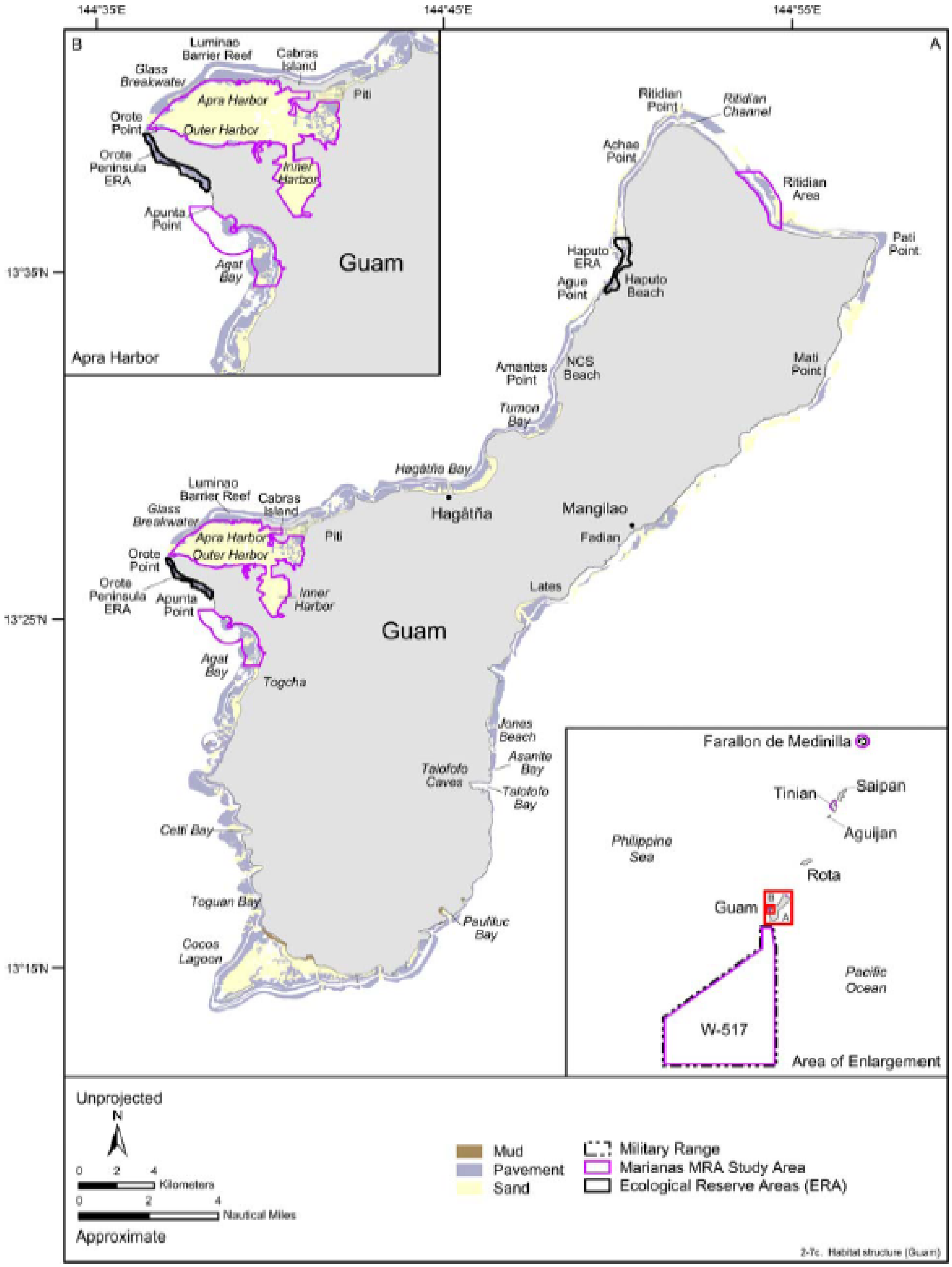

Figure 3-7c. Nearshore benthic habitats of the MIRC study area, Guam: Geomorphological structure. Source data: NCCOS/NOAA (2005).

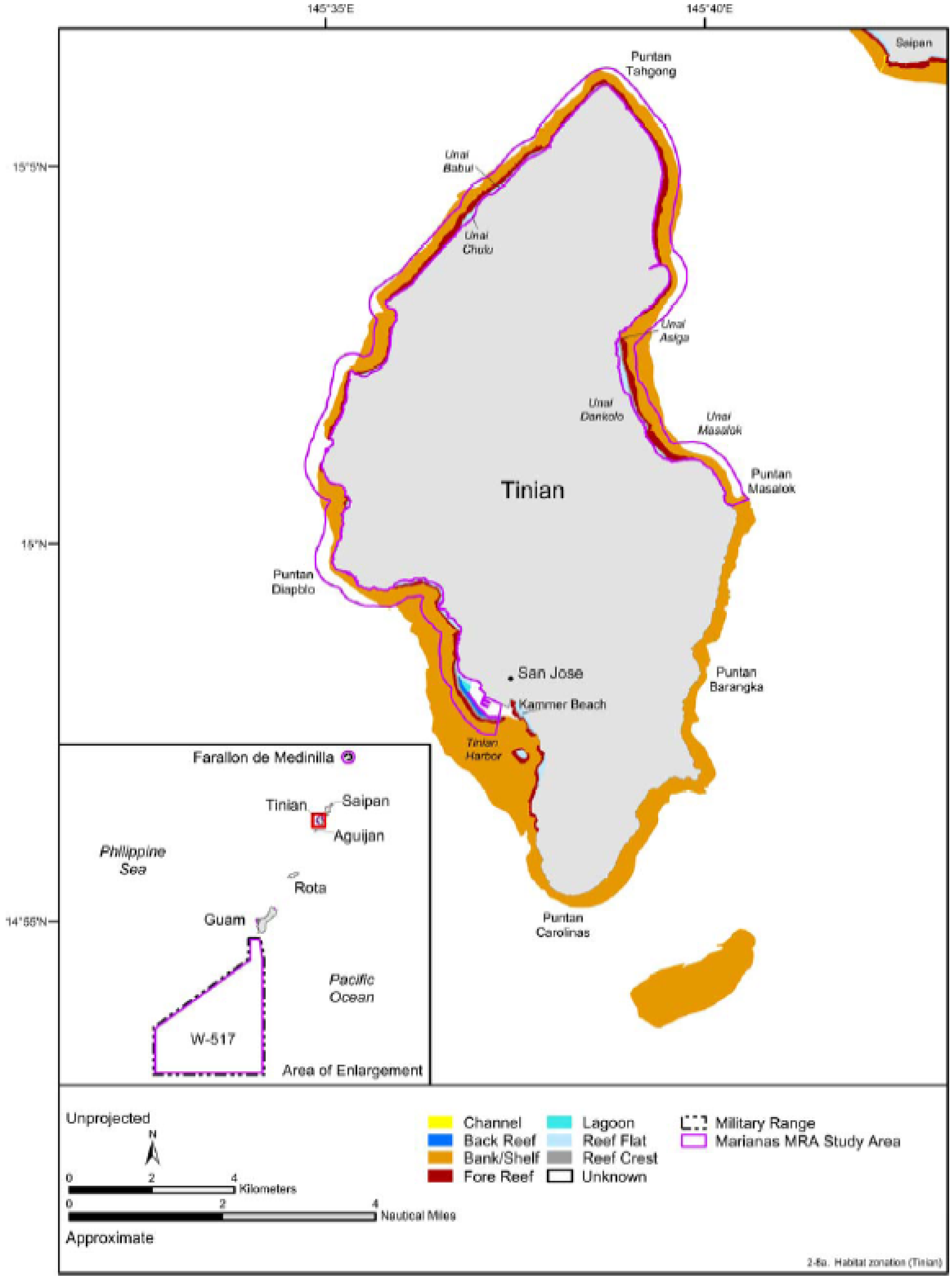

Figure 3-8a. Nearshore benthic habitats of the MIRC study area, Tinian: Habitat zonation. Source data: NCCOS/NOAA (2005).

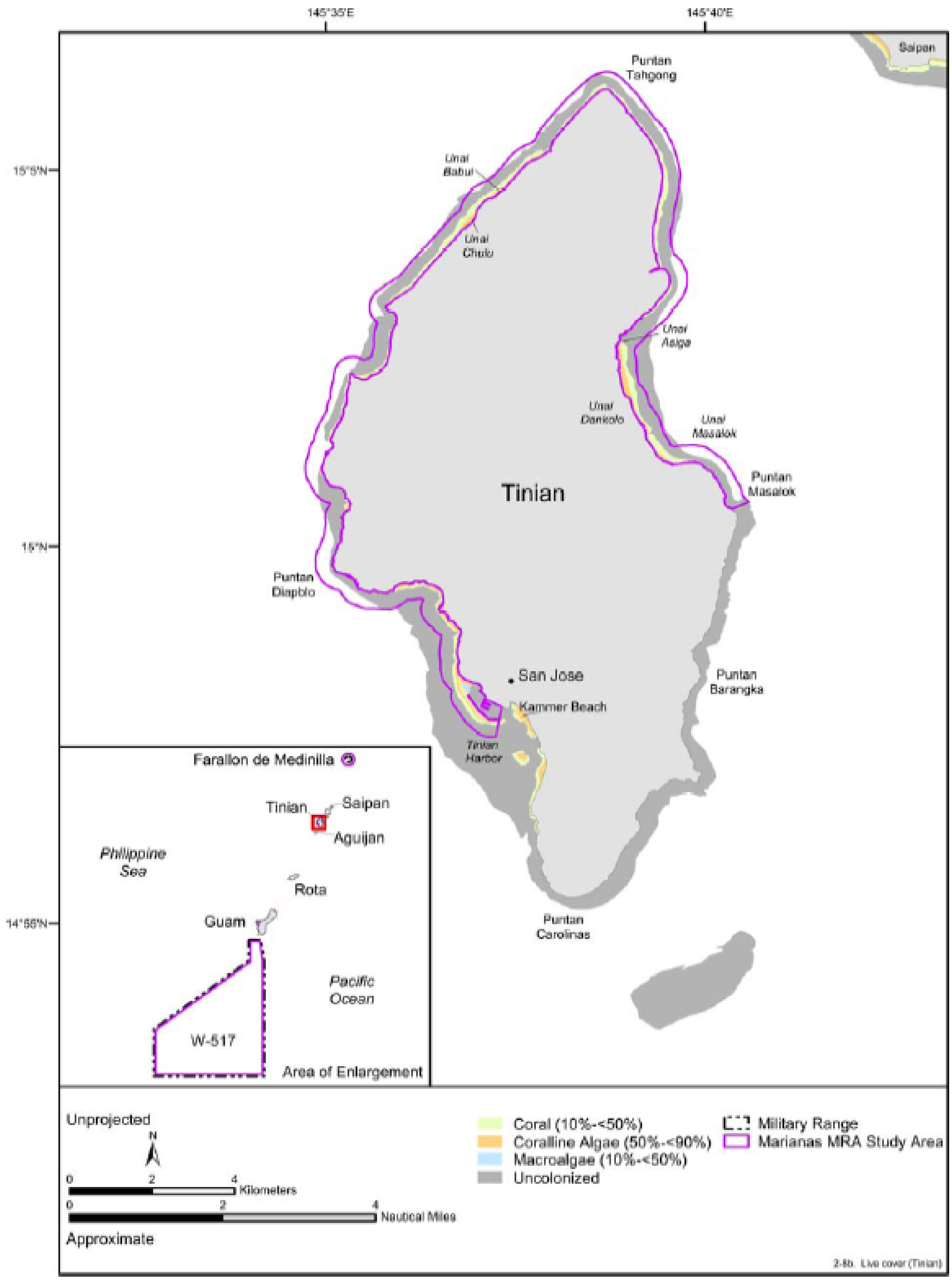

Figure 3-8b. Nearshore benthic habitats of the MIRC study area, Tinian: Live cover. Source data: NCCOS/NOAA (2005).

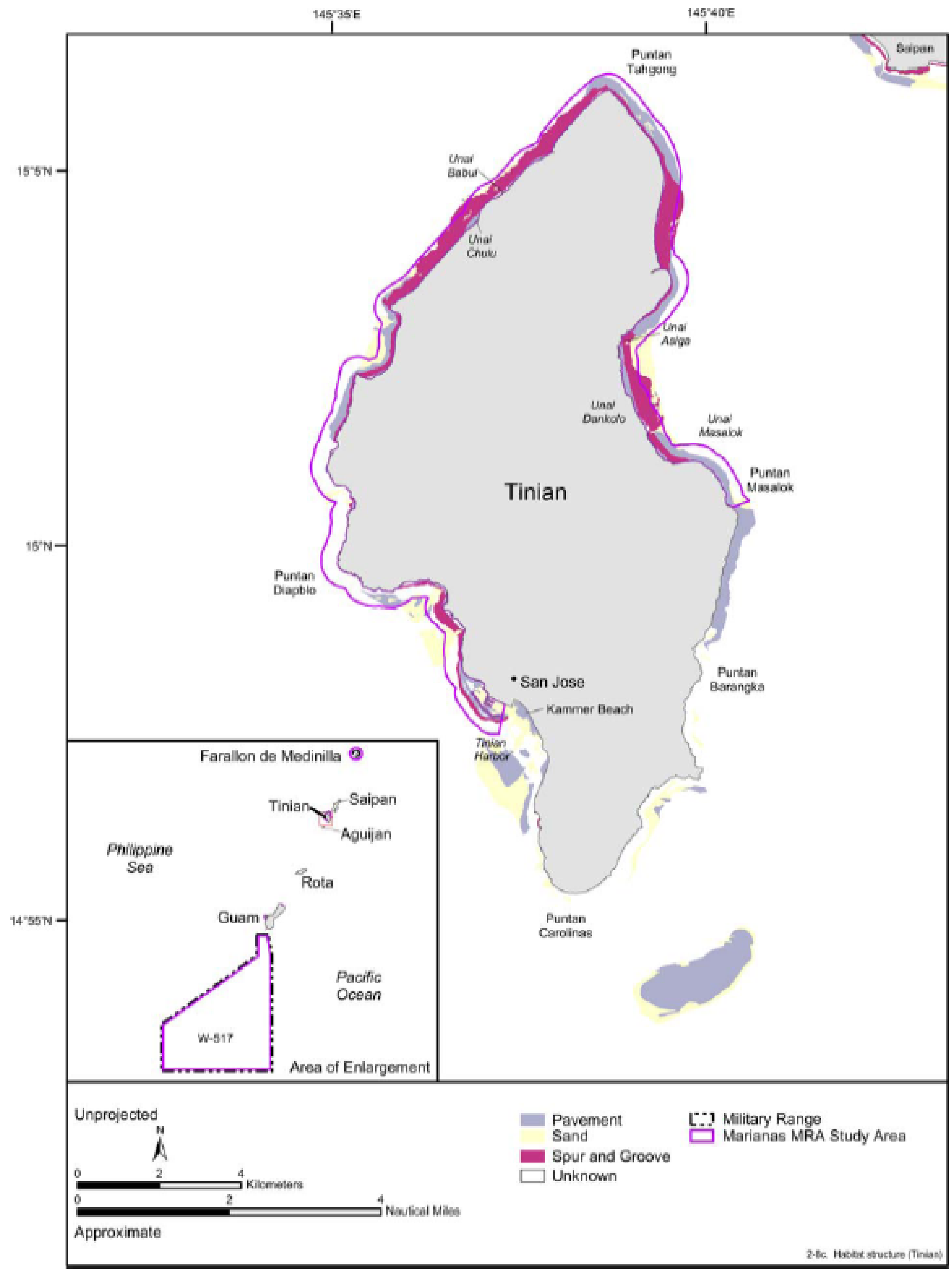

Figure 3-8c. Nearshore benthic habitats of the MIRC study area, Tinian: Geomorphological structure. Source data: NCCOS/NOAA (2005).

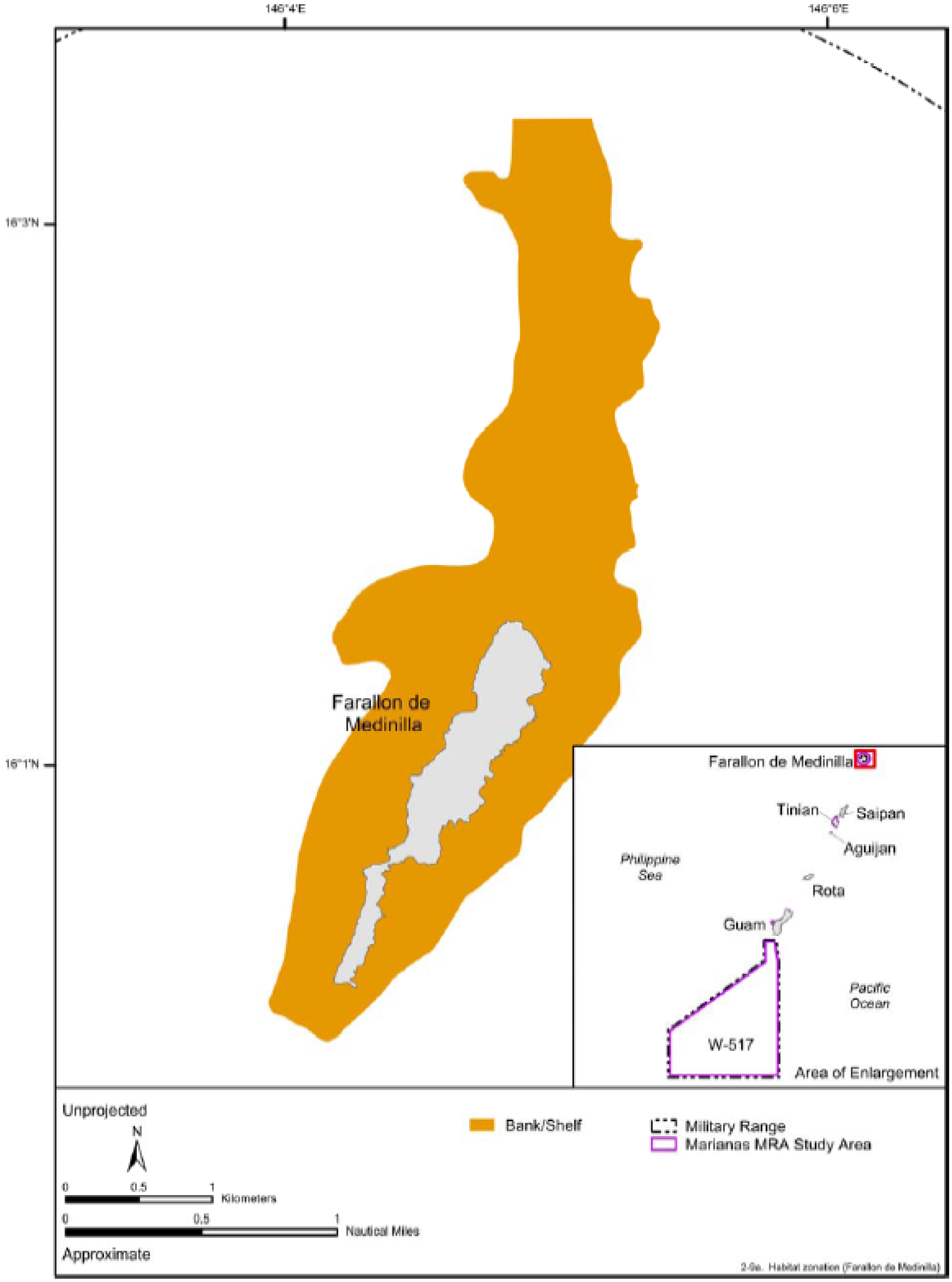

Figure 3-9a. Nearshore benthic habitats of the MIRC study area, Farallon de Medinilla: Habitat zonation. Source data: NCCOS/NOAA (2005).

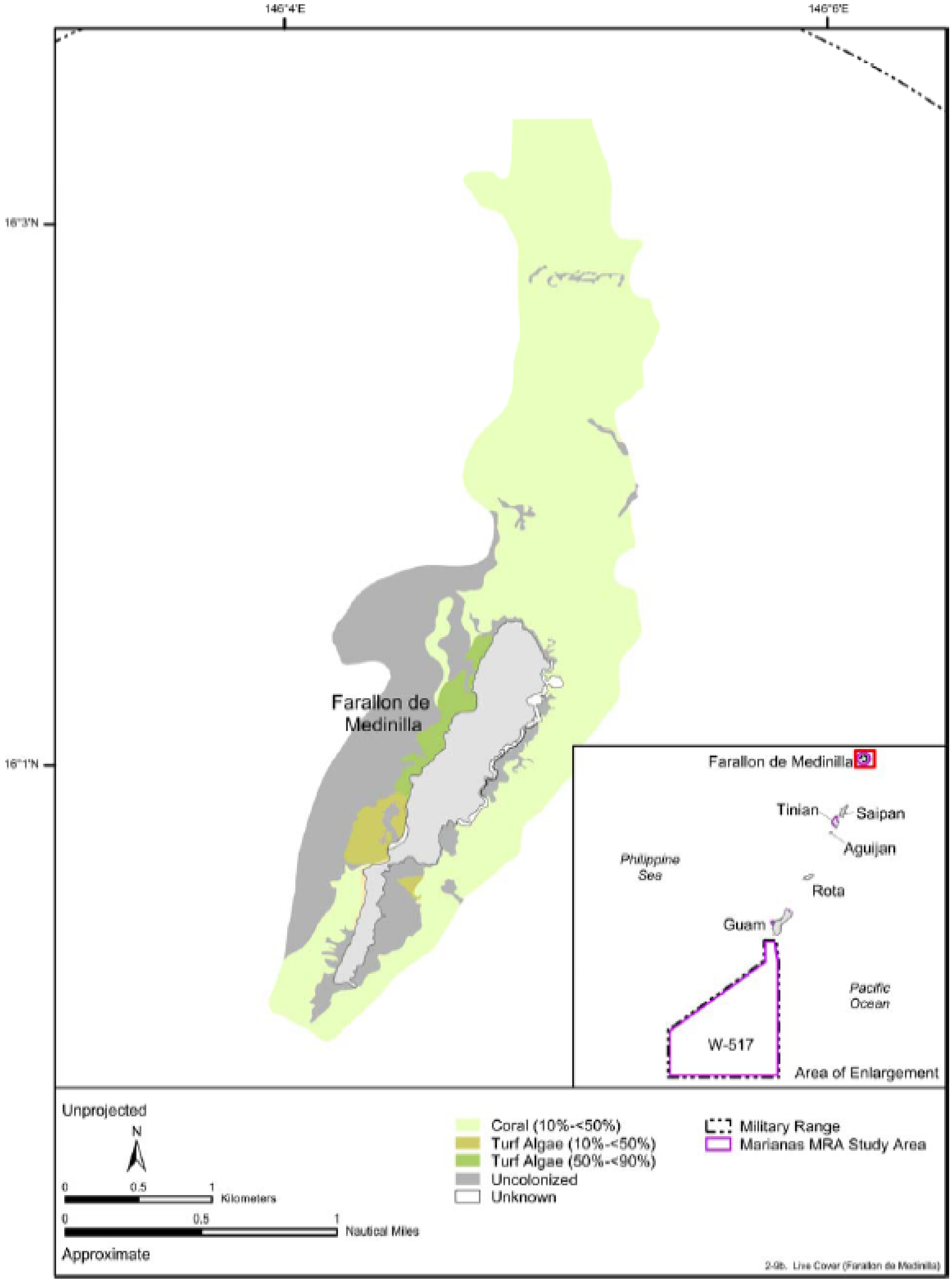

Figure 3-9b. Nearshore benthic habitats of the MIRC study area, Farallon de Medinilla: Live cover. Source data: NCCOS/NOAA (2005).

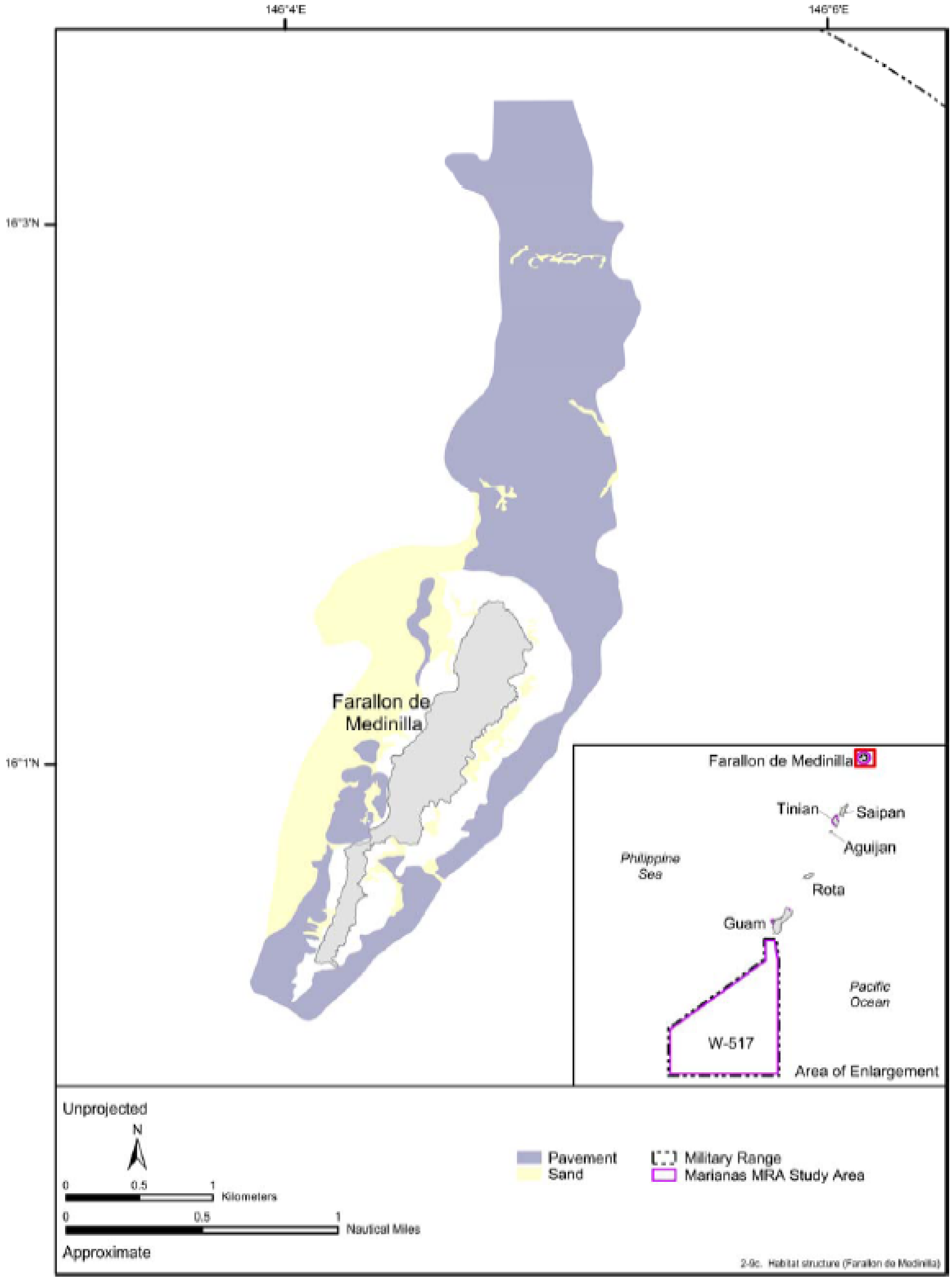

Figure 3-9c. Nearshore benthic habitats of the MIRC study area, Farallon de Medinilla: Geomorphological structure. Source data: NCCOS/NOAA (2005).

3.7.2.1 Regional Distribution, Composition, and Condition

Reefs located in the MIRC 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. Reefs of the Orote Peninsula Ecological Reserve Area (ERA) and the Haputo ERA in Guam are not specifically within the MIRC 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).

Coral communities and reefs are dynamic and changing ecosystems subject to natural and humaninduced 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; DoN 2005b). Typhoons can cause substantial damages to corals on windward coasts (DoN 2005b). 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, nonanastomosing branches like the fingers of a hand), and caespitose (bushy, branching, possibly fused branches) (DoN 2005b). There are currently more acroporids on reefs at Unai Dankulo than in sheltered bays of Lau Lau Bay (southeastern Saipan) or Sasanhaya Bay (southwestern Rota) (DoN 2005b). 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; DoN 2005b).

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, and in spite of the bleaching, Paulay and Benayahu (1999) observed no stony coral mortality during that bleaching event. In August and September 2007 a moderate regional bleaching event occurred, which extended from southern Japan to Palau. At FDM and in Apra Harbor, Guam, bleaching was almost entirely confined to two coral genera, *Pocillopora* and *Acropora*. Mortality of those taxa in Apra Harbor was high; nearly 100% on some *Acropora muricata* patch reefs. In contrast, at FDM, 2008 surveys showed that most bleached specimens recovered (Smith and Marx, 2009). 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; DoN 2005b). Weather and wave action-exposed reefs (e.g., Unai Dankulo, Tinian) appear to be more resilient to COTS outbreaks compared to reefs in sheltered bays (e.g., Lau Lau Bay, Saipan; Sasanhaya Bay, Rota) (DoN 2005b).

Other sources of coral mortality and degradation are freshwater runoff and seismic and volcanic activity. Freshwater runoff naturally affects reefs 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 (EE1997).

<u>Human-Induced Disturbances</u> - 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 MIRC 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.

3.7.2.2 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; DoN 2005b). The depiction of benthic habitats (including reefs) of Guam presented in Figures 3-7a, 3-7b, and 3-7c 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 (DoN 2005b). 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 3-7b). 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 3-7a, 3-7b, and 3-7c). 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.

Hagatna 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 Hagatna, 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 3-7a, 3-7b, and 3-7c). 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 (51 m), the Apra Harbor lagoon is unique to the MIRC 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; DoN 2005b). Coral cover in the outer harbor is greater than what is depicted in Figure 3-7b. Figure 3-7b is based on the

NCCOS/NOAA (2005) delineation (DoN 2005b); 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 3-7a (DoN 2005b). The bottom of Apra Harbor is a complex environment that includes substantially more reef than depicted in Figures 3-7b and 3-7c (DoN 2005b). More detailed surveys and benthic habitat maps for specific locations within Apra Harbor were produced for an artifical reef feasibility study (DoN 2007), and are depicted in Figures 3-10 to 3-13.

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, Figures 3-10 and 3-11). 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, Smith and Marx 2006, Figure 3-12). 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; Smith 2007).

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 (DoN 2005b). 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* (DoN 2005b). 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 (Smith 2007).

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*.

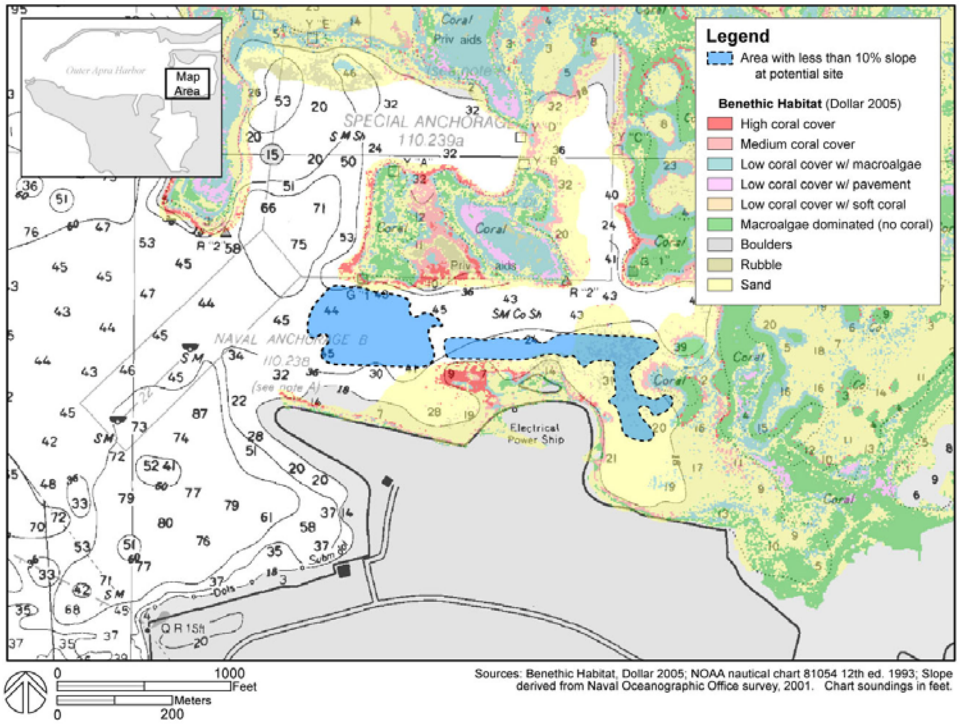

Figure 3-10. Benthic habitats of the Sasa Bay Artificial Reef Site. From DoN 2007.

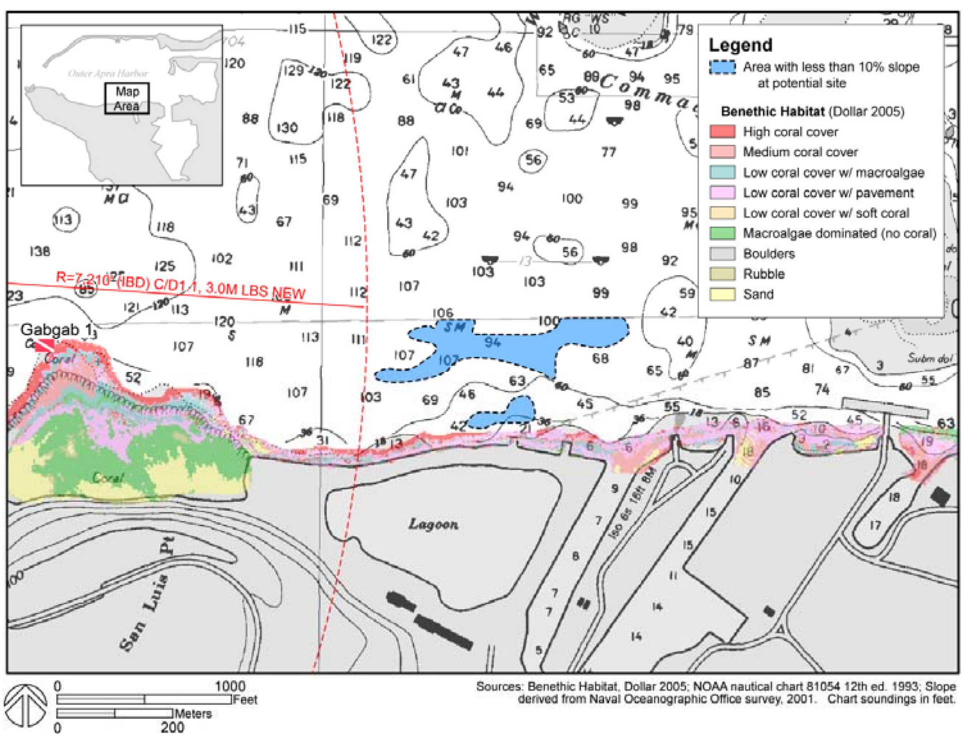

Figure 3-11. Benthic habitats of the San Luis Beach Artificial Reef Site. From DoN 2007.

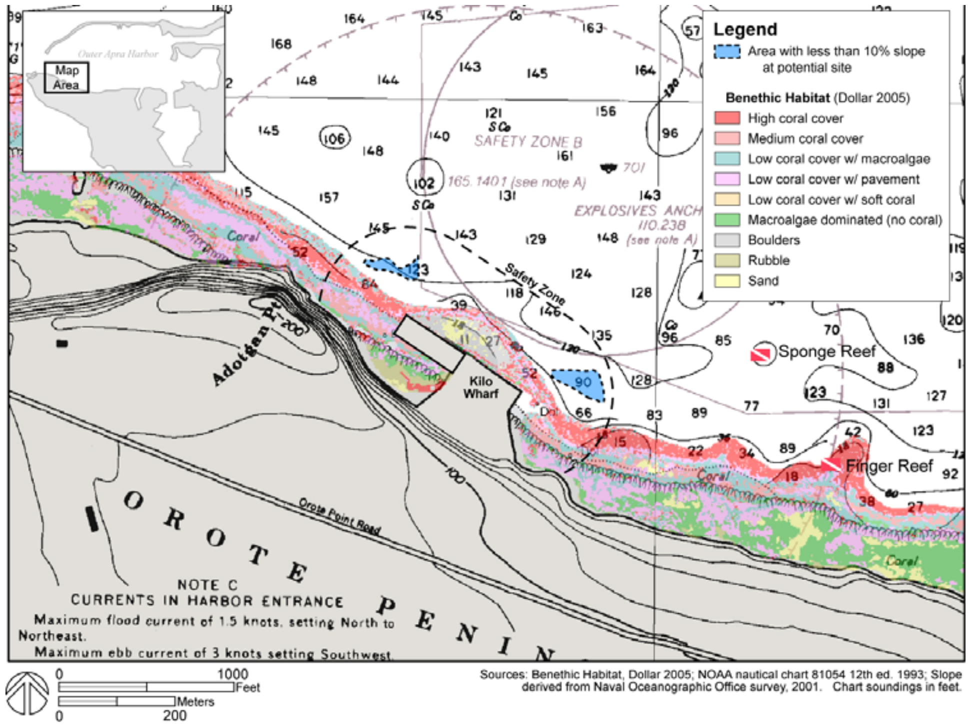

Figure 3-12. Benthic habitats of the Kilo Wharf Artificial Reef Site. From DoN 2007.

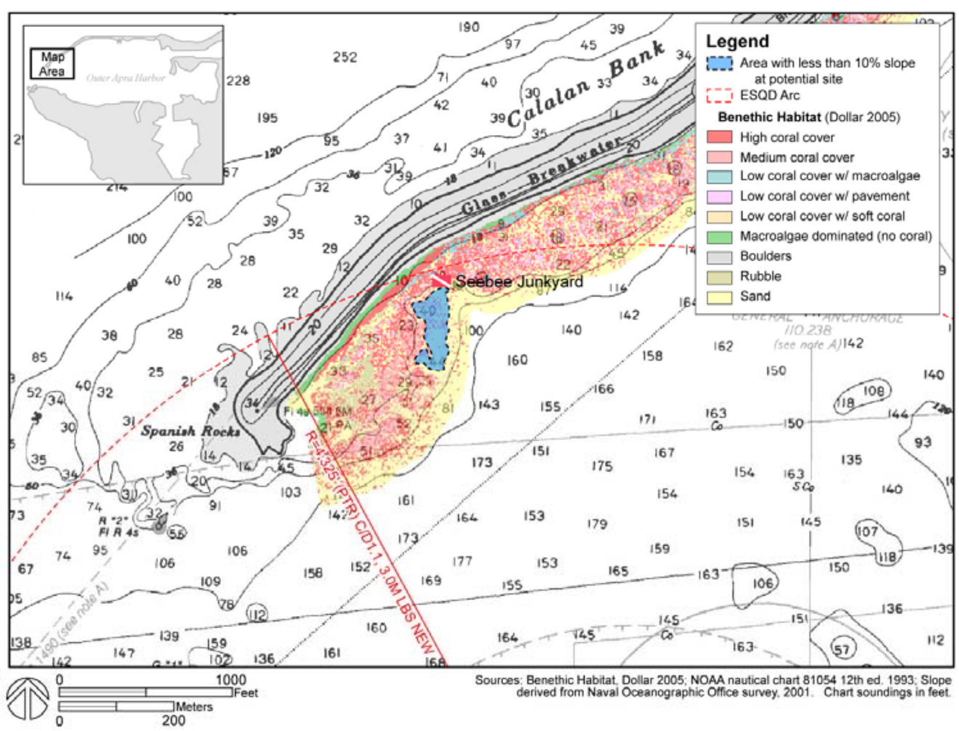

Figure 3-13. Benthic habitats of the Glass Breakwater Artificial Reef Site. From DoN 2007.

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, Figure 3-13). 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 1980-1981 Randall et al. survey, and 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 3-7a, 3-7b, and 3-7c). 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 one-third 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 (*Leptoria 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> - Located on the northern shore of Guam, the area 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 3-7a, 3-7b, and 3-7c). 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 3- 7a, 3-7b, and 3-7c). 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 (DoN 2005b).

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*) (DoN 2005b).

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 3-7a, 3-7b, and 3-7c). Paulay et al. (2001) recently surveyed coral reefs from Orote Point to the northern half of Agat Bay. 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.

3.7.2.3Coral 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 3-8a, 3-8b, and 3-8c). 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. 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, 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 3-8a, 3-8b, and 3-8c). 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 Dankulo are three beach areas and nearshore reefs within the MIRC 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 Dankulo 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, flattopped, 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 Dankulo 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).

3.7.2.4 Coral Communities and Reefs of Farallon de Medinilla

In contrast with the other southern Mariana Islands, FDM does not include fringing or fore reefs (Figures 3-9a, 3-9b, and 3-9c). 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; DoN 2005). 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, 2006). 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 narrow rocky spur reef extends several hundred meters southward. The shallowest portions of the spur are less than 3 m deep; the sides of the spur are steep, 45 to 90 degrees and extend deeper than 30 m. Between depths of about 7 and 25 m, stony coral cover exceeds 50% in some areas, comprised primarily of pocilloporids. The densest fish populations on the island are found along this spur and at the north west end of FDM.

Near the cliff edge on the reef terrace of the eastern side of FDM, there is estimated to be less than 5% coral cover (DoN 2005). Further offshore, there is estimated to be 10 to 20% coral cover composed of encrusting *Porites* and head coral forming *Pocillopora*. Coral cover on the boulders is estimated to be 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 are estimated to be from 15 to 25%, and is composed of *Porites* and *Pocillopora*. Sea urchin populations have fluctuated dramatically during the survey years. All species of urchins were sparse during the 2005, 2006 and 2007 surveys. In 2008, urchin levels were high and probably comparable to those noted in 2004. Stony coral cover is greatest below 7 m on the tops of boulders/cliff blocks, on submerged cliff faces and on the plateau off the isthmus. Based upon percent sea floor cover and frequency of occurrence *Pocillopora meandrina* and *Pocillopora eydouxi* are the dominant corals at FDM, followed by head forming species of *Porites*.

Since 1971, FDM has been a target site for live-fire military exercises (ship-to-shore gunfire, aerial gunnery and bombing) (DoN 2005). FDM is divided into four areas: Areas 2 and 4 are designated “no fire /no drop.” While some ordnance items and ordnance fragments have been observed underwater, offshore all four areas, the vast majority have been sighted off Area 1 and the southern half of Area 3 (Appendix A, Figure A-3).

Yearly assessments of the near shore marine and fisheries resources at FDM have been conducted since 1999. The surveys conducted through 2004 were performed by a Navy contract biologist, with assistance from a NOAA, USFWS, and CNMI representative. Support was also provided by Navy EOD personnel. The 2005, 2006, 2007, and 2008 surveys were performed by Navy marine ecologists, with support from Navy EOD personnel. Based upon the observations made between 1999 and 2008, fish stocks around FDM are robust and healthy. In fact, based upon subjective estimates of size, total numbers and health, the fish stocks around FDM are probably among the best in the entire archipelago (DoN 2009). Sea turtle sightings have remained relatively stable between 1999 and 2008; both green sea turtles and hawksbill turtles have been regularly sighted. With the exception of the 2004 survey, there has never been any evidence that the range activities have had an adverse impact to the coral community, or other near shore marine natural resources. During the 2004 survey, it was noted that many of the corals with branching or plating type growth forms sustained significant breakage. Some members of the 2004 survey team suggested this could be the result of bombing/training activities. However, based upon observations at other locations, bombing levels in previous and subsequent years, plus observations made during the 2005, 2006, 2007, and 2008 surveys, it is clear that the damage observed in 2004 was a result of a direct hit on FDM by Typhoon Ting Ting shortly before the 2004 survey was conducted (DoN 2006). In conclusion, the near shore marine natural resources at FDM are thriving; the island in fact, is serving as a de-facto preserve due to the restricted fishing access (DoN 2009; also see Riegl et al. 2008 for comparable results at Vieques, Puerto Rico).

3.7.3 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 3-7 through 3-9). 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 (DoN 2005b).

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; DoN 2005b) and are important feeding grounds for migratory shorebirds (Scott 1993, Figures 3-7 through 3-9).

Softbottom substrates in coastal regions of the MIRC 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 3-7c) 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 (DoN 2005b).

3.7.4 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 MIRC 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 MIRC study area (Day et al. 1999). Rather, mangroves, the tropical equivalent of salt marshes, occur within the MIRC 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 MIRC study area including sand flats, mud flats, lagoons, and mangroves can be found within this section.

3.7.5 LAGOONS

A lagoon 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). By geomorphological definition, true lagoons lie only behind barrier reefs, while moats (a shallow analogue of lagoons) can lie behind fringing reefs (DoN 2005b). 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 (DoN 2005b).

The MIRC 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 3-7 through 3-9). 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 3-7a). 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 3-7a). 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 3-7a).

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 Figure 3-8a), 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 "semilagoon" 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).

3.7.6 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 3-14), 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).

3.7.7 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 MIRC study area, however, are only present on the islands of Guam and Saipan (Figure 3-14), with the mangroves of Guam being the most extensive and diverse, 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 3-14). 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 atthe southern tip of the Inner Apra Harbor (Sites H, O, P, and Q) amount to 12.4 ha of mangrove forests (Figure 3-14). 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 3-14). 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 Apra 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.

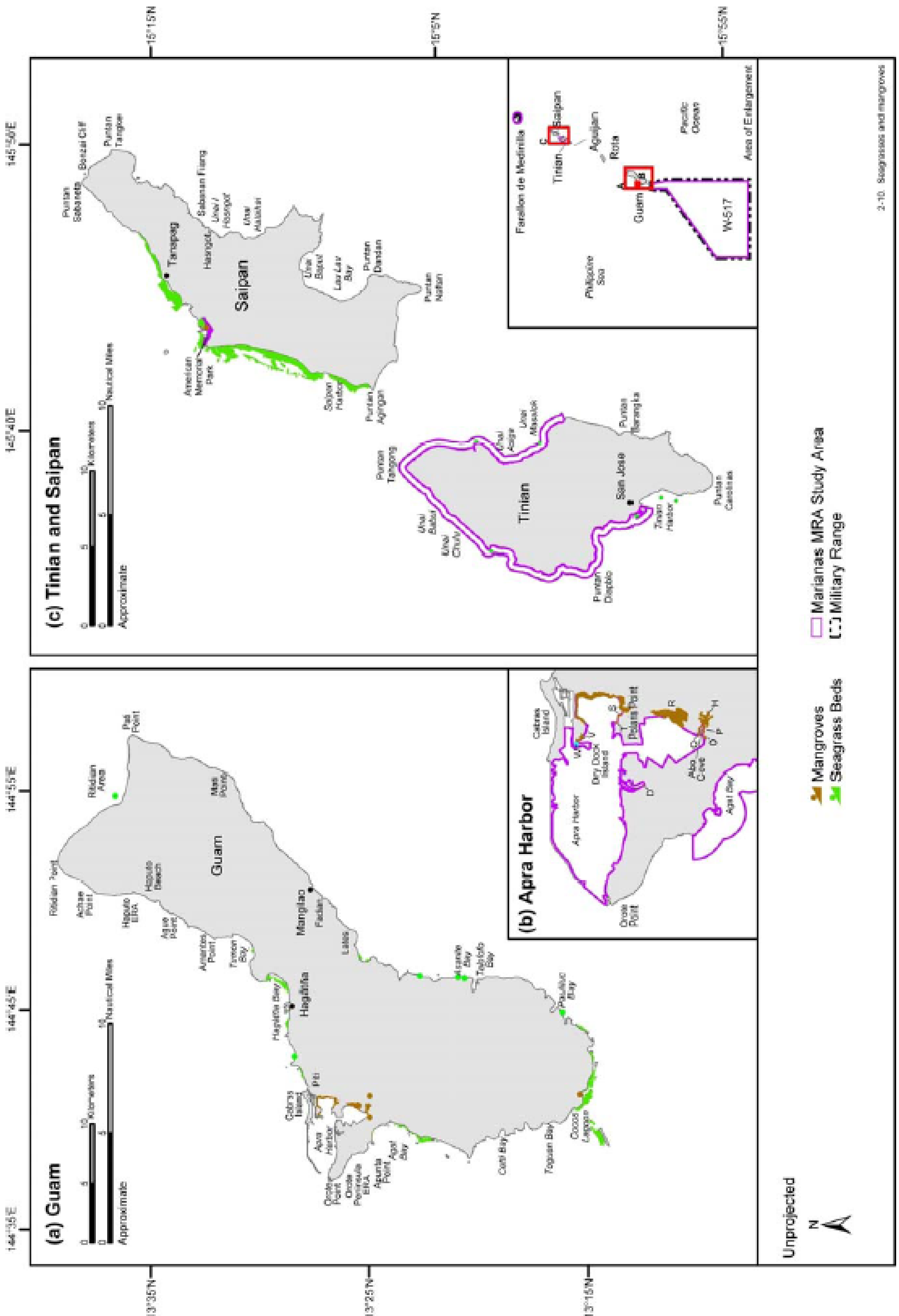

Figure 3-14. Distribution of seagrass and mangrove communities in the MIRC study area (a) Guam, (b) Apra Harbor, (c) Tinian and Saipan. Source data: Jones et al. (1974), Scott (1993), DoN (1999, 2003), and NCCOS/NOAA (2005).

3.7.8 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, Fish Aggregating Devices (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).

3.7.8.1 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 within the MIRC study area: Agat Bay, Guam and Apra Harbor, Guam (Figure 3-15). 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 (DoN 2005b). 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 MIRC study area. The passage of tropical cyclones and typhoons have probably damaged and/or displaced the reefs placed in Cocos Lagoon (DoN 2005b). The installation of artificial reefs around Guam is currently prohibited (DoN 2005b).

3.7.8.2 Shipwrecks

Many shipwrecks are found within the MIRC study area including grounded vessels and military wreckage (Figure 3-15). 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 MIRC study area have become popular dive sites. 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), Hagatna 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 abandoned vessels documented in the Piti Channel and the Hagatna 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.

Coral growth, on the steel hulled vessels, causeways and other metallic items sunk in Apra Harbor and at other locations within the Mariana Archipelago, is highly variable. Some wrecks support diverse and robust coral growth, while other wrecks at the same depth and in close proximity support only meager coral growth. The reason for these differences is not known, but may be related to the type of steel and presence/absence of anti-fouling/anti-corrosion coatings on the steel (Smith, S.H. personal communication).

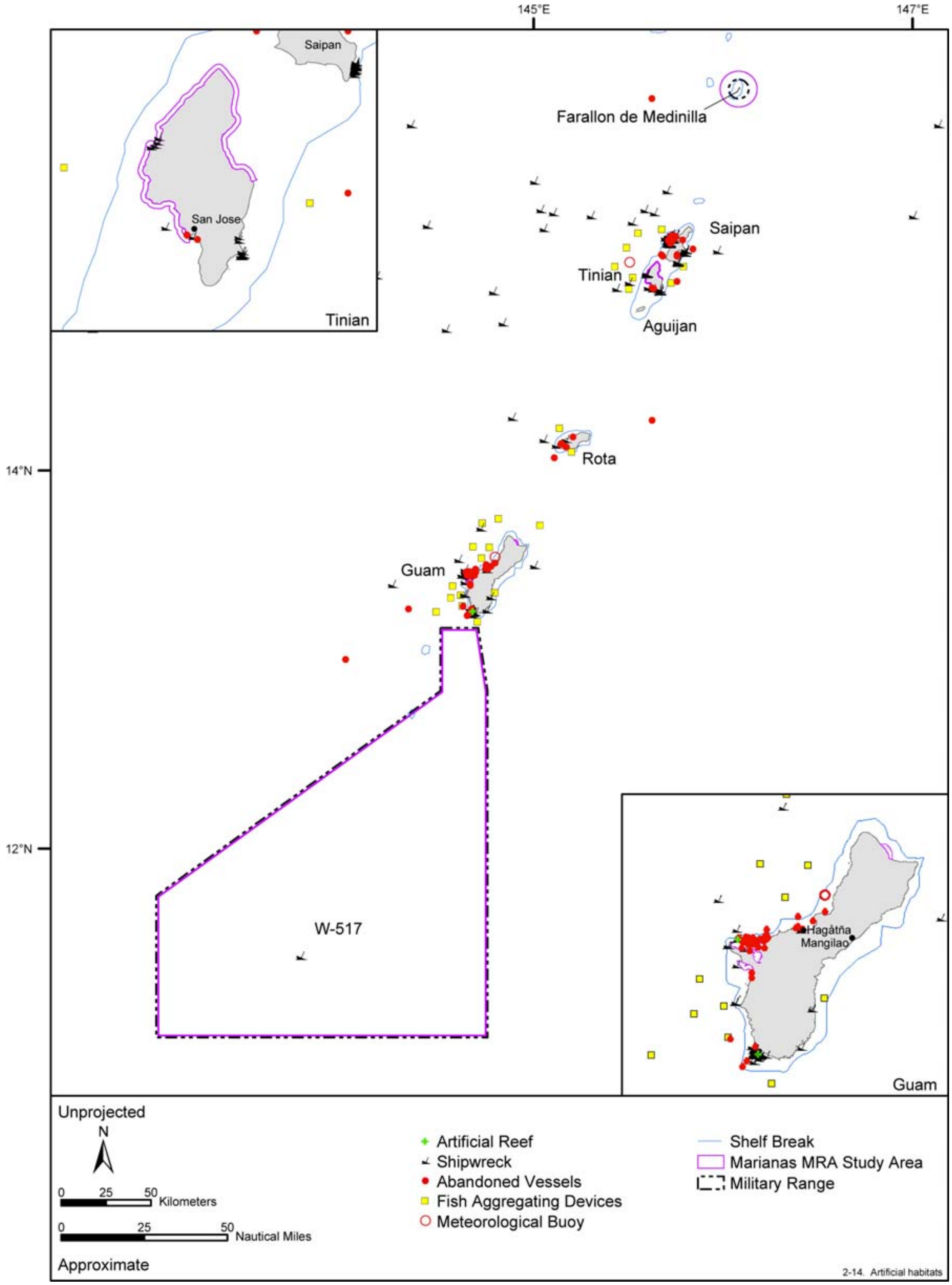

Figure 3-15. Distribution of artificial reefs, shipwrecks, and fish aggregating devices in the MIRC study area. Source data: Eldredge (1979), Veridian Corporation (2001), NOAA (2004c), DAWR (2004), and CNMI DFW (2005).

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).

3.7.8.3 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 MIRC 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 3-15). 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).

<u>Buoys</u> - 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 MIRC study area (Figure 3- 15). 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 3-15). 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 MIRC study area, and has surface buoys on Rota, Saipan, Pagan, Maug (DoN 2005b).

4.0 ESSENTIAL FISH HABITAT

EFH information and citations provided below come from the *Marine Resources Assessment for the Marianas Operating Area* (DoN 2005b), with additional technical information and changes incorporated throughout this section. Life history information for manged species is provided in Appendix B.

4.1 FISH AND FISHERIES

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 (NMFSPIR 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 MIRC 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 MIRC 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 MIRC study area show strong seasonal fluctuation, usually related to juvenile recruitment (Amesbury et al. 1986).

Fish species composition within the MIRC 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 MIRC 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 MIRC 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 MIRC 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: MANAGEMENT JURISDICTION

The Western Pacific Regional Fishery Management Council (WPRFMC) manages major fisheries within the Exclusive Economic Zone (EEZ) around Hawaii 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 MIRC 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 MIRC study area that require regional management. The WPRFMC currently oversees five major Fishery Management Plans (FMPs) and their associated amendments for bottomfish, pelagics, crustaceans, precious corals, and coral reef ecosystems.

The MSFCMA, as amended by the Sustainable Fisheries Act (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: invasive 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 may also 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 listed in Table 4-1 and discussed in Appendix B. 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 with figures provided in Appendix B.

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 4-2; 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 deepwater 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 MIRC 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 B-1, B-2, B-3, and B-4; Table 4-2)

<u>Eggs and Larvae</u> - 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.

<u>Juveniles and Adults</u> - 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 deepwater complexes.

HAPC Designations - (WPRFMC 1998; Figures B-1, B-2, B-3, and B-4). Based on the known distribution and habitat requirements, all life stages of the BMUS have HAPC designated in the MIRC study area that includes all slopes and escarpments between 40 and 280 m.

Table 4-1. The fish and invertebrate species with essential fish habitat (EFH) designated in the MIRC 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 rutilansi*)

Pelagic Management Unit Species

Marketable Species Complex:

Temperate Species
Striped marlin (*Tetrapurus audax*)
Broadbill swordfish (*Xiphias gladius*)
Northern bluefin tuna (*Thunnus thynnus)*
Albacore *(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*)
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*)

Shark Species Complex

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* sp*.*)
Chinese slipper lobster (*Parribacus antarticus*)

Coral Reef Ecosystem *

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

Table 4-1. The fish and invertebrate species with EFH designated in the MIRC study area (continued).

Surgeonfishes (Acanthuridae) (continued)
- 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 (*Balistapus viridescens*)
- Clown triggerfish (*Balistoides conspicillum*)
- Orangestripped triggerfish (*Balistapus undulatus*)
- Pinktail triggerfish (*Melichtys vidua*)
- Black triggerfish (*Melichtys niger*)
- Blue triggerfish (*Pseudobalistes fuscus*)
- Picassofish (*Rhinecanthus aculeatus*)
- Wedged picassofish (*Rhinecanthus rectangulus*)
- Bridled 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*)
- 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*)*
- Grey 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 (*Xyricthys pavo*)
- Whitepatch wrasse (*Xyrichtes aneitensis*)
- Cigar wrasse (*Cheilio inermis*)
- Saddleback hogfish (*Bodianus bilunulatus*)
- 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 cyclostomus*)
- Side-spot goatfish (*Parupeneus pleurostigma*)
- Multi-barred goatfish (*Parupeneus multifaciatus*)
- Bantail goatfish (*Upeneus arge*)

Mullets (Mugilidae)
- Engel's mullet (*Moolgarda engeli*)
- False mullet (Neomyxus leuciscus)
- Fringelip mullet (Crenimugil crenilabis)

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

Octopuses (Octopodidae)
- Day squid (*Octopus cyanea*)
- Night squid (*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*)

Table 4-1. The fish and invertebrate species with EFH designated in the MIRC study area (continued).

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*)

<u>Aquarium Taxa/Species</u>

Surgeonfishes (Acanhturidae)
- Yelow tang (*Zebrasoma flavescens*)
- Yellow-eyed surgeonfish (*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*)
- 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)

<u>Potentially Harvested Coral Reef Taxa (PHCRT):</u>

<u>Fish Management Unit Species</u>

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 (Millidae) [1]
Other Surgeonfishes (Acanthuridae spp.) [1]
Other Emperor Fishes (Lethrinidae) [4]
False Moray Eels (Chlopsidae) [1]
Conger and Garden Eels (Congridae) [1]
Spaghetti Eels (Moringuidae) [1]
Snake Eels (Ophichthidae) [1]
Other Moray Eels (Muraenidae) [1]
Cardinalfishes (Apogonidae)
Bigeyes (Pricanhtidae)
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 Flounderes (Bothidae)
Right-eye Flounderes (Pleuronectidae)
Soles (Soleidae)
Trunkfishes (Ostraciidae)
Pufferfishes (Teradontidae)
Porcupinefishes (Diodontidae)
Spadefishes/Batfishes (Ephippidae)
Monofishes (Monodactylidae)
Grunts (Haemulidae)
Remoras (Echineididae)
Tilefishes (Malacanthidae)
Dottybacks (Pseudochromidae)
Prettyfins (Plesiopidae)
Coral crouchers (Caracanthidae)
Soapfishes (Grammistidae)
Trumpetfishes (Aulostomidae)
- Chinese Trumpetfish (*Aulostomus chinensis*)

Cornetfishes (Fistularidae)
- Reef cornetfish (*Fistularia commersoni*)

Flashlightfishes (Anomalopidae)
Herrings and Sardines (Clupeidae)
Anchovies (Engraulidae)
Gobies (Gobiidae)
Other Snapperes (Lutjanidae) [2]
Other Triggerfishes (Balistidae spp.) [1]
Other Filefishes (Monocanthidae spp.) [1]
Other rabbitfishes (Siganidae) [1]
Rudderfishes (Kyphosidae) [1]
Fusiliers (Caesionidae)
Hawkfishes (Cirrhitidae) [1]
Frogfishes (Antennariidae)
Pipefishes and Seahorses (Syngnathidae)

<u>Invertebrate Management Unit Species</u>

Mollusks (Mollusca) [1]
- Sea Snails and Sea Slugs (Gastropods)
  - Trochus (*Trochus* spp.)
- Bivalve (Oysters and Clams)
  - Black-lipped pearl oyster (*Pinctada margaritifera*)
  - Giant clams (Tridacnidae)
  - Other Clams

Nautiluses, cuttlefishes, squids, and octopuses (Cephalopods)
Tunicates (Ascidians)
Moss Animals (Bryozoans)
Mantis Shrimps, Lobsters, Crabs, and Shrimps (Crustacean) [5]
Sea Cucumbers and Sea Urchins (Echinoderms)
Segmented Worms (Annelids)

Table 4-1. The fish and invertebrate species with EFH designated in the MIRC study area (continued).

<u>Sessile Benthos Management Unit Species</u>

- 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 Rocks

Table 4-2. Bottomfish Management Unit Species EFH Designations.

Management Unit Species/Taxa	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	Comments
BOTTOMFISH											
Shallow-water Species Complex (0 to 100 m)											
Gray jobfish (*Aprion virescens*)		A		J	J	A,J	A,J		A	E,L	Adult depth of 3-180 m
Lunartail grouper (*Variola louti*)		A				A	A			E,L	Adult depth of 4-200 m
Blacktip grouper (*Epinephelus fasciatus*)				J		A,J	A		A	E,L	Adult depth of 0-160 m
Ambon emperor (*Lethrinus amboinensis*)						A,J	A,J		A,J	E,L	ND
Redgill emperor (*Lethrinus rubrioperculatus*)									A	E,L	Adult depth of 0-160 m
Giant trevally (*Caranx ignoblis*)			J		J					E,L	Adult depth of 80 m
Black jack (*Caranx lugubris*)									A	A,J,L,E	Adult depth of 12-354 m
Amberjack (*Seriola dumerili*)						J	A,J		A	A,J,L,E	Adult depth of 0-250 m
Blue stripe snapper (*Lutjanus kasmira*)		A		J		A,J			A	E,L	Adult depth of 0-265 m
Deep-water Species Complex (100 to 400 m)											
Squirrelfish snapper (*Etelis carbunculus*)						A			A	E,L	Adult depth of 90-350 m
Longtail snapper (*Etelis coruscans*)						A			A	E,L	Adult depth of 164-293 m
Pink snapper (*Pristipomoides filamentosus*)					J				A	E,L	Juvenile depth of 65-100 m; 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

Source: 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).

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 4-3). 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).

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

Table 4-3. Pelagic Management Unit Species EFH Designations.

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	No data
Albacore tuna (*Thunnus alalunga*)										A,J,L	Depth Distribution: surface to 380 m
Bigeye tuna (*Thunnus obesus*)										A,J,L,E	Depth Distribution: surface to 600 m
Mackerel (*Scomber* spp.)										A,J,L,E	No data
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	No data
Bullet tuna (*Auxis rochei*)										A,J,L,E	No data
Indo-Pacific blue marlin (*Makaira nigricans*)										A,J,L,E	Depth Distribution: 80-100 m
Black marlin (*Makaira indica*)										A,J,L,E	Depth Distribution: 457-914 m
Shortbill spearfish (*Tetrapturus angustirostris*)										A,J,L,E	Depth Distribution: 40-1,830 m
Sailfish (*Istiophorus platypterus*)										A,J,L,E	Depth Distribution: 10-20 to 200-250 m
Dolphinfishes (Coryphaenidae)											
Dolphinfish (*Coryphaena hippurus*)			A,J							A,J,L,E	No data
Pompano dolphinfish (*Coryphaena equiselas*)										A,J,L,E	No data
Wahoo (*Acanthocybium solandri*)										A,J,L,E	Adult depth <200 m
Moonfish (*Lampris guttatus*)										A,J	Depth Distribution: surface to 500 m
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

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).

Table 4-3. Pelagic Management Unit Species EFH Designations (cont'd).

Management Unit Species/Taxa	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	Comments
Shark Species Complex											
Common thresher shark (*Alopias vulpinus*)		J								A,J	Depth Distribution: surface to 366 m
Pelagic thresher shark (*Alopias pelagicus*)		A				A				A,J	Depth Distribution: surface to 152 m
Bigeye thresher shark (*Alopias superciliosus*)										A,J	Depth Distribution: surface to 500 m
Shortfin mako shark (*Isurus oxyrinchus*)										A,J	Depth Distribution: surface to 500 m
Longfin mako shark (*Isurus paucus*)										A,J	No data
Salmon shark (*Lamna ditropis*)										A,J	Depth Distribution: surface to 152 m
Silky shark (*Carcharhinus falcirormis*)									A	A,J	Adult depth of 18-500 m
Oceanic whitetip shark (*Carcharhinus longimanus*)										A,J	Adult depth of 37-152 m
Blue shark (*Prionace glauca*)										A,J,L,E	Depth Distribution: surface to 152 m

Source: 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).

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 B-5; 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 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 (DoN 2005). None of the species found in the MIRC 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 (DoN 2005b).

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, DoN 2005). 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, DoN 2005). 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 MIRC 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 B-6, B-7, B-8, and B-9; Table 4-4)

<u>Larvae</u> - 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.

<u>Juveniles and Adults</u> - 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.

Table 4-4. Crustaceans Management Unit Species EFH Designations.

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* sp.)		All			A,J	All	All		All	L	Depth Distribution: 9 to 183 m
Chinese slipper lobster (*Parribacus antarticus*)						A					Depth Distribution: 0 to 20 m

Source: 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)

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 Hawaii, the Territories of American 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 Currently Harvested Coral Reef Taxa (CHCRT) and Potentially Harvested Coral Reef Taxa (PHCRT) will only be delineated by specific U.S. Pacific Island areas when information is available. While the MRA focused 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 that 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 MIRC 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 B-11).

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 MIRC study area and their respective fishery management units are found in Table 4-1.

Table 4-5. Coral Reef Ecosystem Management Unit Species EFH Designations.

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 (Acanhthuridae)	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 and Xyricthys spp.		J	J	J	A,J,S	A,J,S	A,J,S		A,J,S	E,L	Juvenile depth of 2 m; Adult depth of 2-20 m
Cheilinus and *Choerodon* spp.		A,J	J		A,J,S	A,J,S	A,J,S		A,J,S	E,L	Adult depth of 1-30 m
Oxycheilinus spp.		A,J			A,J,S	A,J,S	A,J,S		A,J,S	E,L	Adult depth of 1-160 m
Hemigymnus spp.		A,J		J	A,J,S	J	J,S		A,J,S	E,L	Adult depth of 1-40 m
Cheilio spp.											Adult depth of 1-30 m
Halichoeres spp.		A,J	J		A,J,S	A,J,S		A,J		E,L	Adult depth of 1-30 m
Thalassoma spp.		A,J		J	A,J,S	A,J,S	A,J,S			E,L	Adult depth of 1-30 m
Hologynmosus and *Novaculichthys* 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

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). Source: Colin and Arneson 1995, Sorokin 1995, Myers 1999, WPRFMC 2001

Table 4-5. Coral Reef Ecosystem Management Unit Species EFH Designations (cont'd)

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 (Scomberidae)											
Dogtooth tuna (*Gymnosarda unicolor*)		A,J,S			A,J	A,J,S	A,J		A,J	E,L	Adult depth of 0-100 m
Rabbitfishes (Siganidae)	A,J,S	A,J,S	A,J,S	J		A,J,S	A,J,S		E,L		Adult depth of 0-50 m
Barracudas (Sphyraenidae)	A,J	A,J,S	A,J,S	J		A,J,S	A,J,S		A,S	All	Adult depth of 0-100 m
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 (Pomacentirdae)	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
Emperor Fishes (Lehtrinidae)	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

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). Source: Colin and Arneson 1995, Sorokin 1995, Myers 1999, WPRFMC 2001

Table 4-5. Coral Reef Ecosystem Management Unit Species EFH Designations (cont'd)

Management Unit Species/Taxa	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	Comments
False Moray Eels, Conger and Garden Eels, and Snake Eels (Chlopsidae, Congridae, and Ophichthidae)	A,J,S	A,J,S	A,J,S	A,J	A,J,S	A,J,S	A,J,S		A,J,S	E,L	Adult depth of 0-105 m
Cardinalfishes (Apogonidae)	A,J,S	A,J,S	A,J,S	A,J,S		A,J,S	A,J,S		A,J,S	E,L	Adult depth of 0-80 m
Blennies (Blenniidae)		A,J,S	A,J,S		A,J,S	A,J,S	A,J,S		A,J,S	E,L	Adult depth of 1-40 m
Sandperches (Pinguipedidae)				A,J	A,J	A,J	A,J		A	E,L	Adult depth of 1-50 m
Flounders and Soles (Bothidae, Pleuronectidae, and Soleidae)		A,J				A,J	A,J		A,J	L	Adult depth of 1-100 m
Trunkfishes (Ostraciidae)		A	A	J	A,J	A			A	E,L	Adult depth of 1-100 m
Pufferfishes and Porcupinefishes (Tetradontidae and Diodontidae)	A,J	A,J	A,J		A,J	A,J	A,J		A,J	E,L	Adult depth of 0-100 m
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 1-10 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 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

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). Source: Colin and Arneson 1995, Sorokin 1995, Myers 1999, WPRFMC 2001.

Table 4-5. Coral Reef Ecosystem Management Unit Species EFH Designations. (cont'd)

Management Unit Species/Taxa	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	Comments
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											
Mollusks (Mollusca)											
Gastropods	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S		A,J,S	E,L	Adut depth of 1-24 m
Sea Snails (Prosobranchs)	A,J	A,J,S		A,J,S	A,J,S	A,J,S	A,J,S		A,J	E,L	Adult depth of 2-30 m
Trochus (Trochus spp.)		A,J,S				A,J,S	A,J,S			E,L	Adult depth of 7-25 m
Sea Slugs (Opisthobranchs)	A,J	A,J,S				A,J,S	A,J,S		A,J,S	E,L	Adult depth of 2-30 m
Bivalves (Oysters and Clams)											
Black-lipped pearl oyster (*Pinctada margartifera*)	A,J	A,J,S				A,J,S	A,J,S		A,J,S	E,L	Depth Distribution: littoral/subtidal to 40 m
Giant clams (Tridacnidae)		A,J,S			A,J,S	A,J,S	A,J,S			E,L	Depth Distribution: 2-20 m
Other bivalves	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S		A,J,S	E,L	Depth Distribution: 1-27 m
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
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)											
Lobster: Spiny and Slipper		All			A,J	All	All		All	L	Adult depth of 20-55 m
Shrimps and Mantis Shrimps		All	A,J	A,J	A,J	All	All		All	L	Adult depth of 3-70 m
Crabs: True and Hermit	A,J	All	A,J	A,J	A,J	All	All		All	L	Adult depth of 0-115 m
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

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). Source: Colin and Arneson 1995, Sorokin 1995, Myers 1999, WPRFMC 2001.

Table 4-5. Coral Reef Ecosystem Management Unit Species EFH Designations. (cont'd)

Management Unit Species/Taxa	Ma	La	Es	SB	Ss	Cr/Hs	Pr	Sz	DST	Pe	Comments
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
Scleractinian Anthozoans											
Stony Corals (Scleractinia)		A,J,S	A,J,S			A,J,S	A,J,S		A,J,S	E,L	Depth Distribution: 0-60 m
Ahermatypic corals (Azooxanthellate)		A,J,S	A,J,S			A,J,S	A,J,S		A,J,S	E,L	Depth Distribution: shallow water
Ahermatypic Corals (Azooxanthellate)		A,J,S	A,J,S		A,J,S	A,J,S	A,J,S		A,J,S	E,L	Depth Distribution: 44-1,761 m
Non-Scleractinian Anthozoans											
Anemones (Actinaria)	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S	A,J,S		A,J,S	E,L	Depth Distribution: 0-40 m
Colonial Anemones or Soft Zoanthid Corals (Zoanthidae)	A,J,S	A,J,S	A,J,S		A,J,S	A,J,S	A,J,S		A,J,S	E,L	Distribution: lagoon floors, back reef flats, reef crests, shallow sub-littoral zone
Soft Corals and Gorgonians (Alcyonaria)		A,J,S			A,J,S	A,J,S	A,J,S		A,J,S	E,L	Depth Distribution - soft corals: 3-30 m and gorgonians: <30-400 m
Blue coral (*Heliopora coerulea*)		A,J,S	A,J,S			A,J,S	A,J,S		A,J,S	E,L	Depth Distribution: <1 m to >30 m
Organ-pipe corals or star polyps (Tubipora musica)						A,J	A,J				Distribution: shallow lagoons, reef flats, reef slopes
Live Rocks		A,J	A,J			A,J	A,J		A,J	E,L	

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). Source: Colin and Arneson 1995, Sorokin 1995, Myers 1999, WPRFMC 2001.

5.0 POTENTIAL ECOSYSTEM IMPACTS TO EFH AND MANAGED SPECIES

This section discusses potential ecosystem impacts as a result of implementation of the Proposed Action to EFH (including coral reef habitat) and managed species. Species within all FMPs may utilize both nearshore and offshore areas during their lives, as eggs and larvae for most species are planktonic and can occur in nearshore and offshore waters, while adults may be present in nearshore and/or offshore waters. Therefore, all project activities can potentially affect a lifestage of a managed species.

Pursuant to 50 CFR 600.910(a) (*Essential Fish Habitat Consultation Guidance*), an "adverse effect" on EFH is defined as any impact that reduces the quality and/or quantity of EFH. The Navy has determined that temporary or minimal impacts are not considered to adversely affect EFH – that is the Navy's policy, and the Navy used these criteria to determine if an effect would be temporary or minimal (Chief of Naval Operations Instruction [OPNAVINST] 5090.1C).

OPNAVINST] 5090.1C defines temporary impacts. To help identify Navy activities falling within the adverse effect definition, the Navy has determined that temporary or minimal impacts are not considered to "adversely affect" EFH. 50 CFR 600.815(a)(2)(ii) and the EFH Final Rule (67 Fed. Reg. 2354) were used as guidance for this determination, as they highlight activities with impacts that are more than minimal and not temporary in nature, as opposed to those activities resulting in inconsequential changes to habitat. Temporary effects are those that are limited in duration and allow the particular environment to recover without measurable impact (67 Fed. Reg. 2354). Minimal effects are those that may result in relatively small changes in the affected environment and insignificant changes in ecological functions (67 Fed. Reg. 2354). Factors that were considered in the ecosystem-based management analysis included the duration, frequency, intensity, and spatial extent of the impact; the sensitivity/vulnerability of the habitat; the habitat functions that might be altered by the impact; and the timing of the impact relative to when the species or life stages may use or need the habitat.

The proposed training activities in the MIRC have the potential to result in the following impacts:

- Physical disruption of open ocean habitat
- Physical destruction or adverse modification of benthic habitats
- Alteration of water or sediment quality from expended materials or discharge
- Cumulative ecosystem impacts

Due to the nature of each activity (i.e., various vessels, aircrafts, locations, ordnance), quantification of impacts for each activity is not possible. The assessment focuses on activities and impacts common to training activities (i.e., stressors), but also discusses individual exercises/training activities such as MISSILEX, BOMBEX, Expeditionary Assault, TORPEX, and SINKEX that have unique aspects. Each activity and associated ecosystem impacts are discussed in Sections 5.1 through 5.3, and a summary is provided in Table 5-6.

Permanent, adverse impacts to EFH components are not anticipated, as part of the Navy's commitment to sustainable use of resources and environmental stewardship, the Navy incorporates measures that are mitigation of the environment into all of its activities. These include employment of best management practice, standard operating procedures (SOPs), adoption of conservation recommendations, and other measures that mitigate the impacts of Navy activities on the environment. Some of these measures are generally applicable and others are designed to apply to certain geographic areas during certain times of year, for specific types of military training. Mitigation measures covering habitats and species occurring in the Mariana Islands Range Complex have been developed through various environmental analyses conducted by the Navy for land and sea ranges and adjacent coastal waters. However, there are temporary unavoidable impacts associated with several training activities that may result in localized impacts as discussed in Section 5.4. In addition, a single activity may potentially have multiple effects on EFH.

The following analyses are for activities under the No Action Alternative. Analyses for activities under Alternatives 1 and 2 are discussed in Section 5.4.

5.1 PHYSICAL DISRUPTION OF OPEN OCEAN HABITAT

The majority of the training activities in the MIRC occur in open ocean habitat or the pelagic zone. The pelagic zone encompasses the open ocean waters beyond the depth of approximately 200 m, and the pelagic environment in the Mariana Islands extend from the surface to water depths of more than 6,000 m. Pelagic biota live in the water column and have little or no association with the benthos, and consist of drifters (plankton) or swimmers (pelagic animals capable of swimming against currents).

Many of the training activities involve the use of bombs, munitions, missiles, or targets that fall or may fall into the waters of the MIRC producing shock waves, expended materials, and sound impacts. In addition, several training activities involve the use of live ordnance resulting in underwater explosions. Some examples include:

- Mine Neutralization
- Surface-to-Surface Gunnery Exercise
- Surface-to-Surface Missile Exercise
- Air-to-Surface Gunnery Exercise
- Air-to-Surface Missile Exercise
- Air to Ground Bombing Exercises
- Air to Ground Missile Exercises
- BOMBEX (Sea)
- SINKEX
- Antisubmarine Warfare Tracking Exercise
- Antisubmarine Warfare Torpedo Exercise

5.1.1 SHOCK WAVE

Bombs, and intact missiles and targets could impact the water surface with great force and produce a large shock wave (see Tables A-7 and A-8 in Appendix A for annual expenditures and training locations). Impulses of this magnitude could injure or kill all life stages of fish, and larvae of other marine organisms within the immediate area. While many of the exercises are conducted with inert weapons, some exercises use live ordnance or explosives creating a larger area of impact and potentially injuring or killing an even greater number of fish and larvae.

Several factors determine a fish's susceptibility to injury and death from shock wave effects. Most blast injuries in fish and other marine animals involve damage to air- or gas-containing organs (Yelverton 1981). Many species of fish have a swim bladder, which is a gas-filled organ used to control buoyancy. Fish with swim bladders are vulnerable to effects of underwater explosions, whereas fish without swim bladders, like most species of invertebrates, are much more resistant (Yelverton 1981; Young 1991). During exposure to shock waves, the differential speed of shock waves through the body of the fish (which has a density close to water) versus the gas-filled space of the swim bladder causes the bladder to oscillate. If the swim bladder ruptures, it may cause hemorrhaging in nearby organs. In the extreme case, the oscillating swim bladder may rupture the body wall of the fish (Yelverton 1981). Some fish have a swim bladder that is ducted to the intestinal tract and some do not, but there is no difference in susceptibility between fish with these two types of bladders (Yelverton et al. 1975; Yelverton 1981). After a nearby underwater blast, most fish that die do so within 1–4 hours, and almost all do so within 24 hours (Yelverton et al. 1975; Yelverton 1981).

The rapid rise time of the shock wave resulting from detonation of high explosives causes most of the organ and tissue damage. Mortality of fish correlates better with impulse, measured in units of pressure time, than with other blast parameters (Yelverton 1981). The received impulse depends on the depth at which the fish is swimming, the depth of the charge, the mass of the charge, and the distance from charge to fish. Fish near the bottom or near a bank will receive a larger impulse (dicussed later in underwater detonations section). A fish on the bottom over a hard surface would receive a greater impulse than it would in open water (Yelverton et al. 1975; Yelverton 1981). Bottom reflection can also be enhanced if it is focused by bottom terrain.

Data from explosive blast studies indicate that very fast, high-level acoustic exposures can cause physical damage and/or mortally wound fishes (Hastings and Popper 2005). There is also reason to believe that lesser effects might also occur, but these have not been well documented. Just as in investigations testing the effects of sound, however, the number of species studied in tests of the effects of explosives is very limited, and there have been no investigations to determine whether blasts that do not kill fish have had any impact on short- or long-term hearing loss, or on other aspects of physiology (e.g., cell membrane permeability, metabolic rate, stress), and/or behavior (e.g., feeding or reproductive behavior, movement from preferred home sites).

5.1.2 EXPENDED MATERIALS FALL

In addition to impacts occurring near the ocean surface, there is also the possibility that falling fragments may injure or kill FMP species below the ocean surface. Accurate measurements of the size of the expended materials field from the underwater explosion of 5-inch shells are not available. However, the shells are typically fused to explode at the sea surface. This, combined with the high downward velocity of the shell at impact, suggests that the expended materials field from the exploding shell would be restricted in size. As with exploding bombs, the shell fragments rapidly decelerate through contact with the surrounding water. The possibility that the exploding shell fragments and expended materials would significantly affect EFH and fish populations is considered negligible. In addition, most missiles hit their target or are disabled before hitting the water. Therefore, most of these missiles and targets hit the water as fragments, which quickly dissipate their kinetic energy within a short distance from the surface. Similarly, expended small-arms rounds may also strike the water surface with sufficient force to cause injury, but most fish swim some distance below the surface of the water. Therefore, few fish would be injured or killed from falling fragments.

5.1.3 UNDERWATER EXPLOSIONS

Potential effects of explosive charge detonations on fish and EFH include: disruption of habitat (discussed later in section); exposure to chemical by-products (also discussed later in section); disturbance, injury, or death from the shock (pressure) wave; acoustic impacts; and indirect effects including those on prey species and other components of the food web. Concern about potential fish mortality associated with the use of underwater explosives led military researchers to develop mathematical and computer models that predict safe ranges for fish and other animals from explosions of various sizes (e.g., Yelverton et al. 1975; Goertner 1982, Goertner et al. 1994).

Young's (1991) equations for 90 percent survivability were used to estimate fish mortality in the Seawolf Shipshock Trial EIS (DoN 1998b). In that document, Yelverton's (1981) equations were used to predict survival of fish with swim bladders, although the equations apply to simple explosives, and may not apply to all the explosives used in the MIRC. The impulse levels that kill or damage fish with swim bladders have been determined empirically to be as follows (from Yelverton 1981):

- 50 percent Mortality $\ln(I)=3.6136 + 0.3201 \ln(M)$
- 1 percent Mortality $\ln(I)=3.0158 + 0.3201 \ln(M)$
- No Injuries $\ln(I)=2.0042 + 0.3201 \ln(M)$

Where I = impulse (in Pascal•seconds or Pa•s) and M = body mass of a fish (g) with a swim bladder.

Yelverton (1981) cautioned against using these equations for fish weighing more than a few kg because fish used in the experiments from which these equations were derived did not weigh more than 2.2 lb (1 kg). Young's parameters include the size of the fish and its location relative to the explosive source, but are independent of environmental conditions (e.g., depth of fish and explosive shot frequency). An example of such model predictions is shown in Table 5-1, which provides the radius of effect of various charges, depths, and fish size. The 10% mortality range is the distance beyond which 90% of the fish present would be expected to survive.

Table 5-1. Range of Effects for Underwater Demolition.

Charge	Charge Depth	Effect Criterion	Range of Effect
1-lb.	3 m	10% Mortality	103 m for 1 oz. fish 55 m for 1 lb. fish 27 m for 30 lb. fish
10-lb.	38 m	10% Mortality	200 m for 1 oz. fish 129 m for 1 lb. fish 79 m for 30 lb. fish
20-lb.	19 m	10% Mortality	261 m for 1 oz. fish 169 m for 1 lb. fish 106 m for 30 lb. fish
20-lb.	38 m	10% Mortality	283 m for 1 oz. fish 182 m for 1 lb. fish 111 m for 30 lb. fish

Notes: NAVSEA SW061-AA-MMA-010; Technical Manual; "Use of Explosives in Underwater Salvage," January 1994. Shallow water detonations are not covered in safety distances tables. Energy is lost to the atmosphere so reduced proportion of blast energy are propagated into underwater shock waves.

Fish kill data provided by Guam Environmental Protection Agency (GEPA) observations from four deepwater demolition training exercises indicated that a total of 3, 4, 765, and 103 fishes were killed, respectively (GEPA 1998). As exercises occur no more than once per month, the numbers recorded equated to a maximum of about 4 fish per day – well below the number caught daily by fisherman. The majority of the fish were less than 12 inches (30 cm) long, and mortality of fishes and other marine life following exercises was relatively low since the activities are conducted in areas where marine fauna are not abundant.

Typically, bombing exercises (BOMBEX) at sea involve one or more aircraft bombing a target simulating a hostile surface vessel. Practice bombs entering the water would be devoid of combustion chemicals found in the warheads of explosive bombs, and would generate physical shock entering the water, but would not explode. After sinking to the bottom, the physical structure of bombs would be incorporated into the marine environment by natural encrustation and/or sedimentation (discussed in Section 5.2). Air-to-ground bombing using explosive ordnance is mostly conducted at land ranges. However, some live bombs are dropped at sea, and exploding bombs are used in exercises such as SINKEX and in W-517.

As with underwater detonations, the range within which fish may sustain injury or death from an exploding bomb would depend on environmental parameters, the size, location, and species of the fish, and its internal anatomy (e.g., whether it has a swim bladder) (DoN 2005c). Fish without swim bladders are far more resistant to explosions than those with swim bladders (Keevin and Hempen 1997). Explosive bombs will be fused to detonate on contact with the water and it is estimated that 99 percent of them will explode within 5 ft (1.5 m) of the ocean surface (DoN 2005c). Table 5-2, based on Young's (1991) model, displays 10-percent mortality (90-percent survival) ranges for the largest explosive bombs that may be deployed during at-sea exercises.

Table 5-2. Estimated Fish-Effects Ranges for Explosive Bombs.

Warhead Weight NEW (lb-TNT)	10 % Mortality Range by Weight of Fish		
	1 ounce	1 pound	30 pounds
500-lb	1,289 ft (393 m)	899 ft (274 m)	578 ft (176 m)
1,000-lb	1,343 ft (409 m)	937 ft (286 m)	602 ft (184 m)
2,000-lb	1,900 ft (579 m)	1,325 ft (404 m)	852 ft (260 m)

Potential effects from the use of Naval gun systems have been analyzed in a variety of environmental documents (DoN 2000, 2001, 2002, 2004b, 2007). The 5-inch gun has the largest warhead fired during routine gunnery exercises. Most training uses non-explosive 5-inch rounds. The surface area of the ocean impacted by a non-explosive 5-in round has been estimated to be 129 cm^2 (20 in^2) (DoN 2007). Considering the vast expanse of the MIRC, few fish would be directly struck by a shell from a 5-inch gun.

Explosive rounds would have the greatest potential for impacts to fish in surface waters. As previously indicated, biological effects of an underwater explosion depend on many factors, including the size, type, and depth of both the animal and the explosive, the depth of the water column, the standoff distance from the charge to the animal, and the sound-propagation properties of the environment. Potential impacts can range from brief acoustic effects, tactile perception, and physical discomfort, to slight injury to internal organs and the auditory system, to death of the animal (Keevin and Hempen 1997).

Table 5-3 provides an estimation of the potential range of lethal effects on swim bladder fish based on Young's (1991) model for five-inch explosive projectiles. These rounds have a NEW of TNT of approximately 8 lbs (3.6 kg) and are assumed to detonate at a depth of 5 ft (1.3 m). Behavioral reactions of fish would extend over a substantially larger area. The overall impacts to water-column habitat would, however, be minor as fish would return following the activity.

The abundance and diversity of fish and the quality and quantity of fish habitat within the range is unlikely to decrease as a result of gun fire training.

Table 5-3. Estimated Fish-Effects Ranges for 5-in Naval Gunfire Rounds.

Weight of Fish	10% Mortality Range	
	ft	m
1 oz	405	123
1 lb	282	86
30 lbs	181	55

5.1.4 SOUND IMPACTS

Bombs, missiles, and targets could also produce a large noise/sound when impacting the water surface. In addition, exercises such as ASW exercises require the use of sonar or other acoustic transmitters, and Naval gunfire have acoustic effects from: 1) sound generated by firing the gun (muzzle blast), 2) vibration from the blast propagating through the ship's hull, 3) sonic-booms generated by the shell flying through the air, and 4) sound from the impact and explosion of the shell. Some exercises or activities that produce sound or use sonar include:

- Antisubmarine Warfare Tracking Exercise
- Antisubmarine Warfare Torpedo Exercise
- Surface-to-Surface Gunnery Exercise
- Naval Surface Fire Support (Land)

Studies of acoustic capabilities of fishes have been aimed at establishing the range of frequencies (or bandwidth) that a fish can hear, and the "threshold" (lowest level) of the sound detected at each frequency (Hastings and Popper 2005). If, following exposure to intense acoustic input, a higher level of sound is required to detect that frequency, a threshold shift has occurred. For humans, temporary threshold shifts may occur after loud concerts or following exposure to industrial sound. There are two kinds of threshold shifts: temporary threshold shift (TTS) or permanent threshold shift (PTS). A TTS may continue for minutes, hours or days, but the auditory deficit is eventually reversed. With PTS, however, hearing is permanently compromised and never recovers.

Based on current knowledge, all fish are able to perceive lower frequency sounds, from below 50 Hz to 1,500 Hz, whereas some fish have developed accessory hearing structures enabling them to detect higher frequencies over 3,000 Hz (Fay 1988; Ramcharitar and Popper 2004). A select few can even detect sounds over 120 kHz (Mann et al. 2001). Broadly, fishes can be categorized as hearing specialists or hearing generalists. Fishes in the hearing specialist category (e.g. carps, catfishes, and mormyrids) have a broad hearing frequency range with a low auditory threshold due to a mechanical connection between an air filled cavity, such as a swimbladder, and the inner ear. Specialists detect both the particle motion and pressure components of sound and can hear at levels well above 1,000 Hz, whereas generalists are limited to detection of the particle motion component of low frequency sounds at relatively high sound intensities (Amoser and Ladich 2005). The best hearing sensitivity of many hearing generalists is at or around 300 Hz (Popper 2003).

Hearing specializations are most often found in freshwater species, while in marine species, specializations are quite rare (Amoser and Ladich 2005). It can be argued that the evolution of hearing specializations was facilitated by low ambient sound levels found in lakes, slowly flowing waters, and the deep sea (Amoser and Ladich 2005; Ladich and Bass 2003, Popper

1980). This evolution most likely came about due to the essential need to detect abiotic sound, avoid approaching predators and detect prey, and to a much lesser degree, communicate acoustically (Amoser and Ladich 2005; Fay and Popper 2000).

In summary, most marine fish are hearing generalists, however, a few have been shown to detect sounds in the mid-frequency and ultrasonic range. Species for which hearing above 1 kHz has been discovered are listed as specialists in Table 5-4, and include some clupeids, gadids, sciaenids, holocentrids, and pomacentrids. It should be noted that hearing ranges given pertain to pressure and not particle motion component of sound, which generalist species are most sensitive. It is also important to keep in mind that while these species can detect mid-frequency sounds, their best hearing sensitivities are not in the mid-frequency range. If a sound is at the edge of a fish's hearing range, the sound must be louder in order for it to be detected than if in the more sensitive range.

Table 5-4. Marine Fish Hearing Sensitivities.

Family	Description of Family	Common Name	Scientific Name	Hearing Range (Hz) Low	High	Best Sensitivity (Hz)	Reference
Albulidae	Bonefishes	Bonefish	*Albula vulpes*	100	700	300	Tavolga 1974a
Anguillidae	Eels	European eel	*Anguilla anguilla*	10	300	40-100	Jerkø et al. 1989
Ariidae	Catfish	Hardhead sea catfish	*Ariopsis felis* [2]	50	1,000	100	Popper and Tavolga 1981
Batrachoididae	Toadfishes	Midshipman[3]	*Porichthys notatus*	65	385		Sisneros 2007
		Oyster toadfish	*Opsanus tau*	100	800	200	Fish and Offutt 1972
		Gulf toadfish	*Opsanus beta*			<1,000	Remage-Healy et al. 2006
Clupeidae	Herrings, shads, menhaden, sardines	Alewife	*Alosa pseudoharengus*		120+		Dunning et al. 1992
		Blueback herring	*Alosa aestivalis*		120+		Dunning et al. 1992
		American shad	*Alosa sapidissima*	0.1	180	200-800 and 25-150	Mann et al. 1997
		Gulf menhaden	*Brevoortia patronus*		100+		Mann et al. 2001
		Bay anchovy	*Anchoa mitchilli*		4,000		Mann et al. 2001
		Scaled sardine	*Harengula jaguana*		4,000		Mann et al. 2001
		Spanish sardine	*Sardinella aurita*		4,000		Mann et al. 2001
		Pacific herring	*Clupea pallasii*	100	5,000		Mann et al. 2005
Chondrichthyes [Class]	Rays, sharks, skates	Data are for several different species		200	1,000		See Fay 1988; Casper et al. 2003
Cottidae	Sculpins	Long-spined bullhead	*Taurulus bubalis*				Lovell et al. 2005

2 Formerly *Arius felis*
3 Data obtained using saccular potentials, a method that does not necessarily reveal the full bandwidth of hearing.

Table 5-4. Marine Fish Hearing Sensitivities (cont'd)

Gadidae	Cods, gadiforms, grenadiers, hakes	Atlantic Cod	*Gadus morhua*	2	500	20	Chapman and Hawkins 1973, Sand and Karlsen 1986
		Ling	*Molva molva*	60	550	200	Chapman 1973
		Pollack	*Pollachius pollachius*	40	470	60	Chapman 1973
		Haddock	*Melanogrammus aeglefinus*	40	470	110-300	Chapman 1973
Gobidae	Gobies	Black goby	*Gobius niger*	100	800		Dijkgraaf 1952
Holocentridae	Squirrelfish and soldierfish	Shoulderbar soldierfish[4]	*Myripristis kuntee*	100	3,000	400-500	Coombs and Popper 1979
		Hawaiian squirrelfish	*Sargocentron xantherythrum**	100	800		Coombs and Popper 1979
		Squirrelfish	*Holocentrus adscensionis**	100	2,800	600-1,000	Tavolga and Wodinsky 1963
		Dusky squirrelfish	*Sargocentron vexillarium**	100	1,200	600	Tavolga and Wodinsky 1963
Labridae	Wrasses	Tautog	*Tautoga onitis*	10	500	37 - 50	Offutt 1971
		Blue-head wrasse	*Thalassoma bifasciatum*	100	1,300	300 – 600	Tavolga and Wodinksy 1963
Lutjanidae	Snappers	Schoolmaster snapper	*Lutjanus apodus*	100	1,000	300	Tavolga and Wodinksy 1963
Myctophidae[5]	Lanternfishes	Warming's lanternfish	*Ceratoscopelus warmingii*	Specialist			Popper 1977
Pleuronectidae	Flatfish[6]	Dab	*Limanda limanda*	30	270	100	Chapman and Sand 1974
		European plaice	*Pleuronectes platessa*	30	200	110	
Pomadasyidae	Grunts	Blue striped grunt	*Haemulon sciurus*	100	1,000		Tavolga and Wodinsky 1963
Pomacentridae	Damselfish[7]	Sergeant major damselfish	*Abudefduf saxatilis*	100	1,600	100-400	Egner and Mann 2005
		Bicolor damselfish	*Stegastes partitus*	100	1,000	500	Myrberg and Spires 1980
		Nagasaki damselfish[3]	*Pomacentrus nagasakiensis*	100	2,000	<300	Wright et al. 2005, 2007
		Threespot damselfish	*Stegatus planifrons**	100	1,200	500-600	Myrberg and Spires 1980
		Longfish damselfish	*Stegatus diencaeus**	100	1,200	500-600	Myrberg and Spires 1980
		Honey gregory	*Stegatus diencaeus**	100	1,200	500-600	Myrberg and Spires 1980

4 Present in MIRC.
5 Several other species in this family also showed saccular specializations suggesting that the fish would be a hearing specialist. However, no behavioral or physiological data are available.
6 Note, data for these species should be expressed in particle motion since it has no swim bladder. See Chapman and Sand, 1974 for discussion.
7 Formerly all members of this group were *Eupomocentrus*. Some have now been changed to *Stegatus* and are so indicated in this table (as per www.fishbase.org).

Table 5-4. Marine Fish Hearing Sensitivities (cont'd)

		Cocoa damselfish	*Stegastes variabilis**	100	1,200	500	Myrberg and Spires 1980
		Beau gregory[8]	*Stegastes leucostictus**	100	1,200	500-600	Myrberg and Spires 1980
		Dusky damselfish	*Stegastes adustus**[, 9]	100	1,200	400-600	Myrberg and Spires 1980
Salmonidae	Salmons	Atlantic salmon	*Salmo salar*	<100	580		Hawkins and Johnstone 1978, Knudsen et al. 1994
Sciaenidae	Drums, weakfish, croakers	Atlantic croaker	*Micropogonias undulatus*	100	1,000	300	Ramcharitar and Popper 2004
		Spotted seatrout	*Cynoscion nebulosus*	Generalist			Ramcharitar et al. 2001
		Southern kingcroaker	*Menticirrhus americanus*	Generalist			Ramcharitar et al. 2001
		Spot	*Leiostomus xanthurus*	200	700	400	Ramcharitar et al. 2006a
		Black drum	*Pogonias cromis*	100	800	100-500	Ramcharitar and Popper 2004
		Weakfish	*Cynoscion regalis*	200	2,000	500	Ramcharitar et al. 2006a
		Silver perch	*Bairdiella chrysoura*	100	4,000	600-800	Ramcharitar et al. 2004
		Cubbyu	*Pareques acuminatus*	100	2,000	400-1,000	Tavolga and Wodinsky 1963
Scombridae	Albacores, bonitos, mackerels, tunas	Bluefin tuna	*Thunnus thynnus*	Generalist			Song et al. 2006
		Yellowfin tuna[3]	*Thunnus albacares*	500	1,100		Iversen 1967
		Kawakawa[3]	*Euthynnus affinis*	100	1,100	500	Iversen 1969
		Skipjack tuna[3]	*Katsuwonus pelamis*	Generalist			Popper 1977
Serranidae	Seabasses, groupers	Red hind	*Epinephelus guttatus*	100	1,100	200	Tavolga and Wodinsky 1963
Sparidae	Porgies	Pinfish	*Lagodon rhomboides*	100	1,000	300	Tavolga 1974b
Triglidae	Scorpionfishes, searobins, sculpins	Leopard searobin	*Prionotus scitulus*	100	~800	390	Tavolga and Wodinsky 1963

Data were compiled from reviews in Fay (1988) and Nedwell et al. (2004). See the very important caveats about the data in the text. For a number of additional species, we can only surmise about hearing capabilities from morphological data. These data are shown in gray, with a suggestion as to hearing capabilities based only on morphology. Scientific names marked with an asterisk have a different name in the literature. The updated names come from www.fishbase.org.

8 Similar results in Tavolga and Wodinsky 1963.
9 Formerly *Eupomacentrus dorsopunicans*.

5.1.4.1 Behavioral Effects

If the sound is loud enough and within the range of frequencies that a fish can hear, a sound will be detected by a fish at some distance from the source. Because of the variable hearing thresholds summarized above, this distance will vary among species. Theoretically, a yellowfin tuna would have to be much closer than an Atlantic cod to hear a low-frequency sound at a given energy level.

Underwater sounds have been used by fishermen to guide herring and other schooling fish to their nets (Yelverton 1981), or to exclude fish from water intakes (Haymes and Patrick 1986). The sounds made by fishing boats can scare some target fish. Sudden changes in sound level can cause fish to dive or to avoid the sound by changing direction. Time of year, whether the fish have eaten, and the nature of the sound signal may all influence how fish will respond to it.

Short, sharp sounds can startle herring. In one study, the fish changed direction and moved away from the 80–92 Hz source, but schooling behavior was not affected (Blaxter et al. 1981). Schwarz and Greer (1984) studied the responses of penned herring to sounds, with the experimental pen being 3.3 m long on each side. The following responses were noted by Schwarz and Greer (1984):

- *Avoidance* when the fish moved slowly away from the sound source.
- *Alarm* when the school packed, fled at high speed, dove repeatedly, and quickly changed directions.
- *Startle* when fish flexed their bodies powerfully and then swam at high speed without changing direction, or shuddered with each blast (the last noted by Pearson et al. 1992).

The low-frequency (<2 kHz) sounds of large vessels or accelerating small vessels usually caused an initial avoidance response among the herring. The startle response was observed occasionally. Avoidance ended within 10 seconds of the "departure" of the vessel. After the initial response, 25 percent of the fish groups habituated to the sound of the large vessel and 75 percent of the responsive fish groups habituated to the sound of the small boat. Chapman and Hawkins (1969) also noted that fish adjust rapidly to high underwater sound levels, and Schwartz and Greer (1984) found no reactions to an echosounder and playbacks of sonar signals which are much higher than that of medium-frequency active sonar (MFA). Pearson et al. (1992) conducted a controlled experiment to determine effects of low-frequency (mostly <500 Hz), strong sound pulses on several species of rockfish off the California coast. They used an air gun with a source level of 223 dB re 1 µPa. They noted:

- Startle responses at received levels 200–205 dB re 1 µPa and above for two sensitive fish species (olive and black rockfish), but not for two other species exposed to levels up to 207 dB.
- Alarm responses at 177–180 dB for the two sensitive species, and at 186–199 dB for other species.
- An overall threshold for the above behavioral response at ~180 dB.
- An extrapolated threshold of ~161 dB for subtle changes in the behavior of rockfish that included reduced catchability in a hook and line fishery (Skalski et al. 1992).
- A return to pre-exposure behavior types within the 20–60 minute exposure period.

Popper et al (2005) exposed three freshwater fish species (northern pike, broad whitefish, and lake chub) to 20 airgun shots over 15 min at peak received levels >205 dB re 1 µPa. There were no apparent physical effects, and TTS was found in only two of the species, with recovery within 24 h of exposure.

Experiments conducted by Skalski et al. (1992), Dalen and Raknes (1985), Dalen and Knutsen (1986), and Engas et al. (1996) demonstrated that some fish were forced to the bottom and others driven from the area in response to low-frequency airgun sound. The authors speculated that catch per unit effort would return to normal quickly in their experimental area because behavior of the fish returned to normal minutes after the sounds ceased.

In summary, fish often react to sounds, especially continuous strong and/or intermittent sounds of low frequency (<1 kHz) at received levels of 160 dB re 1 µPa and higher. Low-frequency pulses at levels of 180 dB may cause noticeable changes in behavior such as an alarm response and lowered catchability (Chapman and Hawkins 1973; Pearson et al. 1992; Skalski et al. 1992). These sounds are 80–100 dB over and above the fish's hearing threshold. It appears that fish often habituate to repeated strong sounds rather rapidly, on time scales of minutes to an hour or so. However, the habituation does not endure, and resumption of the disturbing activity may again elicit disturbance responses from the same fish.

5.1.4.2 Physiological Effects

Several studies have shown that underwater explosions or other loud, impulsive sounds can cause injury or mortality in fishes (Hastings and Popper 2005) if the animals are close enough to the explosion. Unlike MFA, impulsive sounds are low-frequency, broadband sounds that are probably within most fishes' hearing range. Experiments by Engas et al. (1996) and by Engas and Lokkeburg (2002) showed decreased catches of cod and haddock for several days after a seismic airgun was used in the area. Slotte et al. (2004) showed similar effects of airguns on blue whiting and Norwegian spring spawning herring; and Skalski et al. (1992) showed a 52% decrease in rockfish catch after a single airgun emission. Thus, fish have been shown to be affected by anthropogenic sounds however, these sounds were not in the frequency range of the operational sonars of the Proposed Action. Effects, are therefore, not anticipated to be similar, and explained in later in this section.

5.1.4.3 Examples and Effects of Sound Sources

5.1.4.3.1 Vessel Movement

The sound from Navy vessels could affect fish behavior. However, Navy vessels are quiet compared to commercial vessels.

Studies documenting behavioral responses of fish to vessels show that fish may exhibit avoidance responses to engine sound, sonar, depth finders, and fish finders . Avoidance reactions are quite variable depending on the type of fish, its life history stage, behavior, time of day, and, the sound propagation characteristics of the water (Schwartz 1985). Misund (1997) found that fish ahead of a ship, that showed avoidance reactions, did so at ranges of 160 to 490 ft (50 to 350 m). When the vessel passed over them, some species of fish responded with sudden escape responses that included lateral avoidance and/or downward compression of the school.

The low-frequency sounds of large vessels or accelerating small vessels caused avoidance responses among the herring (Chapman and Hawkins 1973). Avoidance ended within 10 seconds after the vessel departed. Twenty five percent of the fish groups habituated to the sound of the large vessel and 75 percent of the responsive fish groups habituated to the sound small boats.

Fish are capable of active avoidance and ship strikes would be a rare event. Behavioral impacts would be transient with return to normal behavior after a ship passes. MIRC vessel movement would not have adverse effects on EFH.

5.1.4.3.2 Naval Gun Fire

Firing a deck gun produces a shock wave in air that propagates away from the muzzle in all directions, including toward the air/water surface. Direct measurements of shock wave pressures transferred through the air/water interface from the muzzle blast of a 5-inch gun are well below levels known to be harmful at shallow depths (DoN 2000, Yagla and Stiegler 2003). Navy watch standers would observe waters surrounding the ship to ensure significant biological aggregations are not in proximity to the ship during firing exercises. Sound produced during gunfire may disturb fish in the vicinity of the ship. Because the sound is brief, no extended disruption of fish behavior is expected.

Gun fire sends energy through the ship structure, into the water, and away from the ship. This effect was also investigated in conjunction with the measurement of 5-inch caliber gun blasts described above (DoN 2000, Yagla and Stiegler 2003). The energy transmitted through the ship to the water for a typical round was found to be about 6% of that from the air blast impinging on the water. Therefore, sound transmitted from the gun, through the hull into the water should have negligible impact on marine life.

The sound generated by a shell in its flight at supersonic speeds above the water is transmitted into the water in much the same way as a muzzle blast (Pater 1981). The region of underwater sound influence from a single traveling shell is relatively small, diminishes quickly as the shell gains altitude, and is of short duration. The penetration of sound through the air\water interface is relatively limited (Miller 1991, Yagla and Stiegler 2003). Studies reviewed in DoN 2007surfret indicate only a small number of submerged species would be exposed to the pressure waves from sonic booms from 5-inch shells fired during routine training exercises.

The potential exists for energy from multiple sonic booms to accumulate over time from multiple, possibly rapid firings of a gun. However, because the area directly below the shells' path, where the conditions are correct for energy to enter the ocean is small, it is highly unlikely that the energy from more than two or three shells would be additive.

Behavioral effects from the sound of Naval gunnery shells exploding would be similar to that already described for other types of underwater explosions. Although fish in the vicinity of the explosion may exhibit avoidance reactions, the sounds generated are relatively short-term and localized, and behavioral disruptions would not be expected to have lasting impacts on the survival, growth, or reproduction of fish populations.

5.1.4.3.3 Sonar

ASW and MIW exercises include training sonar operators to detect, classify, and track underwater objects and targets. There are two basic types of sonar: passive and active. Passive sonars only listen to incoming sounds and, since they do not emit sound energy in the water, lack the potential to acoustically affect the environment. Active sonars emit acoustic energy to obtain information about a distant object from the reflected sound energy. Active sonars are the most effective detection systems against modern, ultra-quiet submarines and sea mines in shallow water.

Modern sonar technology has developed a multitude of sonar sensor and processing systems. In concept, the simplest active sonars emit acoustic pulses ("pings") and time the arrival of the reflected echoes from the target object to determine range. More sophisticated active sonars emit a ping and then scan the received beam to provide directional as well as range information. Only about half of the U.S. Navy's ships are equipped with active sonar and their use is generally limited to training and maintenance activities - 90% of sonar activity by the Navy is passive (DoN 2007b).

Active sonars operate at different frequencies, depending on their purpose. High frequency sonar (>10 kHz) is mainly used for establishing water depth, detecting mines, and guiding torpedoes. At higher frequencies, sound energy is greatly attenuated by scattering and absorption as it travels through the water. This results in shorter ranges, typically less than five nautical miles. Mid frequency sonar is the primary tool for identifying and tracking submarines. Mid frequency sonar (1 kHz - 10 kHz) suffers moderate attenuation and has typical ranges of 1-10 nautical miles. Low frequency sonar (<1 kHz) has the least attenuation, achieving ranges over 100 nautical miles. Low frequency sonars are primarily used for long-range search and surveillance of submarines. Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) is the U.S. Navy's low frequency sonar system (DoN 2001b, 2005d). It employs a vertical array of 18 projectors using the 100-500 Hz frequency range.

Sonars used in ASW are predominantly in the mid frequency range (DoN 2007b). ASW sonar systems may be deployed from surface ships, submarines, and rotary and fixed wing aircraft. The surface ships are typically equipped with hull mounted sonar but may tow sonar arrays as well. Helicopters are equipped with dipping sonar (lowered into the water). Helicopters and fixed wing aircraft may also deploy both active and passive sonobuoys and towed sonar arrays to search for and track submarines.

Submarines also use sonars to detect and locate other subs and surface ships. A submarine's mission revolves around stealth, and therefore submarines use their active sonar very infrequently since the pinging of active sonar gives away their location. Submarines are also equipped with several types of auxiliary sonar systems for mine avoidance, for top and bottom soundings to determine the submarine's position in the water column, and for acoustic communications. ASW training targets simulating submarines may also emit sonic signals through acoustic projectors.

Sonars employed in MIW training are typically high frequency (greater than 10 kHz). They are used to detect, locate, and characterize mines that are moored, laid on the bottom, or buried (DoN 2002b, 2005e, 2005f). MIW sonars can be deployed from multiple platforms including towed systems, unmanned underwater vehicles (UUVs), surf zone crawlers, or surface ships.

Torpedoes use high-frequency, low-power, active sonar. Their guidance systems can be autonomous or electronically controlled from the launching platform through an attached wire. The autonomous guidance systems are acoustically based. They operate either passively, exploiting the emitted sound energy by the target, or actively, ensonifying the target and using the received echoes for tracking and targeting.

Military sonars for establishing depth and most commercial depth sounders and fish finders operate at high frequencies, typically between 24 and 200 kHz.

5.1.4.3.3.1 Low Frequency Sonar

Low frequency sound travels efficiently in the deep ocean and is used by whales for long-distance communication (Richardson et al. 1995, NRC 2003, 2005). Concern about the potential for low frequency sonar (<1 kHz) to interfere with cetacean behavior and communication has prompted extensive debate and research (DoN 2001b, 2005d, NRC 2000, 2003).

Some studies have shown that low frequency sound will alter the behavior of fish. For example, research on low frequency devices used to deter fish away from turbine inlets of hydroelectric power plants showed stronger avoidance responses from sounds in the infrasound range (5-10 Hz) than from 50 and 150 Hz sounds (Knudsen et al. 1992, 1994). In test pools, wild salmon exhibit an apparent avoidance response by swimming to a deeper section of the pool when exposed to low frequency sound (Knudsen et al. 1997).

Turnpenny et al. (1994) reviewed the risks to marine life, including fish, of high intensity, low frequency sonar. Their review focused on the effects of pure tones (sine waves) at frequencies between 50-1000 Hz. Johnson (2001) evaluated the potential for environmental impacts of employing the SURTASS LFA sonar system. While concentrating on the potential effects on whales, the analysis did consider the potential effects on fish, including bony fish and sharks. It appears that the swimbladders of most fish are too small to resonate at low frequencies and that only large pelagic species such as tunas have swimbladders big enough to resonate in the low frequency range. However, investigations by Sand and Hawkins (1973), and Sand and Karlsen (1986) revealed resonance frequencies of cod swim bladders from 2 kHz down to 100 Hz.

Hastings et al. (1996) studied the effects of low frequency underwater sound on fish hearing. More recently, Popper et al. (2005) investigated the impact of U. S. Navy SURTASS LFA sonar on hearing and on non-auditory tissues of several fish species. In this study, three species of fish in Plexiglas cages suspended in a freshwater lake were exposed to high intensity LFA sonar pulses for periods of time considerably longer than likely LFA exposure. Results showed no mortality and no damage to body tissues either at the gross or histological level. Some individuals exhibited temporary hearing loss but recovered within several days of exposure. The study suggests that SURTASS LFA sonar does not kill or damage fish even in a worst case scenario.

Although some behavioral modification might occur, adverse impacts from low frequency sonar on fish are not expected.

5.1.4.3.3.2 Mid Frequency Sonar

ASW training activities use mid frequency (1-10 kHz) sound sources. Most fish only detect sound within the 1-3 kHz range (Popper 2003, Hastings and Popper 2005). Thus, it is expected that most fish species would be able to detect the ASW mid frequency sonar at the lower end of its frequency range.

Some investigations have been conducted on the effect on fish of acoustic devices designed to deter marine mammals from gillnets (Gearin et al. 2000, Culik et al. 2001). These devices generally have a mid frequency range, similar to the sonar devices that would be used in ASW exercises. Adult sockeye salmon exhibited an initial startle response to the placement of inactive acoustic alarms designed to deter harbor porpoise. The fish resumed their normal swimming pattern within 10 to 15 seconds. After 30 seconds, the fish approached the inactive alarm to within 30 cm (1 ft). The same experiment was conducted with the alarm active. The fish exhibited the same initial startle response from the insertion of the alarm into the tank; however, within 30 seconds, the fish were swimming within 30 cm (1 ft) of the active alarm. After five minutes of observation, the fish did not show any reaction or behavior change except for the initial startle response. This demonstrated that the alarms were either inaudible to the fish, or the fish were not disturbed by the mid frequency sound.

Jørgensen et al. (2005) carried out experiments examining the effects of mid frequency (1 to 6.5 kHz) sound on survival, development, and behavior of fish larvae and juveniles. Experiments were conducted on the larvae and juveniles of Atlantic herring, Atlantic cod, saithe *Pollachius virens*, and spotted wolfish *Anarhichas minor*. Swimbladder resonance experiments were attempted on juvenile Atlantic herring, saithe, and Atlantic cod. Sound exposure simulated Naval sonar signals. These experiments did not cause any significant direct mortality among the exposed fish larvae or juveniles, except in two (of a total of 42) experiments on juvenile herring where significant mortality (20-30%) was observed. Among fish kept in tanks one to four weeks after sound exposure, no significant differences in mortality or growth related parameters (length, weight and condition) between exposed groups and control groups were observed. Some incidents of behavioral reactions were observed during or after the sound exposure - ‘panic’ swimming or confused and irregular swimming behavior. Histological studies of organs, tissues, or neuromasts from selected Atlantic herring experiments did not reveal obvious differences between control and exposed groups.

The work of Jørgensen et al. (2005) was used in a study by Kvadsheim and Sevaldsen (2005) to examine the possible 'worse case' scenario of sonar use over a spawning ground. They conjectured that normal sonar activities would affect less than 0.06% of the total stock of a juvenile fish of a species, which would constitute less than 1% of natural daily mortality. However, these authors did find that the use of continuous-wave transmissions within the frequency band corresponding to swim bladder resonance will escalate this impact by an order of magnitude. The authors therefore suggested that modest restrictions on the use of continuous-wave transmissions at specific frequencies in areas and at time periods when there are high densities of Atlantic herring present would be appropriate.

Experiments on fish classified as hearing specialists (but not those classified as hearing generalists) have shown that exposure to loud sound can result in temporary hearing loss, but it is not evident that this may lead to long-term behavioral disruptions in fish that are biologically significant (Amoser and Ladich 2003, Smith et al. 2004 a,b). There is no information available that suggests that exposure to non-impulsive acoustic sources results in fish mortality.

In summary, most species of fish species would be expected to detect mid frequency sonar at the lower end of its frequency range. Behavioral responses would be brief, reversible, and not biologically significant. Sustained auditory damage is not expected to occur. Sensitive life stages (juvenile fish, larvae and eggs) very close to the sonar source may experience injury or mortality, but area-wide effects would likely be minor. The use of Navy mid frequency sonar would not compromise the productivity of fish or adversely affect their habitat.

5.1.4.3.3.3 High Frequency Sonar

Although most fish cannot hear sound frequencies over 10 kHz, some shad and herring species can detect sounds in the ultrasonic range, i.e., over 20 kHz. (Mann 2001, Higgs et al. 2004). Ross et al. (1995, 1996) reviewed the use of high frequency sound to deter alewives from entering power station inlets. The alewife, a member of the herring family (Clupeidae) and shad subfamily (Alosinae) can hear sounds at ultrasonic frequencies (Mann et al., 2001), uses high frequency hearing to detect and avoid predation by cetaceans. Wilson and Dill (2002) demonstrated that exposure to broadband sonar-type sounds with high frequencies cause behavioral modification in Pacific herring.

Since high-frequency sound attenuates quickly in water, high levels of sound from mine hunting sonars would be restricted to within a few meters of the source. Even for fish able to hear sound at high frequencies, only short-term exposure would occur, thus high frequency military sonars are not expected to have significant effects on resident fish populations.

Because a torpedo emits sonar pulses intermittently and is traveling through the water at a high speed, individual fish would be exposed to sonar from a torpedo for a brief period. At most, an individual animal would hear one or two pings from a torpedo and would be unlikely to hear pings from multiple torpedoes over an exercise period. Most fish hear best in the low- to mid-frequency range and therefore are unlikely to be disturbed by torpedo pings.

Dipping sonar is also only active for short periods. Sonobuoys operate at relatively high frequencies, well beyond the hearing range of most fish. The area within which fish could hear the high frequency signals from active sonobuoys would be limited by the low signal strengths emitted.

The effects of high frequency sonar, on fish behavior, for species that can hear high frequency sonar, would be transitory and of little biological consequence. Most species would probably not hear these sounds and would therefore experience no disturbance.

5.1.4.4 Invertebrate Hearing and Sound Production

Very little is known about sound detection and use of sound by invertebrates (see Budelmann 1992a, b, Popper et al. 2001 for reviews). The limited data indicates that some crabs are able to detect sound, and there has been the suggestion that some other groups of invertebrates are also able to detect sounds. In addition, cephalopods (octopus and squid) and decapods (lobster, shrimp, and crab) are thought to sense low-frequency sound (Budelmann 1992b). Packard et al. (1990) reported sensitivity to sound vibrations between 1-100 Hz for three species of cephalopods. Lovell et al. (2005) concluded that at least one species from the invertebrate sub-phylum of crustacean (*Palaemon serratus*), is sensitive to the motion of water particles displaced by low frequency sounds ranging from 100 Hz up to 3000 Hz. Wilson et al. (2007) documents a lack of physical or behavioral response for squid exposed to experiments using high intensity sounds designed to mimic killer whale echolocation signals. In contrast, McCauley et al. (2000) reported that caged squid would show behavioral responses when exposed to sounds from a seismic airgun.

There has also been the suggestion that invertebrates do not detect pressure since few, if any, have air cavities that would function like the fish swim bladder in responding to pressure (URI 2007). It is important to note that some invertebrates, and particularly cephalopods, have specialized end organs, called statocysts, for determination of body and head motions that are similar in many ways to the otolithic end organs of fish. The similarity includes these invertebrates having sensory cells which have some morphological and physiological similarities to the vertebrate sensory hair cell, and the “hairs” from the invertebrate sensory cells are in contact with a structure that may bear some resemblance to vertebrate otolithic material (reviewed in Budelmann 1992a, b). As a consequence of having statocysts, it is possible that these species could be sensitive to particle displacement (Popper et al. 2001).

It is also important to note that invertebrates may have other organs that potentially detect the particle motion of sound, the best known of which are special water motion receptors known as chordotonal organs (e.g., Budelmann 1992a). These organs facilitate the detection of potential predators and prey and provide environmental information such as the movement of tides and currents. Indeed, fiddler crab (*Uca* sp.) and spiny lobster (*Panulirus* sp.) have both been shown to use chordotonal organs to respond to nearby predators and prey.

Like fish, some invertebrate species produce sound, with the possibility that it is used for communication. Sound is used in territorial behavior, to deter predators, to find a mate, and to pursue courtship (Popper et al. 2001). Well known sound producers include lobsters (*Panulirus* sp.) (Latha et al. 2005) and snapping shrimp (Alpheus heterochaelis) (Heberholz and Schmitz 2001). Of all marine invertebrates, perhaps the one best known to produce sound are the snapping shrimp (Heberholz and Schmitz 2001). Snapping shrimp are found in oceans all over the world and make up a significant portion of the ambient sound budget in many locales (Au and Banks 1998).

McCauley et al. (2000) found evidence that squid exposed to seismic airguns show a behavioral response including inking. However, these were caged animals, and it is not clear how unconfined animals may have responded to the same signal and at the same distances used. In another study, Wilson et al. (2007) played back echolocation clicks of killer whales to two groups of squid (*Loligo pealeii*) in a tank. The investigators observed no apparent behavioral effects or any acoustic debilitation from playback of signals up to 199 to 226 dB re 1 μPa. It should be noted, however, that the lack of behavioral response by the squid may have been because the animals were in a tank rather than being in the wild.

In another report on squid, Guerra et al. (2004) claimed that dead giant squid turned up around the time of seismic airgun operations off of Spain. The authors suggested, based on analysis of carcasses, that the damage to the squid was unusual when compared to other dead squid found at other times. However, the report presents conclusions based on a correlation to the time of finding of the carcasses and seismic testing, but the evidence in support of an effect of airgun activity was totally circumstantial. Moreover, the data presented showing damage to tissue is highly questionable since there was no way to differentiate between damage due to some external cause (e.g., the seismic airgun) and normal tissue degradation that takes place after death, or due to poor fixation and preparation of tissue. To date, this work has not been published in peer-reviewed literature, and detailed images of the reportedly damaged tissue are also not available.

There has been a recent and unpublished study in Canada that examined the effects of seismic airguns on snow crabs (DFO 2004). However, the results of the study were not at all definitive, and it is not clear whether there was an effect on physiology and reproduction of the animals.

There is also some evidence that an increased background sound (for up to three months) may affect at least some invertebrate species. Lagardère (1982) demonstrated that sand shrimp (*Crangon crangon*) exposed in a sound proof room to sound that was about 30 dB above ambient for three months demonstrated decreases in both growth rate and reproductive rate. In addition, Lagardère and Régnault (1980) showed changes in the physiology of the same species with increased sound, and that these changes continued for up to a month following the termination of the signal.

Finally, there was a recently published statistical analysis that attempted to correlate catch rate of rock lobster in Australia over a period of many years with seismic airgun activity (Parry and Gason 2006). The results, while not examining any aspects of rock lobster behavior or doing any experimental study, suggested that there was no effect on catch rate from seismic activity.

5.1.5 SUMMARY

Physical disruptions of the open ocean habitat from proposed activities, such as shock waves, expended materials, underwater detonations, and sound could result in temporary and localized impacts on FMP species due to the unavoidable direct loss of pelagic fishes and larvae, and potential prey items. However, given the random distribution of juvenile and adult pelagic fish species, planktonic eggs and larvae, and prey items, the relatively large area of the MIRC, and the relatively infrequent number of training activities in any given area, recovery is expected to occur quickly, and no long-term adverse impacts on ecosystem structure and function or ecosystem services are anticipated.

5.2 PHYSICAL DESTRUCTION OR ADVERSE MODIFICATION OF BENTHIC HABITATS

The majority of the training activities that use live munitions, bombs, or missiles occur in the open ocean away from sensitive nearshore habitats. However, some training activities involving the use of explosives, or traversing with vessels (e.g., LCAC, CRRC), vehicles, and troops in nearshore waters may damage EFH or HAPC, such as rocky substrate or coral reef habitat. Some examples of exercises that may result in temporary impacts to benthic habitats include:

- Ship to Objective Maneuver
- Sink Exercise
- Air to Ground Bombing Exercises
- Air to Ground Missile Exercises
- Insertion/Extraction
- Direct Action
- Over the Beach
- Naval Surface Fire Support

- Expeditionary Raid
- Underwater Demolition

Rocky substrate can support extensive communities and provides habitat for a diverse ecosystem of fish, invertebrates, and algae. Live bottoms, as defined by the Bureau of Land Management, are areas "containing biological assemblages consisting of such sessile invertebrates as sea fans, sea whips, hydroids, anemones, ascidians, sponges, bryozoans, and hard corals living upon and attached to naturally occurring hard or rocky formations with rough, broken, or smooth topography; and whose lithotope favors accumulation of turtles, pelagic and demersal fish."

In the MIRC, colonized hardbottom, macroalgae, invertebrates, and deep-slope terraces are found on every island (Figures 3-7, 3-8, 3-9). Subtidal colonized hardbottom habitats in the Mariana Islands include coral reefs and communities and deep-slope terrace, and the marine benthic invertebrate assemblages are extremely diverse and include representatives of nearly all phyla.

The WPRFMC identifies HAPC, which are specific habitats within EFH that are of greater importance to the life cycle of federally managed species. For example, 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 Guam (WPRFMC 2001). Another example of HAPC designated in the MIRC study area includes all slopes and escarpments between 40 and 280 m for all life stages of the BMUS.

5.2.1 DETONATIONS IN NEARSHORE WATERS

Training activities using live ordnance in nearshore waters may have direct effects on EFH (see Section 5.1), and additionally, may directly affect sensitive EFH and/or HAPC due to the greater likelihood of encountering rocky substrate that may support managed species. Training activities, such as BOMBEX (Land), MISSILEX (A-G), and FIREX (Land) have occurred at FDM since 1971, and although there are designated targets on land, short shots may damage rocky intertidal and subtidal habitat that support managed species (see Tables A-7 and A-8 in Appendix A for annual expenditures and training locations). Existing habitat data indicates that the nearshore waters of FDM are predominantly ephemeral or opportunistic turf species, with relatively low coral densities (Figure 5-1); however, the data do not allow a detailed analysis due to the lack of resolution. It is likely that these training activities may have temporary, localized impacts to EFH, although annual surveys suggest the near shore marine natural resources at FDM are thriving, and that the island is serving as a de-facto preserve due to the restricted fishing access (DoN 2006, DoN 2009).

EOD training activities involve the locating and neutralizing of a deepwater mine by EOD divers. The neutralization of the mine (the portion of the exercise that involves the use of ordnance) is typically scheduled during daylight hours for safety reasons and completed within a two hour period. Divers deploy from combat rubber raiding craft (CRRC) and a diver will place the explosive next to or on each inert mine shape. Once the neutralization charge is placed on or near the mine, the divers will return to the CRRC and proceed to a safe location for detonation. Based on charge size and operating conditions, EOD will determine a "safe time" and distance needed from the mine before they detonate the charge. Typically two shots per training event are conducted, with a second charge detonated one to two hours after the first shot. After the detonation portion of the exercise is completed, the mine shape is typically recovered unless destroyed by the charge. Divers are redeployed to the detonation area to verify that the mine shape was destroyed or to aid in recovery of the mine. Mine Neutralization training in Inner

Apra Harbor (IAH) is conducted by EODMU-5 and consists of locating and neutralizing LIMPET mines (see Tables A-7 and A-8 in Appendix A for annual expenditures and training locations).

Shallow water MCM sites include Tipalao Beach, while deepwater MCM sites are located in Outer Apra Harbor at a depth of 125 ft (38 m), and Dadi Beach, in a water depth ranging from 108 to 115 ft (33 to 35 m). The Piti Floating Mine Neutralization Area lies north of Apra Harbor and supports some EOD training.

Agat Bay supports deepwater EOD MCM training and dive training activites (Figure 5-2). Underwater detonation charges up to 10 pounds are permitted (see Tables A-7 and A-8 in Appendix A for annual expenditures and training locations). Hydrographic surveys are periodically conducted in this area in conjunction with coral surveys. Dadi Beach has a shallow nearshore reef, with algae, small reef fish, starfish, and sea cucumbers. Corals in this zone are rare, but present. Tipalao Beach has essentially no macrobiota on either the reef flat or the hard, scoured substrate beyond the rubble flat (MRC 1997). The beach rock bench in the Tipalao Beach intertidal zone is barren of macroorganisms other than short algal turfs. The sand zone, within which coral are virtually absent, extends to approximately 65 ft (20 m) offshore and does not exceed 3 ft (1 m) in depth. Throughout Tipalao Bay, benthic biota are extremely uncommon (MRC 1997); living corals comprise less than one percent bottom cover, and benthic macrofauna are essentially absent (Figure 5-2).

Detonations in nearshore subtidal habitat can lead to a temporary and localized impact on FMP species due to death or injury, and depending on the location of the charge, the loss of benthic epifauna and infauna that may serve as prey items for managed species, and increased turbidity. Mobile species are expected to rapidly move back into the area following detonations, whereas sedentary species would be eliminated and may or may not recover to previous abundances depending on the spatial overlap and time interval between detonations. Increases in turbidity could temporarily decrease the foraging efficiency of fishes, however, given the dynamic nature of the habitat and the grain size of the material, turbidity is expected to be minimal and localized.

For mine neutralization training activities, all demolition activities are conducted in accordance with Commander Naval Surface Forces Pacific (COMNAVSURFPAC) Instruction 3120.8F, Procedures for Disposal of Explosives at Sea/Firing of Depth Charges and Other Underwater Ordnance. Before any explosive is detonated, divers are transported a safe distance away from the explosive. Standard practices for tethered mines require ground mine explosive charges to be suspended 10 feet below the surface of the water. For mines on the shallow water floor (less than 40 feet of water), only sandy areas that avoid/minimize potential impacts to coral are used for explosive charges.

5.2.2 BEACH LANDING TRAINING ACTIVITIES

Amphibious landings consist of a seaborne force from over the horizon assaulting across a beach in a combination of helicopters, aircraft, landing craft air cushion (LCAC), light armored vehicle (LAV), CRRCs, or other landing craft. Locations where amphibious landings occur in the MIRC include the Exclusive Military Use Area (EMUA), which is DoD-leased land covering the northern third of Tinian. The EMUA has two small sandy beaches (Unai Chulu and Unai Dankulo) that are capable of supporting amphibious landing training activities. Existing habitat data indicates that the nearshore waters of Unai Chulu and Unai Dankulo are predominantly ephemeral turf species, with relatively low coral densities (Figures 5-3 and 5-4); however, these data do not allow a detailed analysis due to the lack of resolution. Recent surveys conducted at Unai Chulu indicated that the reef crest is shallow, except where cut by a deeper channel in the reef crest (USMC 2009). The reef crest appears to have a high density of coral colonies, while the reef slope is a well-developed spur and groove system that grades steeply with depth.

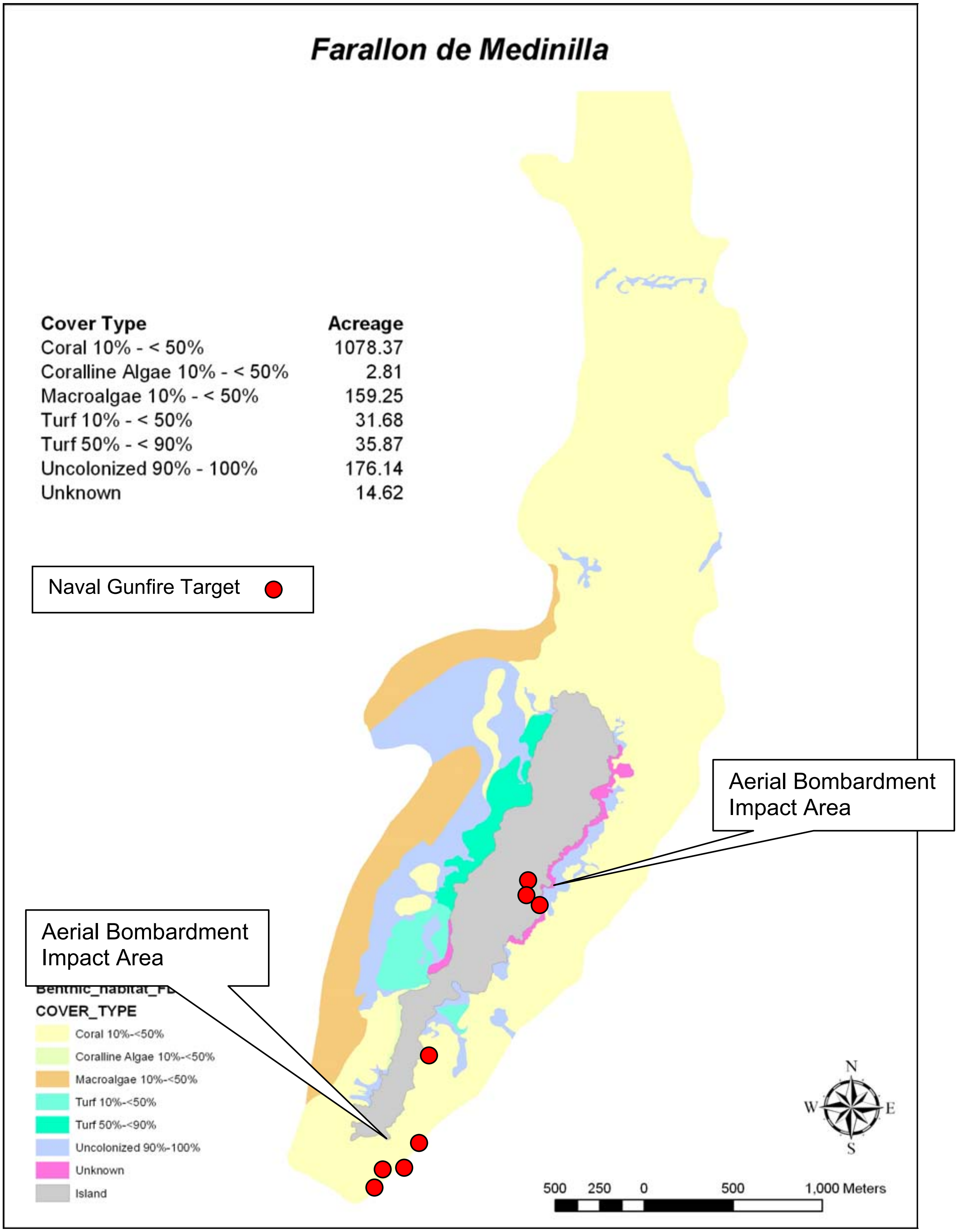

Figure 5-1. Nearshore benthic habitats of Farallon de Medinilla: Live cover. Source data: NCCOS/NOAA (2005).

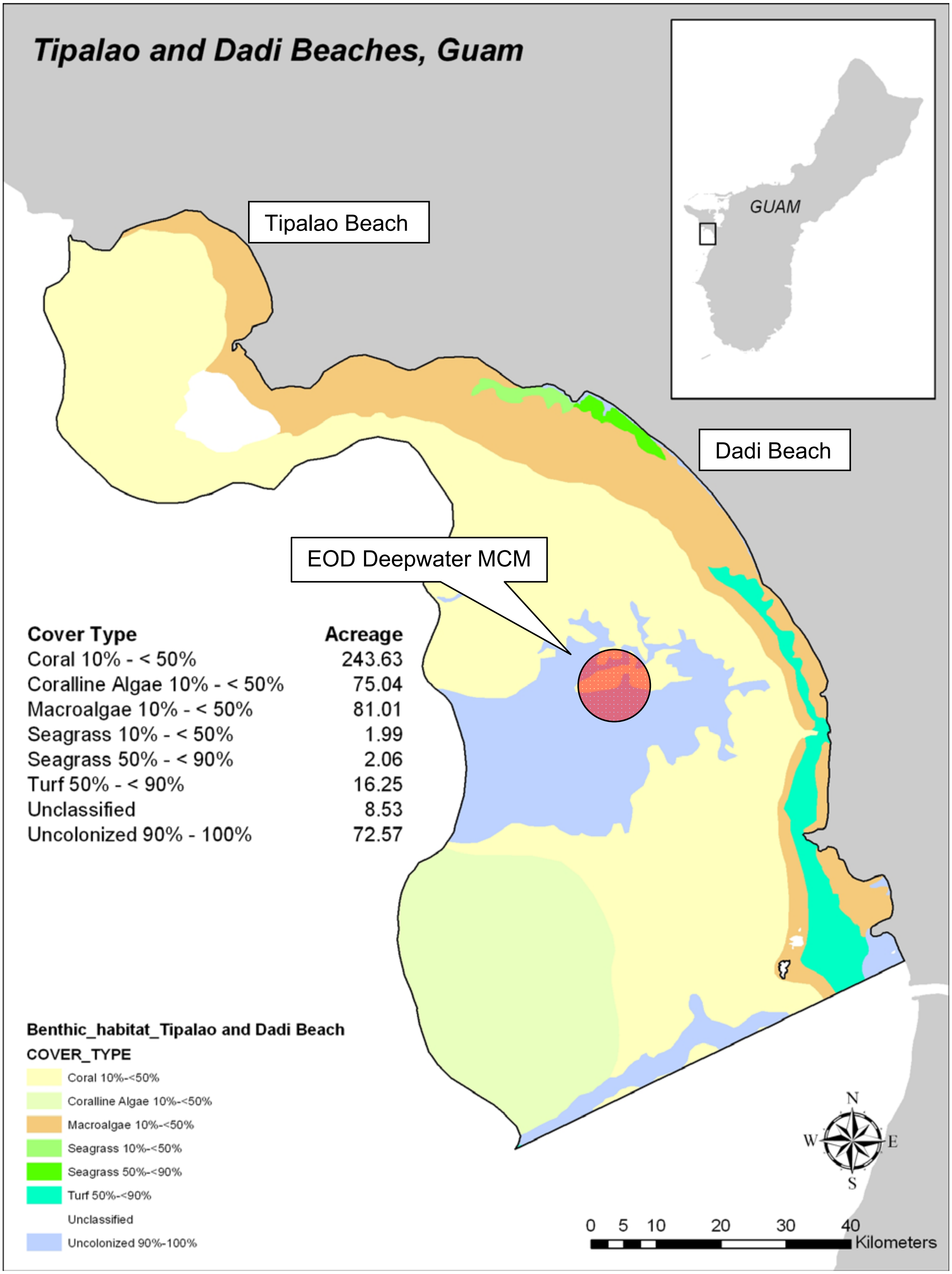

Figure 5-2. Nearshore benthic habitats of Agat Bay: Live cover. Source data: NCCOS/NOAA (2005).

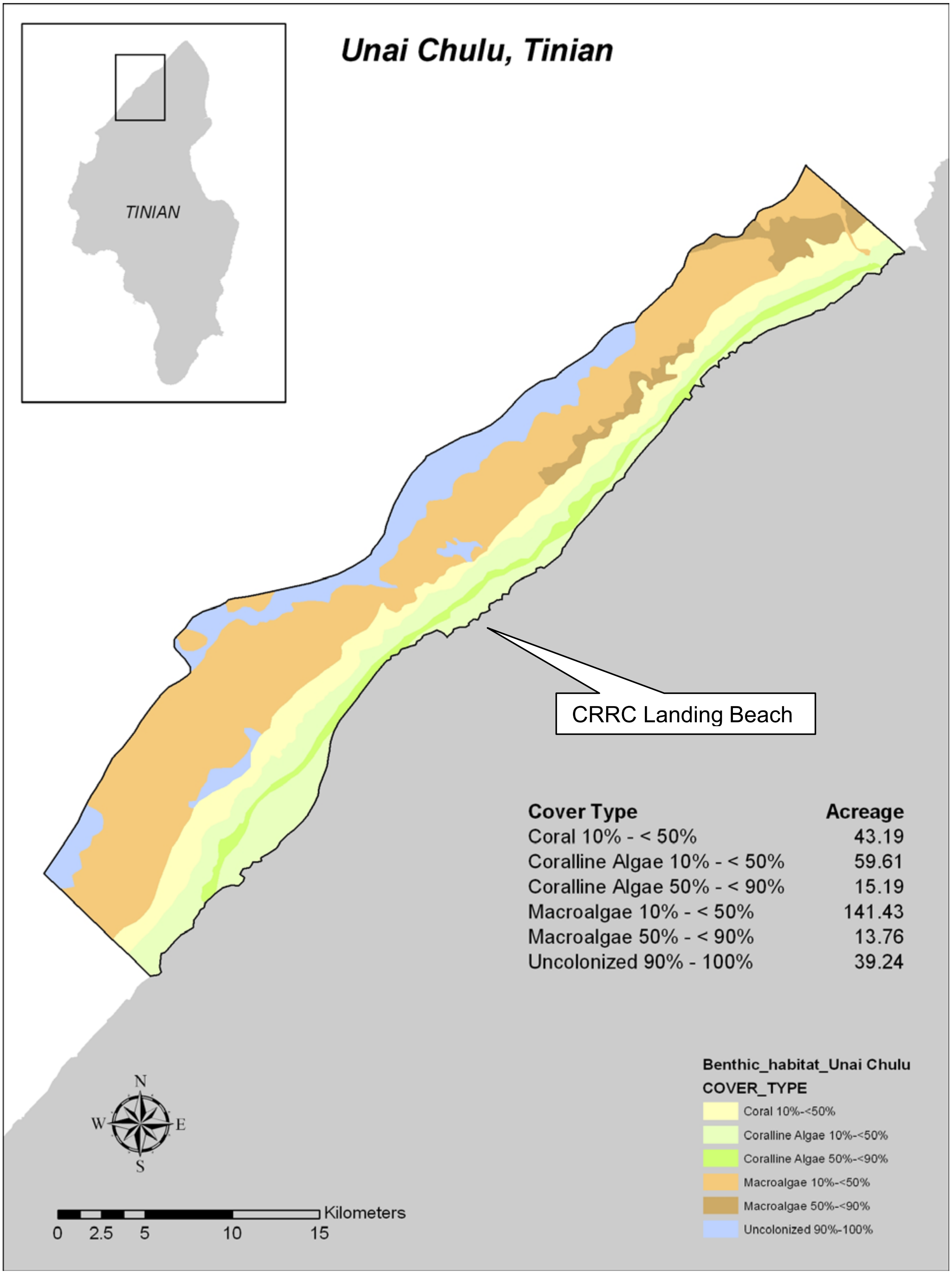

Figure 5-3. Nearshore benthic habitats of the Unai Chulu, Tinian: Live cover. Source data: NCCOS/NOAA (2005).

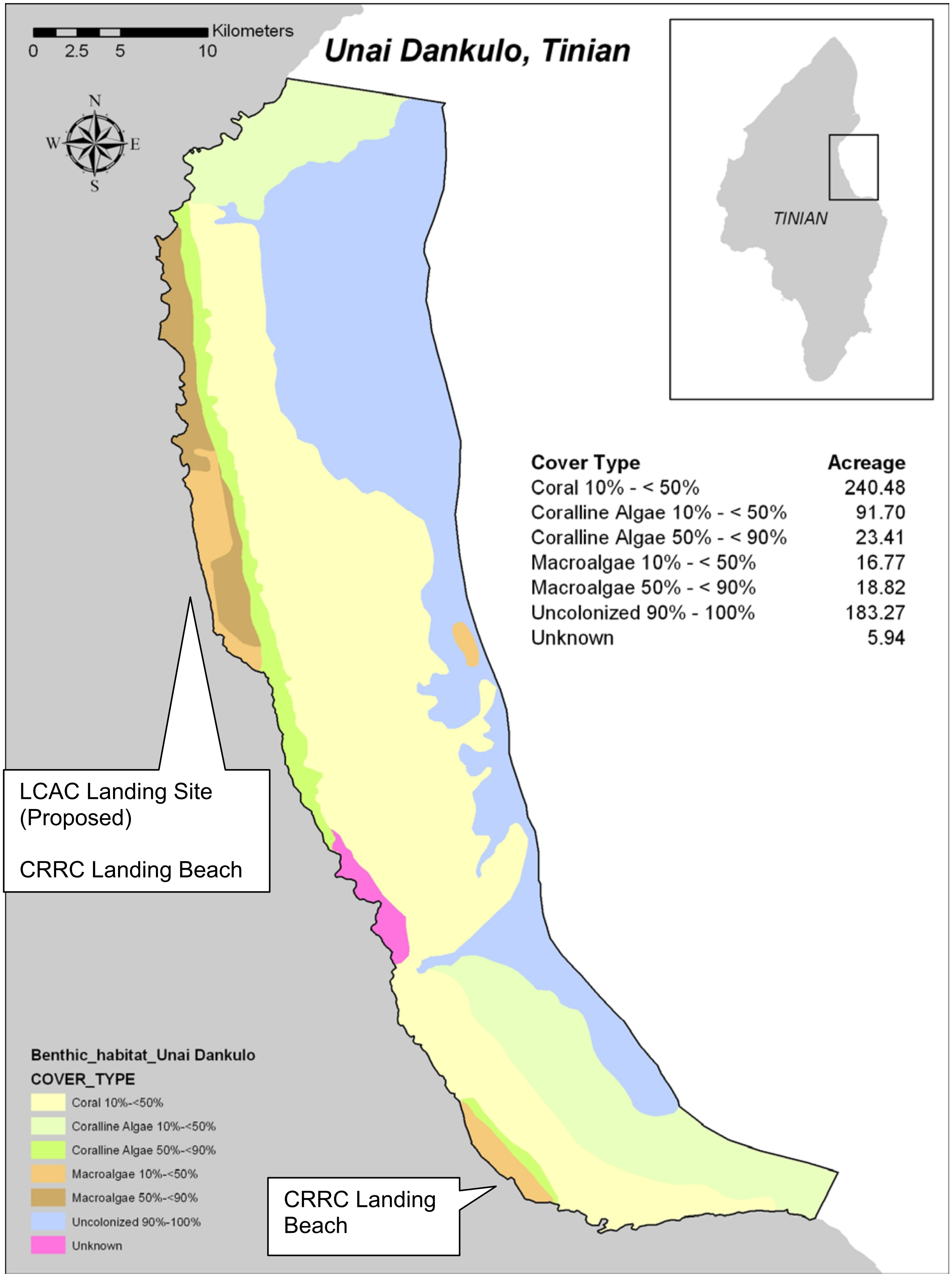

Figure 5-4. Nearshore benthic habitats of Unai Dankulo, Tinian: Live cover. Source data: NCCOS/NOAA (2005).

Fifteen coral taxa in seven genera were found on the Unai Chulu reef flat, with corals in the genus *Acropora* the most common. The coral community on the reef slope was taxonomically diverse with 79 taxa in 24 genera observed, and appeared to be a typical spur and groove coral community, dominated primarily by the taxa in the genera *Goniastrea*, *Favia*, and *Galaxea* (USMC 2009).

In contrast to Unai Chulu, Unai Dankulo consists of numerous long sandy beaches within a wide embayment. The beaches are fronted by a wide reef flat with a shallow reef crest. The Unai Dankulo reef flat had the highest coral density (4.65 ± 1.87 colonies/m^2) and richness (25 taxa in 13 genera) of all the reef flats surveyed in this study, which included Unai Babui and Unai Chulu. The reef slope is a well-developed spur and groove system that grades gently with depth. The Unai Dankulo reef slope had 2.4 times the taxa richness of the reef flat, and had the highest overall taxa richness of all the areas surveyed. The coral community on the reef slope was comprised of 80 taxa in 24 genera, the highest richness found for a single area in the study. Densities of fish and corals were higher on the reef slope than the reef flat, but no trend was apparent for algal cover and non-coral invertebrate densities (USMC 2009).

It is likely that these training activities may have temporary and localized impacts to EFH. Another location includes Tipalao Cove, which provides access to a small beach area capable of supporting a shallow draft amphibious landing craft. As noted in the previous section, benthic biota are extremely uncommon in Tipalao Bay; living corals comprise less than one percent bottom cover, and benthic macrofauna are essentially absent (Figure 5-2).

Although amphibious landings are restricted to specific areas of designated beaches, amphibious landings in nearshore areas can lead to a temporary and localized impact on FMP species due to death or injury, loss of benthic epifauna and infauna that may serve as prey items for managed species, and increased turbidity. Increases in turbidity could temporarily decrease the foraging efficiency of fishes. In sandy areas, given the dynamic nature of the habitat and the grain size of the material, turbidity is expected to be minimal and localized. Although corals are not common in the channels that are used for training, recovery to coral that is affected by amphibious landings would be dependent upon the frequency of additional disturbances and other natural factors. Protective measures are in place to insure that impacts to sensitive habitat are avoided and include pre- and post-activity hydrographic surveys, landing at high tide, and monitoring.

As detailed in Chapter 5, conservation measures for amphibious landings and land-based training at Guam and Tinian to reduce the effects to sea turtles associated with amphibious landing activities, the Navy implements the following training measures, which were minimization measures included in previous consultations with USFWS:

- The Navy maintains a sea turtle nesting monitoring program on beaches on DoD property on Guam. Monitoring on Guam occurs on a weekly basis by NAVFACMAR natural resource specialists.
- The Navy began a monitoring program for sea turtles on Tinian in 1998, which involves surveys of all sandy areas within military lease lands on Tinian on a monthly basis (approximate) (DoN 2008b). During the monthly surveys, crawls, nests, potential nests, body pits, and hatchling tracks are noted. Monitoring occurs at Unai Dankulo (Long Beach), Unai Chulu, Unai Masalok, and Unai Lamlam. Lepresarium Beach was once part of the monitoring program, however, monitoring at this location ceased when the MLA boundary was updated to not include this beach. In addition to beach surveys, the Navy conducts semiannual in-water surveys at Unai Chulu and Unai Babui. Surveys also are conducted semiannually at Unai Lamlam to serve as a control site for baseline sea turtle activity where no landings occur. Semiannual surveys measure percent coral

cover, turbidity, fish assemblage, sedimentation rates, and site topography. Monitoring data is shared with both CNMI DFW and USFWS.

- The Navy maintains "No Wildlife Disturbance" (NWD) and "No Training" (NT) areas at Orote Peninsula, Tarague Beach, Unai Chulu, Unai Chiget, and Unai Dankulo (Long Beach). Cross-country off-road vehicle travel, pyrotechnics, demolition, digging/excavation (without prior approval of Joint Region Marianas or 36 Civil Engineering Squadron (CEV) environmental monitors), open fires, mechanical vegetation clearing, live ammunition, firing blanks, flights below 1,000 ft (313 m), and helicopter landings (except for designated landing zones) are prohibited in NWD areas. All entry or training, except specifically authorized administrative troop and vehicle movement on designated roads or trails, are prohibited in NT areas, in addition to prohibitions in NWD areas. The Navy evaluates NWD and NT boundaries based on additional survey information obtained during monthly monitoring surveys for sea turtle nesting activity on Tinian.
- Navy biologists monitor beaches during night-time landing exercises. If sea turtles are observed or known to be within the area, training activities are halted until all nests have been located and sea turtles have left the area. Identified nests are avoided during the night-time landing exercise.
- Prior to beach landings by amphibious vehicles, known sea turtle nesting beaches are surveyed by Navy biologists for the presence of sea turtle nests no more than six hours prior to a landing exercise. Areas free of nests are flagged, and vehicles are directed to remain within these areas. NAVFACMAR biologists survey landing beaches no more than six hours prior to the first landing. Further, each landing activity has a "beach master" that would "wave off" vehicle approaches if sea turtles or sea turtle nests were observed in the water or on the land.

The Navy recognizes that surge waves generated by slow moving LCACs could break off coral heads and cause beach scour, degrading foraging and nesting habitat for sea turtles. To minimize the surge effect, LCAC landings on Tinian are scheduled for high-tide. LCACs stay on-cushion until clear of the water and within a designated Craft Landing Zone (CLZ). Amphibious assault vehicle (AAV) landings at Unai Babui are restricted to an established approach lane and land at high tide one vehicle at a time. Within the CLZ, LCAC come off-cushion with the LCAC oriented to permit expeditious vehicle and cargo offload onto a cleared offload and vehicle traffic area. The Navy recognizes ruts resulting from vehicle traffic on beaches may prevent sea turtle hatchlings from reaching the water and expose them to predation or desiccation. Although LCAC and expeditionary vehicle traffic typically do not leave ruts, some compaction of sand in vehicle tracks is possible. If restoration of beach topography is required, it is conducted using non-mechanized methods.

5.2.3 EXPENDED MATERIALS

Training activities involving the sinking of large vessels (SINKEX) may have the likelihood to affect EFH or HAPC, such as deep water coral reef habitat. The Environmental Protection Agency (EPA) grants the Navy a general permit through the Marine Protection, Research, and Sanctuaries Act to transport vessels "for the purpose of sinking such vessels in ocean waters…" (40 CFR Part 229.2). Each SINKEX uses an excess vessel hulk as a target that is eventually sunk during the course of the exercise. The target is an empty, cleaned, and environmentally remediated ship hull that is towed to a designated location where various platforms would use multiple types of weapons to fire shots at the hulk. Platforms can consist of air, surface, and subsurface elements. Weapons can include missiles, precision and non-precision bombs, gunfire, and torpedoes (see Tables A-7 and A-8 in Appendix A for annual expenditures and training locations). If none of the shots result in the hulk sinking, either a submarine shot or placed explosive charges would be used to sink the ship. Charges ranging from 100 to 200 pounds, depending on the size of the ship, would be placed on or in the hulk. These activities can have an adverse impact on FMP species (See Section 5.1.3). To reduce impacts to EFH and HAPC, all vessel sinkings are conducted in water at least 1,000 fathoms (6,000 feet) deep and at least 50 nm from land. Therefore, SINKEX training activities would have short-term, localized impact associated with the operation (such as in-water detonations); however, it would not destroy or adversely affect sensitive benthic habitats, although it may alter soft bottom habitats and may provide a beneficial use by providing habitat in the deep water environment.

Training activities involving relatively smaller weapons or equipment (e.g., sonobuoys, inert mines, torpedoes, targets, munitions, intact missiles) may also physically affect benthic habitats. All of the expendable materials would eventually sink to the bottom, but are unlikely to result in any physical impacts to the seafloor because they would sink into a soft bottom, where they eventually would be covered by shifting sediments. Soft bottom habitats are considered less sensitive than hard bottom habitats, and in such areas, the effects of expended materials would be minimal because the density of organisms and expended materials are low. Expended materials may also serve as a potential habitat or refuge for invertebrates and fishes. Given the smaller size of expended materials (compared to SINKEX) and the large size of the range, these items are not expected to adversely affect sensitive EFH or FMP species. Over time, these materials would degrade, corrode, and become incorporated into the sediments. Rates of deterioration would vary, depending on material and conditions in the immediate marine and benthic environment. Table 5-5 summarizes estimates of the area, volume, and weight from ordnance expended annually within open water habitat. Calculations were based on the annual expenditures for ordnance used in the offshore training range (Table 2-8 in Appendix A), and making several assumptions, such as no targets (as they vary), items remaining intact, using dimensions of the ordnance to calculate a surface area and volume as a cylinder, and multiplying that to estimate how much is entering into the ocean for each alternative. Based on the estimates in Table 5-5, and given the large area of the range (approximately 14,000 nm^2), the amount of material expended annually is neglible (e.g., 1.3 pounds per nm^2), and would not result in any long-term accumulation, as the likelihood of overlapping activities is low.

Chaff is deployed to confuse radar tracking devices (USAF 2002). Chaff canisters burst in the air releasing millions of aluminum coated glass or silicon fibers (see Tables A-7 and A-8 in Appendix A for annual expenditures and training locations). Chaff particles are very light and designed to remain airborne as long as possible. Depending on wind speed and direction, chaff particles may be distributed over a wide area. When finally reaching the water, they may remain suspended on the surface for a while before sinking (NRL 1997, DoN 2007c). Eventually, chaff particles would sink or be carried away by currents. Ocean floor sediments are largely composed of silicates (crystalline solids such as quartz and feldspar make up a large percentage of the earth's crust). The ocean water is constantly exposed to these silicates. Likewise, aluminum is a natural component of the ocean environment, entering the water from sediments and through hydrothermal vents. So, the addition of small amounts of these chemicals from chaff would unlikely have an effect on water or sediment composition (NRL 1999). Effects of chaff on resident populations of fish are likely to be short-term and would not be expected to adversely affect fisheries or their management.

A fish surfacing in an area where chaff has fallen on the ocean surface could have its skin covered with the particles (NRL 1999). However, it is unlikely that the concentration of chaff particles would be great enough to restrict mobility. As the animal submerges, the particles would either disperse into the water, or remain temporarily attached. Fish are unlikely to suffer physical effects from chaff lodging in their gills or ingesting toxic quantities of chaff (USAF 1997).

Table 5-5. Area, Volume, and Weight Entering Ocean (> 3 nm) from Ordnance Expended Annually in MIRC.

	AREA (ft^2)			VOLUME (ft^3)			WEIGHT (lbs) – Includes SINKEX		
SINKEX	**No Action**	**Alternative 1**	**Alternative 2**	**No Action**	**Alternative 1**	**Alternative 2**	**No Action**	**Alternative 1**	**Alternative 2**
HARM	93	186	186	25	50	50	All Missiles		
SLAM-ER	210	421	421	57	114	114	776	1,543	1,654
HARPOON	232	464	464	63	125	125			
5” Gun Shells	1,040	2,080	2,080	80	160	160	All Bombs		
HELLFIRE	21	41	41	3	6	6	8,309	12,463	12,525
MAVERICK	218	435	435	51	102	102			
GBU-12	552	1104	1104	189	378	378	All Torpedoes		
GBU-10	235	470	470	70	141	141	1,512	3,528	4,608
MK-48	NA	NA	NA	NA	NA	NA			
TOTAL	2,600	5,200	5,200	538	1075	1075			
	AREA (ft^2)			**VOLUME (ft^3)**			**WEIGHT (lbs) – Includes SINKEX**		
ALL OTHER ACTIVITIES	**No Action**	**Alternative 1**	**Alternative 2**	**No Action**	**Alternative 1**	**Alternative 2**	**No Action**	**Alternative 1**	**Alternative 2**
MK-48 EXTORP	NA	NA	NA	NA	NA	NA	All Gun Shells		
REXTORP	NA	NA	NA	NA	NA	NA	37,486	76,161	81,540
Air Deployed Mines [MK-62; MK-56]*	14,880	22,320	22,320	5,600	8,400	8,400			
Inert Bomb Training Rounds [MK-82 I; BDU-45; MK-76]**	582	873	1092	115	173	216	Sonobuoys		
5” Gun Shells	416	832	1040	32	64	80	304	313	339
AIM-7 Sparrow	102	153	204	16	25	33			
AIM-9 Sidewinder	62	93	124	4	7	9	TOTAL WEIGHT (lbs)		
AIM-120 AMRAAM	145	217	290	40	61	81	10,597	17,534	18,787
RIM-7 Sea Sparrow/ RIM-116 RAM / RIM-67 SM II ER	467.8	935.6	935.6	550.1	1100.2	1100.2			
Sonobuoys	98	117	130	98	117	130	Weight per sq. nautical mile (lbs/nm^2)		
TOTAL	16,754	25,542	26,136	6,457	9,946	10,049	0.8	1.3	1.3

Ordnance expenditures from Table 2-8 in EIS/OEIS.
Assumes item remains intact, does not explode, and settles to bottom.
Conservative calculation of area and volume based on largest dimension as a cylinder.
For comparison purposes, W-517 is approx. 14,000 nm^2.

*assumes 50% MK-62 and 50% MK-56
** assumes 33% MK-82, 33% BDU-45, 33% MK-76
Calculations do not include small arms, chaff, or flares.
Calculations do not include target, as target may vary.

The probability of fish ingesting expended materials would depend on factors such as the location of the spent materials, size of the materials, and the level of benthic foraging that occurs in the impact area, which is a function of benthic habitat quality, prey availability, and species-specific foraging strategies. It is possible that persistent expended material could be colonized by benthic organisms, and mistaken for prey, or that expended materials could be accidentally ingested while foraging for natural prey items. Ingestion of expended materials may affect individual fish; however, it would not result in adverse effects to fish populations, and as discussed in Section 5.3, no long-term impacts to water or sediment quality are anticipated from expended materials.

5.3 ALTERATION OF WATER OR SEDIMENT QUALITY FROM EXPENDED MATERIALS OR DISCHARGE

One potential impact to water quality would primarily be associated with the incidental release of materials from surface ships, submarines, or other vessels. Hazardous constituents of concern possibly emitted from the surface ship or submarine (i.e., fuel, oil) are less dense than seawater and would remain near the surface and therefore would not affect the benthic community. Sheens produced from these activities are not expected to cause any significant long-term impact on water quality or EFH because a majority of the toxic components would evaporate within several hours to days and/or be degraded by biogenic organisms (e.g., bacteria, phytoplankton, zooplankton).

The resulting expended materials and/or discharges from training activities may also affect the physical and chemical properties of benthic habitats and the quality of surrounding marine waters, in turn, affecting EFH. Hazardous constituents can be released from sonobuoys, targets, torpedoes, missiles, and underwater explosions (discussed individually below). Impacts from hazardous materials, primarily batteries, may affect water or sediment quality in the vicinity of the expended materials. The release of metal ions (e.g., Pb^{+2}, Cu^{+2}, and Ag^{+}) during operation of the seawater batteries or as a result of corrosion of sonobuoy or target components represents a source of potential environmental degradation for marine invertebrates. In general, the toxicological impact of exposure to high concentrations of heavy metals can result in either immediate mortality of exposed organisms (acute effect) or accumulation of heavy metal residues by these same species. Benthic communities exposed to high concentrations of heavy metals (specifically copper and zinc) are characterized by reduced species richness (number of species), reduced abundance (number of organisms), and a shift in community composition from sensitive to more tolerant taxa.

Sonobuoys are expendable devices used for the detection of underwater acoustic sources and for conducting vertical water column temperature measurements (see Table A-9 in Appendix A for annual expenditures and training activity). The primary source of contaminants in each sonobuoy is the seawater battery; these batteries have a maximum operational life of 8 hours, after which the chemical constituents in the battery are consumed. Long-term releases of lead and other metal from the remaining sonobuoy components would be substantially slower than the release during seawater battery operation. Lead has the potential to accumulate in bottom sediments, but the potential concentrations would be well below sediment quality criteria based on thresholds for negative biological effects. By far the greatest amount of material would likely to be deposited in a relatively inert form, as the lead ballast weights would become encrusted with lead oxide and other salts and would be covered by the bottom sediments. Lead, copper, and silver are heavy, naturally-occurring metals, widely distributed in the marine environment. They have relatively low solubility in seawater and slow corrosion rates (D'Itri 1990). The slow rate at which metal components are corroded by seawater translates into slow release rates into the marine environment. Once the metal surfaces corrode, the rate of metal released would decline. Releases of chemical constituents from all metal and non-metal sonobuoy components would be further minimized as a result of natural encrustation of exposed surfaces.

Sonobuoy emissions are not anticipated to accumulate or result in additive effects on water or sediment quality as would occur within an enclosed body of water since the constituents of sonobuoys would be widely dispersed in space and time throughout training areas. In addition, dispersion of released metals and other chemical constituents due to currents near the ocean floor would help minimize any long-term degradation of water and sediment quality. As a result, sonobuoy training activities may have a short-term and localized effect, but would not adversely affect sediment quality, water quality, or EFH.

Most air targets contain jet fuel, oils, hydraulic fluid, batteries, and explosive cartridges as part of their operating systems (see Tables A-7 and A-8 in Appendix A for annual expenditures and training locations). Following an activity, targets are generally flown (using remote control) to a pre-determined recovery point. Fuel is shut off by an electronic signal, the engine stops, and the target descends. A parachute is activated and the target drops to the ocean surface where it is retrieved by range personnel using helicopters or range support boats. However, some targets are physically hit by missiles, and these targets fall into the ocean, and could potentially result in temporary, localized impacts on water quality. This would occur in the open ocean away from sensitive EFH. Most of the hazardous constituents of concern (i.e., fuel, oil) are less dense than seawater and would remain near the surface and therefore would not affect sediment quality. Ocean currents at the surface and within the water column would also rapidly dilute any metal ions or other chemical constituents released by the target. Sheens (e.g., oil or fuel) produced from these activities would not adversely effect EFH because a majority of the toxic components (e.g., aromatics) would evaporate within several hours to days or be degraded by biogenic organisms. This process may occur at a faster rate depending on sea conditions (e.g., wind and waves). Potential effects of torpedoes on water or sediment quality are associated with propulsion systems, chemical releases, or expended accessories. During normal exercise activities, none of the potentially hazardous or harmful materials are released into the marine environment because the torpedo is sealed and, at the end of a run, the torpedos are recovered. It would be unlikely that OTTO Fuel II contained in a torpedo would be released into the marine environment. Under the worst-case scenario of a catastrophic failure, however, up to 59 pounds (lb) (27 kg) could be released from a MK-46 (DoN 1996). It is anticipated that in the event of such a maximum potential spill, temporary and localized impacts to water quality and EFH would occur, but no long-term adverse impacts to water quality are anticipated because:

- The water volume and depth of the MIRC would dilute the spill.
- Although OTTO Fuel II may be toxic to marine organisms (DoN 1996), in particular, sessile benthic animals and vegetation, mobile organisms may move away from areas of high OTTO Fuel II concentrations.
- Common marine bacteria degrade and ultimately break down OTTO Fuel (DoN 1996).

Missiles contain hazardous materials as normal parts of their functional components (see Tables A-7 and A-8 in Appendix A for annual expenditures and training locations). In general, the largest single hazardous material type is solid propellant, but there are numerous hazardous materials used in igniters, explosive bolts, batteries, and warheads. For missiles falling in the ocean, the principal source of potential impacts to water and sediment quality would be the unburned solid propellant residue and batteries. The remaining solid propellant fragments would sink to the ocean floor and undergo changes in the presence of seawater. Testing has demonstrated that water penetrates only 0.06 inches (0.14 centimeters [cm]) into the propellant during the first 24 hours of immersion, and that fragments would very slowly release ammonium and perchlorate ions. These ions would be expected to be rapidly diluted and disperse in the surrounding water such that local concentrations would be extremely low. However, assuming that all of the propellant on the ocean floor would be in the form of 4-inch cubes, only 0.42 percent of it would be wetted during the first 24 hours. If all the ammonium perchlorate leaches out of the wetted propellant, then approximately 0.01 lb (0.003 kg) would enter the surrounding seawater. The concentration would decrease over time as the leaching rate decreases and further dilution occurs. The aluminum would remain in the propellant binder and would eventually be oxidized by seawater to aluminum oxide. The remaining binder material and aluminum oxide would not pose a threat to the marine environment. Therefore, effects from missile propellant may have temporary and localized impacts on water quality and EFH, but would not be adverse.

Both chaff and flares are used during aircraft training exercises (see Tables A-7 and A-8 in Appendix A for annual expenditures and training locations). Chaff is an aluminum coated glass fiber used as a defensive mechanism to reflect radar. All of the components of the aluminum coating are present in seawater in trace amounts, except magnesium, which is present at 0.1 percent. The stearic acid coating is biodegradable and nontoxic. The potential for chaff to have a long-term adverse impact on water quality and sensitive EFH is very unlikely, and chemicals leached from the chaff would also be diluted by the surrounding seawater, thus reducing the potential for concentrations to build up to levels that could have effects on sediment quality and benthic habitats.

Flares are used over water during training. They are composed of a magnesium pellet that burns quickly at a very high temperature leaving ash and end caps and pistons. Laboratory leaching tests of flare pellets and residual ash using synthetic seawater found barium in the pellet tests, while boron and chromium were found in the ash tests. The pH of the test water was raised in both tests. Ash from flares would be dispersed over the water surface and then settle out. Chemical leaching would occur throughout the settling period through the water column, and any leaching after the particles reached the bottom would be dispersed by currents. Therefore, localized and temporary impacts to water quality and EFH may occur, but no long-term adverse impact is anticipated.

The majority of objects that fall to the sea floor become buried in the sediment. Metals like lead, copper, and silver will oxidize in the upper part of the sediment where bioturbation creates oxygen-rich conditions. Below this level, oxidation is less likely, and when leaching does occur, the metals tend to adsorb onto the particulate organic carbon in the sediments (Ankley 1996). Acid volatile sulphide is formed in anoxic zones and complexes with the metal ions in the porewater, rendering the metal relatively nontoxic and less subject to bioaccumulation. Metals can also form complexes with soluble ligands (both organic and inorganic) in pore water (Ankley 1996). Many of the heavier expendable objects are made of metal and tend to sink deeply into the anoxic layer of the sediments.

Unexploded five-inch shells and non-explosive ordnance practice shells would not be recovered and would sink to the bottom. The rapid-detonating explosive (RDX) material of unexploded ordnance would not be exposed to the marine environment, as it is encased in a non-buoyant cylindrical package. Should the RDX be exposed on the ocean floor, it would break down within a few hours (DoN 2001). It does not bioaccumulate in fish or in humans. Over time, the RDX residue would be covered by ocean sediments or diluted by ocean water.

Solid-metal components of unexploded ordnance and non-explosive ordnance would be corroded by seawater at slow rates, with comparable slow release rates. Exposure of fish to chemical constituents from all metallic and non-metallic ordnance components would be further reduced as a result of natural encrustation of external surfaces. Consequently, the release of contaminants from unexploded ordnance and non-explosive ordnance would not adversely affect EFH.

Turbidity is the only potential water quality impact from detonations, since products from the detonation of high explosives are non-hazardous (e.g., CO, CO_2, H_2, H_2O, N_2, and NH_3). In shallow water, underwater explosions would resuspend sediments into the water column creating a turbidity plume. This would be a localized event and impacts would not be considered adverse because the turbidity plume would eventually dissipate as particles return to the bottom and/or currents disperse the plume.

5.4 ALTERNATIVES ANALYSIS

5.4.1 ALTERNATIVE 1

Under Alternative 1, in addition to accommodating the No Action Alternative will be the addition of increased training activities as a result of upgrades and modernization of existing ranges and training areas. This alternative also includes increased training activities from meeting new training and capability requirements for personnel and platforms, to an overall increase in the number and types of activities [including major exercises, the Intelligence, Surveillance and Reconnaissance /Strike (ISR/Strike) Air Force initiative at Andersen AFB, USMC activities, and the participation of the allied forces in major exercises in the MIRC]. Training activities will increase as a result of the development of a laser certified range area in W-517. This laser range capability will aid in the training of aircrews in the delivery of air-to-surface missiles against surface vessel targets. Primarily conducted in W-517, the weapon systems commonly used in this training activity are the laser guided HELLFIRE missile or an inert captive air training missile (CATM). The CATM is a missile shape that contains electronics only, and it remains attached to the aircraft weapon mounting points. The MISSILEX involves in-flight laser designation and guidance, and arming and releasing of the air to surface weapon by aircraft, typically against a small stationary, towed, or maneuvering target; however a CATM Exercise (CATMEX) may be conducted against any laser reflective target mounted on or towed by a target support vessel. Training activities will also increase as a result of the acquisition and development of new Portable Undersea Tracking Range (PUTR) capabilities supporting anti-submarine warfare (ASW), and new facility capabilities supporting Military Operations in Urban Terrain (MOUT) training. Of the proposed activities, only PUTR and increased training activities may affect EFH.

The PUTR system allows targets, torpedoes, and submarines to be tracked underwater in conjunction with Navy training exercises, and would consist of ten 800 lbs. (363 kg) transponders spread on the ocean floor over a specified area. The transponders are anchored to the bottom one at a time using a 275 lbs. (125 kg) clump weight and then surveyed in place using acoustic survey techniques. During exercises, the Shipboard Processing Unit aboard the support boat communicates with the transponders using a hydrophone, and outputs unclassified ping arrival time information to a radio modem that transmits the data to shore. The transponders currently uses a stack of 90 D-cells, and when the transponder batteries are depleted over the course of several weeks, the support boat recovers the transponders by activating their acoustic releases. The transponders are returned to shore, and maintenance is performed prior to the next deployment cycle.

No area supporting a PUTR system has been identified; however, potential impacts to EFH can be assessed based on several assumptions. Assuming that transponders are not deployed on sensitive or coral reef habitat, but rather on soft bottom habitats, impacts would be similar to those discussed in Section 5.2.3 – Expended Materials. There would be direct impact to soft bottom habitat where the clump weight contacted the bottom, which may result in localized mortality to epifauna and infauna within the footprint, although it is anticipated that recolonization would occur within a relatively short period of time. Upon completion of the exercise, the transponders are recovered, which eliminates any potential impacts associated with hazardous materials such as batteries and electronic components. The clump weight is not recovered, and since it is composed of inert material, it is not a potential source of contaminants, and could provide a substrate for benthic fauna. There may also be indirect effects associated with increased turbidity due to resuspension of sediments from the clump weight contacting the bottom. The turbidity plume is expected to be localized and temporary, as sediment would eventually settle to the ocean floor or be dispersed by ocean currents. Therefore, localized and temporary impacts to benthic fauna and water quality and EFH may occur from the PUTR, but no long-term adverse impact is anticipated.

Training activities would be increased to include training in major exercises, multi-Service and Joint exercises involving multiple strike groups and task forces. As discussed in the Cumulative Impact Section (Section 5.5), impacts were assessed based on single events or activities; however, during major range exercises, multiple activities could be conducted simultaneously over a relatively short period of time. Due to the temporal and spatial variation of major range events, which would include multiple training activities over a large area, and avoidance of HAPCs, they are not expected to result in long-term adverse impacts to EFH. Although some individual activities could affect EFH or managed species at the individual level due to localized impacts, these impacts are not additive when considering major range events or the increase in tempo.

5.4.2 ALTERNATIVE 2

Training activities would be increased to include training in major exercises, multi-Service and Joint exercises involving multiple strike groups and task forces (See Appendix A, Table A-7). As discussed in the Cumulative Impact Section (Section 5.5), impacts were assessed based on single events or activities; however, during major range exercises, multiple activities could be conducted simultaneously over a relatively short period of time. Due to the temporal and spatial variation of major range events which would include multiple training activities over a large area, and avoidance of HAPCs, they are not expected to result in long-term adverse impacts to EFH. Although some individual activities could affect EFH or managed species at the individual level due to localized impacts, these impacts are not additive when considering major range events or the increase in tempo. Therefore, no long-term adverse impacts to EFH would be expected from major range events or increased tempo.

5.5 CUMULATIVE ECOSYSTEM IMPACTS

Federal and DoN regulations implementing NEPA (42 USC § 4321 et seq. and 32 CFR 775 respectively) require that the cumulative impacts of a Proposed Action be assessed. NEPA defines cumulative impact as:"the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future action regardless of what agency (federal or non-federal) or person undertakes such other actions. Cumulative ecosystem impacts can result from individually minor but collectively significant actions taking place over a period of time" (40 CFR § 1508.7). In general, a particular action or group of actions must meet all of the following criteria to be considered a cumulative ecosystem impact: effects of several actions occur in a common locale or region; effects on a particular resource are similar in nature, such that the same specific element of a resource is affected in the same specific way; and, effects are long-term as short-term ecosystem impacts dissipate over time and cease to contribute to cumulative ecosystem impacts.

Human uses of the MIRC include prior, current, and future Navy activities, navigation, transportation, coastal development, oil/gas exploration and development, sand and mineral mining, dredge and fill operations, cooling water intake and discharge, wastewater discharge, mariculture, and recreational and commercial fishing. Potential threats to EFH and managed species include sound from aircraft and vessel traffic, degradation of water quality, habitat modification, pollution (thermal, chemical, marine expended materials, etc.), introduction of exotic species, disease, natural events, and global climate change (Field et al. 2001).

Fishing activities, individually or in combination, can adversely affect EFH and managed species (NOAA 1998, Dayton et al. 2003, Morgan and Chuenpagdee 2003, Levin et al. 2006). Potential impacts of commercial fishing include over-fishing of targeted species and bycatch, both of which negatively affect fish stocks (Barnette 2001, NRC 2002). Mobile fishing gears such as bottom trawls disturb the seafloor and reduce structural complexity (Auster and Langton 1998, Johnson 2002). Indirect effects of trawls include increased turbidity; alteration of surface sediment, removal of prey (leading to declines in predator abundance), removal of predators, ghost fishing, and generation of marine expended materials (Hamilton 2000). Lost gill nets, purse seines, and long-lines may foul and disrupt bottom habitats. Recreational fishing also poses a threat because of the large number of participants and the concentrated use of specific habitats (Coleman et al. 2004).

Natural stresses include storms and climate-based environmental shifts, such as harmful algal blooms and hypoxia (DoN 2005b). Disturbance from ship traffic and exposure to biotoxins and anthropogenic contaminants may stress animals, weaken their immune systems, and make them vulnerable to parasites and diseases that would not normally compromise natural activities or be fatal (Pew Oceans Commissions 2003). As evidenced by Carpenter et al. (2008), approximately one-third of the world's reef building corals face extinction risk from bleaching and diseases driven by ocean acidification and globally elevated sea surface temperatures, as well as human-induced impacts at the local level. Development of the world's coasts has accelerated, with some 37% of the world's population living within 60 miles (100 km) of the coast, at a population density twice the global average (UNEP 2006). Heavy population pressure on the coasts is causing the destruction or modification of more and more of the natural environment. Halpern et al. (2008) developed an ecosystem-specific, multiscale spatial model to synthesize 17 global data sets of anthropogenic drivers of ecological change for 20 marine ecosystems. Their analysis indicated that no area is unaffected by human influence and that a large fraction (41%) is strongly affected by multiple drivers. Small human population and coastal watershed size predicted light human impact, but do not ensure it, as shipping, fishing, and climate change affect even remote locations. Their data suggested that almost half of all coral reefs experience medium high to very high impact; however, it appeared that the area emcompassing the MIRC study area was regarded as experiencing medium impact.

Potential cumulative impacts of Navy training exercises include release of chemicals into the ocean, introduction of expended materials into the water column and onto the seafloor, mortality and injury of marine organisms near the detonation or impact point of ordnance or explosives, and, physical and acoustic impacts of vessel activity. Impacts to EFH were assessed based on single events, and based on single events, some training activities would result in temporary and localized impacts to FMP species. This finding was based on the generally small area that was affected, the avoidance of HAPCs, the relatively large size of the MIRC, and the distribution of FMP species. Due to the temporal and spatial variation of each training activity, multiple concurrent activities and/or actions proposed under Alternatives 1 and 2 (i.e., major training and increased tempo), would not contibute to long-term adverse impacts to EFH. For training activities that occur in nearshore waters, there is a greater probability that these activities could affect EFH and HAPC, such as coral reefs. However, administrative controls reduce the likelihood of impacts to coral reefs and HAPC, such as conducting nearshore activities in less sensitive habitats, like sandy bottom habitat. Although, there may still be impacts to these less sensitive habitats, the impacts would be localized and temporary. The incremental contribution by the Proposed Action and alternatives to impacts on the marine ecosystem structure and function and associated ecosystem services is expected to be insignificant. The overall effect on fish stocks would be negligible compared to the impact of commercial and recreational fishing in the MIRC. After completion of an exercise, repopulation of an area by fish should take place within a matter of hours. Implementation of protective measures designed to avoid adverse or long-term impacts would further protect marine life and the environment.

Because of the transient nature of the training exercises and the minor, localized potential ecosystem effects, there would not be incremental or synergistic impacts on present or reasonably foreseeable future ecosystem structure and function or ecosystem services within the MIRC. The Proposed Action and alternatives would not make a significant contribution to the regional cumulative ecosystem impacts on EFH or Managed Species.

5.6 CONCLUSIONS

Using an ecosystems-based management approach, and considering:

- local, regional and global effects of Navy actions to the structure and function of ecosystems and the provision of ecosystem services in the MIRC Study Area; and
- protective measures implemented to protect sensitive habitats in nearshore waters and other habitats in the MIRC Study Area;

it is concluded that no long-term, permanent adverse impact would occur as a result of implementation of the Proposed Action and alternatives on EFH and their associated management units relative to the major FMP's administered by the WPRFMC.

Table 5-6. Summary of Potential Impacts to EFH by Activity

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION OF ACTIVITY	POTENTIAL IMPACTS TO EFH				
				POTENTIAL STRESSOR	NO IMPACT	TEMPORARY OR LOCALIZED IMPACT	SIGNIFICANT OR PERMANENT ADVERSE IMPACT	DESCRIPTION OF IMPACT AND AVOIDANCE MEASURES
NO ACTION ALTERNATIVE								
ARMY TRAINING								
	Surveillance and Reconnaissance (S&R)	Finegayan House, Barrigada House, Tinian-Exclusive Military Use Area, and the Lease Back Area	S&R are conducted to evaluate the battlefield, enemy forces, and gather intelligence. For training of assault forces, opposition forces (OPFOR) units may be positioned ahead of the assault force and permitted a period of time to conduct S&R and prepare defenses to the assaulting force.	None	**X**			**N/A**
	Field Training Exercise (FTX)	Polaris Point Field, Tinian-Exclusive Military Use Area, Orote Point Airfield/Runway, Fire Break #3, Andersen Air Force Base - Northwest Field, and Andersen South housing Area	An FTX is an exercise where the battalion and its combat and combat service support units deploy to field locations to conduct tactical training activities under simulated combat conditions. A company or smaller-sized element of the Army Reserve, Guam Army National Guard, or Guam Air National Guard will typically accomplish an FTX within the MIRC, due to the constrained environment for land forces. The headquarters and staff elements may simultaneously participate in a Command Post Exercise (CPX) mode.	None	**X**			**N/A**
	Live Fire	Tarague Beach Small Arms Range	Live fire training is conducted to provide direct fire in support of combat forces.	None	**X**			**N/A**
	Parachute Insertions and Air Assault	Orote Point Triple Spot, Polaris Point Field, and the Ordnance Annex Breacher House	These air training activities are conducted to insert troops and equipment by parachute and/or air land by fixed or rotary wing aircraft to a specified objective area.	None	**X**			**N/A**
	Military Operations in Urban Terrain (MOUT)	Orote Point CQC House, the Ordnance Annex Breacher House, Barrigada Housing, and the Andersen South Housing Area	MOUT training activities encompass advanced offensive close quarter battle techniques used on urban terrain conducted by units trained to a higher level than conventional infantry. Techniques include advanced breaching, selected target engagement, and dynamic assault techniques using organizational equipment and assets. MOUT is primarily an offensive operation, where noncombatants are or may be present and collateral damage must be kept to a minimum.	None	**X**			**N/A**

Table 5-6. Summary of Potential Impacts to EFH by Activity (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION OF ACTIVITY	POTENTIAL IMPACTS TO EFH				
				POTENTIAL STRESSOR	NO IMPACT	TEMPORARY OR LOCALIZED IMPACT	SIGNIFICANT OR PERMANENT ADVERSE IMPACT	DESCRIPTION OF IMPACT AND AVOIDANCE MEASURES
MARINE CORP TRAINING								
	Ship to Objective Maneuver (STOM)	EMUA on Tinian	STOM is conducted to gain a tactical advantage over the enemy in terms of both time and space. The maneuver is not aimed at the seizure of a beach, but builds upon the foundations of expanding the battlespace.	• Vessel Movement • Amphibious Landings		X		• Short-term behavioral responses to vessel movement and extremely low potential for injury/mortality from collisions. • Short-term and localized disturbance to water column. Limited injury or mortality to fish eggs and larvae. • Disturbance to FMP species, and potential loss of benthic epifauna and infauna that may serve as prey items for managed species at beach landing locations. • Temporary impacts to water quality due to increased turbidity may reduce foraging efficiency of FMP species or increase sedimentation. • No long-term population-level effects or reduction in the quality and/or quantity of EFH. Avoidance Measures: • Amphibious landings are restricted to specific areas of designated beaches away from sensitive EFH or HAPC, and are conducted in accordance to mitigation measures outlined in Chapter 5 of this EIS/OEIS, which includes landings at high tide, LCACs under full cushion, reach beach prior to coming off cushion, and pre- and post-activity surveys.
	Operational Maneuver	Fire Break #3 and the Southern Land Navigation Area	This training exercise supports forces achieving a position of advantage over the enemy for accomplishing operational or strategic objectives.	None	X			**N/A**
	Non-Combatant Evacuation Order (NEO)	EMUA on Tinian	NEO training activities are conducted when directed by the Department of State, the Department of Defense, or other appropriate authority whereby noncombatants are evacuated from foreign countries when their lives are endangered by war, civil unrest, or natural disaster to safe havens or to the United States.	None	X			**N/A**
	Assault Support (AS)	Polaris Point Field, Orote Point KD Range, and EMUA on Tinian	Assault Support exercises provide helicopter support for command and control, assault escort, troop lift/logistics, reconnaissance, search and rescue (SAR), medical evacuation (MEDEVAC), reconnaissance team insertion/extract and Helicopter Coordinator (Airborne) (HC(A)) duties.	None	X			**N/A**
	Reconnaissance and Surveillance (R & S)	EMUA on Tinian	R & S is conducted to evaluate the battlefield, enemy forces, and gather intelligence. For training of assault forces, OPFOR units may be positioned ahead of the assault force and permitted a period of time to conduct R&S and prepare defenses to the assaulting force	None	X			**N/A**
	Military Operations in Urban Terrain (MOUT)	Ordnance Annex Breacher House	Marine Corps MOUT training is similar in nature and intent to Army MOUT training.	None	X			**N/A**

Table 5-6. Summary of Potential Impacts to EFH by Activity (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION OF ACTIVITY	POTENTIAL IMPACTS TO EFH				
				POTENTIAL STRESSOR	NO IMPACT	TEMPORARY OR LOCALIZED IMPACT	SIGNIFICANT OR PERMANENT ADVERSE IMPACT	DESCRIPTION OF IMPACT AND AVOIDANCE MEASURES
	Direct Fire	FDM, Orote Point KD Range and ATCAA 3A airspace	Direct Fires, similar in nature and content to Navy Marksmanship exercises, are used to train personnel in the use of all small arms weapons for the purpose of defense and security. Another form of Marine Corp Direct Fires exercises involves the use of aircraft acting as forward observers for Naval Surface Fires Support. During these training activities, Marine aircraft will act as spotters for the ships and relay targeting and battle hit assessments information.	• Vessel Movement • Aircraft Overflight • Weapons Firing· • Expended Materials		X		• Short-term behavioral responses to vessel movement and extremely low potential for injury/mortality from collisions. • Short-term and localized disturbance to water column. Low potential for injury or mortality to fish. • Possible short-term behavioral responses to aircraft overflight. • Shock wave could injure or kill all life stages of fish and larvae of other marine organisms within the immediate area. • Temporary impacts to water quality due to increased turbidity and release of hazardous materials. • Expended materials may physically affect benthic habitats. Long-term, minor, and localized accumulation of expended materials in benthic habitat. Limited potential for ingestion or exposure to hazardous materials. • Temporary impacts to water quality due to increased turbidity and release of hazardous materials. • No long-term population-level effects or reduction in the quality and/or quantity of EFH.
	Exercise Command and Control (C2)	Andersen AFB	C2 provides primary communications training for command, control, and intelligence, providing critical interpretability and situation awareness information.	None	X			**N/A**
	Protect and Secure Area of Operations (Protect the Force)	Northwest Field on Andersen Air Force Base	Force protection training activities increase the physical security of military personnel in the region to reduce their vulnerability to attacks. Force protection training includes moving forces and building barriers, detection, and assessment of threats, delay, or denial of access of the adversary to their target, appropriate response to threats and attack, and mitigation of effects of attack.	None	X			**N/A**

Table 5-6. Summary of Potential Impacts to EFH by Activity (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION OF ACTIVITY	POTENTIAL IMPACTS TO EFH				
				POTENTIAL STRESSOR	NO IMPACT	TEMPORARY OR LOCALIZED IMPACT	SIGNIFICANT OR PERMANENT ADVERSE IMPACT	DESCRIPTION OF IMPACT AND AVOIDANCE MEASURES
NAVY TRAINING								
Anti-Submarine Warfare (ASW)	Antisubmarine Warfare Tracking Exercise	MIRC Offshore Areas, W-517	ASW TRACKEX trains aircraft, ship, and submarine crews in tactics, techniques, and procedures for search, detection, localization, and tracking of submarines. The use of sonobuoys is generally limited to areas greater than 100 fathoms, or 600 feet, in depth.	• Vessel Movement • Underwater Explosions· • Sonar· • Collision		X		• Short-term behavioral responses to vessel movement and extremely low potential for injury/mortality from collisions. • Short-term and localized disturbance to water column and benthic habitats. Mortality to fish in immediate vicinity of explosions, with increased susceptibility by juvenile fish, small fish, and fish with swim bladders. Injury may include permanent or temporary hearing loss with effects diminishing further from the detonation. Behavioral effects include startle response and temporarily leaving an exercise area. • Temporary impacts to water quality due to increased turbidity and release of hazardous materials. • Long-term, minor, and localized accumulation of expended materials in benthic habitat. Limited potential for ingestion or exposure to hazardous materials. • Potential for mortality (swim bladder rupture) or injury (such as hearing loss), or displacement of prey items. Potential for masking of sounds within frequency ranges of LFA, MFA, and HFA sonar systems that overlap with some fish species' hearing. • Potential for injury or mortality from direct strikes of fish by inert torpedoes. • No long-term population-level effects or reduction in the quality and/or quantity of EFH.

Table 5-6. Summary of Potential Impacts to EFH by Activity (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION OF ACTIVITY	POTENTIAL IMPACTS TO EFH				
				POTENTIAL STRESSOR	NO IMPACT	TEMPORARY OR LOCALIZED IMPACT	SIGNIFICANT OR PERMANENT ADVERSE IMPACT	DESCRIPTION OF IMPACT AND AVOIDANCE MEASURES
Anti-Submarine Warfare (ASW)	Antisubmarine Warfare Torpedo Exercise	MIRC Offshore Areas, W-517	ASW TORPEX training activities train crews in tracking and attack of submerged targets, using active or passive acoustic systems, and firing one or two Exercise Torpedoes (EXTORPs) or Recoverable Exercise Torpedoes (REXTORPs). TORPEX targets used in the Offshore Areas include live submarines, MK-30 ASW training targets, and MK-39 Expendable Mobile ASW Training Targets (EMATT).	• Vessel Movement • Underwater Explosions· • Sonar· • Collision		X		• Short-term behavioral responses to vessel movement and extremely low potential for injury/mortality from collisions. • Short-term and localized disturbance to water column. Temporary impacts to water quality due to increased turbidity and release of hazardous materials. Limited injury or mortality to fish eggs and larvae. • Short-term and localized disturbance to water column and benthic habitats. Mortality to all life stages of fish and larvae of other marine organisms in immediate vicinity of explosions, with increased susceptibility by juvenile fish, small fish, and fish with swim bladders. Injury may include permanent or temporary hearing loss with effects diminishing further from the detonation. Behavioral effects include startle response and temporarily leaving an exercise area. • Long-term, minor, and localized accumulation of expended materials in benthic habitat. Limited potential for ingestion or exposure to hazardous materials. • Potential for mortality (swim bladder rupture) or injury (such as hearing loss), or displacement of prey items.. Potential for masking of sounds within frequency ranges of LFA, MFA, and HFA sonar systems that overlap with some fish species' hearing. • Potential for injury or mortality from direct strikes of fish by inert torpedoes. • No long-term population-level effects or reduction in the quality and/or quantity of EFH.
Anti-Air Warfare (AAW)	Missile Firing Exercises (MISSILEX)	MIRC Offshore Areas, W-517, ATCAA 1/2/3/4/5	MISSILEX is an operation in which missiles are fired from either aircraft or ships against aerial targets. Air-to-Air exercises involve a fighter or fighter/attack aircraft firing a missile at an aerial target. Aerial targets are typically launched. In the MIRC this event refers to training activities in which air-to-air missiles are fired from aircraft against unmanned aerial target drones, gliders, or flares. The missiles fired are not recovered.	• Vessel Movement • Aircraft Overflight • Weapons Firing • Expended Materials·		X		• Short-term behavioral responses to vessel movement and extremely low potential for injury/mortality from collisions. • Possible short-term behavioral responses to aircraft overflight. • Shock wave could injure or kill all life stages of fish and larvae of other marine organisms within the immediate area. • Temporary impacts to water quality due to increased turbidity and release of hazardous materials. • Expended materials may physically affect benthic habitats. Long-term, minor, and localized accumulation of expended materials in benthic habitat. Limited potential for ingestion or exposure to hazardous materials. • Short-term and localized disturbance to water column and benthic habitats. Temporary impacts to water quality due to increased turbidity and release of hazardous materials. Low potential for injury or mortality to fish. • No long-term population-level effects or reduction in the quality and/or quantity of EFH.

Table 5-6. Summary of Potential Impacts to EFH by Activity (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION OF ACTIVITY	POTENTIAL IMPACTS TO EFH				
				POTENTIAL STRESSOR	NO IMPACT	TEMPORARY OR LOCALIZED IMPACT	SIGNIFICANT OR PERMANENT ADVERSE IMPACT	DESCRIPTION OF IMPACT AND AVOIDANCE MEASURES
Anti-Air Warfare (AAW)	Chaff Exercise	MIRC Offshore Areas, W-517, ATCAA 1/2	A CHAFFEX trains aircraft and shipboard personnel in the use of chaff to counter antiship missile threats. Chaff is a radar confusion reflector, consisting of thin, narrow metallic strips of various lengths and frequency responses, which are used to reflect echoes to deceive radars.	• Aircraft Overflight • Expended Materials·		**X**		• Possible short-term behavioral responses to aircraft overflight. • Long-term, minor, and localized accumulation of expended materials in benthic habitat. Limited potential for ingestion or exposure to hazardous materials. • Short-term and localized disturbance to water column and benthic habitats. Temporary impacts to water quality due to in release of hazardous materials. Low potential for injury or mortality to fish. • No long-term population-level effects or reduction in the quality and/or quantity of EFH.
Anti-Air Warfare (AAW)	Flare Exercise	MIRC Offshore Areas, W-517	A flare exercise is an aircraft defensive operation in which the aircrew attempts to cause an infrared (IR) or radar energy source to break lock with the aircraft.	• Aircraft Overflight • Expended Materials·		**X**		• Possible short-term behavioral responses to aircraft overflight. • Long-term, minor, and localized accumulation of expended materials in benthic habitat. Limited potential for ingestion or exposure to hazardous materials. • Short-term and localized disturbance to water column and benthic habitats. Temporary impacts to water quality due to in release of hazardous materials. Low potential for injury or mortality to fish. • No long-term population-level effects or reduction in the quality and/or quantity of EFH.
Anti-Surface Warfare (ASUW)	Surface-to-Surface Gunnery Exercise (GUNEX)	MIRC Offshore Areas, W-517	Surface-To-Surface GUNEX take place in the open ocean to provide gunnery practice for Navy and Coast Guard ships utilizing shipboard gun systems and small craft crews supporting NSW, EOD, and Mobile Security Squadrons (MSS) utilizing small arms. GUNEX training activities conducted in W-517 involve only surface stationary targets such as a MK-42 Floating At Sea Target (FAST), MK-58 marker (smoke) buoys, or 55 gallon drums. The systems employed against surface targets include the 5-inch, 76mm, 25mm chain gun, 20mm Close In Weapon System (CIWS), .50 caliber machine gun, 7.62mm machine gun, small arms, and 40mm grenade.	• Vessel Movement • Weapons Firing· • Expended Materials·		**X**		• Short-term behavioral responses to vessel movement and extremely low potential for injury/mortality from collisions. • Shock wave could injure or kill all life stages of fish and larvae of other marine organisms within the immediate area. • Low potential for injury or mortality from direct strike of fish by weapon systems. • Short-term and localized disturbance to water column. Injury or mortality to all life stages of fish and larvae of other marine organisms in immediate vicinity of explosions. Temporary impacts to water quality due to increased turbidity and release of hazardous materials. • Long-term, minor, and localized accumulation of expended materials in benthic habitat. Limited potential for ingestion or exposure to hazardous materials. • No long-term population-level effects or reduction in the quality and/or quantity of EFH.

Table 5-6. Summary of Potential Impacts to EFH by Activity (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION OF ACTIVITY	POTENTIAL IMPACTS TO EFH				
				POTENTIAL STRESSOR	NO IMPACT	TEMPORARY OR LOCALIZED IMPACT	SIGNIFICANT OR PERMANENT ADVERSE IMPACT	DESCRIPTION OF IMPACT AND AVOIDANCE MEASURES
Anti-Surface Warfare (ASUW)	Air-to-Surface Gunnery Exercise (GUNEX)	MIRC Offshore Areas, W-517	Air-to-Surface GUNEX training activities are conducted by rotary-wing aircraft against stationary targets (FAST and smoke buoy). Rotary-wing aircraft involved in this operation would use either 7.62mm or .50 caliber door-mounted machine guns. GUNEX training occurs frequently in the MIRC Offshore Areas other than W-517, but exact data on this open ocean training evolution outside of W-517 is not recorded or tracked.	• Vessel Movement • Aircraft Overflight • Weapons Firing· • Expended Materials·		X		• Short-term behavioral responses to vessel movement and extremely low potential for injury/mortality from collisions. • Possible short-term behavioral responses to aircraft overflight. • Shock wave could injure or kill all life stages of fish and larvae of other marine organisms within the immediate area. • Low potential for injury or mortality from direct strike of fish by weapon systems. • Short-term and localized disturbance to water column. Injury or mortality to all life stages of fish and larvae of other marine organisms in immediate vicinity of explosions. Temporary impacts to water quality due to increased turbidity and release of hazardous materials. • Long-term, minor, and localized accumulation of expended materials in benthic habitat. Limited potential for ingestion or exposure to hazardous materials. • No long-term population-level effects or reduction in the quality and/or quantity of EFH.
Anti-Surface Warfare (ASUW)	Visit Board Search and Seizure (VBSS)	MIRC Offshore Areas, W-517, Outer Apra Harbor	These exercises involve the interception of a suspect surface ship by a Navy ship and are designed to train personnel to board a ship, other vessel or transport to inspect and examine the vessel's papers or examine it for compliance with applicable laws and regulations. Seizure is the confiscating or taking legal possession of the vessel and contraband (goods or people) found in violation of laws and regulations. A VBSS can be conducted both by ship personnel trained in VBSS or by Naval Special Warfare (NSW) SEAL teams trained to conduct VBSS on uncooperative vessels. Employment onto the vessel designated for inspection is usually done by small boat or by helicopter.	• Vessel Movement·		X		• Short-term behavioral responses to vessel movement and extremely low potential for injury/mortality from collisions. • Short-term and localized disturbance to water column. Limited injury or mortality to fish eggs and larvae. • No long-term population-level effects or reduction in the quality and/or quantity of EFH.

Table 5-6. Summary of Potential Impacts to EFH by Activity (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION OF ACTIVITY	POTENTIAL IMPACTS TO EFH				
				POTENTIAL STRESSOR	NO IMPACT	TEMPORARY OR LOCALIZED IMPACT	SIGNIFICANT OR PERMANENT ADVERSE IMPACT	DESCRIPTION OF IMPACT AND AVOIDANCE MEASURES
Anti-Surface Warfare (ASUW) (Continued)	Sink Exercise	MIRC Offshore Areas, W-517	A SINKEX provides training to ship and aircraft crews in delivering live ordnance on a real target. Each SINKEX uses an excess vessel hulk as a target that is eventually sunk during the course of the exercise. The target is an empty, cleaned, and environmentally remediated ship hull that is towed to a designated location where various platforms would use multiple types of weapons to fire shots at the hulk.	• Vessel Movement· • Aircraft Overflight • Weapons Firing· • Underwater Explosions • Expended Materials·		**X**		• Short-term behavioral responses to vessel movement and extremely low potential for injury/mortality from collisions. • Possible short-term behavioral responses to aircraft overflight. • Shock wave could injure or kill all life stages of fish and larvae of other marine organisms within the immediate area. • Low potential for injury or mortality from direct strike of fish by weapon systems. • Short-term and localized disturbance to water column. Injury or mortality to all life stages of fish and larvae of other marine organisms in immediate vicinity of explosions. Temporary impacts to water quality due to increased turbidity and release of hazardous materials. Low potential for injury or mortality to fish. • Long-term, minor, and localized accumulation of expended materials in benthic habitat. Limited potential for ingestion or exposure to hazardous materials. • No long-term population-level effects or reduction in the quality and/or quantity of EFH.
Strike Warfare (STW)	Air to Ground Bombing Exercises (Land) (BOMBEX-Land)	FDM, ATCAA 3	BOMBEX (Land) allows aircrews to train in the delivery of bombs and munitions against ground targets. The weapons commonly used in this training are inert training munitions (e.g., MK-76, BDU-45, BDU-48, BDU-56 and MK-80-series bombs), and live MK-80-series bombs and precision guided munitions (Laser Guided Bombs [LGBs] or Laser Guided Training Round [LGTRs]). BOMBEX exercises can involve a single aircraft, a flight of two, four, or multiple aircraft.	• Aircraft Overflight • Explosive Ordnance • Expended Materials		**X**		• Possible short-term behavioral responses to aircraft overflight. • Shock wave could injure or kill all life stages of fish and larvae of other marine organisms within the immediate area. • Short-term and localized disturbance to water column and benthic habitats in shallow water. Mortality to all life stages of fish and larvae of other marine organisms in immediate vicinity of explosions, with increased susceptibility by juvenile fish, small fish, and fish with swim bladders. Injury may include permanent or temporary hearing loss with effects diminishing further from the detonation. Behavioral effects include startle response and temporarily leaving an exercise area. • Long-term, minor, and localized accumulation of expended materials in benthic habitat. Limited potential for ingestion or exposure to hazardous materials. • No long-term population-level effects or reduction in the quality and/or quantity of EFH.

Table 5-6. Summary of Potential Impacts to EFH by Activity (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION OF ACTIVITY	POTENTIAL IMPACTS TO EFH				
				POTENTIAL STRESSOR	NO IMPACT	TEMPORARY OR LOCALIZED IMPACT	SIGNIFICANT OR PERMANENT ADVERSE IMPACT	DESCRIPTION OF IMPACT AND AVOIDANCE MEASURES
Strike Warfare (STW)	Air to Ground Missile Exercises (MISSILEX)	FDM, ATCAA 1/2/3/5	Air-to-ground Missile Exercise trains aircraft crews in the use of air-to-ground missiles. It is conducted mainly by H-60 Aircraft using Hellfire missiles and occasionally by fixed wing aircraft using Maverick missiles. A basic air-to-ground attack involves one or two H-60 aircraft. Typically, the aircraft will approach the target, acquire the target, and launch the missile. The missile is launched in forward flight or at hover at an altitude of 300 feet Above Ground Level (AGL).	• Aircraft Overflight • Explosive Ordnance • Expended Materials		**X**		• Possible short-term behavioral responses to aircraft overflight. • Shock wave could injure or kill all life stages of fish and larvae of other marine organisms within the immediate area. • Short-term and localized disturbance to water column and benthic habitats in shallow water. Mortality to all life stages of fish and larvae of other marine organisms in immediate vicinity of explosions, with increased susceptibility by juvenile fish, small fish, and fish with swim bladders. Injury may include permanent or temporary hearing loss with effects diminishing further from the detonation. Behavioral effects include startle response and temporarily leaving an exercise area. • Long-term, minor, and localized accumulation of expended materials in benthic habitat. Limited potential for ingestion or exposure to hazardous materials. • No long-term population-level effects or reduction in the quality and/or quantity of EFH.
Naval Special Warfare (NSW)	Naval Special Warfare Operations (NSW OPS)	Various	NSW personnel perform special activities using tactics that are applicable to the specific tactical situations where the NSW personnel are employed.	• Vessel Movement • Weapons Firing • Expended Materials· • Amphibious Landings·		**X**		• Short-term behavioral responses to vessel movement and extremely low potential for injury/mortality from collisions. • Shock wave could injure or kill all life stages of fish and larvae of other marine organisms within the immediate area. • Short-term and localized disturbance to water column and benthic habitats in shallow water. Mortality to all life stages of fish and larvae of other marine organisms in immediate vicinity of explosions, with increased susceptibility by juvenile fish, small fish, and fish with swim bladders. Injury may include permanent or temporary hearing loss with effects diminishing further from the detonation. Behavioral effects include startle response and temporarily leaving an exercise area. • Long-term, minor, and localized accumulation of expended materials in benthic habitat. Limited potential for ingestion or exposure to hazardous materials. • Disturbance to FMP species, and potential loss of benthic epifauna and infauna that may serve as prey items for managed species at beach landing locations. Temporary impacts to water quality due to increased turbidity may reduce foraging efficiency of FMP species or increase sedimentation. • No long-term population-level effects or reduction in the quality and/or quantity of EFH. Avoidance Measures: • Amphibious landings are restricted to specific areas of designated beaches away from sensitive EFH or HAPC, and are conducted in accordance to B.O. 1-2-98-F-07, which includes landings at high tide, LCACs under full cushion, reach beach prior to coming off cushion, and pre- and post-activity surveys.

Table 5-6. Summary of Potential Impacts to EFH by Activity (cont'd)

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				POTENTIAL STRESSOR	NO IMPACT	TEMPORARY OR LOCALIZED IMPACT	SIGNIFICANT OR PERMANENT ADVERSE IMPACT	DESCRIPTION OF IMPACT AND AVOIDANCE MEASURES
Naval Special Warfare (NSW)	Airfield Seizure	Northwest Field on Andersen Air Force Base	Airfield Seizure training activities are used to secure key facilities in order to support follow-on forces, or enable the introduction of follow-on forces. An airfield seizure consists of a raid/seizure force from over the horizon assaulting across a hostile territory in a combination of helicopters, vertical takeoff and landing (VTOL aircraft), and other landing craft with the purpose of securing an airfield or a port.	None	**X**			**N/A**
Naval Special Warfare (NSW)	Breaching	Navy Munitions Site Breacher house	Special Warfare, Army, and USMC personnel use explosives to gain access to buildings where enemy personnel or material could be located or to investigate the building itself.	None	**X**			N/A
Naval Special Warfare (NSW)	Direct Action	Gab Gab Beach to Apra Harbor and Orote Point training areas, FDM	NSW Direct Action is either covert or overt directed against an enemy force to seize, damage, or destroy a target and/or capture or recover personnel or material. Training activities are small-scale offensive actions including raids; ambushes; standoff attacks by firing from ground, air, or maritime platforms; designate or illuminate targets for precision-guided munitions; support for cover and deception activities; and sabotage inside enemy-held territory. They arrive in the area by helicopter or small rubber boats (CRRC) across a beach. Once at FDM, small arms, grenades, and crew served weapons are employed in direct action against targets on the island.	• Vessel Movement • Aircraft Overflight • Expended Materials· • Amphibious Landings		**X**		• Short-term behavioral responses to vessel movement and extremely low potential for injury/mortality from collisions. • Possible short-term behavioral responses to aircraft overflight. • Long-term, minor, and localized accumulation of expended materials in benthic habitat. Limited potential for ingestion or exposure to hazardous materials. • Disturbance to FMP species, and potential loss of benthic epifauna and infauna that may serve as prey items for managed species at beach landing locations. Temporary impacts to water quality due to increased turbidity may reduce foraging efficiency of FMP species or increase sedimentation. • No long-term population-level effects or reduction in the quality and/or quantity of EFH. Avoidance Measures: • Designated land targets. • Amphibious landings are restricted to specific areas of designated beaches away from sensitive EFH or HAPC, and are conducted in accordance to B.O. 1-2-98-F-07, which includes landings at high tide, LCACs under full cushion, reach beach prior to coming off cushion, and pre- and post-activity surveys.

Table 5-6. Summary of Potential Impacts to EFH by Activity (cont'd)

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Naval Special Warfare (NSW)	Insertion/Extraction	Outer Apra Harbor, Inner Apra Harbor, Gab Gab Beach (western half), Reserve Craft Beach, Orote Point Airfield, and Polaris Point Field	Insertion/extraction training activities train forces, both Navy (primarily Special Forces and EOD) and Marine Corps, to deliver and extract personnel and equipment. These training activities include, but are not limited to, parachute, fast rope, rappel, Special Purpose Insertion/Extraction (SPIE), CRRC, and lock-in/lock-out from underwater vehicles. Additionally, parachute, fast rope, and rappel training activities have been conducted at Orote Point Airfield/Runway, Orote Point Triple Spot, Orote Point CQC House, Dan Dan Drop Zone, Orote Point KD Range, and the Ordnance Annex Breacher House.	• Vessel Movement • Aircraft Overflight • Amphibious Landings		**X**		• Short-term behavioral responses to vessel movement and extremely low potential for injury/mortality from collisions. • Possible short-term behavioral responses to aircraft overflight. • Disturbance to FMP species, and potential loss of benthic epifauna and infauna that may serve as prey items for managed species at beach landing locations. Temporary impacts to water quality due to increased turbidity may reduce foraging efficiency of FMP species or increase sedimentation. • No long-term population-level effects or reduction in the quality and/or quantity of EFH. Avoidance Measures: • Amphibious landings are restricted to specific areas of designated beaches away from sensitive EFH or HAPC, and are conducted in accordance to B.O. 1-2-98-F-07, which includes landings at high tide, LCACs under full cushion, reach beach prior to coming off cushion, and pre- and post-activity surveys.
Naval Special Warfare (NSW)	Military Operations in Urban Terrain (MOUT)	Ordnance Annex, Orote Pt. CQC House, Breacher House	Navy (NSW) MOUT training is similar in nature and intent to Army and Marine Corps MOUT training, but typically on a smaller scale.	None	**X**			**N/A**
Naval Special Warfare (NSW)	Over the Beach (OTB)	Various	NSW personnel use different methods of moving forces from the sea across a beach onto land areas in order to get closer to a tactical assembly area or target depending on threat force capabilities. A typical OTB exercise would involve a squad to a platoon or more of NSW personnel being covertly inserted into the water off of a beach area of a hostile land area. However, the insertion could accomplished by other means, such as fixed-winged aircraft, helicopter, submarine, or surface ship. From the insertion point several miles at sea, the SEALs may use a CRRC, RHIB, SDV, ASDS, or swim to reach the beach, where they will move into the next phase of the exercise and on to the objective target area and mission of that phase of the exercise.	• Vessel Movement • Aircraft Overflight • Expended Materials • Amphibious Landings		**X**		• Short-term behavioral responses to vessel movement and extremely low potential for injury/mortality from collisions. • Possible short-term behavioral responses to aircraft overflight. • Long-term, minor, and localized accumulation of expended materials in benthic habitat. Limited potential for ingestion or exposure to hazardous materials. • Disturbance to FMP species, and potential loss of benthic epifauna and infauna that may serve as prey items for managed species at beach landing locations. Temporary impacts to water quality due to increased turbidity may reduce foraging efficiency of FMP species or increase sedimentation. • No long-term population-level effects or reduction in the quality and/or quantity of EFH. Avoidance Measures: • Designated land targets. • Amphibious landings are restricted to specific areas of designated beaches away from sensitive EFH or HAPC, and are conducted in accordance to B.O. 1-2-98-F-07, which includes landings at high tide, LCACs under full cushion, reach beach prior to coming off cushion, and pre- and post-activity surveys.

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MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION OF ACTIVITY	POTENTIAL IMPACTS TO EFH				
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Amphibious Warfare (AMW)	Naval Surface Fire Support (FIREX Land)	FDM	FIREX (Land) consists of the shore bombardment of an Impact Area by Navy guns as part of the training of both the gunners and Shore Fire Control Parties (SFCP). A SFCP consists of spotters who act as the eyes of a Navy ship when gunners cannot see the intended target. From positions on the ground or air, spotters provide the target coordinates at which the ship's crew directs its fire. The spotter provides adjustments to the fall of shot, as necessary, until the target is destroyed.	• Vessel Movement • Weapons Firing • Expended Materials· • Amphibious Landings		**X**		• Short-term behavioral responses to vessel movement and extremely low potential for injury/mortality from collisions. • Shock wave could injure or kill all life stages of fish and larvae of other marine organisms within the immediate area. • Short-term and localized disturbance to water column and benthic habitats in shallow water. Mortality to all life stages of fish and larvae of other marine organisms in immediate vicinity of explosions, with increased susceptibility by juvenile fish, small fish, and fish with swim bladders. Injury may include permanent or temporary hearing loss with effects diminishing further from the detonation. Behavioral effects include startle response and temporarily leaving an exercise area. • Long-term, minor, and localized accumulation of expended materials in benthic habitat. Limited potential for ingestion or exposure to hazardous materials. • Disturbance to FMP species, and potential loss of benthic epifauna and infauna that may serve as prey items for managed species at beach landing locations. Temporary impacts to water quality due to increased turbidity may reduce foraging efficiency of FMP species or increase sedimentation. • No long-term population-level effects or reduction in the quality and/or quantity of EFH. Avoidance Measures: • Designated land targets. • Amphibious landings are restricted to specific areas of designated beaches away from sensitive EFH or HAPC, and are conducted in accordance to B.O. 1-2-98-F-07, which includes landings at high tide, LCACs under full cushion, reach beach prior to coming off cushion, and pre- and post-activity surveys.
Amphibious Warfare (AMW)	Marksmanship	Orote Point and Finegayan small arms ranges, and Orote Point KD range	Marksmanship exercises are used to train personnel in the use of all small arms weapons for the purpose of ship self defense and security. Basic marksmanship training activities are strictly controlled and regulated by specific individual weapon qualification standards. Small arms include but are not limited to 9mm pistol, 12-gauge shotgun, and 7.62mm rifles.	None	**X**			**N/A**

Table 5-6. Summary of Potential Impacts to EFH by Activity (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION OF ACTIVITY	POTENTIAL IMPACTS TO EFH				
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Amphibious Warfare (AMW)	Expeditionary Raid	Reserve Craft Beach	An Expeditionary Raid is an attack involving swift incursion into hostile territory for a specified purpose. The attack is then followed by a planned withdrawal of the raid forces. A raid force can consist of varying numbers of aviation, infantry, engineering, and fire support forces. A key influence in every raid is the ability to insert, complete the assigned mission, and extract without providing the enemy force with opportunity to reinforce their forces or plan for counter measures. In FY03 up to 300 31st MEU personnel and equipment were moved ashore at Reserve Craft Beach via LCAC.	• Vessel Movement • Aircraft Overflight • Expended Materials· • Amphibious Landings		**X**		• Short-term behavioral responses to vessel movement and extremely low potential for injury/mortality from collisions. • Possible short-term behavioral responses to aircraft overflight. • Long-term, minor, and localized accumulation of expended materials in benthic habitat. Limited potential for ingestion or exposure to hazardous materials. • Disturbance to FMP species, and potential loss of benthic epifauna and infauna that may serve as prey items for managed species at beach landing locations. Temporary impacts to water quality due to increased turbidity may reduce foraging efficiency of FMP species or increase sedimentation. • No long-term population-level effects or reduction in the quality and/or quantity of EFH. Avoidance Measures: • Designated land targets. • Amphibious landings are restricted to specific areas of designated beaches away from sensitive EFH or HAPC, and are conducted in accordance to B.O. 1-2-98-F-07, which includes landings at high tide, LCACs under full cushion, reach beach prior to coming off cushion, and pre- and post-activity surveys.
Amphibious Warfare (AMW)	Hydrographic Surveys	FDM, Outer Apra Harbor, Tinian EMUA, and Tipalao Cove	Hydrographic Reconnaissance is conducted to survey underwater terrain conditions and report findings to provide precise analysis typically in support of amphibious landings and precise ship and small craft movement through cleared routes (Q-Routes). Exercises involve the methodical reconnoitering of beaches and surf conditions during the day and night to find and clear underwater obstacles and to determine the feasibility of landing an amphibious force on a particular beach. EOD units periodically survey FDM to determine the condition of coral around the island and to detect the presence of Unexploded Ordnance (UXO).	• Vessel Movement • Amphibious Landings·		**X**		• Short-term behavioral responses to vessel movement and extremely low potential for injury/mortality from collisions. • Disturbance to FMP species, and potential loss of benthic epifauna and infauna that may serve as prey items for managed species at beach landing locations. Temporary impacts to water quality due to increased turbidity may reduce foraging efficiency of FMP species or increase sedimentation. • No long-term population-level effects or reduction in the quality and/or quantity of EFH. Avoidance Measures: • Amphibious landings are restricted to specific areas of designated beaches away from sensitive EFH or HAPC, and are conducted in accordance to B.O. 1-2-98-F-07, which includes landings at high tide, LCACs under full cushion, reach beach prior to coming off cushion, and pre- and post-activity surveys.

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Mine Warfare (MIW)	Mine Counter Measures	Agat Bay, Apra Harbor	MIW involves the locating and neutralizing of a deepwater mine by EOD divers. The neutralization of the mine (the portion of the exercise that involves the use of ordnance) is typically scheduled during daylight hours for safety reasons and completed within a two hour period. Divers deploy from combat rubber raiding craft (CRRC) and a diver will place the explosive next to or on each inert mine shape. Based on charge size and operating conditions, EOD will determine a "safe time" and distance needed from the mine before they detonate the charge. Typically two shots per training event are conducted, with a second charge detonated one to two hours after the first shot. After the detonation portion of the exercise is completed, the mine shape is typically recovered unless destroyed by the charge.	• Vessel Movement· • Underwater Explosions		**X**		• Short-term behavioral responses to vessel movement and extremely low potential for injury/mortality from collisions. • Short-term and localized disturbance to water column and benthic habitats. Mortality to all life stages of fish and larvae of other marine organisms in immediate vicinity of explosions, with increased susceptibility by juvenile fish, small fish, and fish with swim bladders. Injury may include permanent or temporary hearing loss with effects diminishing further from the detonation. Behavioral effects include startle response and temporarily leaving an exercise area. • Temporary impacts to water quality due to increased turbidity. • Long-term, minor, and localized accumulation of expended materials in benthic habitat. Limited potential for ingestion or exposure to hazardous materials. • No long-term population-level effects or reduction in the quality and/or quantity of EFH. Avoidance Measures: • Utilize sandy areas that avoid/minimize potential impacts to coral habitat.
Explosive Ordnance Disposal (EOD)	Land Demolition	Inner Apra Harbor, Gab Gab Beach, Reserve Craft Beach, Polaris Point Field, Orote Point Airfield/Runway, Orote Point CQC House, Orote Point Radio Tower, Ordnance Annex Breacher House, Ordnance Annex Detonation Range, Fire Break # 3, Ordnance Annex Galley Building 460, Southern Land Navigation Area, and Barrigada Housing.	Training activities using land demolitions are designed to develop and hone EOD detachment mission proficiency in location, excavation, identification, and neutralization of buried land mines. During the training, teams transit to the training site in trucks or other light wheeled vehicles. A search is conducted to locate inert (non-explosively filled) land mines or IEDs and then designate the target for destruction. Buried land mines and UXO require the detachment to employ probing techniques and metal detectors for location phase. Use of hand tools and digging equipment is required to excavate. Once exposed and/or properly identified, the detachment neutralizes threats using simulated or live explosives. Land demolition training is actively conducted throughout the MIRC.	None	**X**			**N/A**

Table 5-6. Summary of Potential Impacts to EFH by Activity (cont'd)

<table>
<tr><th rowspan="2">MISSION AREA</th><th rowspan="2">EVENT</th><th rowspan="2">ACTIVITY AREA</th><th rowspan="2">BRIEF DESCRIPTION OF ACTIVITY</th><th colspan="5">POTENTIAL IMPACTS TO EFH</th></tr>
<tr><th>POTENTIAL STRESSOR</th><th>NO IMPACT</th><th>TEMPORARY OR LOCALIZED IMPACT</th><th>SIGNIFICANT OR PERMANENT ADVERSE IMPACT</th><th>DESCRIPTION OF IMPACT AND AVOIDANCE MEASURES</th></tr>
<tr><td>Explosive Ordnance Disposal (EOD)</td><td>Underwater Demolition</td><td>Outer Apra Harbor, Piti and Agat Bay Floating Mine Neutralization</td><td>Underwater demolitions are designed to train personnel in the destruction of mines, obstacles or other structures in an area to prevent interference with friendly or neutral forces and non-combatants. It provides NSW and EOD teams experience detonating underwater explosives. Outer Apra Harbor supports this training near the Glass Breakwater at a depth of 125 feet and with up to a 10 pound net explosive weight (NEW) charge. Piti and Agat Bay Floating Mine Neutralization areas also support this type of training.</td><td>• Vessel Movement
• Expended Materials·
• Explosive Ordnance</td><td></td><td>X</td><td></td><td>• Short-term behavioral responses to vessel movement and extremely low potential for injury/mortality from collisions.
• Short-term and localized disturbance to water column and benthic habitats. Mortality to fish in immediate vicinity of explosions, with increased susceptibility by juvenile fish, small fish, and fish with swim bladders. Injury may include permanent or temporary hearing loss with effects diminishing further from the detonation. Behavioral effects include startle response and temporarily leaving an exercise area.
• Temporary impacts to water quality due to increased turbidity and release of hazardous materials.
• Long-term, minor, and localized accumulation of expended materials in benthic habitat. Limited potential for ingestion or exposure to hazardous materials.
• No long-term population-level effects or reduction in the quality and/or quantity of EFH.</td></tr>
<tr><td>Logistics and Combat Services Support</td><td>Combat Mission Area Training</td><td>Orote Point Airfield/Runway</td><td>Special Forces and EOD units conduct mission area training that supports their own and other services combat service needs in both the water and on land. This task includes providing patrolling, scouting, observation, imagery, and air control services and training.</td><td>None</td><td>X</td><td></td><td></td><td>N/A</td></tr>
<tr><td>Logistics and Combat Services Support</td><td>Command and Control (C2)</td><td>Reserve Craft Beach</td><td>C2 training activities provide primary communications for command, control, and intelligence, providing critical interpretability and situation awareness information.</td><td>None</td><td>X</td><td></td><td></td><td>N/A</td></tr>
<tr><td>Combat Search and Rescue (CSAR)</td><td>CSAR Training activities</td><td>North Field on Tinian</td><td>CSAR training activities train rescue forces personnel the tasks needed to be performed to affect the recovery of distressed personnel during war or military activities other than war. These activities could include aircraft, surface ships, submarines, ground forces (NSW and Marine Corps), and their associated personnel in the execution of training events.</td><td>• Vessel Movement
• Aircraft Overflight
• Expended Materials
• Amphibious Landings</td><td></td><td>X</td><td></td><td>• Short-term behavioral responses to vessel movement and extremely low potential for injury/mortality from collisions.
• Possible short-term behavioral responses to aircraft overflight.
• Long-term, minor, and localized accumulation of expended materials in benthic habitat. Limited potential for ingestion or exposure to hazardous materials.
• Disturbance to FMP species, and potential loss of benthic epifauna and infauna that may serve as prey items for managed species at beach landing locations. Temporary impacts to water quality due to increased turbidity may reduce foraging efficiency of FMP species or increase sedimentation.
• No long-term population-level effects or reduction in the quality and/or quantity of EFH.

Avoidance Measures:
• Designated land targets.
• Amphibious landings are restricted to specific areas of designated beaches away from sensitive EFH or HAPC, and are conducted in accordance to B.O. 1-2-98-F-07, which includes landings at high tide, LCACs under full cushion, reach beach prior to coming off cushion, and pre- and post-activity surveys.</td></tr>
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Protect and Secure Area of Operations	Embassy Reinforcement (Force Protection)	Main Base, Inner Apra Harbor, Kilo Wharf, Reserve Craft Beach, Orote Point Airfield/Runway, Orote Point Close Quarters Combat House, Orote Point Radio Tower, and Orote Point Triple Spot	Force protection training activities increase the physical security of military personnel in the region to reduce their vulnerability to attacks. Force protection training includes moving forces and building barriers, detection, and assessment of threats, delay, or denial of access of the adversary to their target, appropriate response to threats and attack, and mitigation of effects of attack. Force protection includes employment of offensive as well as defensive measures.	None	**X**			**N/A**
Protect and Secure Area of Operations	Anti-Terrorism (AT)	Inner Apra Harbor, Polaris Point Site III, Ordnance Annex Breacher House, and Orote Annex Detonation Range, Northwest Field	AT training activities concentrate on the deterrence of terrorism through active and passive measures, including the collection and dissemination of timely threat information, conducting information awareness programs, coordinated security plans, and personal training. The goal is to develop protective plans and procedures based upon likely threats and strike with a reasonable balance between physical protection, mission requirements, critical assets and facilities, and available resources to include manpower. AT training activities may involve units of Marines dedicated to defending both U.S. Navy and Marine Corps assets from terrorist attack.	None	**X**			**N/A**

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MAJOR EXERCISES								
Major Exercises	Joint Exercise/USPACOM; USMC-Navy STOM/USMC-Navy; USMC Urban Ops/USMC	Various	Multiple Strike Group Exercises (Primarily Offshore; annual event, but may include nearshore, Guam, FDM, and CNMI) and Amphibious Assault Group Exercise – No Action Alternative would be one of the two exercises. Alt 1 and Alt 2 consist of one Multiple Strike Group Exercise, and on Amphibious Assault Exercise Expeditionary Warfare Exercise (Offshore/Nearshore/ Tinian/Guam/Saipan/Rota/FDM) Urban Warfare Exercise (Sustainment) (Primarily on Guam; semi-annually, 3-4 weeks per event; may include STOM and Tinian/Saipan/Rota)	• Vessel Movement • Aircraft Overflight • Weapons Firing· • Expended Materials • Underwater Explosions· • Amphibious Landings· • Sonar • Collision		X		• Short-term behavioral responses to vessel movement and extremely low potential for injury/mortality from collisions. • Possible short-term behavioral responses to aircraft overflight. • Shock wave could injure or kill all life stages of fish and larvae of other marine organisms within the immediate area. • Short-term and localized disturbance to water column and benthic habitats. Mortality to fish in immediate vicinity of explosions, with increased susceptibility by juvenile fish, small fish, and fish with swim bladders. Injury may include permanent or temporary hearing loss with effects diminishing further from the detonation. Behavioral effects include startle response and temporarily leaving an exercise area. • Temporary impacts to water quality due to increased turbidity and release of hazardous materials. • Long-term, minor, and localized accumulation of expended materials in benthic habitat. Limited potential for ingestion or exposure to hazardous materials. • Disturbance to FMP species, and potential loss of benthic epifauna and infauna that may serve as prey items for managed species at beach landing locations. Temporary impacts to water quality due to increased turbidity may reduce foraging efficiency of FMP species or increase sedimentation. • Potential for mortality (swim bladder rupture) or injury (such as hearing loss), or displacement of prey items. Potential for masking of sounds within frequency ranges of LFA, MFA, and HFA sonar systems that overlap with some fish species' hearing. • Potential for injury or mortality from direct strikes of fish by inert torpedoes. • No long-term population-level effects or reduction in the quality and/or quantity of EFH. Avoidance Measures: • Designated land targets. • Amphibious landings are restricted to specific areas of designated beaches away from sensitive EFH or HAPC, and are conducted in accordance to B.O. 1-2-98-F-07, which includes landings at high tide, LCACs under full cushion, reach beach prior to coming off cushion, and pre- and post-activity surveys.

Table 5-6. Summary of Potential Impacts to EFH by Activity (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION OF ACTIVITY	POTENTIAL IMPACTS TO EFH				
				POTENTIAL STRESSOR	NO IMPACT	TEMPORARY OR LOCALIZED IMPACT	SIGNIFICANT OR PERMANENT ADVERSE IMPACT	DESCRIPTION OF IMPACT AND AVOIDANCE MEASURES
AIR FORCE TRAINING								
	Counter Land	FDM, ATCAA 3	Counter Land is similar in nature and content to the Navy's BOMBEX (Land) operation.	• Aircraft Overflight • Explosive Ordnance • Expended Materials.		X		• Possible short-term behavioral responses to aircraft overflight. • Shock wave could injure or kill all life stages of fish and larvae of other marine organisms within the immediate area. • Short-term and localized disturbance to water column and benthic habitats in shallow water. Mortality to all life stages of fish and larvae of other marine organisms in immediate vicinity of explosions, with increased susceptibility by juvenile fish, small fish, and fish with swim bladders. Injury may include permanent or temporary hearing loss with effects diminishing further from the detonation. Behavioral effects include startle response and temporarily leaving an exercise area. • Long-term, minor, and localized accumulation of expended materials in benthic habitat. Limited potential for ingestion or exposure to hazardous materials. • No long-term population-level effects or reduction in the quality and/or quantity of EFH. Avoidance Measures: • Designated land targets.
	Counter Sea (Chaff)	W-517, ATCAA 1 & 2	Counter Sea os similar in nature and content to the Navy's Chaff Exercise	• Aircraft Overflight • Expended Materials		X		• Possible short-term behavioral responses to aircraft overflight. • Long-term, minor, and localized accumulation of expended materials in benthic habitat. Limited potential for ingestion or exposure to hazardous materials. • Short-term and localized disturbance to water column and benthic habitats. Temporary impacts to water quality due to in release of hazardous materials. Low potential for injury or mortality to fish. • No long-term population-level effects or reduction in the quality and/or quantity of EFH.
	Airlift	Northwest Field, Andersen Air Force Base	Airlift training activities provide airlift support to combat forces.	None	X			**N/A**
	Air Expeditionary	Northwest Field, Andersen Air Force Base	This type of training provides air expeditionary support to forward deployed forces.	None	X			**N/A**
	Force Protection	Northwest Field, Tarague Beach Small Arms Range, Main, Andersen Air Force Base	This type of training is to provide Force Protection to individuals, buildings, and specific areas of interest.	None	X			**N/A**

Table 5-6. Summary of Potential Impacts to EFH by Activity (cont'd)

MISSION AREA	EVENT	ACTIVITY AREA	BRIEF DESCRIPTION OF ACTIVITY	POTENTIAL IMPACTS TO EFH				
				POTENTIAL STRESSOR	NO IMPACT	TEMPORARY OR LOCALIZED IMPACT	SIGNIFICANT OR PERMANENT ADVERSE IMPACT	DESCRIPTION OF IMPACT AND AVOIDANCE MEASURES
ALTERNATIVE 1— INCREASE OPERATIONAL TRAINING, MODERNIZATION AND UPGRADES								
Major Exercises	Joint Exercise/USPACOM; USMC-Navy STOM/USMC-Navy; USMC Urban Ops/USMC	Various	Training activities would be increased to include training in major exercises, multi-Service and Joint exercises involving multiple strike groups and task forces.	Similar to No Action Alternative		**X**		Similar to No Action Alternative
ISR/Strike		Andersen AFB	The Air Force has established the ISR/Strike program at Andersen AFB, Guam. ISR/Strike will be implemented in phases over a planning horizon of FY 2007–FY 2016. ISR/Strike force structure consists of up to 48 fighter, 12 aerial refueling, six bomber, and four unmanned aircraft with associated support personnel and infrastructure. Aircraft activities out of Andersen AFB ultimately will increase by 45 percent over the current level (FY 2006).	None	**X**			**N/A**
Modernization and Upgrades of Ranges and Training Areas	Anti-Submarine Warfare (ASW)	No Undersea Tracking Range site has been identified for the Mariana Islands.	A critical component of ASW training is the Undersea Training (or Tracking) Range (UTR). This is an instrumented range that allows near real-time tracking and feedback to all participants. The tracking range should provide for both a shallow water and deep water operating environment, with a variety of bottom slope and sound velocity profiles similar to potential contingency operating areas. Guam-homeported submarine crews, as well as crews of transient submarines require ASW training events to maintain qualifications. A MIRC instrumented ASW portable undersea tracking range (PUTR), target support services, and assigned torpedo retriever craft would meet support requirements for TORPEX and TRACKEX activities in the MIRC in support of SSN and SSGN and other deployed forces.	• Vessel Movement • Expended Materials		**X**		• Short-term behavioral responses to vessel movement and extremely low potential for injury/mortality from collisions. • Long-term, minor, and localized accumulation of expended materials in benthic habitat. Limited potential for ingestion or exposure to hazardous materials. • Short-term and localized disturbance to water column and benthic habitats. Temporary impacts to water quality due to turbidity. Low potential for injury or mortality to fish. • No long-term population-level effects or reduction in the quality and/or quantity of EFH.
	Military Operations in Urban Terrain (MOUT)		The MIRC will need to acquire range space, design, and develop a MOUT facility that will support the training requirements of the Army, Marine Corps, and special warfare units stationed at or deployed into the MIRC.	None	**X**			**N/A**
ALTERNATIVE 2— NEW DEDICATED CAPABILITIES ON EXISTING DOD RANGES AND TRAINING AREAS								
Increase Major At Sea Exercises and Training	Major At Sea Exercises (similar to ANNUALEX), WESTPAC USWEX, SHAREM	Various	Training activities would be increased to include training in major exercises, multi-Service and Joint exercises involving multiple strike groups and task forces.	Similar to No Action Alternative		**X**		Similar to No Action Alternative

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APPENDIX A

DESCRIPTION OF PROPOSED ACTION AND ALTERNATIVES

APPENDIX A
LIST OF FIGURES

LIST OF TABLES

A PROPOSED ACTION

The Department of Defense (DoD) Representative Guam, Commonwealth of the Northern Mariana Islands (CNMI), Federated States of Micronesia (FSM) and Republic of Palau (DoD REP) proposes to improve training activities in the Mariana Islands Range Complex (MIRC) by selectively improving critical facilities, capabilities, and training capacities. The Proposed Action would result in focused critical enhancements and increases in training that are necessary to maintain a state of military readiness commensurate with the national defense mission. The Proposed Action includes minor repairs and upgrades to facilities and capabilities but does not include any military construction requirements. This is part of the periodically scheduled reviews of facilities and capabilities within the MIRC.

The U.S. Military Services (Services) need to implement actions within the MIRC to support current, emerging, and future training and Research, Development, Test and Evaluation (RDT&E) activities. These actions will be evaluated in the Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS) and include:

- Maintaining baseline training and RDT&E activities at mandated levels;
- Increasing training activities and exercises from current levels;
- Accommodating increased readiness activities associated with the force structure changes (human resources, new platforms, additional weapons systems, including undersea tracking capabilities and training activities to support Intelligence Surveillance and Reconnaissance [ISR]/Strike); and
- Implementing range complex investment strategies that sustain, upgrade, modernize, and transform the MIRC to accommodate increased use and more realistic training scenarios.

A.1 DESCRIPTION OF THE MIRC STUDY AREA

Military activities in MIRC occur (1) on the ocean surface, (2) under the ocean surface, (3) in the air, and (4) on land. Summaries of the land, air, sea, undersea space addressed in the EIS/OEIS are provided in Tables A-1, A-2, A-3, A-4, A-5 in this Appendix. To aid in the description of the training areas covered in the MIRC EIS/OEIS, the range complex is divided into major geographic and functional areas. Each of the individual training areas fall into one of three major MIRC training areas:

- The Surface/Subsurface Area consists of all sea and undersea training areas in the MIRC.
- The Airspace Area includes all Special Use Airspace (SUA) in the MIRC.
- The Land Area includes all land training area in the MIRC.

Figure A-1 depicts the major geographic divisions of the training areas, and Table A-1 provides a summary of the area within the major geographical areas. Table A-2, A-3, A-4, and A-5 summarize the functional training areas of the MIRC.

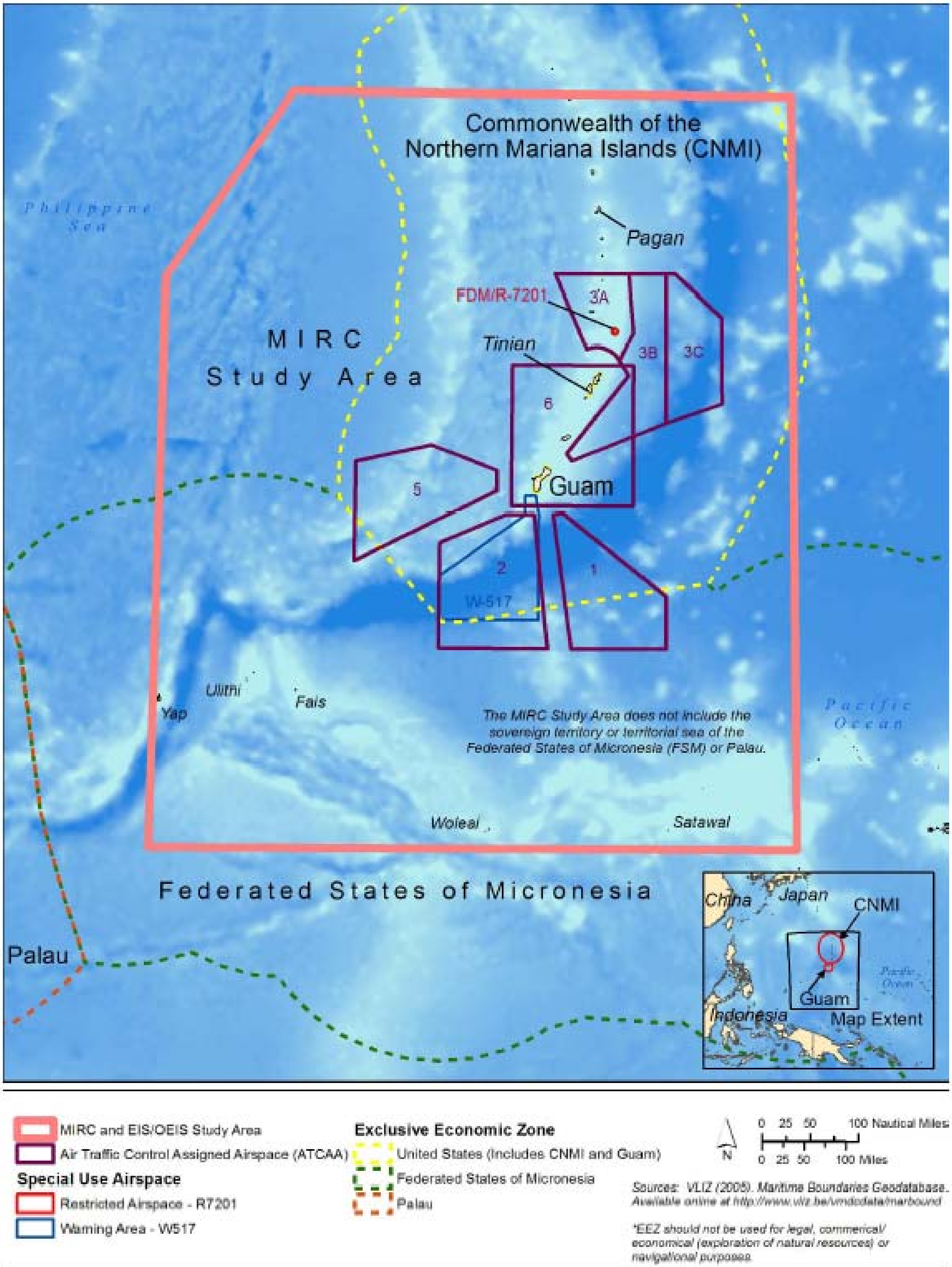


Figure A-1. Mariana Islands Range Complex and EIS/OEIS Study Area.

Table A-1. Summary of the MIRC Air, Sea, Undersea, and Land Space *

Area Name	Airspace (nm^2)			Sea Space (nm^2)	Undersea Space (nm^2)	Land Range (acres)
	Warning Area	Restricted Airspace	ATCAA / Other			
MIRC	14,000	28	63,000	501,873	14,000	24,894

* Sources: 366 Report to Congress. Notes: nm^2 – square nautical miles; ATCAA - Air Traffic Control Assigned Airspace.

The military Services use suitable MIRC air, land, sea, and undersea areas for various military training activities. For purposes of scheduling, managing, and controlling these activities and the ranges, the MIRC is divided into multiple components that are overseen by specific Services.

A.1.1 NAVY CONTROLLED AND MANAGED TRAINING AREAS OF THE MIRC

The MIRC includes land training areas, ocean surface areas, and undersea areas as depicted in Figure A-1. These areas extend from the waters south of Guam to north of Pagan (CNMI), and from the Pacific Ocean east of the Mariana Islands to the Philippine Sea to the west; encompassing 501,873 square nautical miles (nm^2) (1,299,851 square kilometers [km^2]) of open ocean and littorals. The MIRC does not include the sovereign territory (including waters out to 12 nautical miles [nm]) of the FSM. Portions of the Marianas Trench National Monument, which was established in January 2009 by Presidential Proclamation under the authority of the Antiquities Act (16 U.S.C. 431), lie within the Study Area.

Table A-2 provides an overview of each Navy controlled and managed area and its location. Figures A-1 through A-10 depict these training areas.

Table A-2. Navy Controlled and Managed MIRC Training Areas.

Training Area	Detail/Description
Warning Area (Figure A-2)	
W-517	W-517 is special -use airspace (SUA) (approximately 14,000 sq nm^2) that overlays deep open ocean approximately 50 miles south-southwest of Guam and provides a large contiguous area that is relatively free of surface vessel traffic. Commercial air traffic lanes constrain the warning area; however, Air Traffic Control Assigned Airspace (ATCAA) 2 overlays most of W-517, permitting coordination of scheduling of short-lived air space training events with the Federal Aviation Administration (FAA). W-517 altitude limits are from the surface to infinity and capable of supporting Gunnery Exercise (GUNEX), Chaff and Electronic Combat (EC), Missile Exercise (MISSILEX), Mine Exercise (MINEX), Sinking Exercise (SINKEX), Torpedo Exercise (TORPEX), and Carrier training activities.

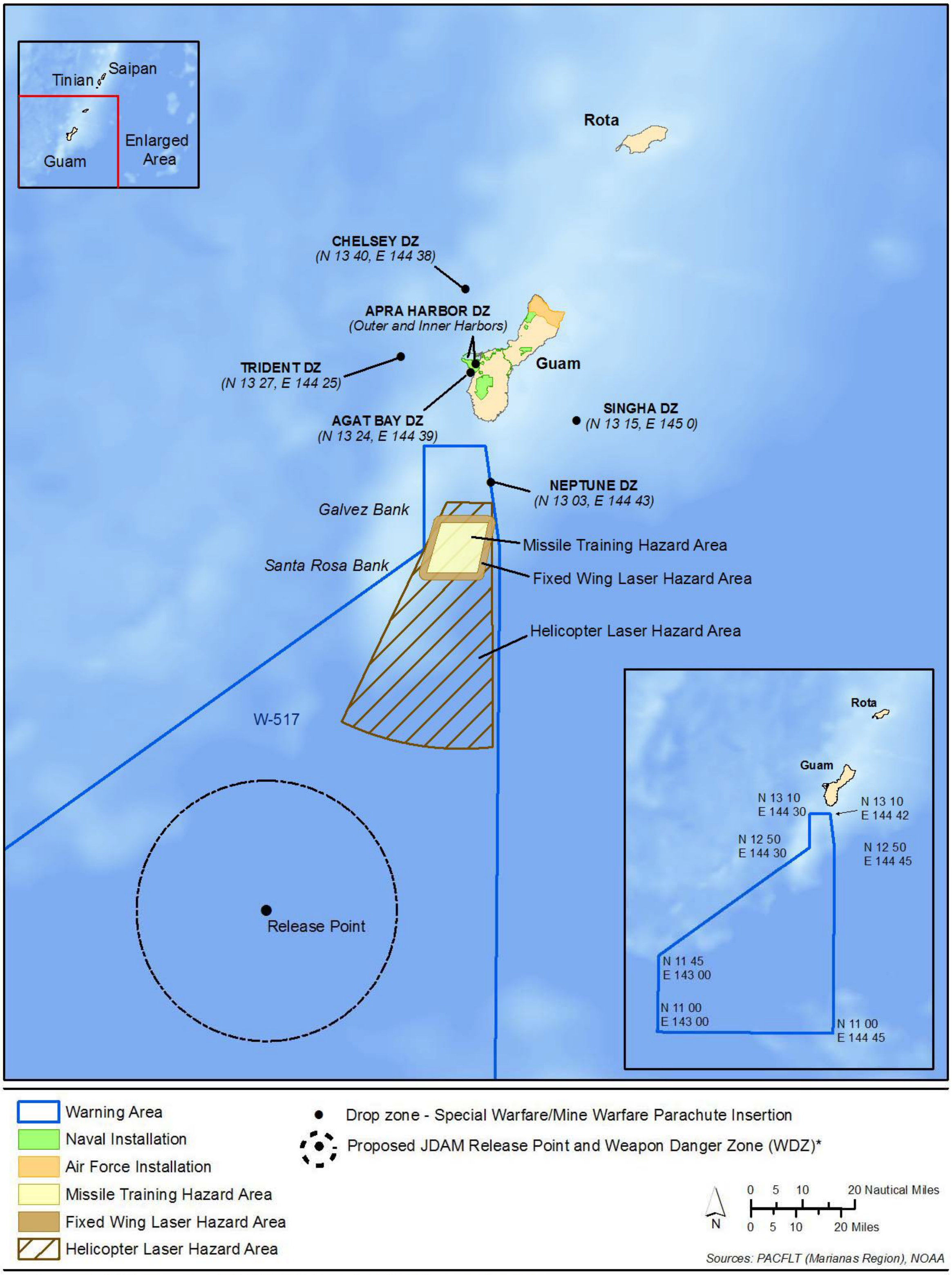
Training Area	Detail/Description
Restricted Area (Figure A-3 and Figure A-4)	
Farallon de Medinilla (FDM)/ R-7201	FDM, which is leased by the DoD from the CNMI, consists of the island land mass and the restricted airspace designated R-7201. The land mass (approximately 182 acres), is approximately 1.7 miles long and 0.3 miles wide. It contains a live-fire and inert bombing range and supports live-fire and inert engagements such as surface-to-ground and air-to-ground GUNEX, BOMBEX, MISSILEX, Fire Support, and Precision Weapons (including laser seeking). R-7201 is the Restricted Area surrounding FDM (extending 3-nm radius from center of FDM, encompassing 28 nm^2, and altitude limits from surface to FL600). Public access to FDM is strictly prohibited and there are no commercial or recreational activities on or near the island. During training exercises, marine vessels are restricted within a 3-nm (5-kilometer [km]) radius, although published Notices to Mariners (NOTMARs) may advise restrictions beyond a 3-nm (5-km) radius out to 30 nm (56 km) or greater as needed for certain training events. These increased advisory restrictions are used in an effort to ensure better protection to the military and the public during some training sessions. For these specific exercises, NOTMARs and Notices to Airmen (NOTAMs) are issued at least 72 hours in advance.
Offshore (Figure A-5)	
Agat Bay	Agat Bay supports deepwater Mine Countermeasure (MCM) training, military dive activities, and parachute insertion training. Underwater detonation charges up to 20 pounds Net Explosive Weight (NEW) are used. Hydrographic surveys to determine hazards for military approaches are periodically conducted in this area.
Tipalao Cove	Tipalao Cove provides access to a small beach area capable of supporting a shallow draft amphibious landing craft and has been proposed for use as a Landing Craft Air Cushion (LCAC) and Amphibious Assault Vehicle (AAV) landing site. Tipalao Cove supports military diving activities and hydrographic survey training.
Drop Zones	Drop Zones (DZ) in the Offshore Areas are shown in Figure 2-4. A DZ may be used for the air to surface insertion of personnel/equipment.
Piti Floating Mine Neutralization Area	The Piti Floating Mine Neutralization Area lies north of Apra Harbor and supports Explosive Ordnance Disposal (EOD) training, with underwater explosive charges up to 20 pounds NEW.
Apra Harbor (Figure A-5)	
Outer Apra Harbor (OAH)	Commanding Officer United States (U.S.) Coast Guard (USCG) is the Captain of the Port and controls OAH. Navy Security zones extend outward from the Navy controlled waterfront and related military anchorages/moorings. OAH supports frequent and varied training requirements for Navy Sea, Air, Land Forces (SEALs), EOD, and Marine Support Squadrons including underwater detonations (explosive charges up to 10 pounds NEW are permitted at a site near Buoy 702), military diving, logistics training, small boat activities, security activities, drop zones, visit board search, and seizures (VBSS) and amphibious craft navigation (LCAC, LCU, and AAVs).

Training Area	Detail/Description
Kilo Wharf	Kilo Wharf is used for ordnance handling and is a training site with limited capabilities due to explosive safety constraints; however, when explosive constraints are reduced it is used for Anti-Terrorism/Force Protection (AT/FP) training and VBSS activities.
Apra Harbor Naval Complex (Main Base): The Main Base comprises a total of approximately 4,500 acres. (Figure A-5)	
Inner Apra Harbor	The inner portion of Apra Harbor (sea space) is Navy controlled and includes the submerged lands, waters, shoreline, wharves, and piers and is associated with the Main Base (658 acres). Activities include military diving, logistics training, small boat activities, security activities, drop zones, torpedo/target recovery training, VBSS, and amphibious landings (LCAC, LCU, and AAVs).
Gab Gab Beach	Gab Gab Beach is used for both military and recreational activities. The western half of Gab Gab Beach is primarily used to support EOD and Naval Special Warfare (NSW) training requirements. Activities include military diving, logistics training, small boat activities, security activities, drop zones, and AT/FP.
Reserve Craft Beach	Reserve Craft Beach is a small beach area located on the western shoreline of Dry Dock Island. It supports both military and recreational activities. It is used as an offload area for amphibious landing craft including LCACs; EOD inert training activities; military diving, logistics training, small boat activities, security activities, and AT/FP.
Sumay Channel/Cove	Sumay Channel/Cove provides moorage for recreational boats and an EOD small boat facility. It supports both military and recreational activities. It is used for insertion/extraction training for NSW and amphibious vehicle ramp activity, military diving, logistics training, small boat activities, security activities, and AT/FP.
Clipper Channel	Clipper Channel provides insertion/extraction training for NSW, military diving, logistics training, small boat activities, security activities, and AT/FP. The Clipper Channel has the potential to support amphibious vehicle ramp activity.
San Luis Beach	San Luis Beach is used for both military and recreational activities. San Luis Beach is used to support EOD and NSW training requirements. Activities include military diving, logistics training, small boat activities, security activities, drop zones, and AT/FP.
Main Base/ Polaris Point (Figure A-5)	
Polaris Point Field (PPF)	Polaris Point Field supports both military and recreational activities and beach access to small landing craft. PPF supports small field training exercises, temporary bivouac, craft laydown, parachute insertions (freefall), assault training activities, AT/FP, and EOD and Special Forces Training.
Polaris Point Beach	Polaris Point Beach supports both military and recreational activities and beach access to small landing craft and LCAC. Polaris Point Beach supports military diving, logistics training, small boat activities, security activities, drop zones, and AT/FP.
Polaris Point Site III	Polaris Point Site III is where Guam-homeported submarines and the submarine tender are located and is the primary site location for docking, training, and support infrastructure. Additionally, it supports AT/FP and torpedo/target logistics training.

Main Base/ Orote Point (Figure A-5)	
Orote Pt. Airfield/Runway	Orote Point Airfield consists of expeditionary runways and taxiways and is largely encumbered by the Explosive Safety Quantity Distance (ESQD) arcs from Kilo Wharf. Orote Pt. Airfield runways are used for vertical and short field military aircraft. They provide a large flat area that supports Field Training Exercise (FTX), parachute insertions, emergency vehicle driver training, and EOD and Special Warfare training. The airfield is on the National Register of Historic Places (NRHP).
Orote Pt. Close Quarter Combat Facility (OPCQC)	The OPCQC, commonly referred to as the Killhouse, is a small one-story building providing limited small arms live-fire training. Close Quarter combat (CQC) is one activity within Military Operations in Urban Terrain (MOUT)-type training. It is a substandard training facility and the only designated live-fire CQC facility in the MIRC.
Orote Pt. Small Arms Range/ Known distance Range (OPKDR)	The Orote Pt. Known Distance Range (OPKDR) supports small arms and machine gun training (up to 7.62mm), and sniper training out to a distance of 500 yards. The OPKDR is a long flat cleared area with an earthen berm that is used to support marksmanship. The OPKDR is currently being upgraded to an automated scored range system.
Orote Pt. Triple Spot	The Orote Pt. Triple Spot is a helicopter landing zone on the Orote Pt. Airfield Runway. It supports personnel transfer, logistics, parachute training, and a variety of training activities reliant on helicopter transport.
Ordnance Annex: The Ordnance Annex comprises approximately 8,800 acres. (Figure A-6)	
Ordnance Annex Breacher House (OABH)	The breacher house is a concrete structure in an isolated part of the Ordnance Annex that is used for tactical entry using a small explosive charge. Live-fire is not authorized in the breacher house. An adjacent flat area allows for a helicopter landing zone (LZ) supporting airborne raid type events.
Ordnance Annex Emergency Detonation Site (OAEDS)	The OAEDS is located within a natural bowl-shaped high valley area within the Ordnance Annex and is used for emergency response detonations, up to 3,000 pounds. A flat area near OAEDS allows for helicopter access. EOD activities are the primary types of training occurring at OAEDS.
Ordnance Annex Sniper Range	The Ordnance Annex Sniper Range is an open terrain, natural earthen backstop area that is used to support marksmanship training. The Ordnance Annex Sniper Range is approved for up to .50 cal sniper rifle with unknown distance targets.
Northern Land Navigation Area (NLNA)	The NLNA is located in the northeast corner of Ordnance Annex where small unit FTX and foot and vehicle land navigation training occurs.
Southern Land Navigation Area (SLNA)	The SLNA is located in the southern half of Ordnance Annex where foot land navigation training occurs.
General	Air training activities occur here, including combat search and rescue (CSAR), insertion/extraction, and fire bucket training.

Communications Annex: The Communications Annex is comprised of approximately 3,000 acres at Finegayan (Figure A-7) and 1,800 acres at Barrigada (Figure A-8). The annex includes open area and secondary forest available for small field exercises, and Haputo Beach for small craft (combat rubber raiding craft [CRRC]) type landings	
Finegayan Communications Annex	Finegayan Communications Annex supports FTX and MOUT training. Haputo Beach is used for small craft (e.g., CRRC) landings and Over the Beach insertions. Haputo Beach is part of the Haputo ecological reserve area. The Finegayan Small Arms Ranges (FSAR) are located in the Finegayan Communications Annex. Also referred to as the "North Range," FSAR supports qualification and training with small arms up to 7.62mm. The small arms ranges are known distance ranges consisting of a long flat cleared, earthen bermed area that is used to support marksmanship. Within the Finegayan Housing area is a small group of unoccupied buildings that support a company-sized (approximately 200-300) ground combat unit to conduct MOUT-type training, including use of LZ and DZ. A new DZ (called Ferguson-Hill) is under review with the FAA. Open areas provide command and control (C2) and logistics training; bivouac, vehicle land navigation, and convoy training; and other field activities.
Barrigada Communications Annex	Barrigada Communications Annex supports FTX and MOUT training. The Barrigada Housing area contains a few unoccupied housing units available for MOUT-type training. Open areas (former transmitter sites) provide command and control (C2) and logistics training; bivouac, vehicle land navigation, and convoy training; and other field activities.

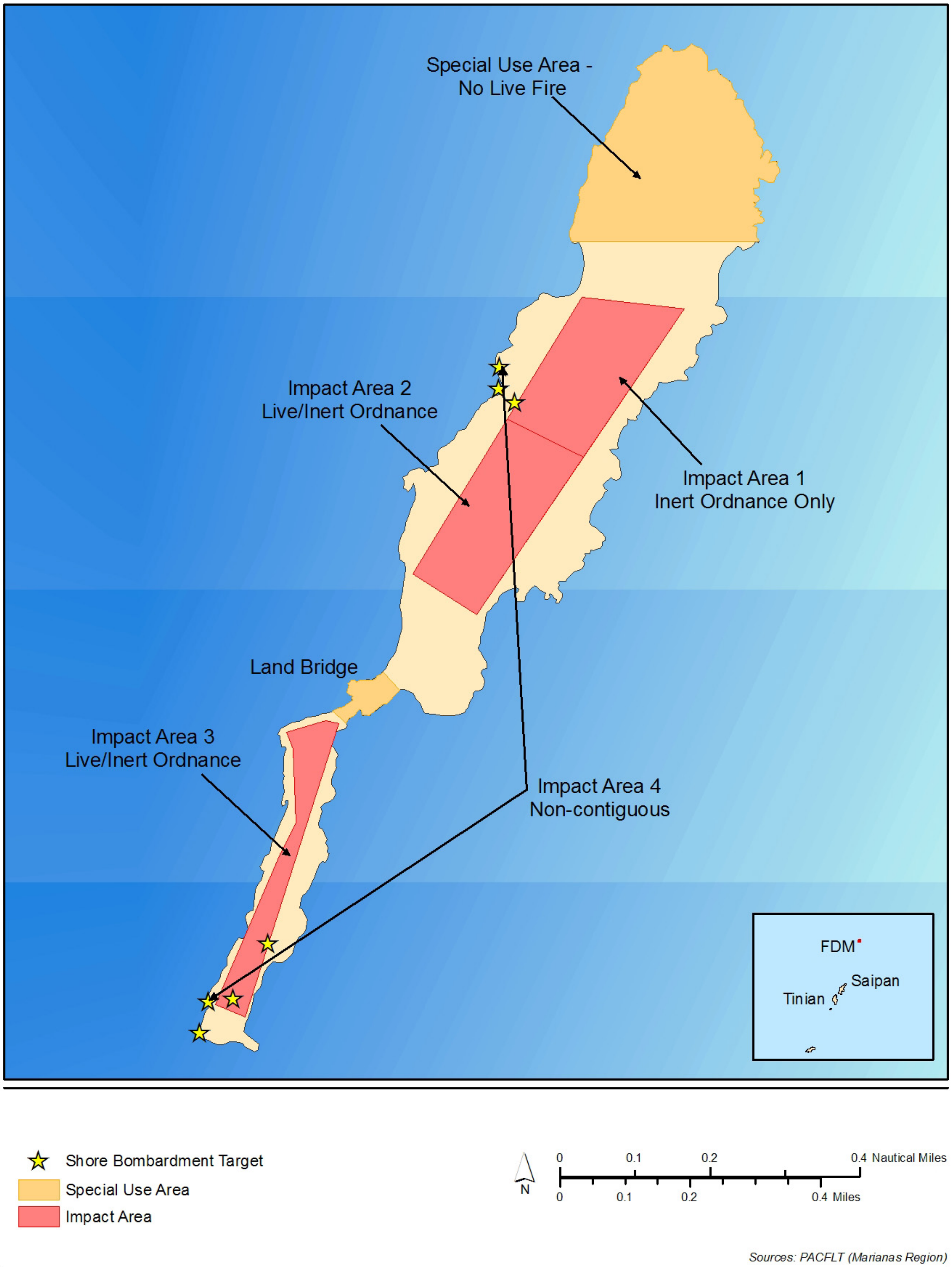
Tinian: Tinian (Figure A-9) consists of the Military Lease Area (MLA), which consists of 15,400 acres divided into two parcels:	
Exclusive Military Use Area (EMUA)	The EMUA is DoD-leased land (7,600 acres) covering the northern third of Tinian. The key feature is North Field, an unimproved expeditionary World War II (WWII) era airfield used for vertical and short-field landings. North Field is also used for expeditionary airfield training including C2, air traffic control (ATC), logistics, armament, fuels, rapid runway repair, and other airfield-related requirements. North Field is a National Historic Landmark. The surrounding area is used for force-on-force airfield defense and offensive training. The EMUA has two sandy beaches, Unai Chulu and Unai Dankulo (Long Beach), that are capable of supporting LCAC training at high tides. Only Unai Chulu has been used for LCAC training; however, storm damage and tree growth requires craft landing zone and beach improvements prior to use. Unai Dankulo also has the capability to support LCAC landings with craft landing zone and beach improvements. Unai Babui is a rocky beach capable of supporting narrow single-lane AAV landings; however, it would require channel, landing zone, and beach improvements. There are no active live-fire ranges on the EMUA, except sniper small arms into bullet traps. Future plans for any live-fire ranges will be addressed in other National Environmental Policy Act (NEPA) documents. Tinian is capable of supporting Marine Expeditionary Unit (MEU) and Marine Air Wing (MAW) events such as ground element training and air element training, Noncombatant Evacuation Operation (NEO), airfield seizure, and expeditionary airfield training, and special warfare activities, including large MEU and MAW training events.
Lease Back Area (LBA)	The LBA is DoD-leased land (7,800 acres) covering the central portion of the island, and makes up the middle third of Tinian. A key feature is the proximity to the commercial airport on the southern boundary of the LBA. The runway is not instrumented; however, it is capable of landing large aircraft. The airport has limited airfield services. The LBA is used for ground element training including MOUT-type training, C2, logistics, bivouac, vehicle land navigation, convoy training, and other field activities. There are no active live-fire ranges on the LBA, except sniper small arms into bullet traps.



* Proposed JDAM release point: (Lat 11 40 N, Long 144 E) and 25 nm radius WDZ

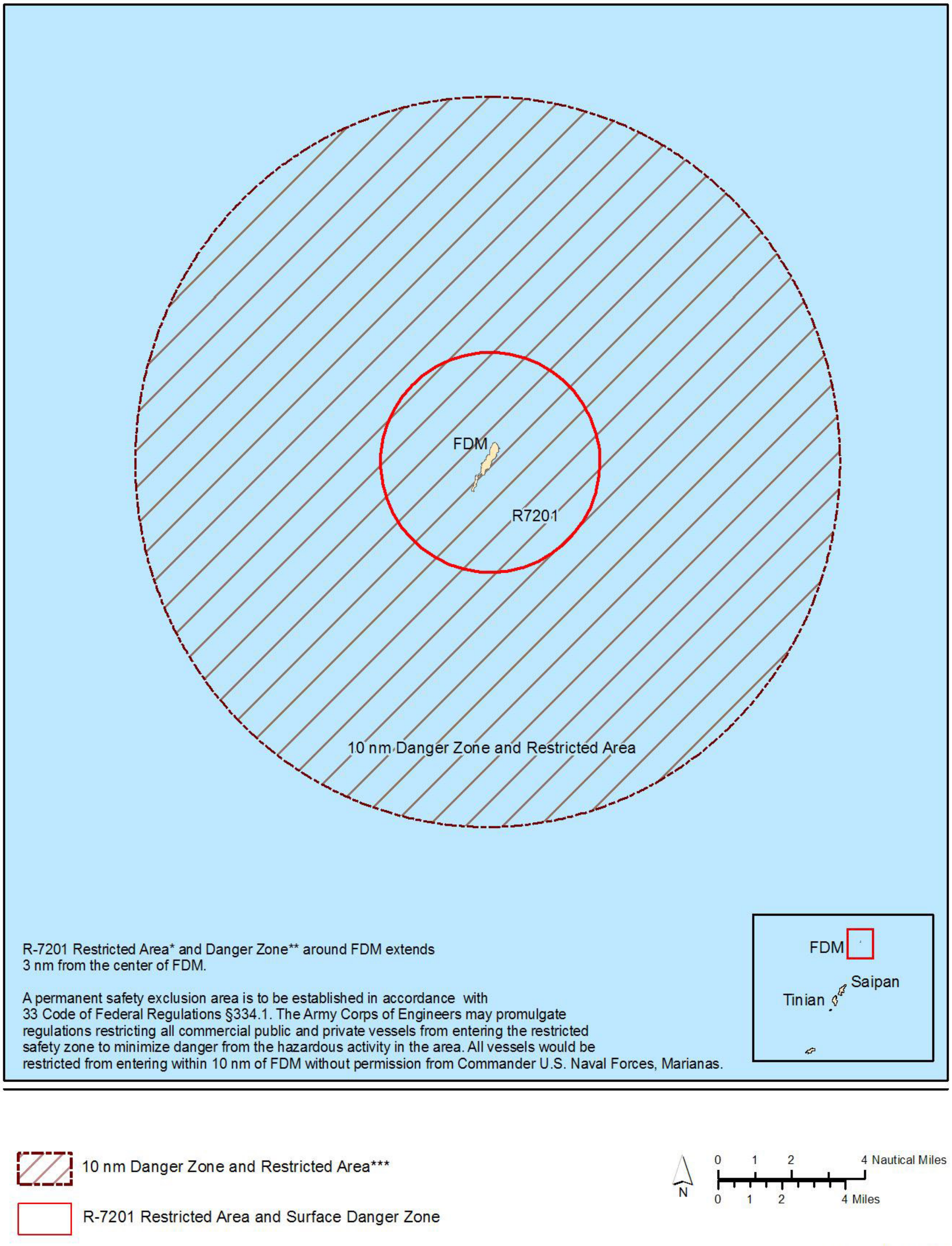
Source: ManTech-SRS

Figure A-2. W-517 Aerial Training Area



Source: ManTech-SRS

Figure A-3. Farallon de Medinilla (FDM)



* In accordance with FAA Order JO 7400.8P: R-7201 center point at lat. 6°01'04"N., long. 146°04'39"E., altitude from surface to FL600.

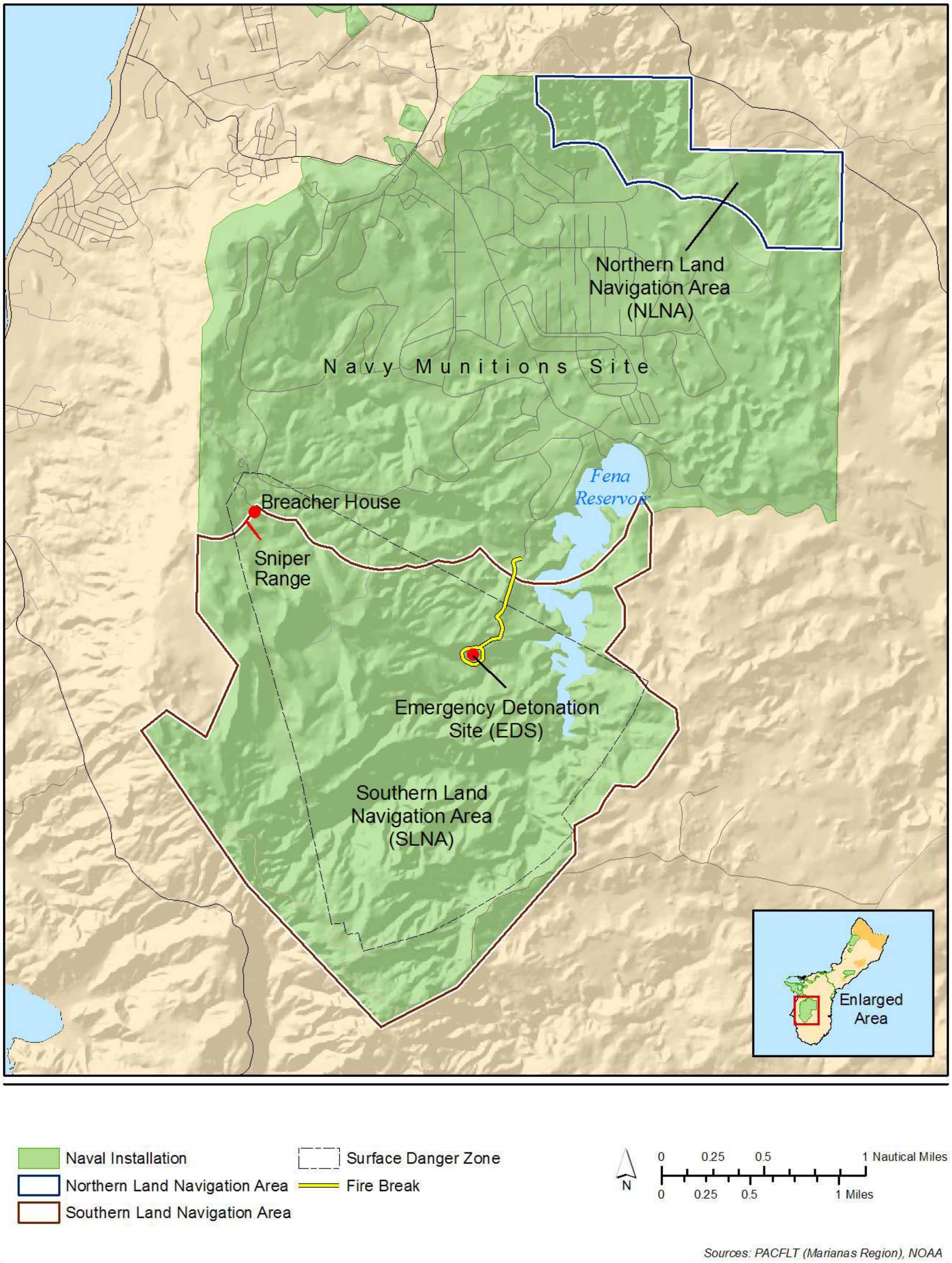
** Danger Zone In accordance with COMNAVMARINST 3502.1 FDM Range User Manual.

*** In accordance with the FDM Lease Agreement, Public access to Farallon de Medinilla Island and the waters of the Commonwealth immediately adjacent thereto are permanently restricted for safety reasons.

Figure A-4. Farallon de Medinilla (FDM) Restricted Area and Danger Zone

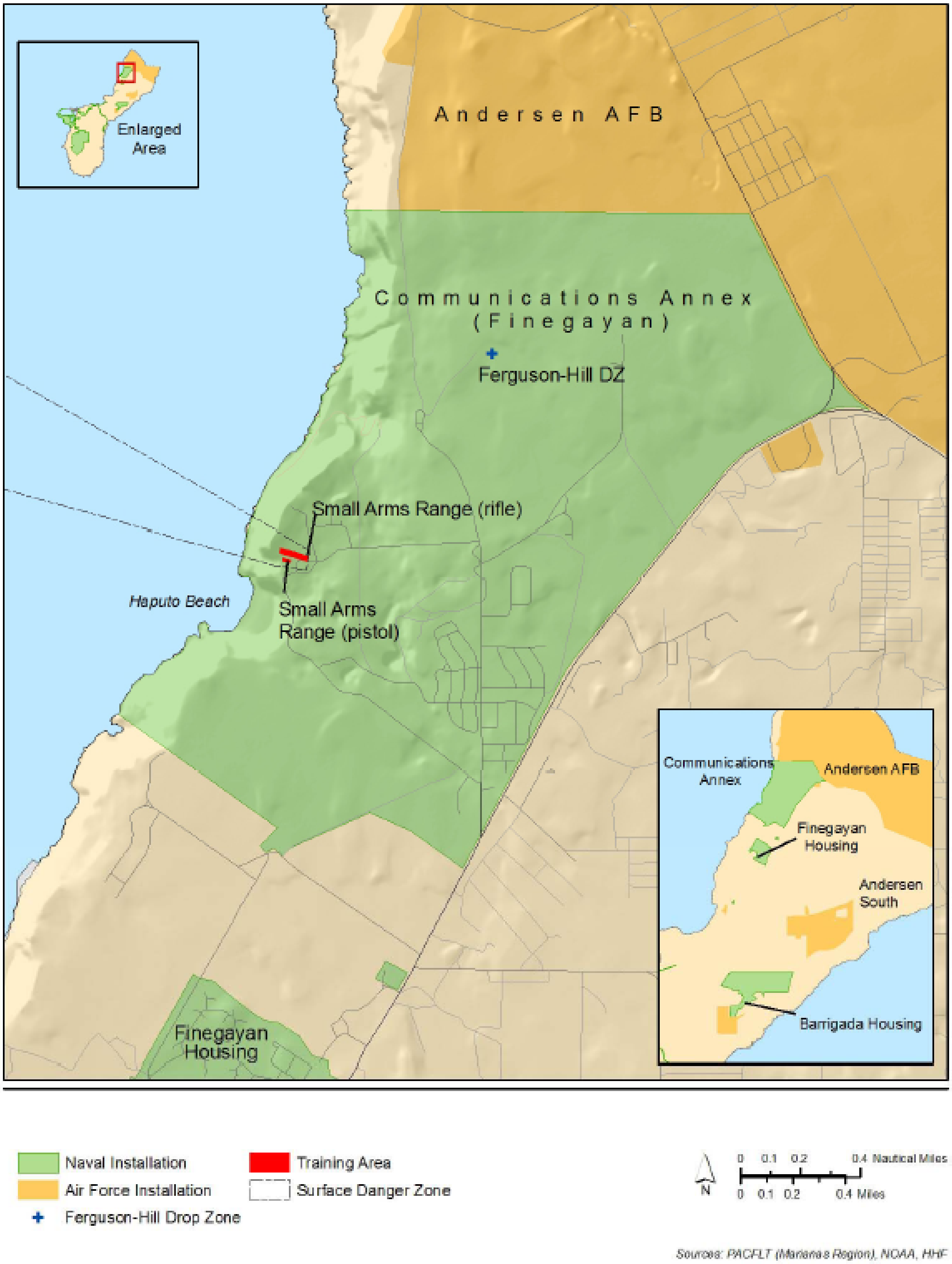
Source: ManTech-SRS

Figure A-5. Apra Harbor and Nearshore Training Areas



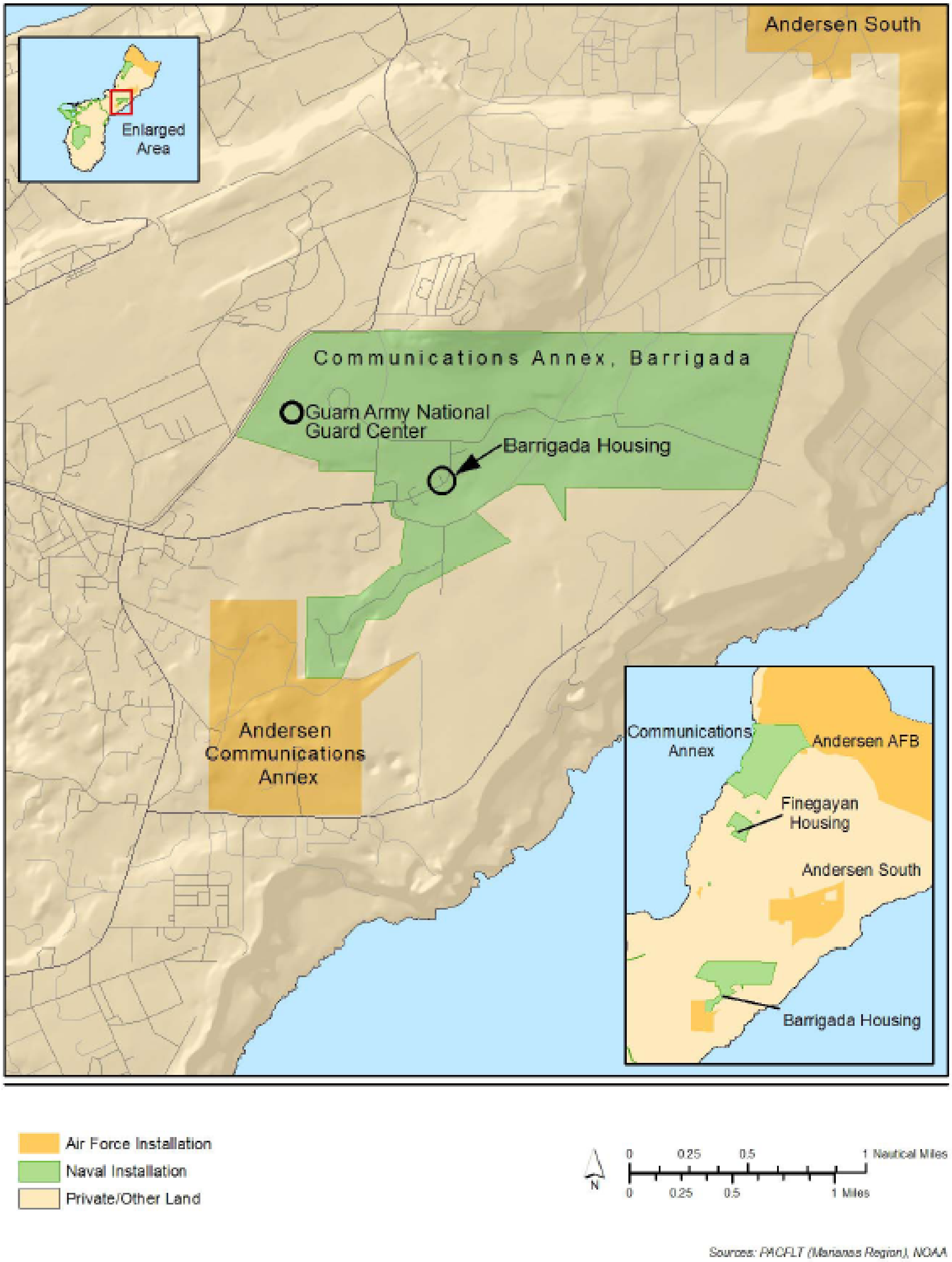
Source: ManTech-SRS

Figure A-6. Navy Munitions Site (aka Ordnance Annex) Training Areas



Source: ManTech-SRS

Figure A-7. Finegayan Communications Annex Training Areas



Source: ManTech-SRS

Figure A-8. Communications Annex, Barrigada

Source: ManTech-SRS

Figure A-9. Tinian Training Land Use and Saipan

*Note the Navy has leased a portion of the EMUA to the VoA_IBB

A.1.2 AIR FORCE CONTROLLED AND MANAGED TRAINING AREAS OF THE MIRC

Administered by 36th Wing, the Main Base at Andersen Air Force Base (AAFB) comprises about 11,500 acres. The base is used for aviation, small arms, and Air Force EOD training. As a large working airfield, the base has a full array of training activities, maintenance, and community support facilities. 36th Wing supports all U.S. military aircraft and personnel transiting the Mariana Islands. 36th Wing is host to deployed bomber and aerial refueling squadrons, and with the completion of the ISR/Strike initiative will host rotationally deployed F-22 aircraft, and permanently deployed air lift and refueling aircraft, and RQ-4 Global Hawk Unmanned Aerial Vehicle (UAV). Facilities are available for cargo staging and inspection. Undeveloped terrain consists of open and forested land. The coastline of the base consists of high cliffs and a long, narrow recreation beach (Tarague Beach) to the northeast. Multiple exposed coral pillars negate use of this beach for amphibious landings by landing craft or amphibious vehicles.

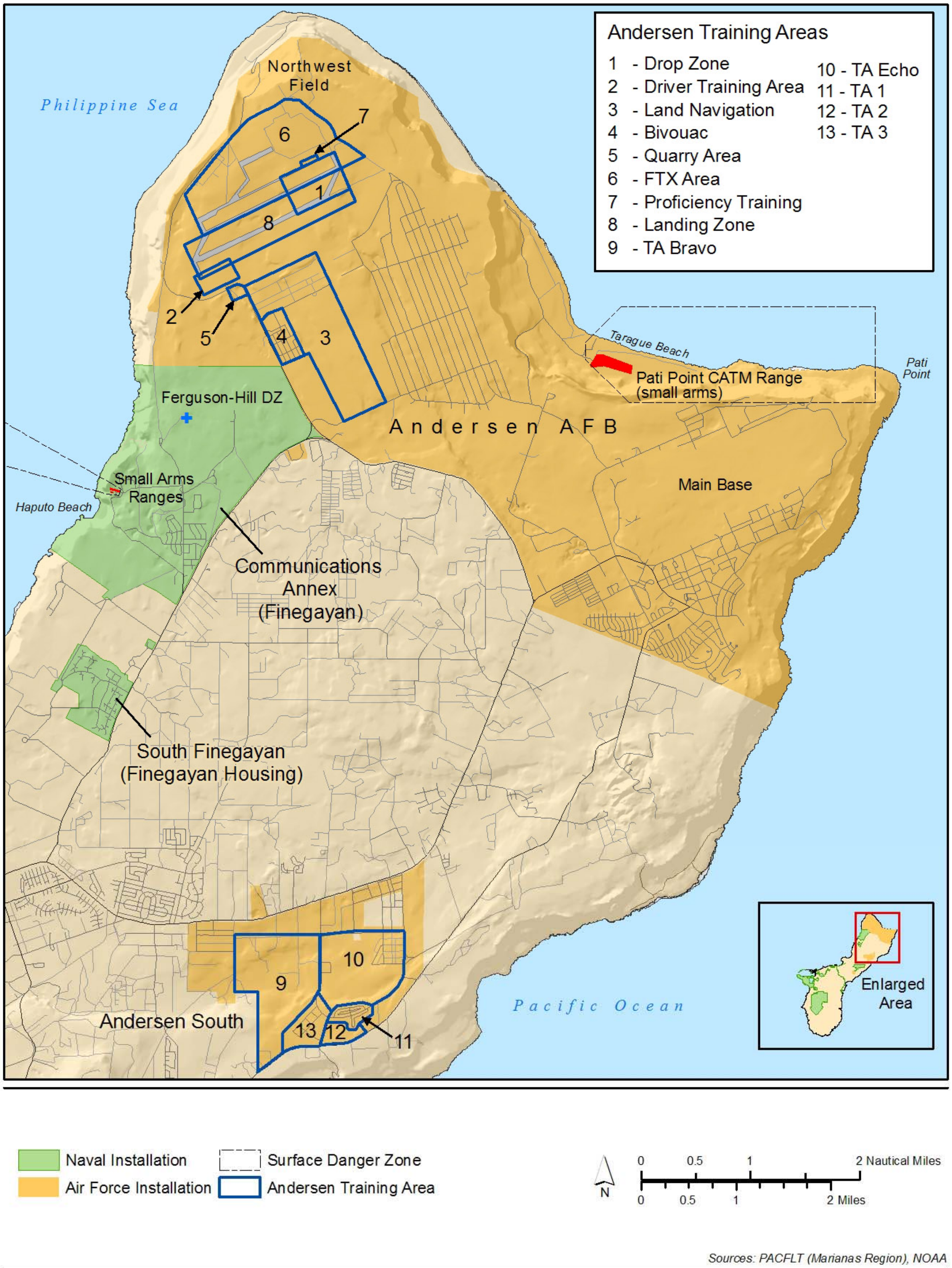
The 36th Contingency Response Group (CRG) is the controlling authority for training activities conducted on Andersen Air Force Base (11,000 acres). Thirty Sixth (36th) CRG controls training at Northwest Field (4,500 acres) and Andersen South (1,900 acres). The 36th Security Forces Squadron (SFS) controls the Pati Pt. Combat Arms Training and Maintenance (CATM) Rifle Range (21 acres).

Table A-3 provides an overview of each Air Force controlled and managed area and its location. Figure A-10 depicts those training areas associated with Andersen AFB.

Table A-3. Air Force Controlled and Managed MIRC Training Areas

Training Area	Detail/Description
Northwest Field	Northwest Field is an unimproved expeditionary WWII era airfield used for vertical and short field landings. Approximately 280 acres of land are cleared near the eastern end of both runways for parachute drop training. The south runway is used for training of short field and vertical lift aircraft and often supports various types of ground maneuver training. Helicopter units use other paved surfaces for Confined Area Landing (CAL), simulated amphibious ship helicopter deck landings, and insertions and extractions of small maneuver teams. About 3,562 acres in Northwest Field are the primary maneuver training areas available at Andersen AFB for field exercises and bivouacs. Routine training exercises include camp/tent setup, survival skills, land navigation, day/night tactical maneuvers and patrols, blank ammunition and pyrotechnics firing, treatment and evaluation of casualties, fire safety, weapons security training, perimeter defense/security, field equipment training, and chemical attack/response. The Air Force will complete its Northwest Field Beddown and Training and Support Initiative, co-locating at Northwest Field the Rapid

Training Area	Detail/Description
	Engineer Deployable Heavy Operations Repair Squadron Engineers (RED HORSE) and its Silver Flag training unit, the Commando Warrior training program, and the Combat Communications squadron. Additional information concerning these activities is contained in the Northwest Field Beddown Initiative Environmental Assessment (EA).
Andersen South	Andersen South consists of abandoned military housing and open area consisting of 1,922 acres. Andersen South open fields and wooded areas are used for basic ground maneuver training including routine training exercises, camp/tent setup, survival skills, land navigation, day/night tactical maneuvers and patrols, blank ammunition and pyrotechnics firing, treatment and evaluation of casualties, fire safety, weapons security training, perimeter defense/security, field equipment training. Vacant single-family housing and vacant dormitories are used for MOUT training and small-unit tactics. The buildings may need repairs and upgrade to be suitable for consistent use in training.
Main Base	Andersen Main Base is dedicated to its primary airfield mission. Administered by 36th Wing, the Main Base at Andersen AFB comprises about 11,500 acres. The base is used for aviation, small arms, and Air Force EOD training. As a working airfield, the base has a full array of operations, maintenance, and community support facilities. 36th Wing supports all U.S. military aircraft and personnel transiting the MIRC. Facilities are available for cargo staging and inspection.
Pati Point (Tarague Beach) Combat Arms and Training Maintenance (CATM) Range and EOD Pit	Pati Point consists of 21 acres used for the CATM small arms range. The CATM range supports training with pistols, rifles, machine guns up to 7.62mm, and inert mortars up to 60mm. Training is also conducted with the M203 40mm grenade launcher using inert training projectiles only.



Source: ManTech-SRS

Figure A-10. Andersen Air Force Base Assets

A.1.3 FEDERAL AVIATION ADMINISTRATION AIR TRAFFIC CONTROLLED ASSIGNED AIRSPACE

As per the Letter of Agreement (LOA) dated 15 May, 2007 between Guam Air Route Traffic Control Center (ARTCC), Commander, U.S. Naval Forces Marianas (COMNAVMAR), and 36th Operations Group, COMNAVMAR is designated the scheduling and using agency for W-517, and ATCAAs 1, 2, 3A, 3B, 3C, 4, 5, and 6. Guam ARTCC is designated the Controlling Agency. Guam ARTCC decommissioned ATCAA 4 in November 2007.

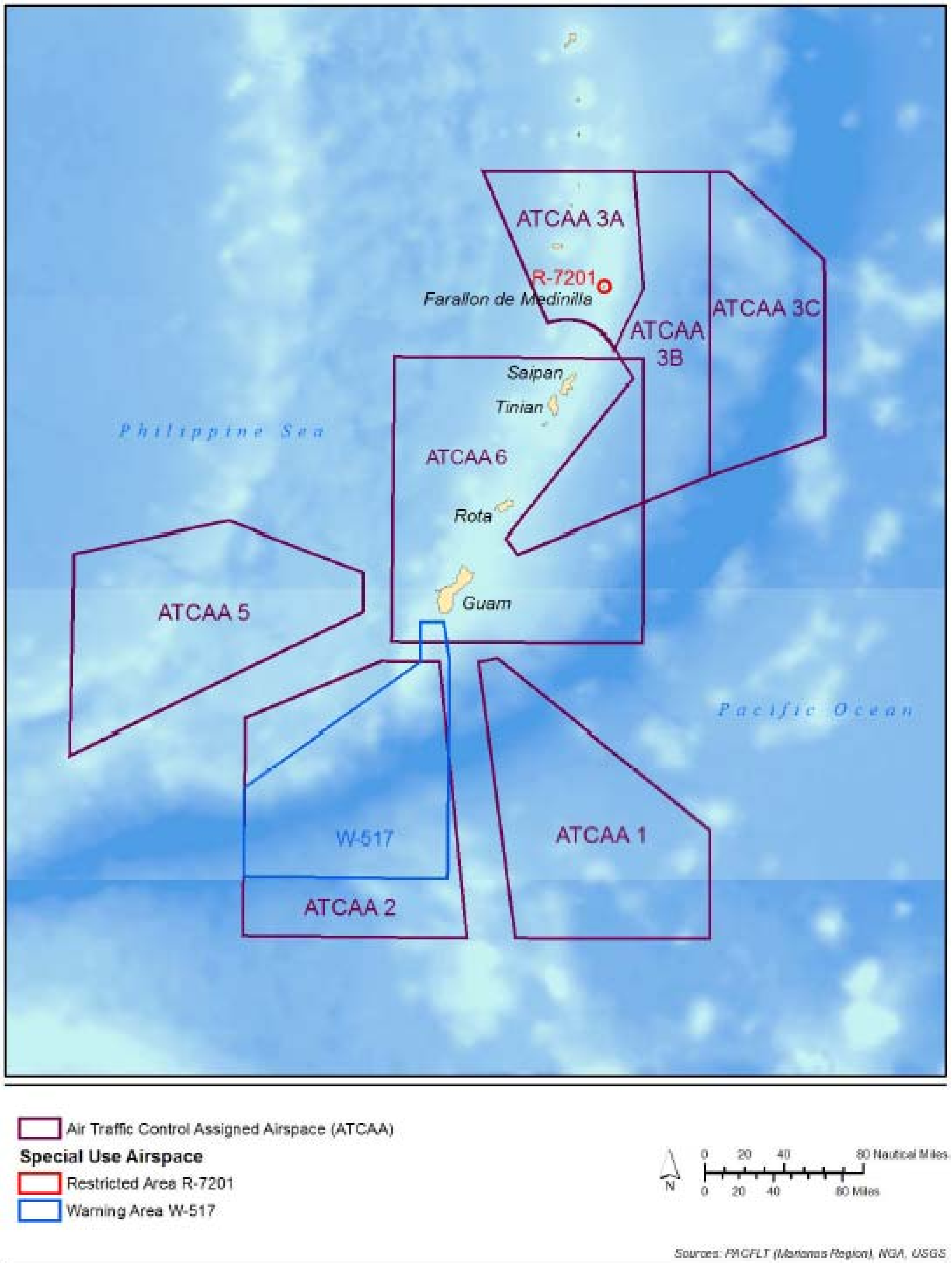
Range control consists of scheduling with operational units and notifying others of that schedule via Notice to Airmen (NOTAM) and Notice to Mariners (NOTMAR).

Table A-4 provides more detailed information about the ATCAA. Figure A-11 shows the location of the ATCAA.

Table A-4. FAA Air Traffic Controlled Assigned Airspace

Training Area				
Air Traffic Controlled Assigned Airspace:				
Airspace	**nm²**	**Lower limit**	**Upper limit**	**Over Land?**
ATCAA 1	10,250	Surface	Unlimited	No
ATCAA 2	13,750	Surface	Unlimited	No
ATCAA 3A	5,000	Surface	Unlimited	No, except for FDM
ATCAA 3B	7,750	Surface	FL300	No
ATCAA 3C	8,000	Surface	Unlimited	No
ATCAA 5	10,500	Surface	FL300	No
ATCAA 6	15,300	FL390	FL430	No
W-517 lies mostly within ATCAA 2. R-7201 lies within ATCAA 3A.				

Sources: Commander, Naval Forces Marianas; Federal Aviation Administration



Source: ManTech-SRS

Figure A-11. Mariana Islands Range Complex ATCAAs

A.1.4 OTHER MIRC TRAINING ASSETS

Other MIRC training areas include training facilities controlled and managed by the AR-Marianas and the Guam Army National Guard (GUARNG) and the Government of the CNMI.

Table A-5 provides more detailed information about these other MIRC training assets. Figure A-9 locates the Army Reserve Center, Saipan. Figure A-12 locates the NSWU-1 leased pier space and lay down area on Rota.

Table A-5. Other MIRC Training Assets

Sub complex Name/Training Area	Detail/Description
Guam:	
Army Reserve Center	Located on Barrigada Communications Annex, and supporting approximately 1,200 Army reservists. Contains an indoor small arms range (9mm).
Guam Army National Guard Center	Located on Barrigada Communications Annex and supports approximately 1,000 Guam Army National Guard personnel. Contains armory, classrooms, administrative areas, maintenance facilities, and laydown areas.
Saipan:	
Army Reserve Center	Saipan Army Reserve Center (Figure 2-8) contains armory, classrooms, administrative areas, maintenance facilities, and laydown areas and supports C2, logistics, AT/FP, bivouac, and other headquarter activities.
Commonwealth Port Authority	The Navy has access to approximately 100 acres of Port Authority area including wharf space which supports VBSS, AT/FP, and NSW training activities.
East Side of northern Saipan (Marpi Pt. area)	With the coordination of the Army Reserve Unit Saipan and the approval of CNMI government, land navigation training is conducted on non-DoD lands.
Rota: Rota (Figure A-12), which is about 40 miles from Guam, is an ideal site for supporting long-range NSW missions between Guam, Tinian, and FDM. Boat refueling is conducted at commercial marinas on Rota, as well as Saipan and Tinian.	
Commonwealth Port Authority	The Navy has access to Angyuta Island seaward of Song Song's West Harbor as a Forward Staging Base/overnight bivouac site. The island is adjacent to the commercial port facility and leased space is used for boat refueling and maintenance.
Municipality of Rota	Certain types of special warfare training including hostage rescue, NEO, and MOUT are conducted with local law enforcement, on non-DoD lands.

Source: ManTech-SRS

Figure A-13. Rota

A.2 NO ACTION – CURRENT TRAINING ACTIVITIES WITHIN THE MIRC

The No Action Alternative is the continuation of training activities, RDT&E activities, and continuing base activities. This includes all multi-Service training activities on DoD training areas, including either a joint expeditionary warfare exercise or a joint multi-strike group exercise. The current military training in the MIRC was initially analyzed in the 1999 Final Environmental Impact Statement Military Training in the Marianas and in several EAs (e.g., OEA Notification for Air/Surface International Warning Areas and Valiant Shield OEA) for more specific training events or platforms. As such, evaluation of the No Action Alternative in this EIS/OEIS provides a baseline for assessing environmental impacts of Alternative 1 (Preferred Alternative), and Alternative 2, as described in the following subsections.

While the No Action Alternative meets a portion of the Service's requirements, it does not meet the purpose and need. This Alternative does not provide for training capabilities for ISR/Strike, undersea warfare improvements, or increased training activities within the MIRC. With reference to the criteria identified in Section 2.2.1 of the EIS/OEIS, the No Action Alternative does not satisfy criteria 7, 8, and 9 (relating to support for the full spectrum of training requirements).

A.2.1 DESCRIPTION OF CURRENT TRAINING ACTIVITIES WITHIN THE MIRC

Each military training activity described in this EIS/OEIS meets a requirement that can be traced ultimately to requirements from the National Command Authority (NCA) composed of the President of the United States and the Secretary of Defense. Based upon NCA requirements, the Joint Staff develops a set of high-level strategic warfighting missions, called the Universal Joint Task List (UJTL). The Joint Forces Command (JFCOM) and each military Service uses the UJTL to develop specific statements of required tactical tasks. Each Service derives its tactical tasks from the UJTLs. These Service-level tactical task lists are in turn applied to training requirements that the MIRC is to support with range and training area capabilities. Service tactical tasks that encompass the current training activities within the MIRC are listed in Table A-7, are briefly described below in Service-specific groupings, and are described in greater detail in Appendix D of the EIS/OEIS. The source for these lists is the MIRC Range Complex Management Plan (RCMP).

A.2.1.1 Army Training

Surveillance and Reconnaissance (S&R). S&R are conducted to evaluate the battlefield and enemy forces, and to gather intelligence. For training of assault forces, opposition forces (OPFOR) units may be positioned ahead of the assault force and permitted a period of time to conduct S&R and prepare defenses against an assaulting force. S&R training has occurred at urban training facilities at Finegayan and Barrigada on Guam, and both the Exclusive Military Use Area (EMUA) and the Lease Back Area (LBA) on Tinian.

Field Training Exercise (FTX). An FTX is an exercise wherein the battalion and its combat and combat service support units deploy to field locations to conduct tactical training activities under simulated combat conditions. A company or smaller-sized element of the Army Reserve, GUARNG, or Guam Air National Guard (GUANG) will typically accomplish an FTX within the MIRC, due to the constrained environment for land forces. The headquarters and staff elements may simultaneously participate in a Command Post Exercise (CPX) mode. FTXs have occurred on Guam at Polaris Point Field, Orote Point Airfield/Runway, NLNA, Andersen Air Force Base Northwest Field, and Andersen South Housing Area, and on Tinian at the EMUA.

Live-Fire. Live-fire training is conducted to provide direct fire in support of combat forces. Limited live-fire training has occurred at Pati Pt. CATM Range.

Parachute Insertions and Air Assault. These air training activities are conducted to insert troops and equipment by parachute and/or by fixed or rotary wing aircraft to a specified objective area. These training activities have occurred at Orote Point Triple Spot, Polaris Point Field, and the Ordnance Annex Breacher House. Additionally, Orote Point Airfield/Runway supports personnel, equipment, and Container Delivery System (CDS) airborne parachute insertions.

Military Operations in Urban Terrain (MOUT). MOUT training activities encompass advanced offensive close quarter battle techniques used on urban terrain conducted by units trained to a higher level than conventional infantry. Techniques include advanced breaching, selected target engagement, and dynamic assault techniques using organizational equipment and assets. MOUT is primarily an offensive operation, where noncombatants are or may be present and collateral damage must be kept to a minimum. MOUT can consist of more than one type. One example might be a “raid,” in which Army Special Forces or Navy SEALs use MOUT tactics to seize and secure an objective, accomplish their mission, and withdraw. Another example might be a Marine Expeditionary Force (MEF) using MOUT tactics to seize and secure an objective for the long term. Regardless of the type, training to neutralize enemy forces must be accomplished in a built-up area featuring structures, streets, vehicles, and civilian population. MOUT training involves clearing buildings; room-by-room, stairwell-by-stairwell, and keeping them clear. It is manpower intensive, requiring close fire and maneuver coordination and extensive training. Limited, non–live-fire, MOUT training is conducted at the OPCQC House, Ordnance Annex Breacher House, Barrigada Housing, and Andersen South Housing Area. Additionally, the OPCQC supports “raid” type MOUT training on a limited basis.

A.2.1.2 Marine Corps Training

Ship to Objective Maneuver (STOM). STOM is conducted to gain a tactical advantage over the enemy in terms of both time and space. The maneuver is not aimed at the seizure of a beach, but builds upon the foundations of expanding the battlespace. STOM has occurred at the EMUA on Tinian.

Operational Maneuver. This training exercise supports forces achieving a position of advantage over the enemy for accomplishing operational or strategic objectives. These exercises have occurred at NLNA and SLNA.

Non-Combatant Evacuation Order (NEO). NEO training activities are conducted when directed by the Department of State, the DoD, or other appropriate authority whereby noncombatants are evacuated from foreign countries to safe havens or to the United States, when their lives are endangered by war, civil unrest, or natural disaster. NEO training activities have occurred at the EMUA on Tinian.

Assault Support (AS). AS exercises provide helicopter support for C2, assault escort, troop lift/logistics, reconnaissance, search and rescue (SAR), medical evacuation (MEDEVAC), reconnaissance team insertion/extract and Helicopter Coordinator (Airborne) duties. Assault support provides the mobility to focus and sustain combat power at decisive places and times. It provides the capability to take advantage of fleeting battlespace opportunities. Polaris Point Field and OPKDR provide temporary sites from which the MEU commander can provide assault support training to his forces within the MIRC. Assault support training activities have also occurred on Tinian at the EMUA.

Reconnaissance and Surveillance (R & S). R&S is conducted to evaluate the battlefield, enemy forces, and gather intelligence. For training of assault forces, OPFOR units may be positioned ahead of the assault force and permitted a period of time to conduct R&S and prepare defenses to the assaulting force. These types of training activities have occurred on Tinian at the EMUA.

Military Operations in Urban Terrain (MOUT). Marine Corps MOUT training is similar in nature and intent to Army MOUT training. MOUT training is conducted at the Ordnance Annex Breacher House. Additionally, the OPCQC supports "raid" type MOUT training on a limited basis.

Direct Fire. Direct Fire, similar in nature and content to Navy Marksmanship exercises, is used to train personnel in the use of all small arms weapons for the purpose of defense and security. Direct Fire training activities are strictly controlled and regulated by specific individual weapon qualification standards. These training activities have occurred at FDM and OPKDR. Another form of Marine Corps Direct Fire exercises involves the use of aircraft acting as forward observers for Naval Surface Fire Support (NSFS). During this training, Marine aircraft will act as spotters for the ships and relay targeting and battle hit assessments information. These types of training activities utilize FDM and ATCAA 3A airspace.

Exercise Command and Control (C2). This type of exercise provides primary communications training for command, control, and intelligence, providing critical interpretability and situation awareness information. C2 exercises have occurred at Andersen AFB.

Protect and Secure Area of Operations (Protect the Force). Force protection training activities increase the physical security of military personnel in the region to reduce their vulnerability to attacks. Force protection training includes moving forces and building barriers, detection, and assessment of threats, delay, or denial of access of the adversary to their target, appropriate response to threats and attack, and mitigation of effects of attack. Force protection includes employment of offensive as well as defensive measures. Force protection training activities have occurred at Northwest Field on Andersen Air Force Base.

A.2.1.3 Navy Training

Anti-Submarine Warfare (ASW) Training. ASW training engages helicopter and sea control aircraft, ships, and submarines, operating alone or in combination, in training to detect, localize, and attack submarines. ASW training involves sophisticated training and simulation devices utilizing sonobuoys, ship sonar systems, submarine sonar systems, and helicopter dipping sonar systems utilizing both passive and active modes. Underwater targets which emit sound through the water are also used. When the objective of the exercise is to track the target but not attack it, the exercise is called a Tracking Exercise (TRACKEX). A Torpedo Exercise (TORPEX) takes the training activity one step further, culminating in the release of an actual torpedo, which can be either a running Exercise Torpedo (EXTORP) or non-running Recoverable Exercise Torpedo (REXTORP). All torpedoes used in such training have inert warheads.

- *ASW Training Targets*. ASW training targets are used to simulate target submarines. They are equipped with one or a combination of the following devices:
    - Acoustic projectors emanating sounds to simulate submarine acoustic signatures;
    - Echo repeaters to simulate the characteristics of the echo of a particular sonar signal reflected from a specific type of submarine; and
    - Magnetic sources to trigger magnetic detectors.

Two anti-submarine warfare targets are used in the Study Area. The first is the MK-30 Mobile ASW Training Target. The MK-30 target is a torpedo-like, self-propelled, battery powered underwater vehicle capable of simulating the dynamic, acoustic, and magnetic characteristics of a submarine. The MK-30 is 21 inches in diameter and 20.5 feet in length. These targets are launched by aircraft and surface vessels and can run approximately four hours dependent on the programmed training scenario. The MK 30 is recovered after the exercise for reconditioning and subsequent reuse.

- *MK-84 Range Pingers*. MK-84 range pingers are used in association with the Portable Underwater Tracking Range and are active acoustic devices that allow ships, submarines, and target simulators to be tracked by means of deployed hydrophones. The signal from a MK-84 pinger is very brief (15 milliseconds) with a selectable frequency at 9.24 kHz, 12.93 kHz, 33.15 kHz, or 36.95 kHz and a source level of approximately 190 dB Sound Pressure Level (SPL).

Air Warfare (AW) Training. AW training includes one or more of the following training activities.

- *Surface-to-Air Missile Exercise (S-A MISSILEX).* Missiles are fired from either aircraft or ships against aerial targets.
- *Air-to-Air Missile/Gun Exercises (A-A MISSILEX/GUNEX).* Involve a fighter or fighter/attack aircraft and may involve firing missiles/guns at an aerial target. The missiles fired are not recovered.
- *Surface-to-Air Gunnery Exercises (S-A GUNEX)*. S-A GUNEX does not occur in the MIRC due to a requirement for commercial air service to tow targets.
- *Chaff/Flare Exercises (CHAFFEX/FLAREX).* Ship and aircraft crews practice defensive maneuvering while expending chaff and/or flares to evade targeting by a simulated missile threat. Chaff consists of thin metallic strips that reflect radio frequency energy, confusing radar. No ordnance used only chaff and flares.
- *Air Combat Maneuver (ACM).* Two to eight fighter aircraft engage in aerial combat, typically at high altitudes, far from land.

Surface Warfare (SUW) Training. SUW training includes one or more of the following training activities.

- *Surface-to-Surface Gunnery Exercise (S-S GUNEX)*: S-S GUNEX activities take place in the open ocean to provide gunnery practice for Navy and Coast Guard ships utilizing shipboard gun systems and small craft crews supporting NSW, EOD, and Mobile Security Squadrons (MSS) utilizing small arms. GUNEX training activities conducted in W-517 involve only surface targets such as a MK-42 Floating At Sea Target (FAST), MK-58 marker (smoke) buoys, or 55 gallon drums. The systems employed against surface targets include the 5-inch, 76mm, 25mm chain gun, 20mm Close In Weapon System (CIWS), .50 caliber machine gun, 7.62mm machine gun, small arms, and 40mm grenade.
- *Air-to-Surface Gunnery Exercise (A-S GUNEX)*: A-S GUNEX training activities are conducted by rotary-wing aircraft against targets (FAST and smoke buoy). Rotary-wing aircraft involved in this operation would use either 7.62mm or .50 caliber door-mounted machine guns. GUNEX training occurs in the MIRC Offshore Areas including W-517.

- *Visit Board Search and Seizure (VBSS)*: These exercises involve the interception of a suspect surface ship by a Navy ship and are designed to train personnel to board a ship, other vessel or transport to inspect and examine the ship's papers or examine it for compliance with applicable laws and regulations. Seizure is the confiscating or taking legal possession of the vessel and contraband (goods or people) found in violation of laws and regulations. A VBSS can be conducted both by ship personnel trained in VBSS or by NSW SEAL teams trained to conduct VBSS on uncooperative vessels. Employment onto the vessel designated for inspection is usually done by small boat or by helicopter.

- *Sinking Exercise (SINKEX):* A SINKEX is typically conducted by aircraft, surface ships, and submarines in order to take advantage of a full-size ship target and an opportunity to fire live weapons. The target is typically a decommissioned combatant or merchant ship that has been made environmentally safe for sinking. SINKEX conducted in the MIRC have been conducted in deep water and beyond 50nm of land in a location where it will not be a navigation hazard to other shipping. Ship, aircraft, and submarine crews typically are scheduled to attack the target with coordinated tactics and deliver live ordnance to sink the target. Inert ordnance may be used during the first stages of the event so that the target may be available for a longer time. The duration of a SINKEX is unpredictable because it ends when the target sinks, but the goal is to give all forces involved in the exercise an opportunity to deliver their live ordnance. Sometimes the target will begin to sink immediately after the first weapon impact and sometimes only after multiple impacts by a variety of weapons. Typically, the exercise lasts for 4 to 8 hours and possibly over 1 to 2 days, especially if inert ordnance, such as 5-inch gun projectiles or MK-76 dummy bombs, is used during the first hours. A SINKEX is conducted under the auspices of a permit from the U.S. Environmental Protection Agency (EPA).

Strike Warfare (STW) Training. STW training consists of the following training activity.

- *Air to Ground Bombing Exercises (Land) (BOMBEX-Land)*: BOMBEX (Land) allows aircrews to train in the delivery of bombs and munitions against ground targets. The weapons commonly used in this training on FDM are inert training munitions (e.g., MK-76, BDU-45, BDU-48, and BDU-56), and live MK-80-series bombs and precision guided munitions (Laser Guided Bombs [LGBs] or Laser Guided Training Round [LGTRs]). Cluster bombs, fuel-air explosives, and incendiary devices are not authorized on FDM. Depleted uranium rounds are not authorized on FDM. BOMBEX exercises can involve a single aircraft, a flight of two, four, or multiple aircraft. The types of aircraft that frequent FDM are F/A-18, F-22, F-15, F-16, B-1B, B-2, B-52, and H-60, and possibly UAVs. FDM is an uncontrolled and un-instrumented, laser certified range with fixed targets, which includes Container Express (CONEX) boxes in various configurations within the live-fire zones, high fidelity anti aircraft missiles, and gun-shape targets within the inert-only zone. COMNAVMAR is the scheduling authority. All aircraft without aid of an air controller must make a clearance pass prior to engaging targets as instructed in the FDM Range Users Manual (COMNAVMAR Instruction [COMNAVMARINST] 3502.1).

- *Air to Ground Missile Exercises (A-G MISSILEX)*: A-G MISSILEX trains aircraft crews in the use of air-to-ground missiles. On FDM it is conducted mainly by H-60 Aircraft using Hellfire missiles and occasionally by fixed-wing aircraft using Maverick missiles. A basic air-to-ground attack involves one or two H-60 aircraft. Typically, the aircraft will approach the target, acquire the target, and launch the missile. The missile is launched in forward flight or at hover at an altitude of 300 feet Above Ground Level (AGL).

Naval Special Warfare (NSW) Training. NSW forces train to conduct military operations in five Special Operations mission areas: unconventional warfare, direct action, special reconnaissance, foreign internal defense, and counterterrorism. Specific training events in the MIRC include:

- *Naval Special Warfare (NSW).* NSW personnel perform special warfare training using tactics that are applicable to the specific tactical situations where the NSW personnel are employed. They are specially trained, equipped, and organized to conduct special operations in maritime, littoral, and riverine environments. Several general training activities and scenarios are called out in this EIS, and while there is a baseline of special operation exercises, training is always evolving to meet the tactical requirements and special weapons required to complete the mission assigned. Exercises involving NSW personnel include, but are not limited to the following:
    - Amphibious Warfare Exercises
    - BOMBEX (Air-to-Ground)
    - Breaching
    - Close Air Support (CAS)
    - Direct Action
    - Escape and Evasion
    - High Mobility Multipurpose Wheeled Vehicle (HMMWV) Training
    - Insertion/Extraction
    - Immediate Action Drills
    - Land Demolitions
    - Land Navigation
    - Maritime Training Activities
    - Marksmanship
    - MOUT
    - Nearshore Hydrographic Reconnaissance
    - NSW Physical Conditioning Training Exercises
    - Over-the-Beach
    - Over-the-Beach Stalk
    - Special Boat Team Training Activities
    - Swimmer/CRRC Over-the-Beach
    - UAV OPS
    - Unmanned Underwater Vehicles (UUV) OPS
    - Underwater Detonation
    - VBSS

References to NSW training activity contained in the list above will be discussed as they occur within the text of this document.

- *Airfield Seizure.* Airfield Seizure training activities are used to secure key facilities in order to support follow-on forces, or enable the introduction of follow-on forces. An airfield seizure consists of a raid/seizure force from over the horizon assaulting across a hostile territory in a combination of helicopters, vertical takeoff and landing (VTOL aircraft), and other landing craft with the purpose of securing an airfield or a port. NSW teams have conducted this training at Northwest Field on Andersen Air Force Base.

- *Breaching.* Breaching training teaches personnel to employ any means available to break through or secure a passage through an enemy defense, obstacle, minefield, or fortification. This enables a force to maintain its mobility by removing or reducing natural and man-made obstacles. In the NSW sense, breacher training activities are designed to provide personnel experience knocking down doors to enter a building or structure. During the conduct of a normal breach activity, battering rams or less than 1 pound net explosive weight (NEW) is used to knock down doors. Training has occurred at OPCQC House and the Ordnance Annex Breacher House (OABH) (Maximum charge permitted at the OABH is no more than 3 pounds NEW.) However, explosives at OPCQC are not permitted, which limits the value of conducting this training at OPCQC.

- *Direct Action*. NSW Direct Action is either covert or overt directed against an enemy force to seize, damage, or destroy a target and/or capture or recover personnel or material. Training activities are small-scale offensive actions including raids; ambushes; standoff attacks by firing from ground, air, or maritime platforms; designate or illuminate targets for precision-guided munitions; support for cover and deception operations; and sabotage inside enemy-held territory. Units involved are typically at the squad or platoon level staged on ships at sea. They arrive in the area of operations by helicopter or CRRC across a beach. NSW teams are capable of using small craft to island hop from Guam to Rota, Rota to Tinian, Tinian to Saipan, and Saipan to FDM; however, this is not a frequent event. Once at FDM, small arms, grenades, and crew-served weapons (weapons that require a crew of several individuals to operate) are employed in direct action against targets on the island. Participation in Tactical Air Control Party/Forward Air Control (TACP/FAC) training in conjunction with a BOMBEX-Land also occurs. NSW and visiting Special Forces training in the MIRC will frequently include training that utilizes the access provided by Gab Gab Beach to Apra Harbor and Orote Point training areas, as well as training in the OPCQC.

- *Insertion/Extraction*. Insertion/extraction activities train forces, both Navy (primarily Special Forces and EOD) and Marine Corps, to deliver and extract personnel and equipment. These activities include, but are not limited to, parachute, fast rope, rappel, Special Purpose Insertion/Extraction (SPIE), CRRC, and lock-in/lock-out from underwater vehicles. Training activities have been conducted at Outer Apra Harbor, Inner Apra Harbor, Gab Gab Beach (western half), Reserve Craft Beach, and Polaris Point Field. Additionally, parachute, fast rope, and rappel training have been conducted at Orote Point Airfield/Runway, Orote Point Triple Spot, OPCQC House, Dan Dan Drop Zone, OPKD Range, and the Ordnance Annex Breacher House.

- *Military Operations in Urban Terrain (MOUT)*. NSW MOUT training is similar in nature and intent to Army and Marine Corps MOUT training, but typically on a smaller scale. MOUT training is conducted at the Ordnance Annex Breacher House. Additionally, the OPCQC supports “raid” type MOUT training on a limited basis.

- *Over the Beach (OTB)*. NSW personnel use different methods of moving forces from the sea across a beach onto land areas in order to get closer to a tactical assembly area or target depending on threat force capabilities. A typical OTB exercise would involve a squad (8 personnel) to a platoon (16 personnel) or more of NSW personnel being covertly inserted into the water off of a beach area of hostile territory. However, the insertion could be accomplished by other means, such as fixed-winged aircraft, helicopter, submarine, or surface ship. From the insertion point several miles at sea, the SEALs may use a CRRC, Rigid Hull Inflatable Boat (RHIB), SEAL

Delivery Vehicle (SDV), Advanced SEAL Delivery System (ASDS), or swim to reach the beach, where they will move into the next phase of the exercise and on to the objective target area and mission of that phase of the exercise.

Amphibious Warfare (AMW) Training. AMW training includes individual and crew, small unit, large unit, and Marine Air Ground Task Force (MAGTF)-level events. Individual and crew training include operation of amphibious vehicles and naval gunfire support training. Small-unit training activities include events leading to the certification of a MEU as "Special Operations Capable" (SOC). Such training includes shore assaults, boat raids, airfield or port seizures, and reconnaissance. Larger-scale amphibious exercises are carried out principally by MAGTFs or elements of MAGTFs embarked with Expeditionary Strike Groups (ESG); and include the following training exercises.

- *Naval Surface Fire Support (FIREX Land.* FIREX (Land) on FDM consists of the shore bombardment of an Impact Area by Navy guns as part of the training of both the gunners and Shore Fire Control Parties (SFCP). A SFCP consists of spotters who act as the eyes of a Navy ship when gunners cannot see the intended target. From positions on the ground or air, spotters provide the target coordinates at which the ship's crew directs its fire. The spotter provides adjustments to the fall of shot, as necessary, until the target is destroyed. On FDM, spotting may be conducted from the special use "no fire" zone or provided from a helicopter platform. No one may land on the island without the express permission of COMNAVMAR (COMNAVMARINST 3502.1).
- *Marksmanship*. Marksmanship exercises are used to train personnel in the use of small arms weapons for the purpose of ship self defense and security. Basic marksmanship training activities are strictly controlled and regulated by specific individual weapon qualification standards. Small arms include but are not limited to 9mm pistol, 12-gauge shotgun, and 7.62mm rifles. These exercises have occurred at Orote Point and Finegayan small arms ranges, and OPKD Range.
- *Expeditionary Raid*. An Expeditionary Raid (Assault) is an attack involving swift incursion into hostile territory for a specified purpose. The attack is then followed by a planned withdrawal of the raid forces. A raid force can consist of varying numbers of aviation, infantry, engineering, and fire support forces. Expeditionary Raids conducted in support to movement of operational forces are normally directed against objectives requiring specific outcomes not possible by other means. A key influence in every raid is the ability to insert, complete the assigned mission, and extract without providing the enemy force with opportunity to reinforce their forces or plan for counter measures. The expeditionary raid is the foundation for all MEU SOC operational missions and is structured based upon mission requirements, situational settings, and force structure. Reserve Craft Beach is capable of supporting a small Expeditionary Raid training event followed by a brief administrative buildup of forces ashore. In Fiscal Year (FY) 2003, up to 300 31st MEU personnel and pieces of equipment were moved ashore at Reserve Craft Beach via LCAC.
- *Hydrographic Surveys*. Hydrographic Reconnaissance is conducted to survey underwater terrain conditions and report findings to provide precise analysis typically in support of amphibious landings and precise ship and small craft movement through cleared routes (Q-Routes). Exercises involve the methodical reconnoitering of beaches and surf conditions during the day and night to find and clear underwater obstacles and to determine the feasibility of landing an amphibious force on a

particular beach. Hydrographic Survey exercises have also occurred at Outer Apra Harbor and Tipalao Cove.

Mine Warfare (MIW) Training

- *Land Demolition.* Training activities using land demolition training are designed to develop and hone EOD detachment mission proficiency in location, excavation, identification, and neutralization of buried land mines. During the training, teams transit to the training site in trucks or other light-wheeled vehicles. A search is conducted to locate inert (nonexplosively filled) land mines or Improvised Explosive Devices (IEDs) and then designate the target for destruction. Buried land mines and Unexploded Ordnance (UXO) require the detachment to employ probing techniques and metal detectors for location phase. Use of hand tools and digging equipment is required to excavate. Once exposed and/or properly identified, the detachment neutralizes threats using simulated or live explosives. Land demolition training is actively conducted throughout the MIRC. Explosive Ordnance Disposal Mobile Unit (EODMU)-5 is stationed at Main Base and EOD Detachment, Marianas (DET MARIANAS) is a small unit of EOD personnel who are permanently attached to COMNAVBASE MARIANAS and are actively involved in disposing of old munitions and UXO found throughout the MIRC. Land demolition training activities have occurred at Inner Apra Harbor, Gab Gab Beach, Reserve Craft Beach, Polaris Point Field, Orote Point Airfield/Runway, OPCQC House, Ordnance Annex Breacher House, Ordnance Annex Emergency Detonation Site, NLNA, SLNA, and Barrigada Housing.
- *Underwater Demolition*. Underwater demolitions are designed to train personnel in the destruction of mines, obstacles, or other structures in an area to prevent interference with friendly or neutral forces and noncombatants. It provides NSW and EOD teams experience detonating underwater explosives. Outer Apra Harbor supports this training near the Glass Breakwater at a depth of 125 feet and with up to a 10-pound net explosive weight (NEW) charge. Piti and Agat Bay Floating Mine Neutralization areas also support this type of training, with up to a 20-pound NEW charge.

Logistics and Combat Services Support. Logistics and combat services support include the following training activities.

- *Combat Mission Area Training.* Special Forces and EOD units conduct mission area training that supports their own and other services combat service needs in both the water and on land. At Orote Point Airfield/Runway, this task includes providing patrolling, scouting, observation, imagery, and air control services and training.
- *Command and* Control *(C2).* C2 training activities provide primary communications for command, control, and intelligence, providing critical interpretability and situation awareness information. EOD personnel have provided USMC C2 support at Reserve Craft Beach.

Combat Search and Rescue (CSAR). CSAR activities train rescue forces personnel in the tasks needed to be performed to affect the recovery of distressed personnel during war or military operations other than war. These training activities could include aircraft, surface ships, submarines, ground forces (NSW and Marine Corps), and their associated personnel in the execution of training events. North Field on Tinian has supported night vision goggle (NVG) familiarization training for CSAR personnel.

Protect and Secure Area of Operations. The following training activities are included in this training category.

- *Embassy Reinforcement (Force Protection)*. Force protection training increase the physical security of military personnel in the region to reduce their vulnerability to attacks. Force protection training includes moving forces and building barriers; detection and assessment of threats; delay or denial of access of the adversary to their target; appropriate response to threats and attack; and mitigation of effects of attack. Force protection includes employment of offensive as well as defensive measures. Base Naval Security Forces and Marine Support Squadrons frequently conduct force protection training throughout the Main Base, but all forces will participate in force protection training to some degree in multiple locations throughout the MIRC, including: Inner Apra Harbor, Kilo Wharf, Reserve Craft Beach, Orote Point Airfield/Runway, Orote Point Close Quarters Combat House, Orote Point Radio Tower, and Orote Point Triple Spot.
- *Anti-Terrorism (AT).* AT training activities concentrate on the deterrence of terrorism through active and passive measures, including the collection and dissemination of timely threat information, conducting information awareness programs, coordinated security plans, and personal training. The goal is to develop protective plans and procedures based upon likely threats and strike with a reasonable balance between physical protection, mission requirements, critical assets and facilities, and available resources to include manpower. AT training activities may involve units of Marines dedicated to defending both U.S. Navy and Marine Corps assets from terrorist attack. The units are designated as the Fleet Anti-Terrorism Security Team, or FAST. FAST Company Marines augment, assist, and train installation security when a threat condition is elevated beyond the ability of resident and auxiliary security forces. They are not designed to provide a permanent security force for the installation. They also ensure nuclear material on submarines is not compromised when vessels are docked. FAST Companies deploy only upon approval of the Chief of Naval Operations (CNO). USMC Security Force FAST Platoons stationed in Yokuska, Japan have conducted AT training with Base Naval Security, NSW, and EOD support in multiple locations within the MIRC, includin: Inner Apra Harbor, Polaris Point Site III, Ordnance Annex Breacher House, and Orote Annex Emergency Detonation Site.

Major Exercise — Training would also include either a joint expeditionary warfare exercise or a joint multi-strike group exercise. This exercise consists of combining the individual training activities described in the No Action Alternative in such a manner as to provide multi-Service and multi-national participation in realistic maritime and expeditionary training activity. This is designed to replicate the types of operations and challenges that could be faced during real-world contingency operations. Major exercises provide training for command elements, submarine, ship, aircraft, expeditionary, and special warfare forces in tactics, techniques, and procedures.

A.2.1.4 Air Force Training

Counter Land. Counter Land is similar in nature and content to the Navy's BOMBEX (Land). These activities have occurred at FDM and utilize ATCAA 3.

Counter Air. Counter air is single to multiple aircraft engaged in advanced, simulated radar, infrared (IR), or visual air-to-air training. During this training, aircraft may dispense chaff and flares as part of missile defense training. Flares are high incendiary devices meant to decoy IR missiles. Burn time for flares usually lasts from 3 to 5 seconds. Chaff exercises train aircraft and/or shipboard personnel in the use of chaff to counter anti-ship and anti-aircraft missile threats. Chaff is a radar confusion reflector, consisting of thin, narrow metallic strips of various lengths and frequency responses, which are used to reflect echoes to deceive radars. During a chaff exercise, the chaff layer combines aircraft maneuvering with deployment of multiple rounds of chaff to confuse incoming missile threats. In an integrated Chaff Exercise scenario, ships/helicopters/fixed wing craft will deploy ship- and air-launched, rapid bloom offboard chaff in preestablished patterns designed to enhance missile defense. Chaff exercises have been conducted in W-517 and ATCAA 1 & 2.

Airlift. Airlift operations provide airlift support to combat forces. Airlift operations and training activity have occurred at Andersen Air Force Base and Northwest Field.

Air Expeditionary. This type of training provides air expeditionary operations support to forward deployed forces. Northwest Field on Andersen Air Force Base is used in support of forward/expeditionary training and is available as an alternate landing and laydown site for short field capable aircraft. Andersen South is utilized to support MOUT type training.

Force Protection. This type of training is to provide force protection to individuals, buildings, and specific areas of interest. Force protection training has occurred on Andersen Air Force Base at Northwest Field, Pati Pt. CATM Range, and Main Base.

A.2.1.5Research, Development, Test and Evaluation Activities

The Services may conduct RDT&E, engineering, and fleet support for command, control, and communications systems and ocean surveillance in the MIRC. These activities may include ocean engineering, missile firings, torpedo testing, manned and unmanned submersibles testing, UAV tests, EC, and other DoD weapons testing.

A.3 ALTERNATIVE 1— CURRENT TRAINING, INCREASED TRAINING SUPPORTED BY MODERIZATION AND UPGRADES/MODIFICATIONS TO EXISTING CAPABILITIES, TRAINING ASSOCIATED WITH ISR/STRIKE, AND MULTI-NATIONAL AND/OR JOINT EXERCISES

Alternative 1 is a proposal designed to meet the Services' current and foreseeable training requirements. If Alternative 1 were to be selected, in addition to accommodating the No Action Alternative, it would include increased training as a result of upgrades and modernization of existing capabilities, and include establishment of a danger zone and restricted area around FDM (a 10-nm zone around FDM to be established in accordance with C.F.R. Title 33 Part 334; see Figure A-4). Alternative 1 also includes training associated with ISR/Strike and other Andersen AFB initiatives. Training will also increase as a result of the acquisition and development of new Portable Underwater Tracking Range (PUTR) capabilities. PUTR trains personnel in undersea warfare including conducting TRACKEX and TORPEX activities. Helicopter, ship, and submarine sonar systems will use this capability. Small arms range capability improvements and MOUT training facility improvements would also increase training activities. Table A-8 summarizes these increases in training activities. These increased capabilities will result in increased multi-national and/or joint exercises.

Alternative 1 meets the Proposed Action's purpose and need; however this Alternative does not optimize the training capabilities of the MIRC.

A.3.1 MAJOR EXERCISES

Training would increase to include additional major exercises involving multiple strike groups and expeditionary task forces (see Table A-6). Major exercises provide multi-Service and multi-national participation in realistic maritime and expeditionary training that is designed to replicate the types of operations and challenges that could be faced during real-world contingency operations. Major exercises provide training for command elements, submarine, ship, aircraft, expeditionary, and special warfare forces in tactics, techniques, and procedures.

(Note: the *Guam and CNMI Military Relocation EIS/OEIS* is being prepared for the relocation of Marine Corps forces from Okinawa to Guam. The Military Relocation EIS/OEIS examines the potential impact from activities associated with the Marine Corps units' relocation, including training activities and infrastructure changes on and off DoD lands. Since the MIRC EIS/OEIS covers DoD training on existing DoD land and training areas in and around Guam and the CNMI, there will be overlap between the two EIS/OEISs in the area of land usage. These documents are being closely coordinated to ensure consistency.)

A.3.2 ISR/STRIKE

The Air Force has established the ISR/Strike program at Andersen AFB, Guam. ISR/Strike will be implemented in phases over a planning horizon of FY2007–FY2016. ISR/Strike force structure consists of up to 48 fighter, 12 aerial refueling, six bomber, and six unmanned aircraft with associated support personnel and infrastructure. Aircraft operations and training out of Andersen AFB ultimately will increase by 45 percent over the current level (FY2006). Environmental impacts associated with ISR/Strike have been analyzed in the *2006 Establishment and Operation of an Intelligence, Surveillance and Reconnaissance/Strike, Andersen Air Force Base, EIS*. The anticipated 45 percent increase in aircraft operations and training out of and into Andersen AFB requires improved range infrastructure to accommodate this increased training tempo, newer aircraft, and weapon systems commensurate with ISR/Strike force structure. There will be increased activity on all the current training areas supporting Air Force training activities: W-517, ATCAAs, and FDM/R-7201. The ISR/Strike EIS analyzed environmental impacts related to the infrastructure improvements required. This EIS/OEIS analyzes the impacts of the increased training resulting from the ISR/Strike implementation.

A.3.3 FDM

Public access to FDM is strictly prohibited and there are no commercial or recreational activities on or near the island. During training exercises, marine vessels are restricted within a 3-nm (5-km) radius. Notice to Mariners (NOTMAR) and Notice to Airmen (NOTAM) are issued at least 72 hours in advance of potentially hazardous FDM range events and may advise restrictions beyond 3 to 30 nm (5-56 km) from FDM or greater for certain training events. These temporary advisory restrictions are used to maintain the safety of the military and the public during training sessions by providing public notice of potentially hazardous training activity and temporary danger zones and restriction areas.

As usage of FDM increases under implementation of either Alternative 1 or Alternative 2, a danger zone and restricted area would be established to restrict all private and commercial vessels from entering the area to minimize danger from the hazardous activity in the area. Development of a 10-nm (18-km) danger zone and restricted area would be an established restriction, supplemented by temporary advisory notices as required.

A.3.4 MODERNIZATION AND UPGRADES OF TRAINING AREAS

Anti-Submarine Warfare (ASW). ASW describes the entire spectrum of platforms, tactics, and weapon systems used to neutralize and defeat hostile submarine threats to combatant and non-combatant maritime forces. A critical component of ASW training is the Underwater Tracking Range (UTR). This is an instrumented range that allows near real-time tracking and feedback to all participants. The tracking range should provide for both a shallow water and deep water operating environment, with a variety of bottom slope and sound velocity profiles similar to potential contingency operating areas. Guam-homeported submarine crews, as well as crews of transient submarines, require ASW training events to maintain qualifications. A MIRC instrumented ASW PUTR, target support services, and assigned torpedo retriever craft would meet support requirements for TORPEX and TRACKEX activities in the MIRC in support of Fast Attack Submarine (SSN) and Ballistic Missile Submarine (SSBN) and other deployed forces.

Military Operations in Urban Terrain (MOUT). MOUT training is conducted within a facility that replicates an urban area, to the extent practicable. The urban area includes a central urban infrastructure of buildings, blocks, and streets; an outlying suburban residential area; and outlying facilities. Suburban area structures should represent a local noncombatant populace and infrastructure. The MIRC will need to repair and upgrade the existing MOUT facilities to support training requirements of units stationed at or deployed to the MIRC.

A.4 ALTERNATIVE 2— CURRENT TRAINING, INCREASED TRAINING SUPPORTED BY MODERIZATION AND UPGRADES/MODIFICATIONS TO EXISTING CAPABILITIES, TRAINING ASSOCIATED WITH ISR/STRIKE, AND INCREASED MULTI-NATIONAL AND/OR JOINT EXERCISES; INCLUDING ADDITIONAL UNDERSEA EXERCISES

Implementation of Alternative 2 would include all the actions proposed for MIRC in Alternative 1 and increased training activity associated with major at-sea exercises (see Tables A-6 and A-7). Additional major at-sea exercises would provide additional ships and personnel maritime training including additional use of sonar that would improve the level of joint operating skill and teamwork between the Navy, Joint Forces, and Partner Nations. Submarine, ship, and aircraft crews train in tactics, techniques, and procedures required in carrying out the primary mission areas of maritime forces. The additional maritime exercises would take place within the MIRC and would focus on carrier strike group training and ASW activities similar to training conducted in other Seventh Fleet locations, including a Fleet Strike Group Exercise, an Integrated ASW Exercise, and a Ship Squadron ASW Exercise.

Major Exercise. The Fleet Strike Group Exercise and an additional Integrated ASW exercise would be conducted in the MIRC by forward-deployed Navy Strike Groups to sustain or assess their proficiency in conducting tasking within the Seventh Fleet. Training would be focused on conducting Strike Warfare or ASW in the most realistic environment, against the level of threat expected in order to effect changes to both training and capabilities (e.g., equipment, tactics, and changes to size and composition) of the Navy Strike Group. Although these exercises would emphasize Strike or ASW, there is significant training value inherent in all at-sea exercises and the opportunity to exercise other mission areas. Each exercise would last a week or less.

The Ship Squadron ASW Exercise overall objective is to sustain and assess surface ship ASW readiness and effectiveness. The exercise typically involves multiple ships, submarines, and aircraft in several coordinated events over a period of a week or less. Maximizing opportunities to collect high-quality data to support quantitative analysis and assessment of training activities is an additional goal of this training.

Table A-6. Major Exercises in the MIRC Study Area

MIRC EIS/OEIS		Major Exercises							
Exercise		Joint Expeditionary Exercise (CSG + ESG)	Joint Multi-strike Group Exercise (3 CSG + USAF)	Fleet Strike Group Exercise (CSG)	Integrated ASW Exercise (CSG)	Ship Squadron ASW Exercise (CRU DES)	MAGTF Exercise (STOM/ NEO)	SPMAGTF Exercise (HADR/ NEO)	Urban Warfare Exercise
Exercise Sponsor		US PACOM	US PACOM	C7F	C7F	C7F	III MEF	III MEF; MEU/UDP	III MEF; MEU/ UDP
Alternative: No Action		1 of the above		0	0	0	1	0	2
Alternative 1		1	1	0	0	0	4	2	5
Alternative 2		1	1	1	1	1	4	2	5
Primary Training Site		Tinian	MI Maritime >12 nm	MI Maritime >12 nm	MI Maritime >3 nm	MI Maritime >3 nm	Tinian	Guam	Guam
Secondary Training Sites		Nearshore to OTH: Guam: Rota; Saipan; FDM	FDM	FDM	FDM	N/A	Nearshore to OTH: Guam: Rota; Saipan; FDM	Tinian, Rota, Saipan	Tinian, Rota, Saipan
Exercise Footprint	Activity Days per Exercise	10	10	7	5	5	10	10	7-21
NAVY SHIPS	CVN	1	3	1	1	0	0	0	0
	CG	1	3	1	1	1	0	0	0
	FFG	2	3	1	1	1	1	0	0
	DDG	5	12	3	3	3	2	0	0
	LHD/ LHA	1	0	1	0	0	1	1	1
	LSD	2	0	0	0	0	2	1	1
	LPD	1	0	0	0	0	1	1	1
	TAOE	1	3	1	0	0	0	0	N/A
	SSN	1	5	1	1	1	0	0	N/A
	SSGN	1	0	0	0	0	1	0	0
	TR	N/A	N/A	0	0	0	N/A	N/A	N/A
Partner National Ships	CG	1	0	0	0	0	0	0	N/A
	DDG	2	0	0	0	0	0	0	N/A
	SS	1	1	0	0	0	0	0	N/A
FIXED WING	F/A-18	4 Squadrons	12 Squadrons	4 Squadrons	4 Squadrons	N/A	N/A	N/A	N/A
	EA-6B	1 Squadron	3 Squadrons	1 Squadron	1 Squadron	N/A	N/A	N/A	N/A
	E-2	1 Squadron	3 Squadrons	1 Squadron	1 Squadron	N/A	N/A	N/A	N/A
	MPA (P-3)	3	5	3	3	3	N/A	N/A	N/A
	AV-8B	1 Squadron	N/A	1 Squadron	N/A	N/A	N/A	N/A	N/A
	C-130	2	N/A	N/A	N/A	N/A	1	1	1
	USAF Bomber	N/A	1 Squadron	N/A	N/A	N/A	N/A	N/A	N/A
	F-15/16/22	N/A	1 Squadron	1 Squadron	N/A	N/A	N/A	N/A	N/A
	A-10	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	E-3	1	1	1	N/A	N/A	N/A	N/A	N/A
	KC-10/135/130	1	2	1	N/A	N/A	N/A	N/A	N/A

Table A-6. Major Exercises in the MIRC Study Area (continued)

MIRC EIS/OEIS		Major Exercises							
Exercise		Joint Expeditionary Exercise (CSG + ESG)	Joint Multi-strike Group Exercise (3 CSG + USAF)	Fleet Strike Group Exercise (CSG)	Integrated ASW Exercise (CSG)	Ship Squadron ASW Exercise (CRU DES)	MAGTF Exercise (STOM/ NEO)	SPMAGTF Exercise (HADR/ NEO)	Urban Warfare Exercise
ROTARY	MH-60R/S	4	12	4	4	4	2	N/A	N/A
	SH-60H	4	12	4	4	4	N/A	N/A	N/A
	HH-60H	4	12	4	4	N/A	N/A	N/A	N/A
	SH-60F	3	9	3	3	N/A	N/A	N/A	N/A
	CH-53	4	N/A	4	N/A	N/A	4	4	4
	CH-46	12	N/A	12	N/A	N/A	12	12	12
	AH-1	4	N/A	4	N/A	N/A	4	4	4
	UH-1	2	N/A	2	N/A	N/A	2	2	2
	MV-22 FY10 (replace CH-46)	10	N/A	10	N/A	N/A	10	10	10
UAS	Ship Based	2	3	1	1	0	1	0	0
	Ground Based	2	1	0	0	0	2	1	1
Landing Craft	LCAC	3-5	N/A	N/A	N/A	N/A	3-5	3	N/A
	LCU	1-2	N/A	N/A	N/A	N/A	1-2	1	N/A
	CRRC	18	N/A	N/A	N/A	N/A	18	18	0
GCE	AAV	14	N/A	N/A	N/A	N/A	14	3	3
	LAV	13	N/A	N/A	N/A	N/A	5	5	5
	HMMWV	78	N/A	N/A	N/A	N/A	78	16	16
	Ground Personnel	1200	N/A	N/A	N/A	N/A	1200	250	250
LCE	Trucks	36	N/A	N/A	N/A	N/A	36	8	8
	Dozer	2	N/A	N/A	N/A	N/A	2	1	1
	Forklift	6	N/A	N/A	N/A	N/A	6	2	2
	ROWPU	2	N/A	N/A	N/A	N/A	2	1	1
	RHIB	2	N/A	N/A	N/A	N/A	2	2	2
	Ground Personnel	300	N/A	N/A	N/A	N/A	300	60	60

Table A-7. Annual Training Activities in the MIRC Study Area

Range Activity	Platform	System or Ordnance	No Action Alternative	Alternative 1	Alternative 2	Location
Anti-Submarine Warfare (ASW)						
ASW TRACKEX (SHIP)	CG/ DDG / FFG SUB/ MK-30/ EMATT	SQS-53C/D SQS-56	10	30	60	PRI: W-517 SEC: MI Maritime, >3 nm from land
ASW TRACKEX (SUB)	SSN; SSGN MK-30	BQQ	5	10	12	PRI: Guam Maritime, >3 nm from land SEC: W-517
ASW TRACKEX (HELO)	SH-60B, SH-60F SUB/ MK-30/ EMATT	AQS-22 DICASS	9	18	62	PRI: W-517 SEC: MI Maritime, >3 nm from land
ASW TRACKEX (MPA)	FIXED WING MPA SUB/ MK-30/ EMATT	DICASS EER/IEER/AEER	5	8	17	PRI: W-517 SEC: MI Maritime, >3 nm from land
ASW TORPEX (SUB)	SSN; SSGN MK-30 TRB / MH-60S	BQQ MK-48 EXTORP	5	10	12	PRI: Guam Maritime, >3 nm from land SEC: W-517
ASW TORPEX (SHIP)	CG/ DDG / FFG SUB/ MK-30/ EMATT TRB / MH-60S/ RHIB	SQS-53C/D SQS-56 REXTORP	0	3	6	PRI: Guam Maritime, >3 nm from land SEC: W-517
ASW TORPEX (MPA / HELO)	MPA / SH-60B/F, SUB/ MK-30/ EMATT TRB / MH-60S/ RHIB	AQS-22 / DICASS REXTORP	0	4	8	PRI: Guam Maritime, >3 nm from land SEC: W-517

Table A-7. Annual Training Activities in the MIRC Study Area (continued)

Range Activity	Platform	System or Ordnance	No Action Alternative	Alternative 1	Alternative 2	Location
MineINE WarfareARFARE (MIW)						
MINEX	B-1/ B-2/ B-52/ FA-18	MK-62 / MK-56	2	3	3	PRI: W-517 SEC: MI Maritime, >12 nm from land
Underwater Demolition	RHIB	Bottom/mid-moored mine shape 5 – 20 lb NEW	22	30	30	PRI: Agat Bay SEC: Apra Harbor (10lb max)
Floating Mine Neutralization	RHIB	Floating mine shape 5 – 20 lb NEW	8	20	20	PRI: Agat Bay SEC: Piti
Surface Warfare (SUW)						
SINKEX	Ship hulk or barge	HARM [2] SLAM-ER [14] HARPOON [5] 5" Rounds [400] HELLFIRE [2] MAVERICK [8] GBU-12 [10] GBU-10 [4] MK-48 [1] Underwater Demolitions [2 -100lb]	1	2	2	PRI: W-517 SEC: MI Maritime, >50 nm from land; ATCAAs
BOMBEX (Air to Surface)	FA-18; AV-8B; MPA (MK 58 Smoke tgt. or towed sled)	MK 82 I; BDU-45; MK 76 (Inert Rounds)	16 (48 rounds)	24 (72 rounds)	30 (90 rounds)	PRI: W-517 SEC: MI Maritime, >12 nm from land; ATCAAs
GUNEX Surface-to-Surface (Ship)	LHA, LHD, LSD, and LPD. Barrel, Inflatable tgt.	.50 cal MG	1 (2,400 rounds)	5 (12,000 rounds)	5 (12,000 rounds)	PRI: W-517 SEC: MI Maritime, >12 nm from land
		.25 mm MG	1 (1,600 rounds)	5 (8,000 rounds)	5 (8,000 rounds)	
	CG and DDG. Barrel or Inflatable tgt. or towed sled.	5" gun	4 (160 rounds)	8 (320 rounds)	10 (400 rounds)	
	FFG. Barrel or Inflatable tgt. or towed sled.	76 mm	2 (60 rounds)	4 (120 rounds)	5 (150 rounds)	

Table A-7. Annual Training Activities in the MIRC Study Area (continued)

Range Activity	Platform	System or Ordnance	No Action Alternative	Alternative 1	Alternative 2	Location
Surface Warfare (SUW) (continued)						
GUNEX Surface-to-Surface (Small arms)	Ship, RHIB, small craft. Barrel or Inflatable tgt.	M-16, M-4, M-249 SAW, M-240G, .50 cal, M-203 (5.56 /7.62 mm/ .50 cal round/ 40mm TP)	24 (12,000 rounds)	32 (16,000 rounds)	40 (20,000 rounds)	PRI: MI Maritime, >3 nm from land SEC: W-517
GUNEX Air-to-Surface	SH-60; HH-60; MH-60R/S; UH-1; CH-53; FA-18; AH-1W; F-15; F16; F-22; AV-8B; A-10 (Barrel or MK-58 smoke tgt.)	7.62 mm MG	150 (30,000 rounds)	200 (40,000 rounds)	200 (40,000 rounds)	PRI: W-517 SEC: MI Maritime, >12 nm from land; ATCAAs
		.50 cal MG	10 (2,000 rounds)	20 (4,000 rounds)	20 (4,000 rounds)	
		20 mm cannon	50 (5,000 rounds)	100 (10,000 rounds)	100 (10,000 rounds)	
		25 mm cannon	10 (1,000 rounds)	40 (4,000 rounds)	40 (4,000 rounds)	
		30 mm cannon	0	15 (1,500 rounds)	15 (1,500 rounds)	
Visit, Board, Search and Seizure/Maritime Interception Operation (VBSS/MIO)	RHIB, Small Craft, Ship, H-60	n/a	3	6	8	PRI: Apra Harbor SEC: MI Maritime
Electronic Combat						
CHAFF Exercise	SH-60; MH-60; HH-60; MH-53	RR-144A/AL	12 sorties (360 rounds)	14 sorties (420 rounds)	14 sorties (420 rounds)	PRI: W-517 SEC: MI Maritime, >12nm from land; ATCAAs
	FA-18; EA-18; AV-8B; MPA; EA-6	RR-144A/AL	16 sorties (160 rounds)	32 sorties (320 rounds)	48 sorties (500 rounds)	
	F-15; F-16; C-130	RR-188	150 sorties (1,500 rounds)	500 sorties (5,000 rounds)	550 sorties (5,500 rounds)	
	CG, DDG, FFG, LHA, LHD, LPD, LSD	MK 214 (seduction); MK 216 (distraction)	12 (72 canisters)	16 (90 canisters)	20 (108 canisters)	

Table A-7. Annual Training Activities in the MIRC Study Area (continued)

Range Activity	Platform	System or Ordnance	No Action Alternative	Alternative 1	Alternative 2	Location
Electronic Combat (EC) (continued)						
FLARE Exercise	SH-60; MH-60; HH-60; MH-53	MK 46 MOD 1C; MJU-8A/B; MJU-27A/B; MJU-32B; MJU-53B; SM-875/ALE	12 sorties (360 flares)	14 sorties (420 rounds)	14 sorties (420 rounds)	PRI: W-517 SEC: MI Maritime, >12nm from land; ATCAAs
	FA-18; EA-18; AV-8B; MPA; EA-6		16 sorties (160 rounds)	32 sorties (320 rounds)	48 sorties (500 rounds)	
	F-15; F-16; C-130	MJU-7; MJU-10; MJU-206	4 sorties (1,500 rounds)	500 sorties (5,000 rounds)	550 sorties (5,500 rounds)	
Strike Warfare (STW)						
BOMBEX (LAND)	FA-18; AV-8B; B-1; B-2; B-52; F-15; F-16; F-22; A-10	High Explosive Bombs ≤ 500 lbs	400 annually	500 annually	600 annually	FDM (R-7201)
		High Explosive Bombs: 750 / 1,000 lbs / 2,000 lbs	1,600 annually	1,650 annually	1,700 annually	
		Inert Bomb Training Rounds ≤ 2,000 lbs	1,800 annually	2,800 annually	3,000 annually	
		Total Sorties (1 aircraft per sortie):	1,000 sorties	1,300 sorties	1,400 sorties	
MISSILEX A-G	FA-18; AV-8B; F-15; F-16; F-22; A-10; MH-60R/S; SH-60B; HH-60H; AH-1	TOW; MAVERICK; HELLFIRE; ROCKETS ≤ 5”	30 annually	60 annually	70 annually	FDM (R-7201)
GUNEX A-G	FA-18; AV-8B; F-15; F-16; F-22; A-10; MH-60R/S; SH-60B; HH-60H; AH-1; AC-130	20 OR 25 MM CANNON	16,500 rounds	20,000 rounds	22,000 rounds	FDM (R-7201)
		30 MM CANNON (A-10)	0	1,500 rounds	1,500 rounds	
		40mm or 105mm CANNON (AC-130)	100 rounds	200 rounds	200 rounds	
Combat Search aAnd Rescue (CSAR)	SH-60; MH-60; HH-60; MH-53; CH-53; C-17; C-130; V-22	NIGHT VISION	30 sorties	60 sorties	75 sorties	PRI: Tinian North Field: Guam Northwest Field SEC: Orote Point Airfield; Rota Airport
Air Warfare (AW)						
Air Combat Manuevers (ACM)	FA-18; AV-8B; F-15; F16.	Captive Air Training Missile (CATM) or Telemetry Pod	360 sorties of 2-4 aircraft per sortie	720 sorties of 2-4 aircraft per sortie	840 sorties 2-4 aircraft per sortie	PRI: W-517 SEC: MI Maritime, >12nm from land; ATCAAs
Air Intercept Control	FA-18; F-15	Search and Fire Control Radars	40 sorties (2-4 aircraft) 20 events	80 sorties (2-4 aircraft) 40 events	100 sorties (2-4 aircraft) 50 events	PRI: W-517 SEC: MI Maritime, >12nm from land; ATCAAs

Table A-7. Annual Training Activities in the MIRC Study Area (continued)

Range Activity	Platform	System or Ordnance	No Action Alternative	Alternative 1	Alternative 2	Location
Air Warfare (AW) (continued)						
MISSILEX / GUNEX Air-to-Air	FA-18; EA-18; AV-8B. TALD tgt.	AIM-7 Sparrow (Non Explosive). 20mm or 25 mm cannon.	4 sorties (2-4 aircraft) (4 missiles; 1,000 rounds)	6 sorties (2-4 aircraft) (6 missiles; 1,500 rounds)	8 sorties (2-4 aircraft) (8 missiles; 2,000 rounds)	PRI: W-517 SEC: MI Maritime, >12nm from land; ATCAAs
		AIM-9 Sidewinder (HE)/AIM-120 (HE or Inert). 20mm or 25 mm cannon.AIM-9 Sidewinder (HE). 20mm or 25 mm cannon.	4 sorties (2-4 aircraft) (4 missiles; 1,000 rounds)	6 sorties (2-4 aircraft) (6 missiles; 1,500 rounds)	8 sorties (2-4 aircraft) (8 missiles; 2,000 rounds)	
MISSILEX Ship-to-Air	CVN, LHD, CG, DDG; BQM-74E.	RIM-7 Sea Sparrow RIM-116 RAM RIM-67 SM-II ER	1 (1 missile)	2 (2 missile)	2 (2 missile)	PRI: W-517 SEC: MI Maritime, >12nm from land; ATCAAs
Amphibious Warfare (AMW)						
FIREX (Land)	CG, DDG	5" Guns and (HE) shells	4 (400 rounds)	8 (800 rounds)	10 (1,000 rounds)	FDM (R-7201)
Amphibious Assault Marine Air Ground Task Force (MAGTF)	1 LHA or LHD, 1 LPD, 1 LSD, 1 CG or DDG, and 2 FFG.	4-14 AAV/EFV or LAV/LAR; 3-5 LCAC; 1-2 LCU; 4 H-53; 12 H-46 or 10 MV-22; 2 UH-1; 4 AH-1; 4 AV-8	1 event (assault, offload, backload)	5 events (assault, offload, backload)	5 events (assault, offload, backload)	PRI: Tinian Military Leased Area; Unai Chulu (beach) and Tinian Harbor; North Field. SEC: Apra Harbor; Reserve Craft Beach; Polaris Point Beach (MWR) and Polaris Point Field; Orote Point Airfield; Sumay Cove and MWR Ramp
Amphibious Raid Special Purpose MAGTF	1 LHA or LHD, 1 LPD, and 1 LSD. Tailored MAGTF.	4-14 AAV/EFV or LAV/LAR; 0-5 LCAC; 0-2 LCU; 4 H-53; 12 H-46 or 10 MV-22; 2 UH-1; 4 AH-1; 4 AV-8	0	2 events (raid, offload, backload)	2 events (raid, offload, backload)	PRI: Apra Harbor; Reserve Craft Beach; Polaris Point Beach (MWR) and Polaris Point Field; Orote Point Airfield; Field; Sumay Cove and MWR Marina Ramp SEC: Tinian Military Leased Area; Unai Chulu (beach) and Tinian Harbor; North Field.

Table A-7. Annual Training Activities in the MIRC Study Area (continued)

Range Activity	Platform	System or Ordnance	No Action Alternative	Alternative 1	Alternative 2	Location
Expeditionary Warfare						
Military Operations in Theater (MOUT) Training	USMC Infantry Company: AH-1, UH-1; H-46 or MV-22; H-53; AAV, LAV, HMMWV, TRUCK	5.56 mm blanks/Simulations	2 events, 7-21 days/event	5 events of 7-21 days/event	5 events of 7-21 days/event	PRI: Guam; AAFB South; Finegayan Communication Annex; Barrigada Housing; Northwest Field SEC: Tinian; Rota; Saipan
	USAF RED HORSE SQUADRON: TRUCK, HMMWV; MH-53; H-60		2 events, 3-5 days/event	4 events, 3-5 days/event	4 events, 3-5 days/event	
	Navy NECC Company: HMWWV, TRUCK		2 events, 3-5 days/event	4 events, 3-5 days/event	4 events, 3-5 days/event	
	Army Reserve/GUARNG Company; HMWWV, TRUCK		2 events, 3-5 days/event	4 events, 3-5 days/event	4 events, 3-5 days/event	
Special Warfare						
Direct Action	SEAL Tactical Air Control Party (TAC-P); RHIB; Small Craft.	M-16, M-4, M-249 SAW, M-240G, .50 cal, M-203 (5.56 /7.62 mm/ .50 cal round/ 40mm HE)	2 (2,000 rounds)	3 (3,000 rounds)	3 (3,000 rounds)	FDM (R-7201)
	SEAL Platoon/Squad; NECC Platoon/Squad; USMC Platoon/Squad; ARMY Platoon/Squad; USAF Platoon/Squad	5.56 mm blanks/Simulations 9mm (Orote Pt. Combat Qualification Center - OPCQC) 1.5 lb NEW C4 (Navy Munitions Site Breaching House)	32 (12,500 9mm) (10.5 lb NEW C4)	40 (15,000 9mm) (15 lb NEW C4)	48 (17,500 9mm) (19.5 lb NEW C4)	PRI: OPCQC and Navy Munitions Site Breacher House SEC: Tarague Beach CQC and Navy Munitions Site Breacher House.

Table A-7. Annual Training Activities in the MIRC Study Area (continued)

Range Activity	Platform	System or Ordnance	No Action Alternative	Alternative 1	Alternative 2	Location
Special Warfare (SW) (ccontinued)						
Military Operations iIn Theater (MOUT) Training	SEAL Platoon/Squad; EOD Platoon/Squad; HMWWV; TRUCK	5.56 mm blanks/Simulations	6 events of 3-5 days/event	8 events of 3-5 days/event	10 events of 3-5 days/event	PRI: Guam; AAFB South; Finegayan Communication Annex; Barrigada Housing; Navy Munitions Site Breaching House SEC: Tinian; Rota; Saipan
Parachute Insertion	SEAL Platoon/Squad; EOD Platoon/Squad; ARMY Platoon/Squad USAF Platoon/Squad; C-130; CH-46; H-60	Square Rig or Static Line	6	12	12	PRI: Orote Pt. Airfield; Northwest Airfield; Orote Pt. Triple Spot SEC: Finegayan DZ; Apra Harbor; Navy Munitions Site Breacher House
Insertion/ Extraction	SEAL Platoon/Squad; EOD Platoon/Squad; ARMY Platoon/Squad; USMC Platoon/Squad; USAF Platoon/Squad: RHIB; Small Craft; CRRC; H-60; H-46 or MV-22	Square Rig or Static Line; Fastrope; Rappel; SCUBA	104	150	150	PRI: Orote Pt. Airfield; Northwest Field; Orote Pt. Triple Spot; Apra Harbor; Gab Gab Beach SEC: Orote Pt. CQC; Finegayan DZ; Haputo Beach; Munitions Site Breacher House; Polaris Pt. Field; Orote Pt. KD Range
Hydrographic Surveys	SEAL Platoon/Squad; EOD Platoon/Squad; USMC Platoon/Squad; Small Craft; RHIB; CRRC; H-60	SCUBA	3	6	6	PRI: FDM; Tinian; Tipalao Cove SEC: Haputo Beach; Gab Gab Beach; Dadi Beach
Breaching (Buildings, Doors)	SEAL Platoon/Squad; EOD Platoon/Squad; ARMY Platoon/Squad; USMC Platoon/Squad;	Breach House (1 lbs NEW C4 max/door)	10 (15 lbs NEW C4)	20 (30 lbs NEW C4)	20 (30 lbs NEW C4)	Navy Munitions Site Breacher House

Table A-7. Annual Training Activities in the MIRC Study Area (continued)

Range Activity	Platform	System or Ordnance	No Action Alternative	Alternative 1	Alternative 2	Location
Special/Expeditionary Warfare						
Land Demolitions (IED Discovery/ Disposal)	NECC EOD Platoon/ Squad; USMC EOD Platoon/ Squad; USAF EOD Platoon/ Squad: HMWWV; TRUCK	IED Shapes	60	120	120	PRI: Guam, Orote Pt. Airfield; Orote Pt. CQC; Polaris Pt. Field; Andersen South; Northwest Field SEC: Northern/Southern Land Navigation Area; Munitions Site Breacher House; Tinian MLA
Land Demolitions (UXO Discovery/ Disposal)	NECC EOD Platoon/ Squad; USMC EOD Platoon/ Squad; USAF EOD Platoon/ Squad: HMWWV; TRUCK	UXO	100	200	200	PRI: Navy Munitions Site EOD Disposal Site (limit 3000 lbs NEW per UXO event) SEC: AAFB EOD Disposal Site (limit 100 lbs per event)
Seize Airfield	SEAL Company/ Platoon USMC Company/ Platoon ARMY Company/ Platoon USAF Squadron C-130; MH-53; H-60; HMWWV; TRUCK	5.56 mm blank/Simulationsimunitions	2	12	12	PRI: Northwest Field SEC: Orote Pt. Airfield; Tinian North Field
Airfield Expeditionary	USAF RED HORSE Squadron. NECC SEABEE Company. USMC Combat Engineer Company USAR Engineer Dozer, Truck, Crane, Forklift, Earth Mover, HMMWV. C-130; H-53.	Expeditionary Airfield Repair and Operation	1	12	12	PRI: Northwest Field SEC: Orote Pt. Airfield; Tinian North Airfield

Table A-7. Annual Training Activities in the MIRC Study Area (continued)

Range Activity	Platform	System or Ordnance	No Action Alternative	Alternative 1	Alternative 2	Location
Special/Expeditionary Warfare (cContinued)						
Intelligence, Surveillance, Reconnaissance (ISR)	SEAL Platoon/Squad; ARMY Platoon/Squad; USMC Platoon/Squad; USAF Platoon/Squad	Night Vision; Combat Camera; 5.56 mm blanks/Simunition	12	16	16	PRI: Guam; Northwest Field; Barrigada Housing; Finegayan Comm. Annex; Orote Pt. Airfield. SEC: Tinian, Rota, Saipan
Field Training Exercise (FTX)	ARMY Company/ Platoon NECC SEABEE Company/ Platoon	Tents; Trucks; HMMWV; Generators	100 events, 2-3 days per event	100 events, 2-3 days per event	100 events, 2-3 days per event	PRI: Guam, Northwest Field; Northern Land Navigation Area SEC: Orote Pt. Airfield; Polaris Pt. Field; Tinian North Field.
Non-Combatant Evacuation Operation (NEO)	Amphibious Shipping (1-LHD; 1-LPD; 1-LSD) USMC Special Purpose MAGTF	HMMWV; Trucks; Landing Craft (LCAC/ LCU); AAV/ LAV; H-46 or MV-22	1 event, 3-5 days	2	2	PRI: Apra Harbor; Reserve Craft Beach; Polaris Point Beach (MWR) and Polaris Point Field; Orote Point Airfield; Northwest Field; Sumay Cove and MWR Marina Ramp SEC: Tinian Military Leased Area; Unai Chulu (beach) and Tinian Harbor; North Field.
MANEUVER (Convoy; Land Navigation)	USMC Company/Platoon Army Company/Platoon	Trucks; HMWWV;AAV/LAV	8	16	16	PRI: Northwest Field; AAFB South; Northern and Southern Land Navigation Area; Tinian MLA SEC: Finegayan Annex; Barrigada Annex; Orote Pt. Airfield;

Table A-7. Annual Training Activities in the MIRC Study Area (continued)

Range Activity	Platform	System or Ordnance	No Action Alternative	Alternative 1	Alternative 2	Location
Special/Expeditionary Warfare (continued)						
Humanitarian Assistance/ Disaster Relief Operation (HADR)	Amphibious Shipping (1-LHD; 1-LPD; 1-LSD) USMC Special Purpose MAGTF	HMMWV; Trucks; Landing Craft (LCAC/ LCU); AAV/ LAV; H-46 or MV-22	1 event, 3-5 days	2	2	PRI: Apra Harbor; Reserve Craft Beach; Polaris Point Beach (MWR) and Polaris Point Field; Orote Point Airfield; Northwest Field; Sumay Cove and MWR Marina Ramp SEC: Tinian Military Leased Area; Unai Chulu (beach) and Tinian Harbor; North Field.
Force Protection / Anti-Terrorism						
Embassy Reinforcement	SEAL Platoon ARMY Platoon USMC Company/ Platoon Trucks; HMMWV; C-130; H-60; H-53	5.56 mm blanks/Simulationsmunitions	42 events, 1-2 days per event	50 events, 2-3 days per event	50 events, 2-3 days per event	PRI: Orote. Pt. Airfield Inner Apra Harbor; Northern and Southern Land Navigation Area SEC: Orote Pt. Triple Spot; Orote Pt. CQC; Kilo Wharf
Force Protection	USAF Squadron/ Platoon NECC SEABEE Company/ Platoon USAR Engineer Company/ Platoon Tents; Trucks; HMMWV; Generators	5.56 mm blanks/Simulations	60 events, 1-2 days per event	75 events, 1-2 days per event	75 events, 1-2 days per event	PRI: Guam, Northwest Field; Northern Land Navigation Area; Barrigada Annex SEC: Orote Pt. Airfield; Polaris Pt. Field; Tinian North Field.
Anti- Terrorism	Navy Base Security USAF Security Squadron USMC FAST Platoon Trucks; HMMWV; MH-60	5.56 mm blanks/Simulations	80 events, 1 day/event	80 events, 1 day/event	80 events, 1 day/event	PRI: Tarague Beach Shoot House and CATM Range; Polaris Pt.; Northwest Field. SEC: Kilo Wharf; Finegayan Comm. Annex; Navy Munitions Site; AAFB Munitions Site

Table A-8: Summary of Ordnance Use by Training Area in the MIRC Study Area[1]

Training Area and Ordnance Type	Number of Rounds Per Year		
	No Action	Alternative 1	Alternative 2
FDM (R-7201)			
Bombs (HE) ≤ 500 lb	400	500	600
Bombs (HE) 750 / 1000 / 2000 lb	1,600	1,650	1,700
Inert Bomb Training Rounds ≤ 2000 lb	1,800	2,800	3,000
Missiles [Maverick; Hellfire; TOW]	30	60	70
Cannon Shells (20 or 25 mm)	16,500	20,000	22,000
Cannon Shells (30 mm)	0	1,500	1,500
AC-130 Cannon Shells (40mm or 105mm)	100	200	200
5-inch Gun Shells	400	800	1,000
Small Arms [5.56mm; 7.62mm; .50 cal; 40mm]	2,000	3,000	3,000
PRI: Guam Maritime > 3 nm from land SEC: W-517			
MK-48 EXTORP	20	40	48
MK-46 or MK-50 REXTORP	0	7	14
MK-84 SUS (Signal Under Surface Device, Electro-Acoustic)	20	40	48

Table A-8. Summary of Ordnance Use by Training Area in the MIRC Study Area[1] (continued)

Training Area and Ordnance Type	Number of Rounds Per Year		
	No Action	Alternative 1	Alternative 2
PRI: W-517 SEC: Marianas Maritime > 12 nm; ATCAAs			
Air Deployed Mines [MK-62; MK-56]	320	480	480
Inert Bomb Training Rounds [MK-82 I; BDU-45; MK-76]	48	72	90
5-inch" Gun Shells	160	320	400
76 mm Gun Shells	60	120	150
.50 cal MG	4,400	16,000	16,000
25 mm MG	1,600	8,000	8,000
7.62 mm MG	30,000	40,000	40,000
20 mm; 25 mm; 30 mm Cannon Shells	8,000	18,500	19,500
RR-144A/AL Chaff Canisters	520	740	920
RR-188 Chaff Canisters	1,500	5,000	5,500
MK-214; MK-216 Chaff Canisters	72	90	108
MK-46 MOD 1C; MJU-8A/B; MJU-27A/B; MJU-32B; MJU-53B; SM-875/ALE Flares	520	740	920
MJU-7; MJU-10; MJU-206 Flares	1,500	5,000	5,500
AIM-7 Sparrow	4	6	8
AIM-9 Sidewinder	4	6	8
AIM-120 AMRAAM	4	6	8
RIM-7 Sea Sparrow/ RIM-116 RAM / RIM-67 SM II ER	12	24	26
PRI: Marianas Maritime > 3 nm SEC: W-517			
EER/IEER/AEER	103	106	115
5.56 mm; 7.62 mm; .50 cal; 40 mm	12,000	16,000	20,000

Table A-8. Summary of Ordnance Use by Training Area in the MIRC Study Area[1] (continued)

Training Area and Ordnance Type	Number of Rounds Per Year		
	No Action	Alternative 1	Alternative 2
PRI: W-517 **SEC: Marianas Maritime > 50 nm; ATCAAs**	**SINKEX**		
HARM	2	4	4
SLAM-ER	14	28	28
HARPOON	5	10	10
5-inc"h Gun Shells	400	800	800
HELLFIRE	2	4	4
MAVERICK	8	16	16
GBU-12	10	20	20
GBU-10	4	8	8
MK-48	1	2	2
Underwater Demolitions [100 lb NEW]	2	4	4
PRI: Agat Bay (20 lb NEW max) **SEC: Apra Harbor (10 lb NEW max)**	**Underwater Demolition**		
5 – 20 lb NEW	22	30	30
PRI: Agat Bay (20 lb NEW max) **SEC: Piti (20 lb NEW max)**	**Floating Mine Neutralization**		
5 – 20 lb NEW	8	20	20

1. Baseline ordnance expenditure estimates were made from review of FY2003-2007 Service records, databases, schedules, and estimates.

Table A-9. Summary of Sonar Activity by Exercise Type in the MIRC Study Area

Exercise Type	No Action	Alternative 1	Alternative 2
Multi-Strike Group: One; [3] CSG; April – September; [10] Days	Activity Guidelines Per CSG: [34] SQS-53C/D; [1] SQS-56 ; [2] Dips per hour; [1] EER/IEER/AEER per hour until 72100; [16] DICASS per hour; Reset Time -12 hours		
Events Per Year	0 or 1 (One Multi-Strike Group Exercise or One Joint Expeditionary Exercise)	1	1
SQS-53C/D	1705 hours	1705 hours	1705 hours
SQS-56	77 hours	77 hours	77 hours
AQS-21&1322	288 dips	288 dips	288 dips
DICASS	1282	1282	1282
Sub BQQ	00	00	00
EER/IEER/AEER	98	98	98
SINKEX : Two [2] Day Event	Activity Guidelines: Sonar Hours in TRACKEX/TORPEX below		
Events Per Year	1	2	2
DICASS	100	200	200
MK-48 (HE)	1	2	2
Joint Expeditionary: One [1] CSG + ESG; [10] Days	Activity Guidelines: [3] SQS-53C/D; [1] SQS-56; Sonar Hours and Sonobuoys in TRACKEX/TORPEX below		
Events Per Year	0 or 1 (One Multi-Strike Group Exercise or One Joint Expeditionary Exercise)	1	1
Fleet Strike Group: One [1] CSG; [7] Days	Activity Guidelines: [34] SQS-53C/D; [1] SQS-56; Sonar Hours and Sonobuoys in TRACKEX/TORPEX below		
Events Per Year	0	0	1
Integrated ASW: One [1] CSG; [5] Days	Activity Guidelines: [34] SQS-53C/D; [1] SQS-56; Sonar Hours and Sonobuoys in TRACKEX/TORPEX below		
Events Per Year	0	0	1

Table A-9. Summary of Sonar Activity by Exercise Type in the MIRC Study Area (continued)

Exercise Type	No Action	Alternative 1	Alternative 2
Ship Squadron ASW: One [1] DESRON; [5] Days	Activity Guidelines: [4] SQS-53C/D; [1] SQS-56; Sonar Hours and Sonobuoys in TRACKEX/TORPEX below		
Events Per Year	0	0	1
MAGTF Exercise (STOM/NEO)	Activity Guidelines: [2] SQS-53C/D; [1] SQS-56; Sonar Hours and Sonobuoys in TRACKEX/TORPEX below		
Events Per Year	1	4	4
ASW TRACKEX (SHIP) : One [1] Reset, One [1] Day Event	Activity Guidelines: [2] SQS-53C/D, [1] SQS-56; Reset Time - 8 hours (sub target), 4 hours (non-sub target); [3] 53C/D, ½ Time Active, [1] 56, ¼ Time Active		
Events Per Year	10	30	60
SQS-53 C/D	120 hours	360 hours	720 hours
SQS-56	20 hours	60 hours	120 hours
ASW TRACKEX (HELO) : One [1] Reset, One [1] Day Event	Activity Guidelines: [2] SH-60B; [1] SH-60F 2 dips per hour; Reset Time - 8 hours (sub target), 4 hours (non-sub target)		
Events Per Year	9	18	62
AQS-22	144 dips	288 dips	576 dips
DICASS	36	72	144
ASW TRACKEX (MPA) : One [1] Reset, [1] Day Per Event	Activity Guidelines: [1] MPA; Reset Time - 8 hours (sub target), 4 hours (non-sub target)		
Events Per Year	5	8	17
DICASS	50	80	170
EER/IEER/AEER	5	8	17
ASW TORPEX (SUB) : One [1] Reset, [1] Day Per Event; [1] EXTORP Per Event	Activity Guidelines: [1] SSN or SSGN; Reset Time - 8 hours (sub target), 4 hours (non-sub target)		
Events Per Year	5	10	12
Sub BQQ	6 hours	12 hours	15 hours
MK-48 EXTORP	20	40	48

Table A-9. Summary of Sonar Activity by Exercise Type in the MIRC Study Area (continued)

Exercise Type	No Action	Alternative 1	Alternative 2
ASW TORPEX (SHIP) : One [1] Reset, [1] Day pPer Event; [1] REXTORP	Activity Guidelines: [32] SQS-53C/D, [1] SQS-56; Reset Time - 8 hours (sub target), 4 hours (non-sub target); ½ Time Active[1] Ship ½ Time, [2] Ship ½ Time		
Events pPer Year	0	3	6
SQS-53 C/D	0	8 hours	16 hours
SQS-56	0	4 hours	8 hours
REXTORP	0	03	6
ASW TORPEX (MPA/HELO) : One [1] Reset, One [1] Day Event; [1] REXTORP	Activity Guidelines: [2] SH-60B; [1] SH-60F; [1] MPA; Reset Time - 8 hours (sub target), 4 hours (non-sub target)		
Events pPer Year	0	4	8
AQS-21&1322	0	16 dips	32 dips
DICASS	0	20	40
REXTORP	0	4	8

APPENDIX B

Essential Fish Habitat

APPENDIX B
LIST OF FIGURES

APPENDIX B
LIST OF FIGURES
(Continued)

CORAL REEF ECOSYSTEM MANAGEMENT UNIT SPECIES

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 MIRC study area (WPRFMC 2001; NMFS 2004c). In addition, another 14 species of surgeonfishes are found in the MIRC 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 MIRC 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 B-10, B-11, B-14, B-17, and B-20; 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.

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 MIRC study area (WPRFMC 2001; NMFS 2004c). Eight additional species of triggerfish are found in the MIRC 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 MIRC 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 pits excavated by the parents. Larvae are pelagic with prejuveniles often being associated with floating algae (WPRFMC 2001).

EFH Designations - (WPRFMC 2001; Figures B-10, B-11, B-14, B-17, and B-20; 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 MIRC study area (WPRFMC 2001; NMFS 2004b). In addition, the remaining 26 species of jacks found in the MIRC 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 MIRC 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 B-10, B-11, B-14, B-17, and B-20; 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 MIRC study area (WPRFMC 2001; NMFS 2004c). In addition, the four other species of requiem sharks found in the MIRC 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 MIRC 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, Hawaii, 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 B-10, B-11, B-14, B-17, and B-20; Table 4-5)

<u>Eggs and Larvae</u>—N/A

<u>Adult and Juveniles</u> - 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 MIRC study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining 16 holocentrid species found in the MIRC 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 MIRC 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 B-10, B-11, B-14, B-17, and B-20; 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 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 MIRC study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining two flagtail species found in the MIRC 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 MIRC 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 B-12, B-15, and B-18; Table 4-5)

<u>Eggs and Larvae</u> - The water column from the shoreline to the outer limits 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 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 MIRC study area (WPRFMC 2001; NMFS 2004c). In addition, the one remaining rudderfish species found in the MIRC 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 MIRC 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 B-13, B-16, and B-19; Table 4-5)

<u>Eggs, Larvae, and Juvenile</u> - The water column from the shoreline to the outer boundary of the EEZ to a depth of 100 m.

<u>Adult</u> - 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 MIRC study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining 65 wrasse species found in the MIRC 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 MIRC 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 B-10, B-11, B-14, B-17, and B-20; 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 MIRC study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining three species of goatfishes found in the MIRC 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 MIRC 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 B-10, B-11, B-14, B-17, and B-20; 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 MIRC study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining two species of mugulids found in the MIRC 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 smallscale, subsistence fisheries are probably also relatively prominent (Harrison and Senou 1999). None of the species found in the MIRC 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 B-12, B-15, and B-18; Table 4-5)

<u>Eggs/Larvae</u> - The water column from the shoreline to the outer limits of the EEZ to a depth of 100 m.

<u>Juvenile/Adult</u> - 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 MIRC study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining 43 species of moray eels found in the MIRC 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 MIRC 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 B-10, A-11, B-14, B-17, and B-20; 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 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 MIRC study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining 22 species of octopus found in the MIRC 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 MIRC 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 Hawaii 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 B-10, B-11, A-14, B-17, and B-20; 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 MIRC 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 Hawaii, 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 B-10, B-11, B-14, B-17, and B-20; 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 MIRC study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining 4 species of bigeyes found in the MIRC 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 B-10, B-11, B-14, B-17, and B-20; 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 MIRC 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 B-10, B-11, B-14, B-17, and B-20; 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 MIRC study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining 21 species of parrotfishes found in the MIRC 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 B-10, B-11, B-14, B-17, and B-20; 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 MIRC study area (WPRFMC 2001; NMFS 2004c). The remaining 2 species of rabbitfish found in the MIRC 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 MIRC 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 B-10, B-11, B-14, B-17, and B-20; 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 MIRC study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining 4 species of barracudas found in the MIRC 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 MIRC 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 B-10, B-11, B-14, B-17, and B-20; Table 4-5)

<u>Eggs, Larvae, Juvenile, and Adult</u> - 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 MIRC 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 MIRC 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 MIRC 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 B-10, B-11, B-14, B-17, and B-20; 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 of 100 m.

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 MIRC 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 MIRC 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 B-10, B-11, B-14, B-17, and B-20; 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 MIRC 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 MIRC study area (WPRFMC 2001; NMFS 2004c). Currently, no data are available to determine if the yelloweyed 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 MIRC 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 MIRC 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 Hawaiian 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 MIRC study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining

15 species of angelfishes found in the MIRC 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 MIRC study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining seven species of hawkfishes found in the MIRC 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 Hawaii 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 MIRC study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining 27 species of butterflyfishes found in the MIRC 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 MIRC 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 MIRC study area (WPRFMC 2001; NMFS 2004c). In addition, the remaining 46 species of damselfishes found in the MIRC 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 MIRC 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 MIRC 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).

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 B-10, B-11, B-14, B-17, and B-20; Table 4-5; WPRFMC 2001).

A complete list of the PHCRT occurring in the MIRC 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.

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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 to 100 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 MIRC 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 MIRC 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 midmorning with a different female each day. Females then deposit the eggs in tufts of algae (Myers 1999). Porcupinefish may spawn pelagic or demersal eggs depending on species. As observed in one species, the spiny balloonfish (*Diodon holacanthus*) spawning takes place at the surface near dawn or dusk as pairs or groups of males with a single female. In Hawaii, 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 tospawning sites on the outer reef slope for group spawning at dusk (WPRFMC 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 MIRC 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 MIRC 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 (WPRFMC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 Hawaii, 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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).

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 MIRC 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 (DoN 2005b).

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; DoN 2005b). 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; DoN 2005b). Sea slugs prey on diverse taxa including soft corals and sponges (Colin and Arneson 1995; DoN 2005b).

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 MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC study area (WPRFMC 2001; NMFS 2004c). While bryozoans are probably very diverse in the MIRC 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 Hawaii 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; DoN 2005b).

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 MIRC 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; DoN 2005b). 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 MIRC 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 MIRC 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 MIRC 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).

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 MIRC 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 MIRC 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 MIRC study area (WPRFMC 2001; NMFS 2004c). Sponges are found throughout the MIRC 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 MIRC study area (WPRFMC 2001; NMFS 2004c). Within the MIRC 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 MIRC 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; DoN 2005b) 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; DoN 2005b). 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 freeswimming 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 MIRC study area (WPRFMC 2001; NMFS 2004c). Major and minor coral (curio trade) fisheries exist within the western central Pacific (Hodgson 1998). Within the MIRC 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 MIRC 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 MIRC 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 MIRC 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 MIRC 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).

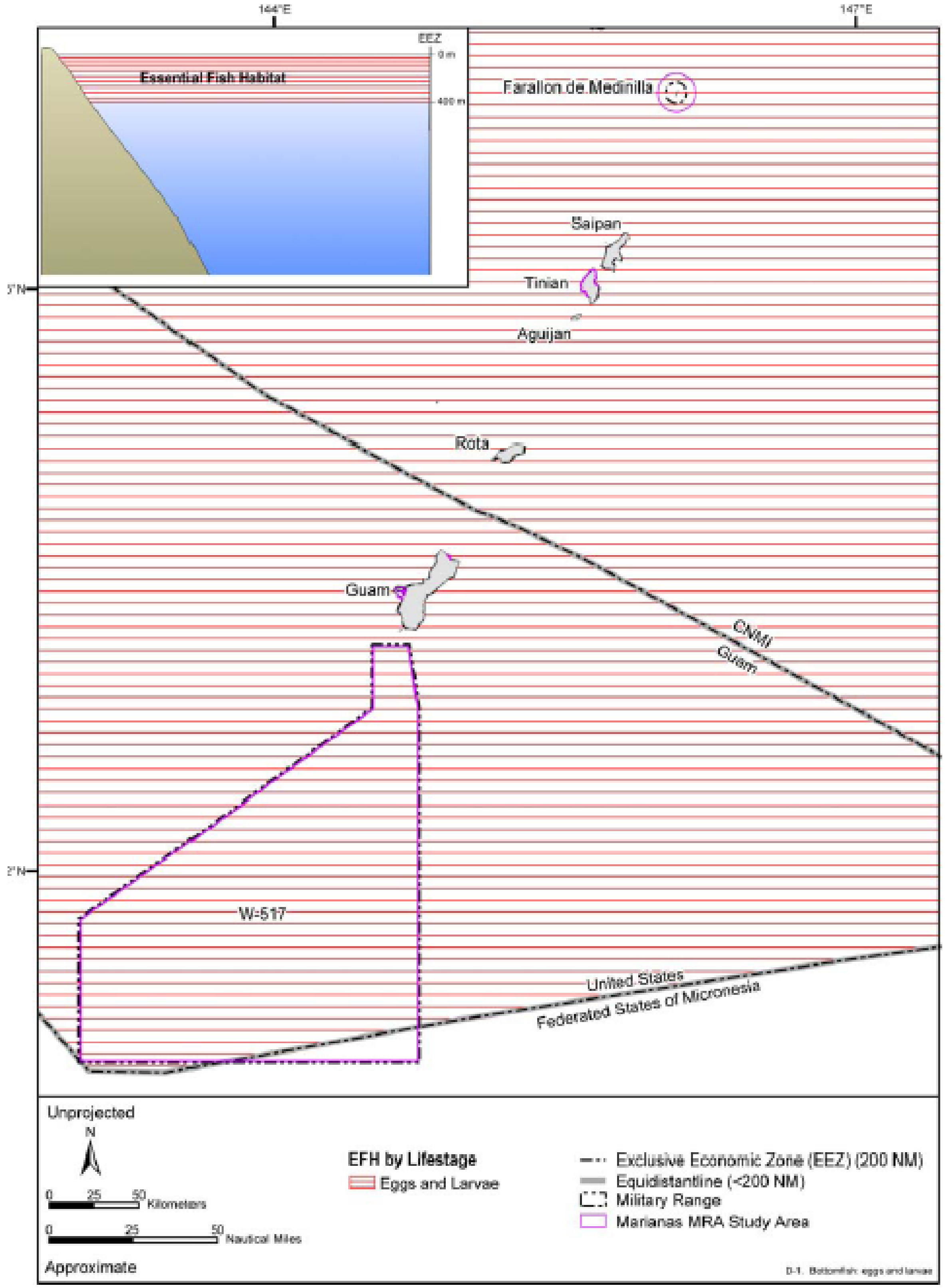


Figure B-1. Essential fish habitat (EFH) for all eggs and larval lifestages of bottomfish designated on Guam, Tinian, and Farallon de Medinilla in the MIRC study area.

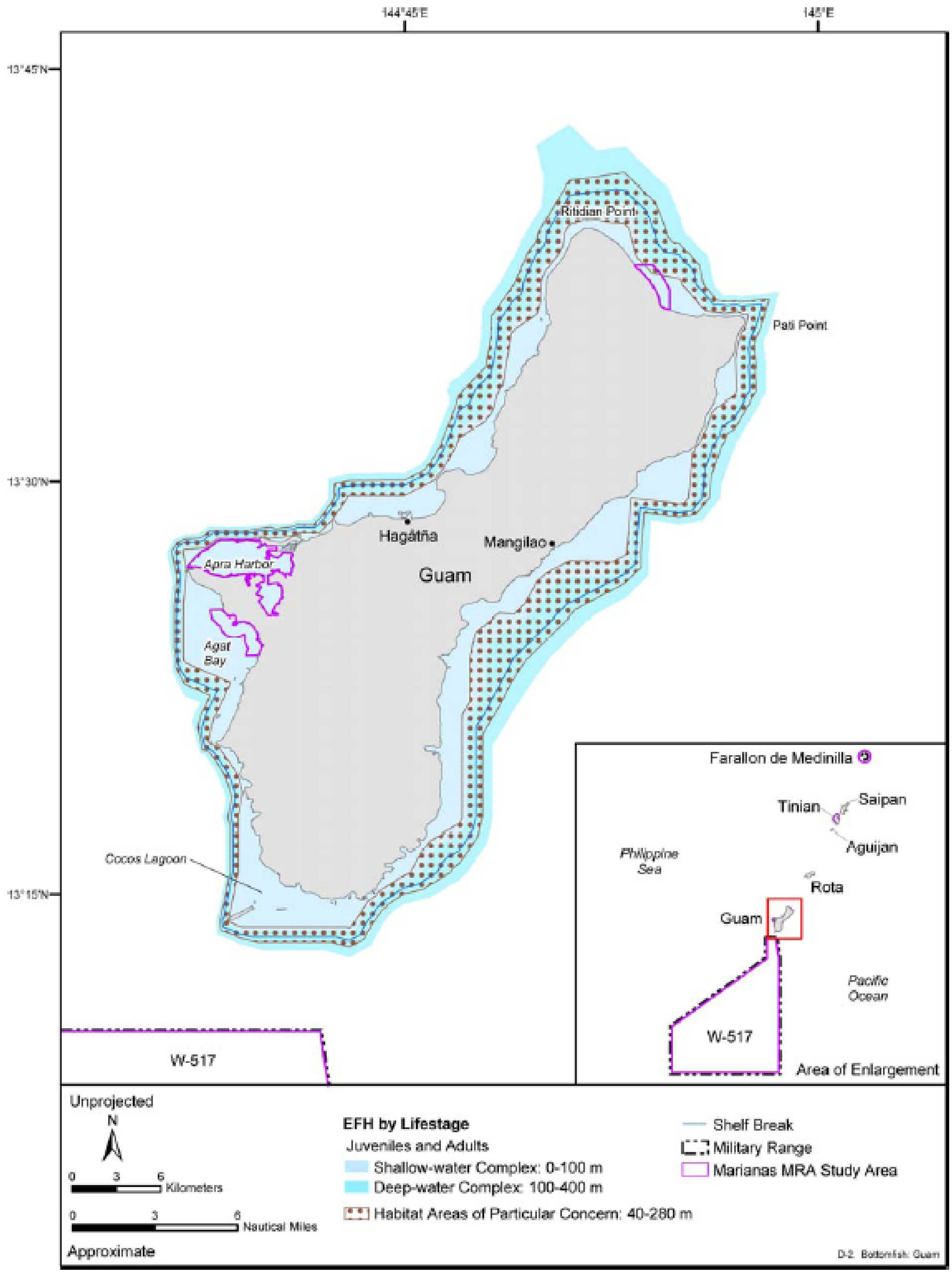


Figure B-2. EFH for all juvenile and adult lifestages of bottomfish and HAPC designated on Guam in the MIRC study area.

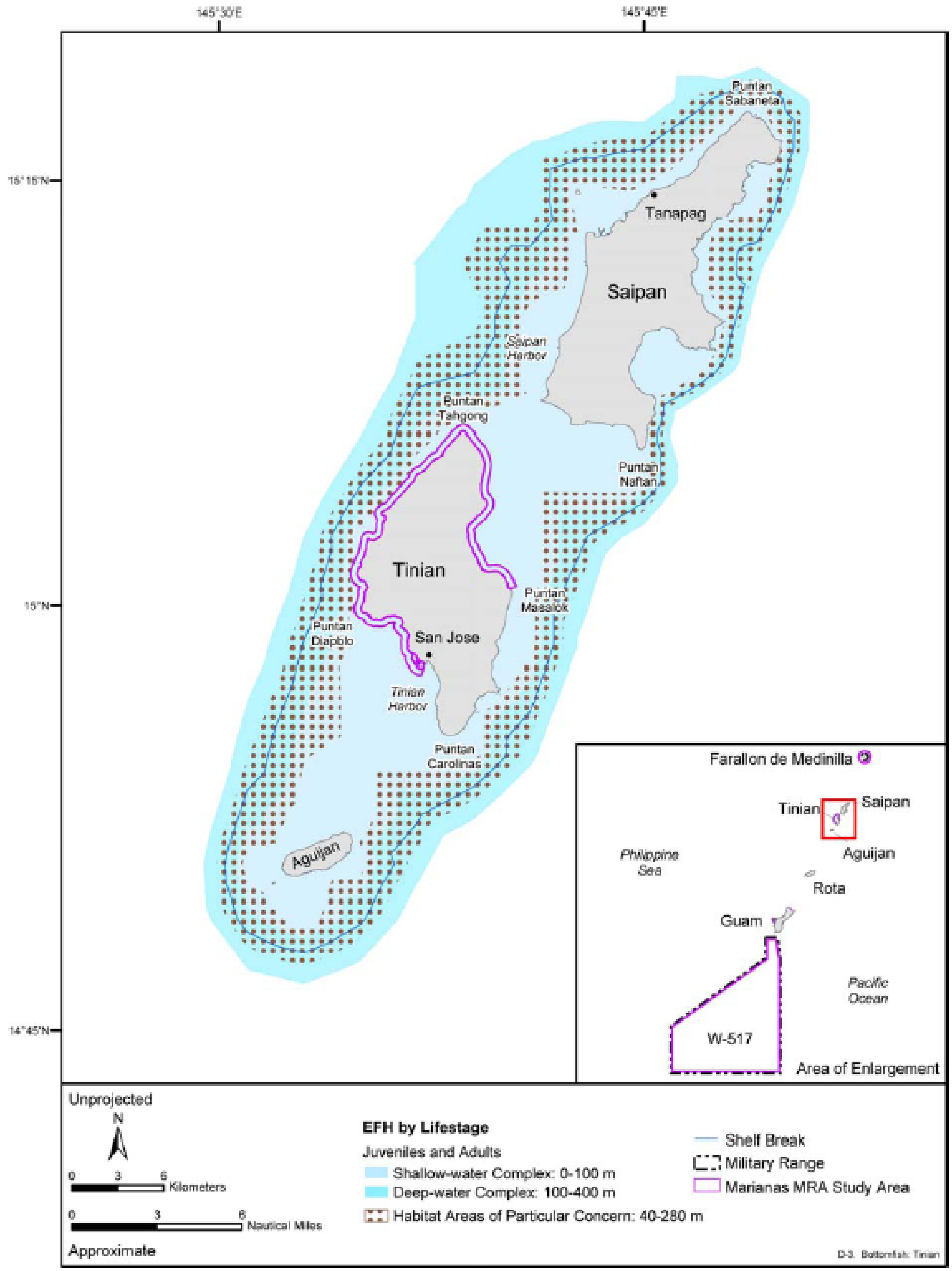


Figure B-3. EFH for all juvenile and adult lifestages of bottomfish and HAPC designated on Tinian in the MIRC study area.

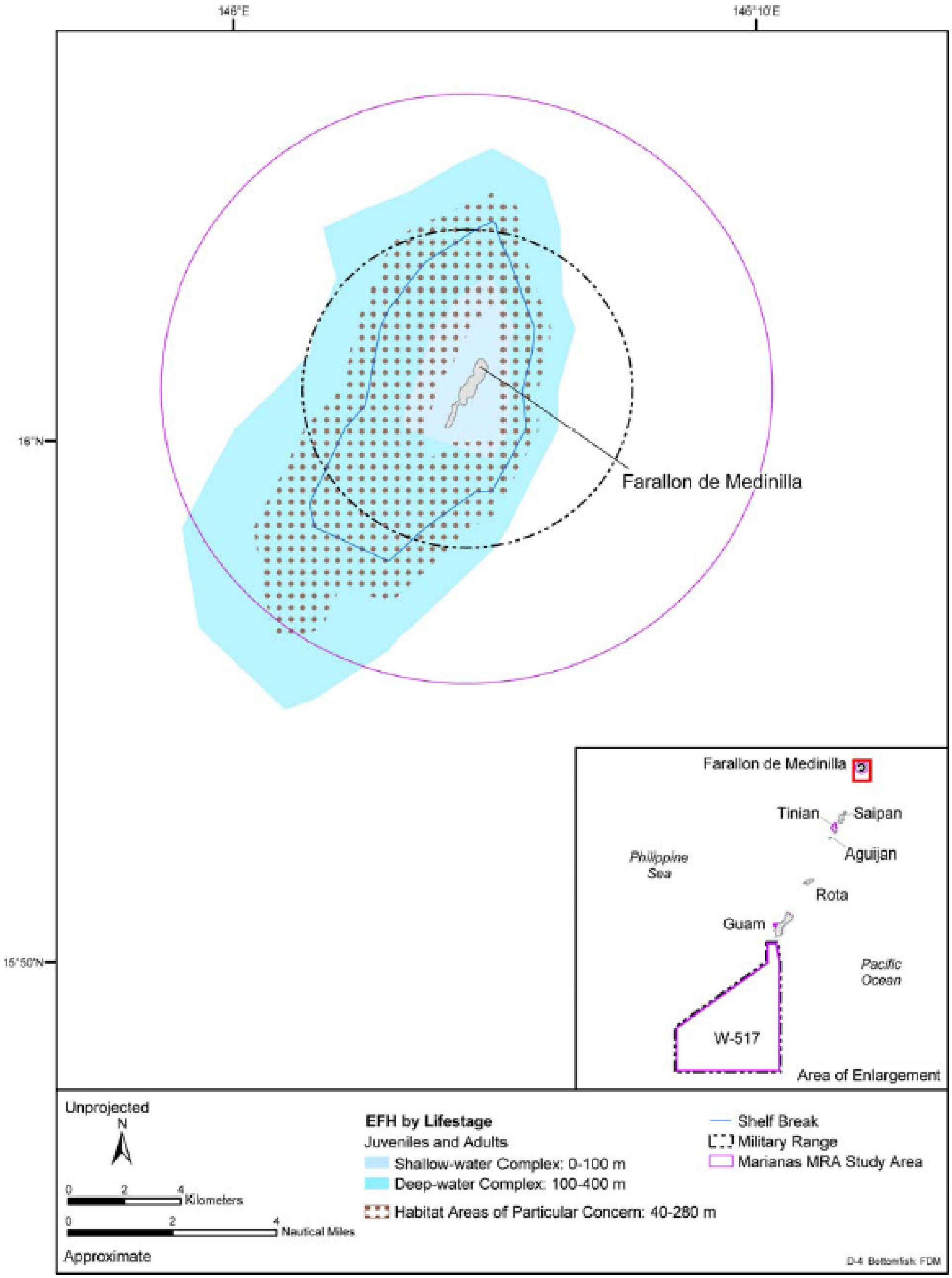


Figure B-4. EFH for all juvenile and adult lifestages of bottomfishes designated on Farallon de Medinilla (FDM) in the MIRC study area.

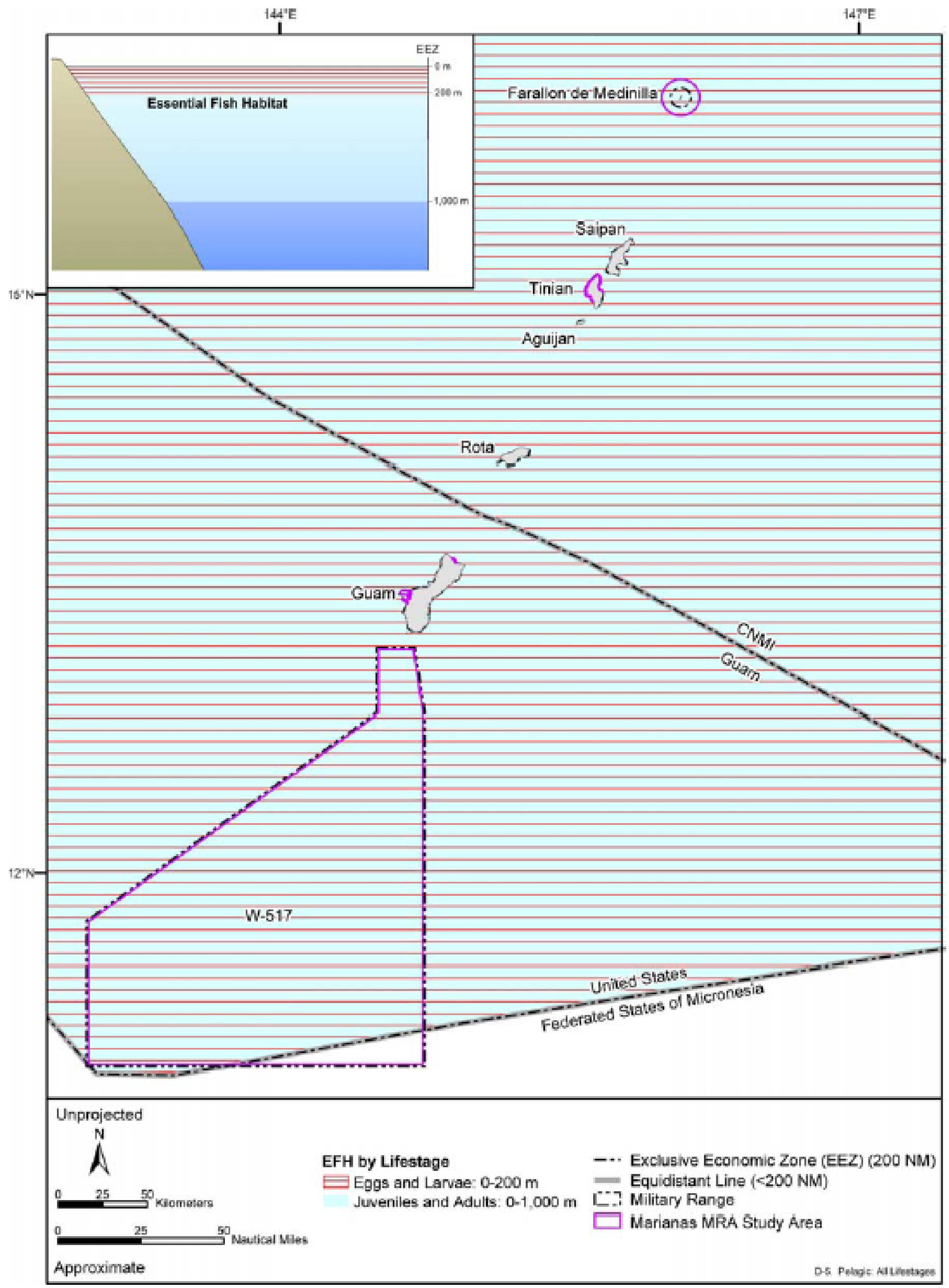


Figure B-5. EFH for all lifestages of pelagic fishes designated on Guam, Tinian, and FDM in the MIRC study area.

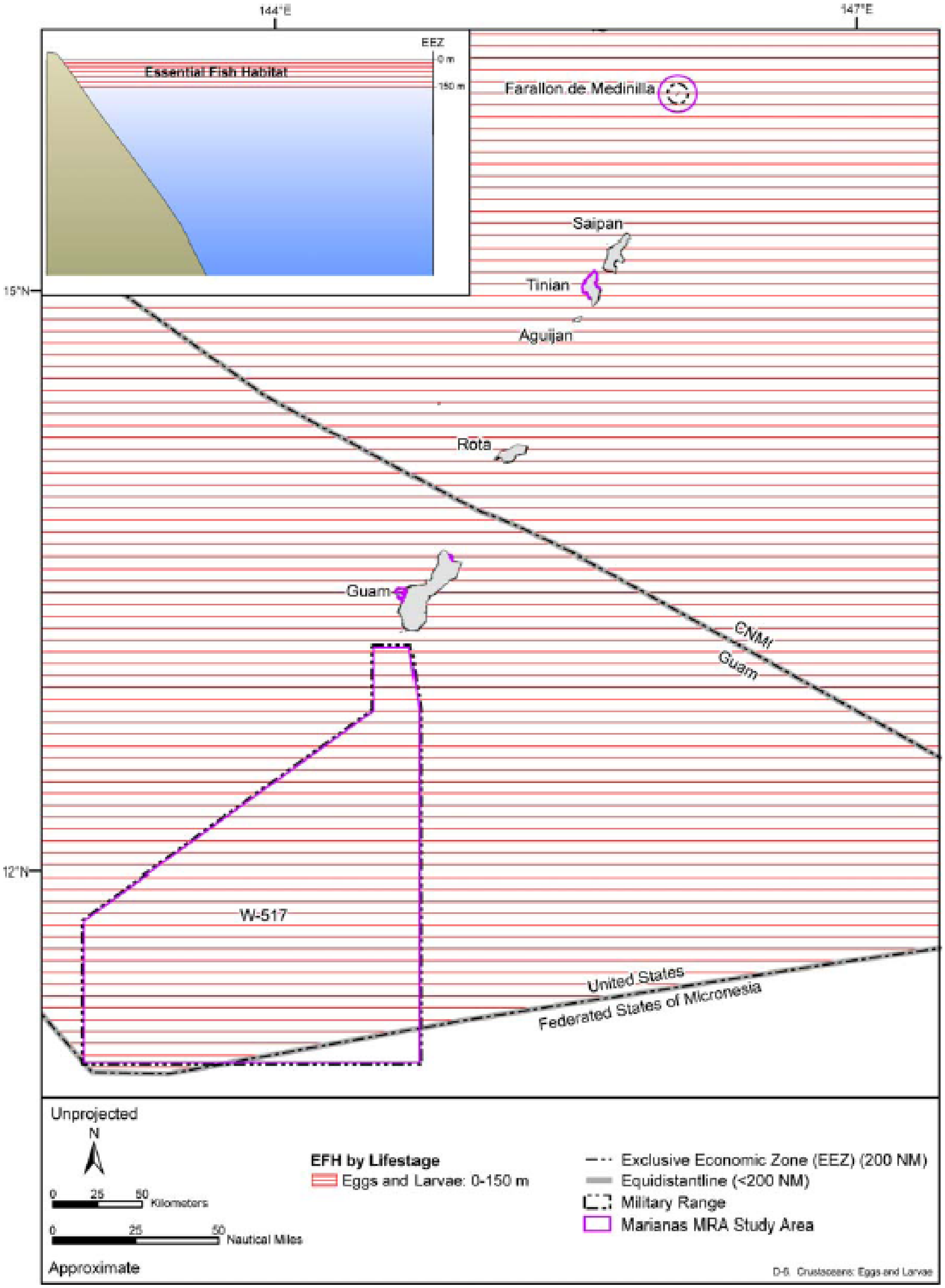


Figure B-6. EFH for all eggs and larval lifestages of crustaceans designated on Guam, Tinian, and FDM in the MIRC study area.

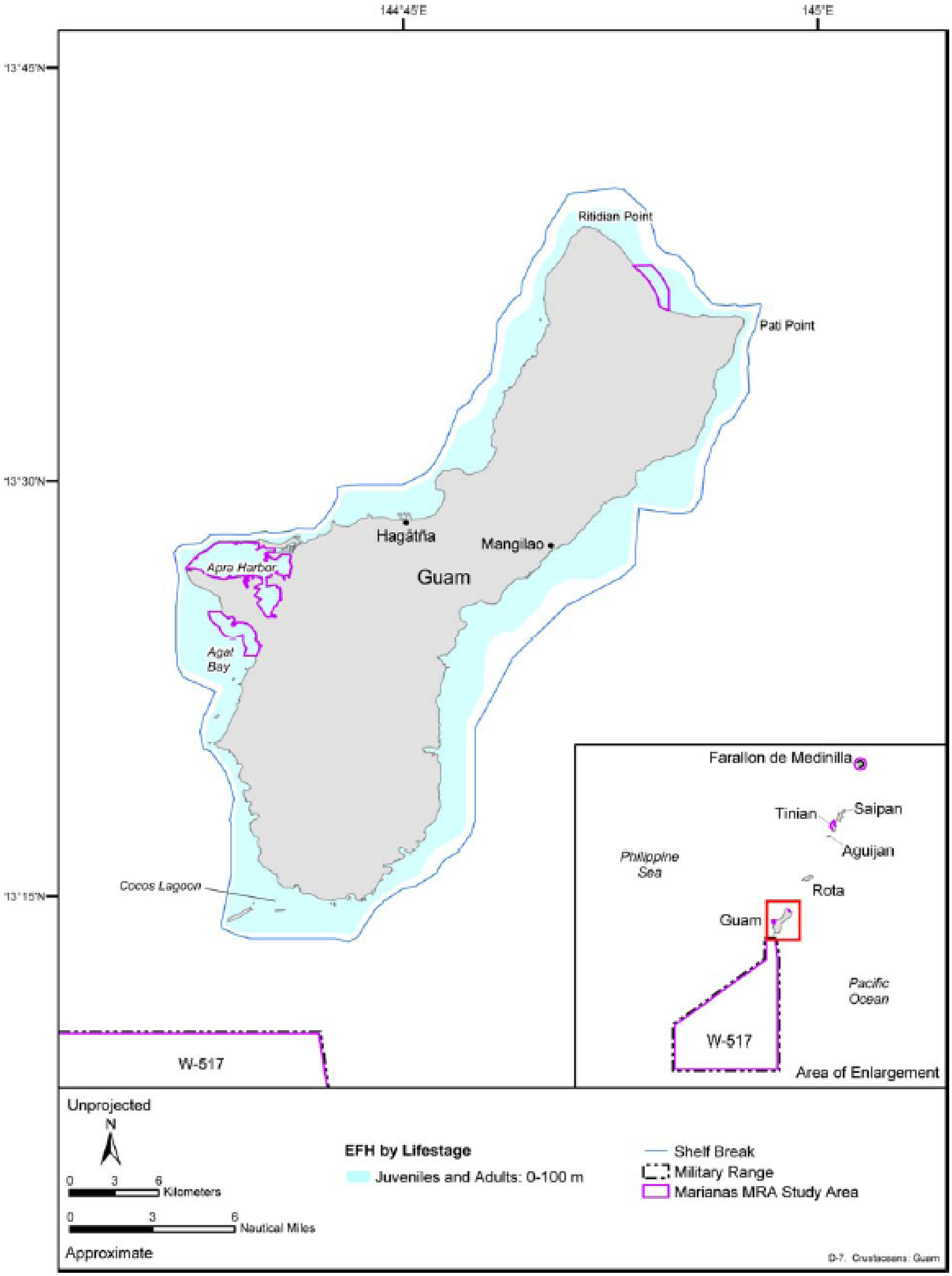


Figure B-7. EFH for all juvenile and adult lifestages of crustaceans designated on Guam in the MIRC study area.

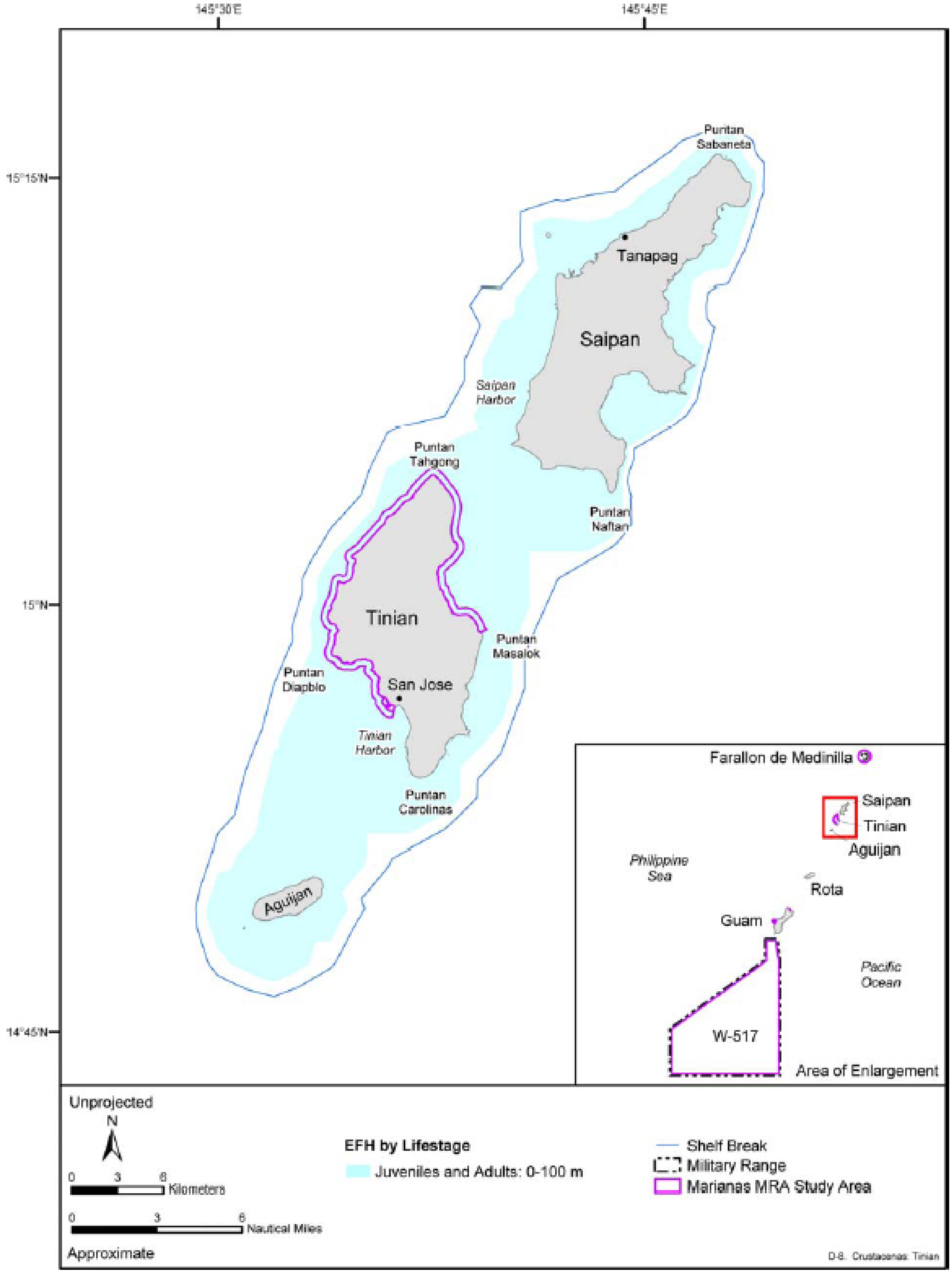


Figure B-8. EFH for all juvenile and adult lifestages of crustaceans designated on Tinian in the MIRC study area.

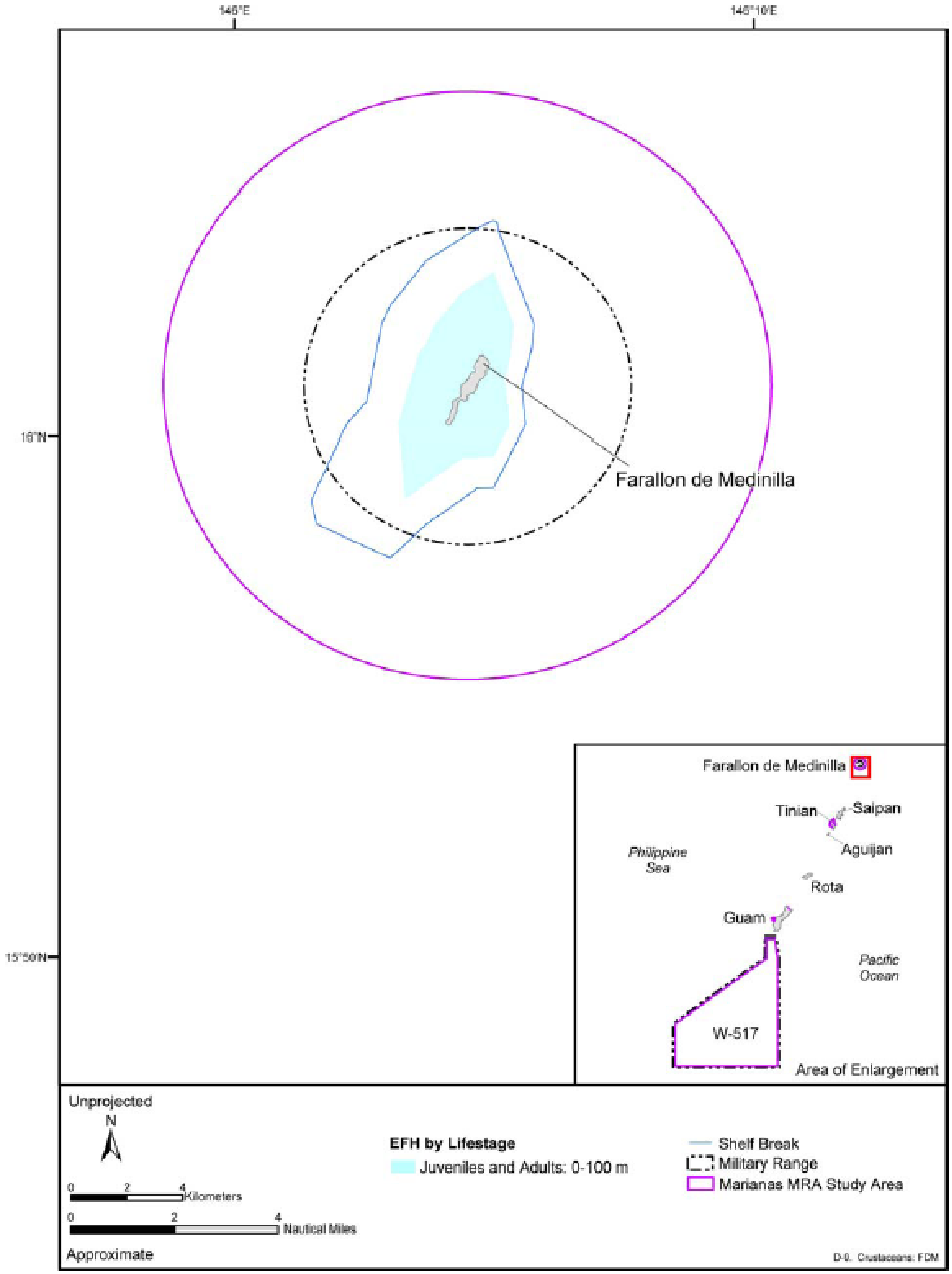


Figure B-9. EFH for all juvenile and adult lifestages of crustaceans designated on FDM in the MIRC study area.

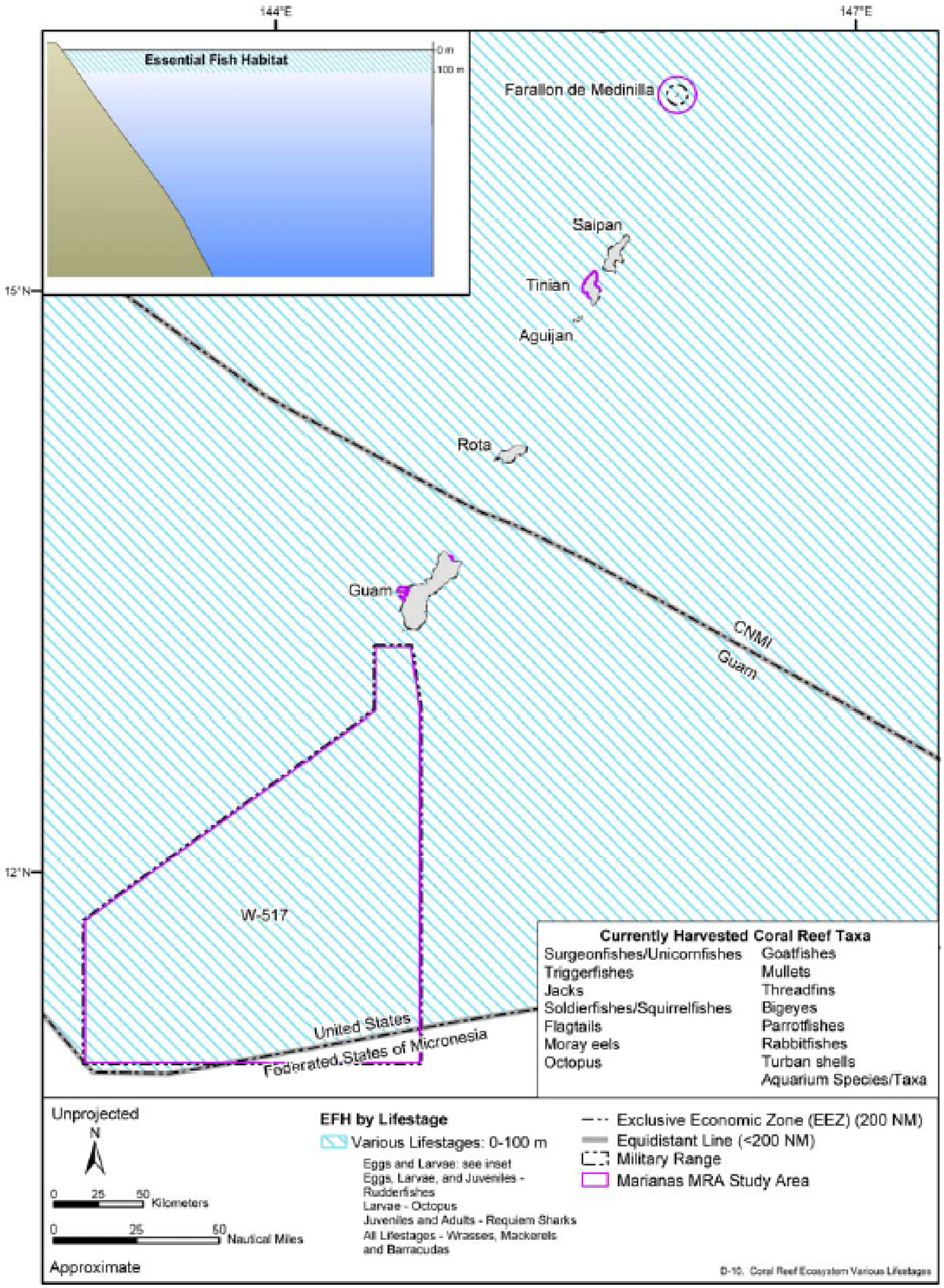


Figure B-10. EFH for various lifestages of the currently harvested coral reef taxa (CHCRT-coral reef ecosystem) and HAPC designated on Guam, Tinian, and FDM in the MIRC study area.

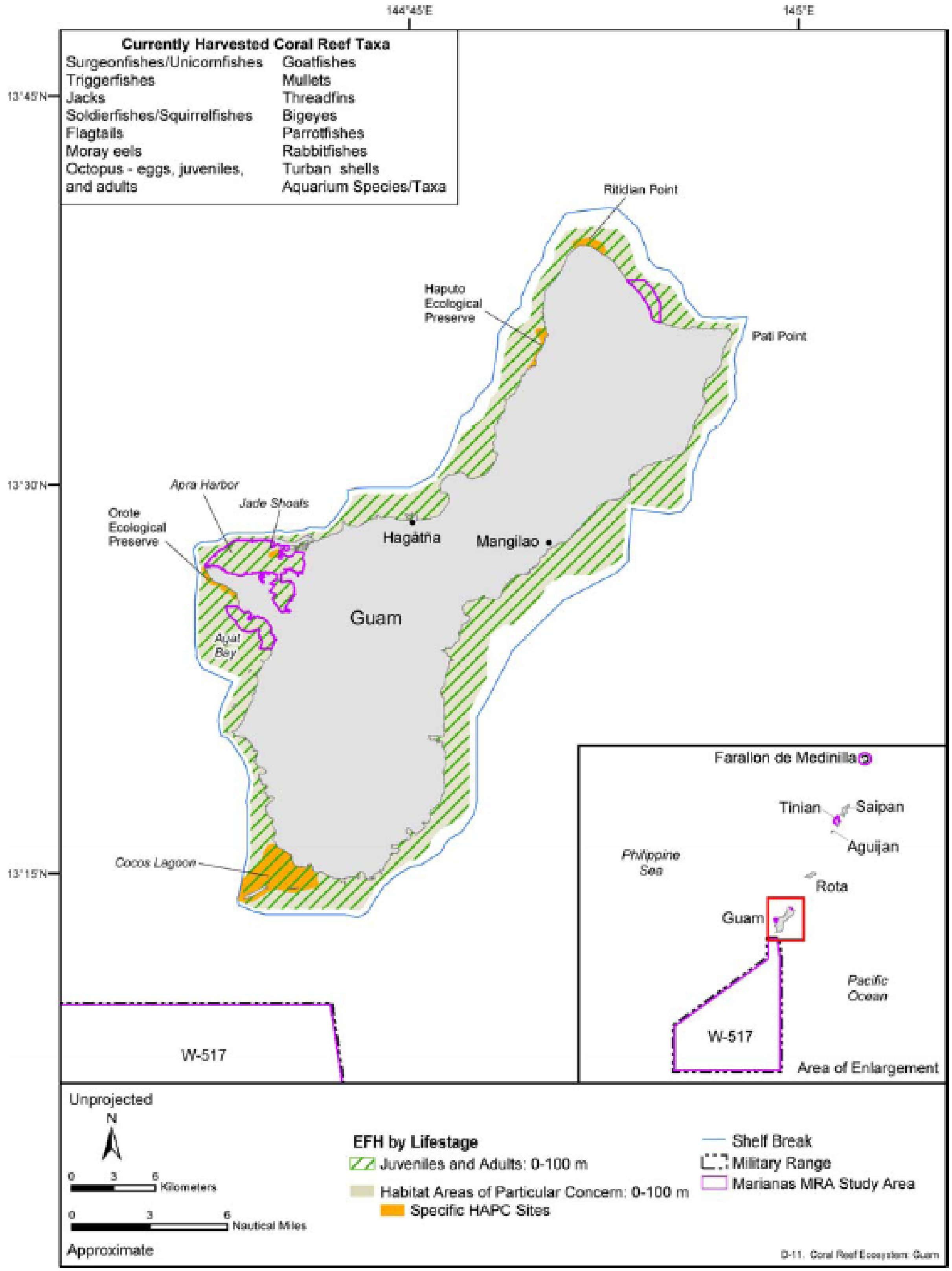


Figure B-11. EFH for all juvenile and adult lifestages of the CHCRT-coral reef ecosystem and HAPC designated on Guam in the MIRC study area.

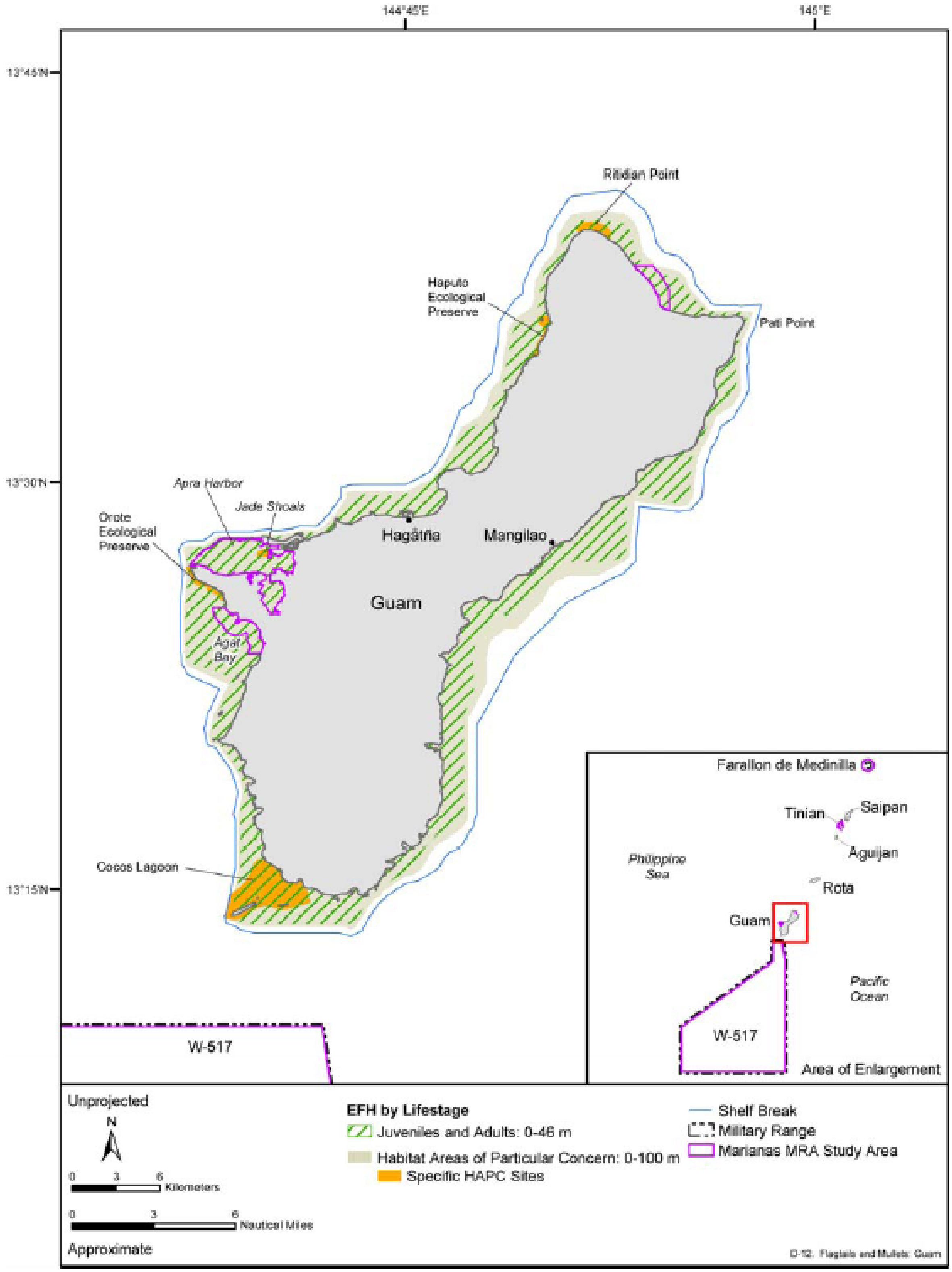


Figure B-12. EFH for all juvenile and adult lifestages of flagtails and mullets (CHCRT-coral reef ecosystem) and HAPC designated on Guam in the MIRC study area.

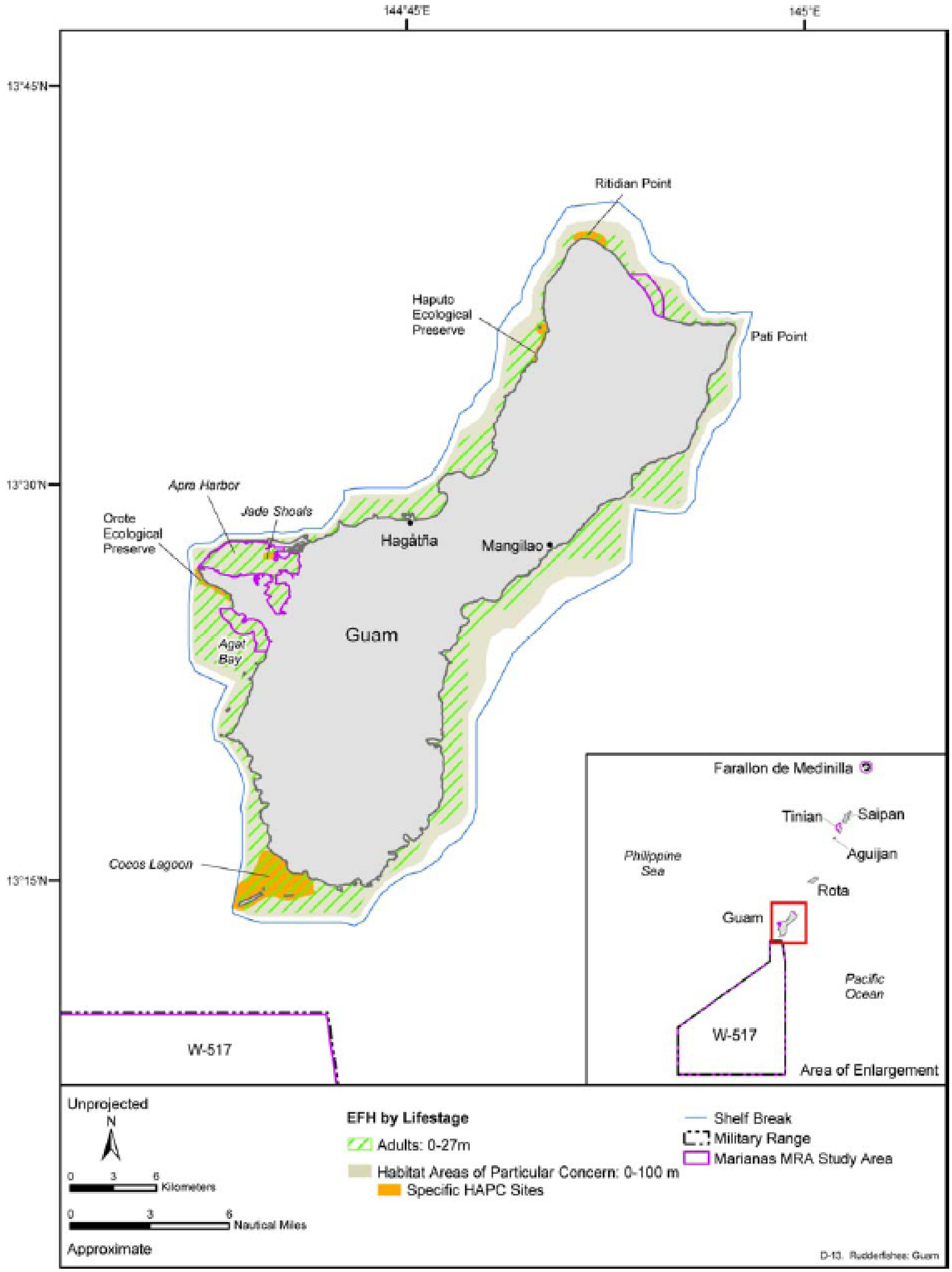


Figure B-13. EFH for all adult lifestages of rudderfishes (CHCRT-coral reef ecosystem) and HAPC designated on Guam in the MIRC study area.

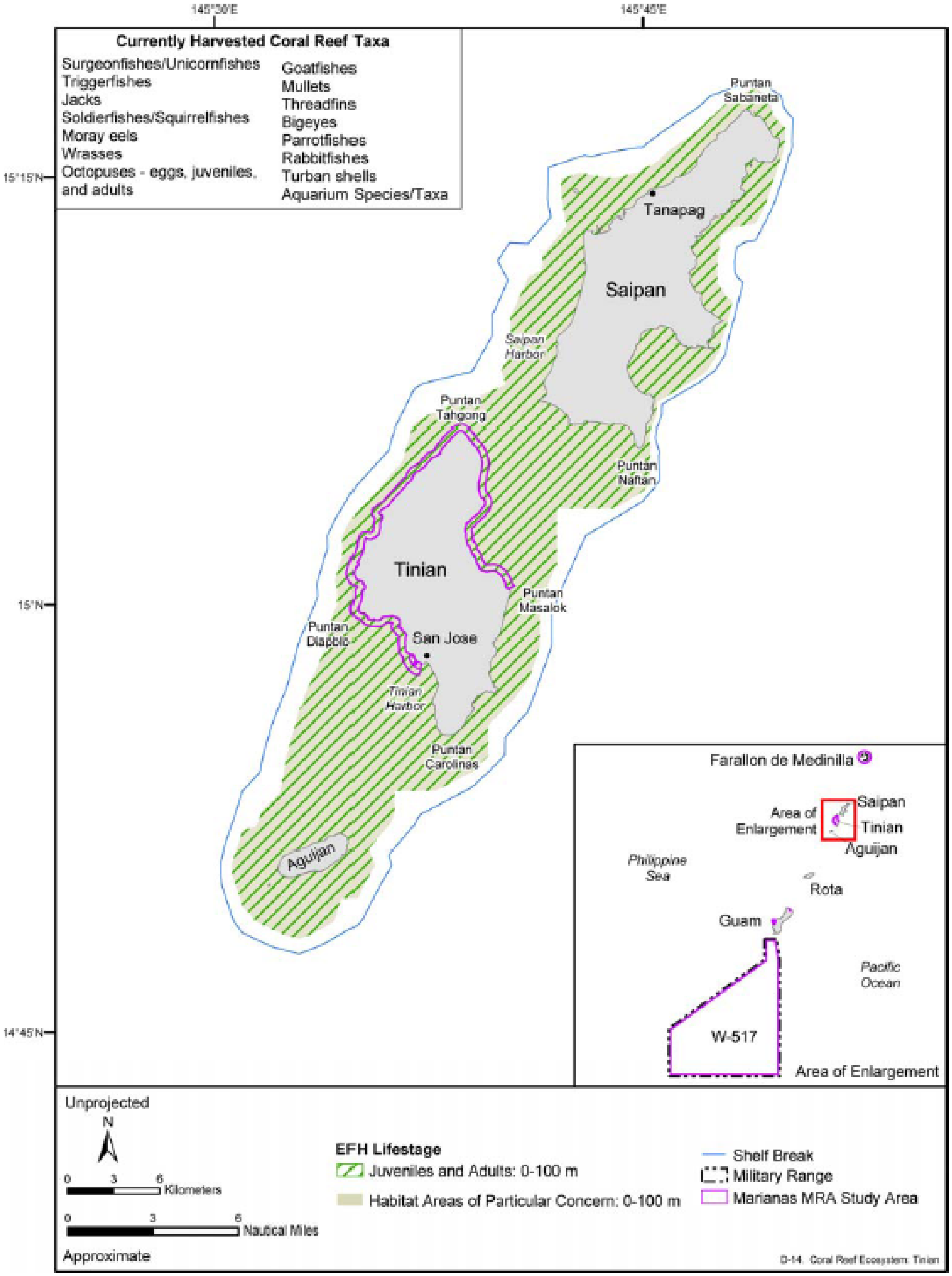


Figure B-14. EFH for all juvenile and adult lifestages of the CHCRT-coral reef ecosystem and HAPC designated on Tinian in the MIRC study area.

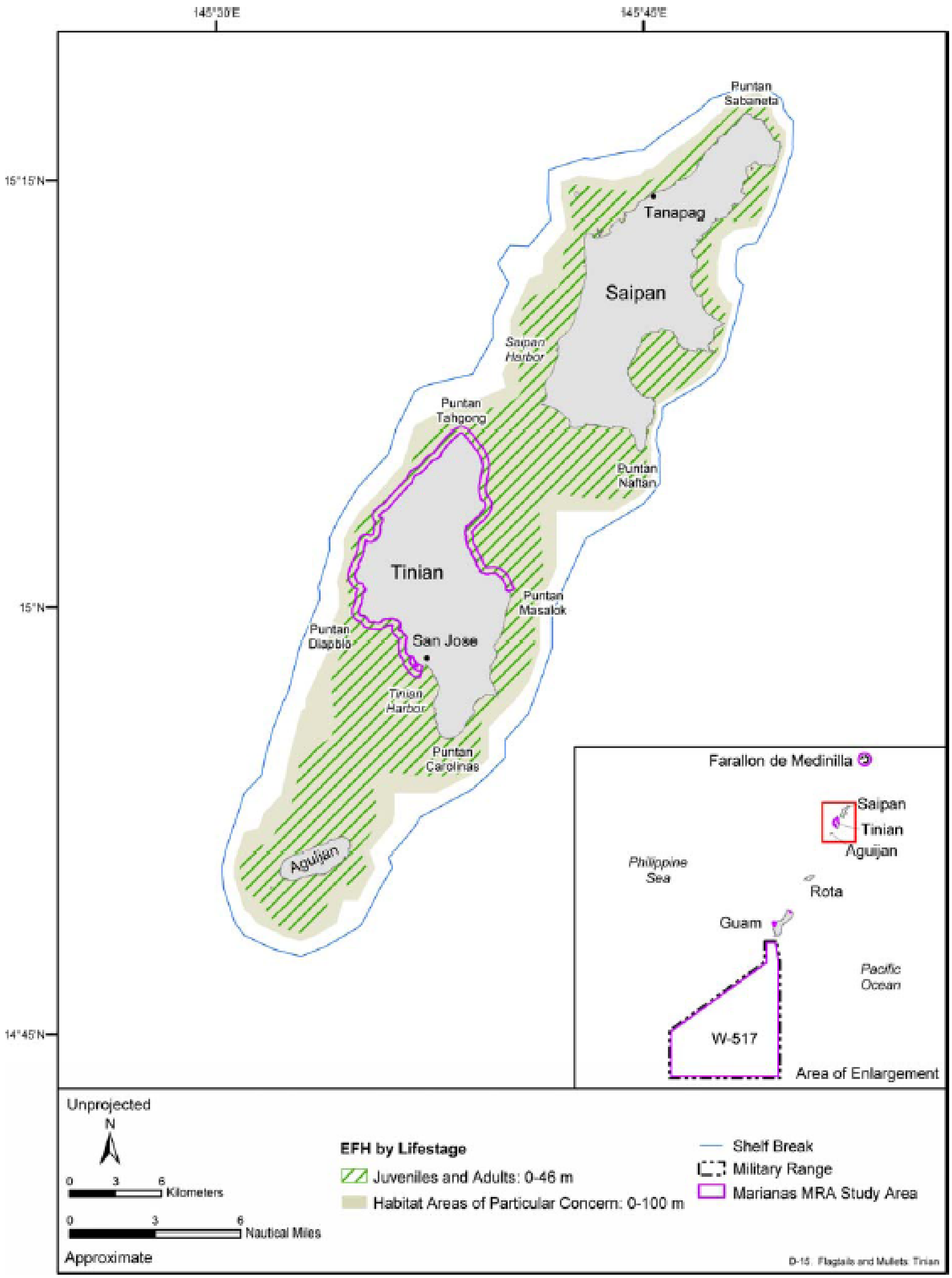


Figure B-15. EFH for all juvenile and adult lifestages of flagtails and mullets (CHCRT-coral reef ecosystem) and HAPC designated on Tinian in the MIRC study area.

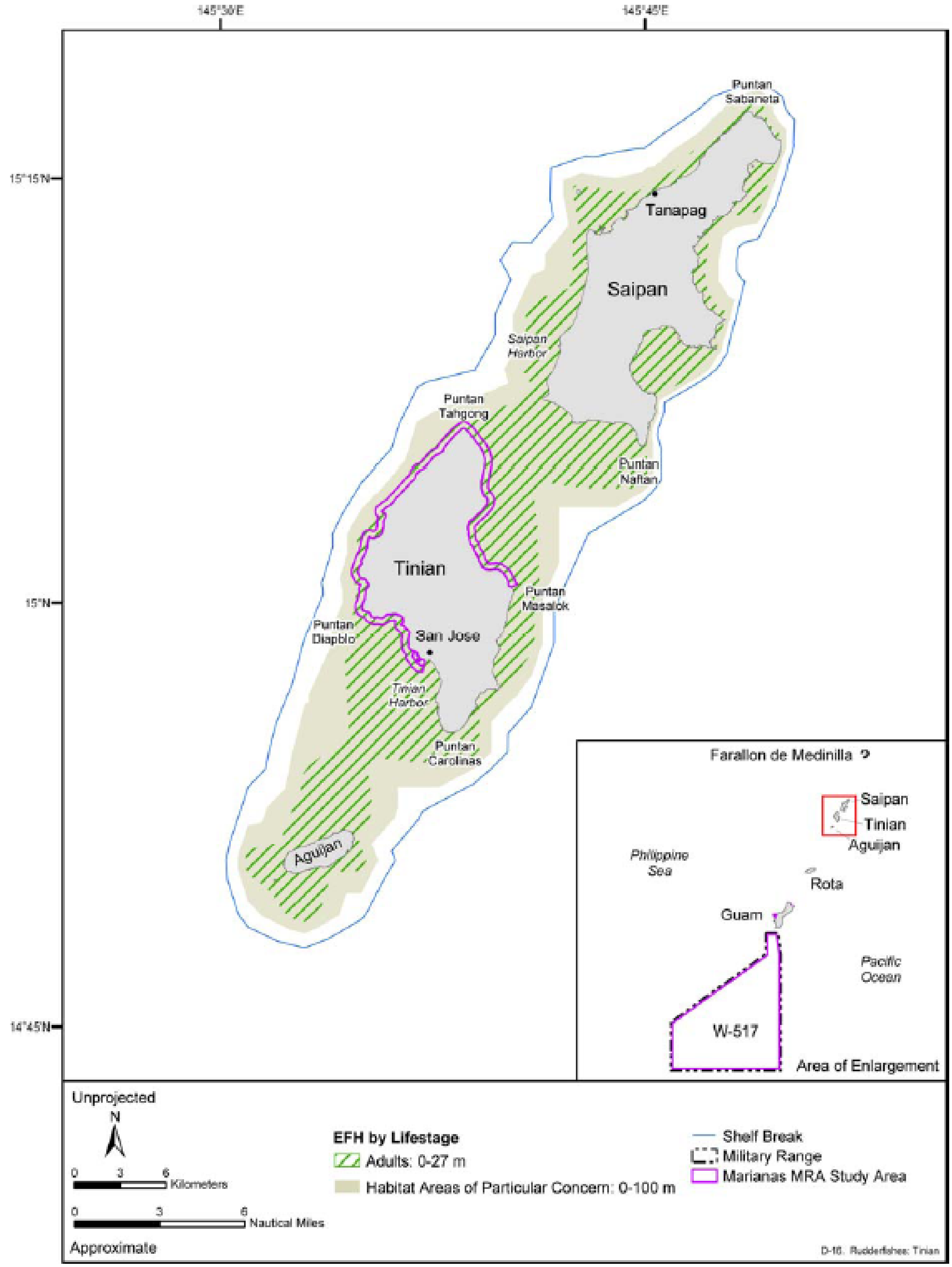


Figure B-16. EFH for all adult lifestages of rudderfishes (CHCRT-coral reef ecosystem) and HAPC designated on Tinian in the MIRC study area.

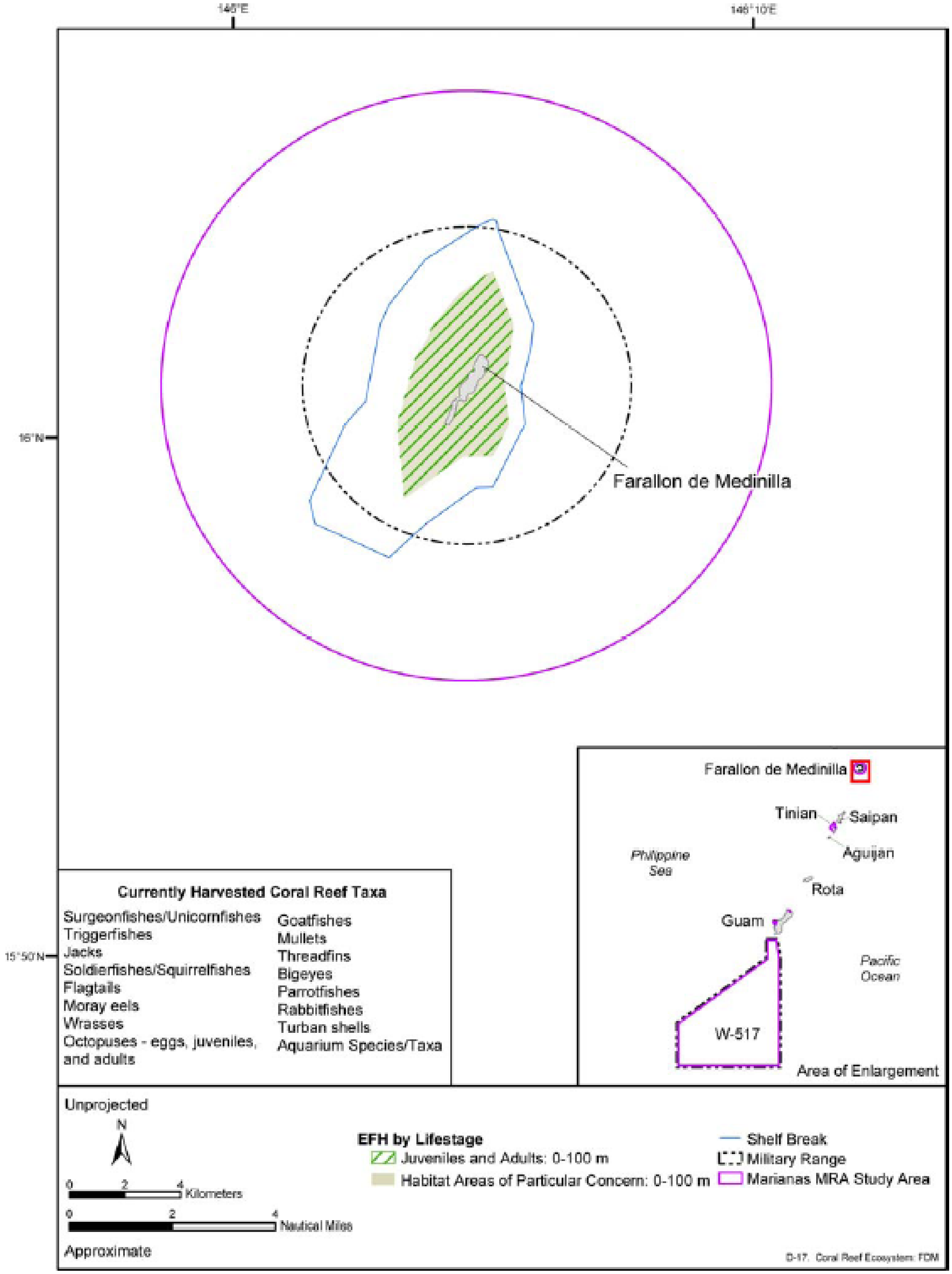


Figure B-17. EFH for all juvenile and adult lifestages of the CHCRT-coral reef ecosystem and HAPC designated on Farallon de Medinilla in the MIRC study area. Map adapted from: WPRFMC (2001).

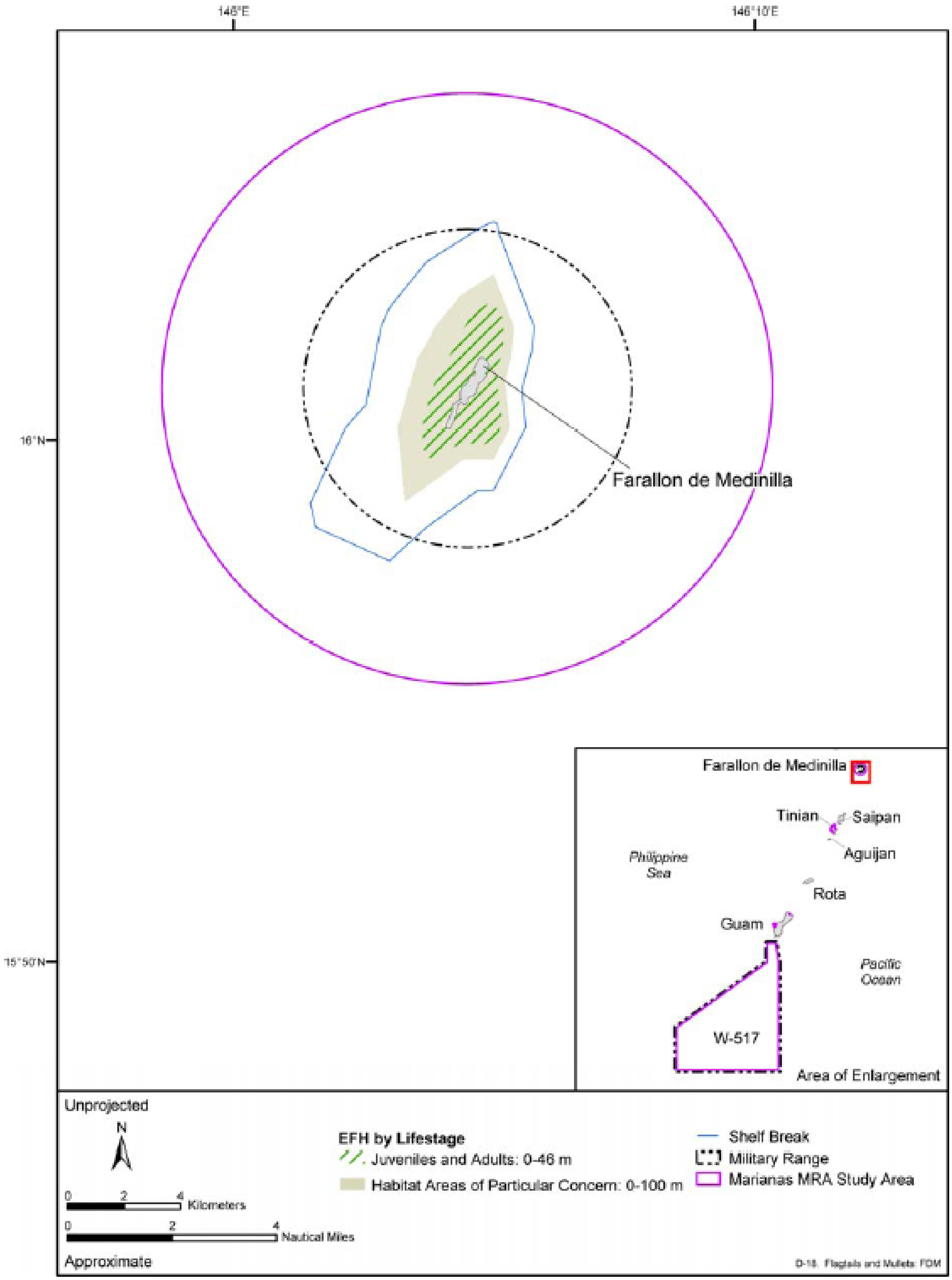


Figure B-18. EFH for all juvenile and adult lifestages of the flagtails and mullets (CHCRT-coral reef ecosystem) and HAPC designated on FDM in the MIRC study area.

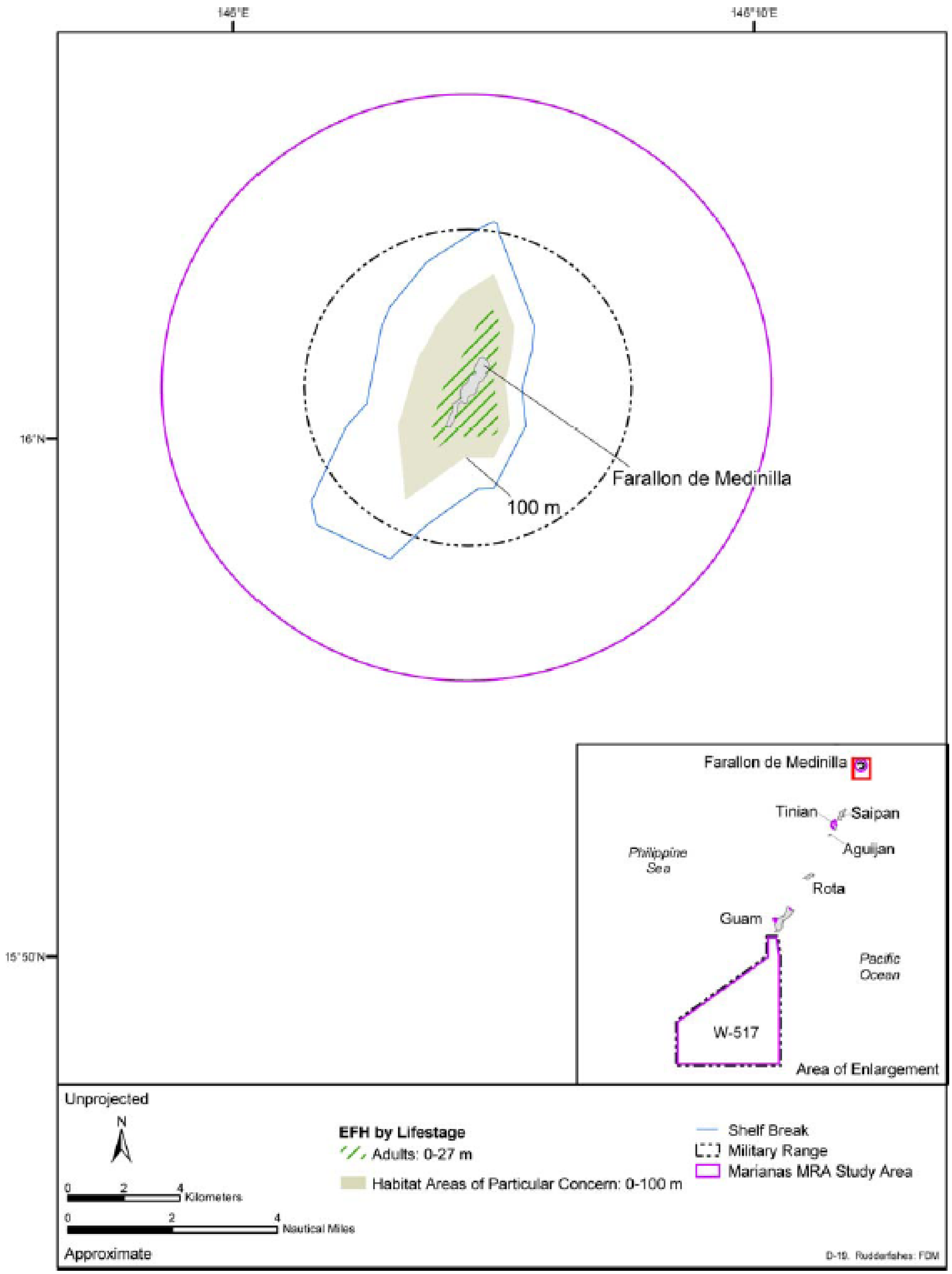


Figure B-19. EFH for all adult lifestages of rudderfishes (CHCRT-coral reef ecosystem) and HAPC designated on FDM in the MIRC study area.

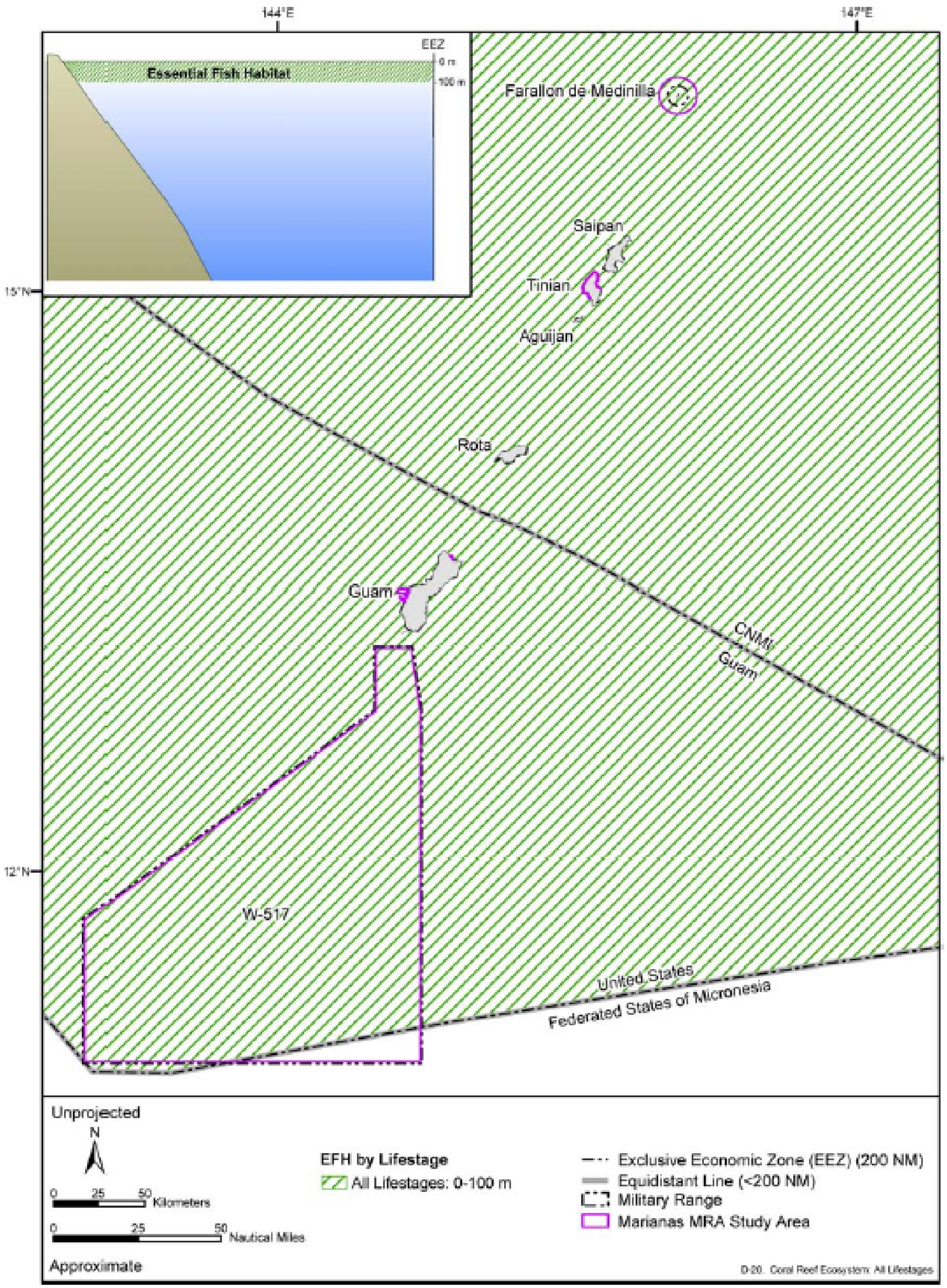


Figure B-20. EFH for all lifestages of the potentially harvested coral reef taxa (PHCRT-coral reef ecosystem) and HAPC designated on Guam, Tinian, and FDM in the MIRC study area.

APPENDIX K

GUAM SHPO, CNMI HPO, ACHP & NPS PROGRAMMATIC AGREEMENT

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**PROGRAMMATIC AGREEMENT AMONG
THE DEPARTMENT OF DEFENSE REPRESENTATIVE
GUAM, COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS,
FEDERATED STATES OF MICRONESIA AND REPUBLIC OF PALAU,
COMMANDER, JOINT REGION MARIANAS,
COMMANDER, 36TH WING, ANDERSEN AIR FORCE BASE,
THE GUAM HISTORIC PRESERVATION OFFICER, AND
THE COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS
HISTORIC PRESERVATION OFFICER
REGARDING
MILITARY TRAINING IN THE MARIANAS**

WHEREAS, the U.S. Department of Defense (DoD), through the Navy as Executive Agent manages the Mariana Islands Range Complex (MIRC); and

WHEREAS the DoD Representative Guam, Commonwealth of the Northern Marianas, Federated States of Micronesia and Republic of Palau (DoD REP), as lead federal agency, has requested that the Commander Pacific Fleet and Naval Facilities Engineering Command, Pacific, coordinate the preparation of an Environmental Impact Statement (EIS)/Overseas EIS (OEIS) under the National Environmental Policy Act of 1969, as amended (P.L. 91-190) for the MIRC that includes all military training in the Marianas and review proposed military training exercises under Section 106 of the National Historic Preservation Act of 1966, as amended (16 United States Code [U.S.C.] 470f) hereinafter Section 106 and Section 110 of the same Act (16 U.S.C. 470h-2(f)); and

WHEREAS, "undertaking" in this document refers to all existing and proposed DoD training exercises in the Marianas as described as the Preferred Alternative in the MIRC EIS/OEIS and which will be stated in the Record of Decision and published in the Federal Register; and

WHEREAS, the MIRC includes property and land under the jurisdiction of the DoD and other entities, including 450,187 nautical miles^2 of open ocean and littorals; and

WHEREAS, the MIRC is currently operating under an existing 1999 Programmatic Agreement (PA) between the DoD REP, the Advisory Council on Historic Preservation (ACHP), and the Commonwealth of the Northern Mariana Islands (CNMI) Historic Preservation Officer (HPO) for military training on Tinian; and

WHEREAS, the MIRC is currently operating under an existing 1999 Memorandum of Agreement (MOA) between the DoD REP, 36 Air Base Wing (now known as 36th Wing), the Guam HPO, and the ACHP for military training on Guam; and

WHEREAS, the DoD REP has determined that the military training program may have an effect upon the Tinian Landing Beaches, Ushi Point Field, and North Field, Tinian Island National Historic Landmark (Tinian NHL) and other historic properties determined eligible for inclusion in the National Register of Historic Places (NRHP) on Guam and Tinian, and has consulted with the ACHP, the Guam HPO, the CNMI HPO, and the National Park Service (NPS) pursuant to 36 Code of Federal Regulations (CFR) §800.3, implementing Section 106; and

WHEREAS, the public has been notified of the proposed military training program and views were solicited through the EIS/OEIS scoping meetings and associated public hearings held on the islands of Guam, Tinian, Saipan, and Rota, and through a public comment period; and

NOW, THEREFORE, the DoD REP, Commander, Joint Region Marianas (Joint Region Marianas), Commander, 36th Wing (36th Wing), the Guam HPO, and the CNMI HPO agree that military training in the Marianas shall be administered in accordance with the following stipulations to satisfy the requirements of Section 106 responsibility for all actions undertaken as part of the proposed military training activities analyzed in the MIRC EIS/OEIS.

STIPULATIONS

The DoD will ensure that the following measures are carried out:

I. APPLICABILITY AND DEFINITIONS

A. This PA applies to all undertakings discussed within the MIRC EIS/OEIS.

B. Unless otherwise noted, this PA will utilize the definitions found at 36 CFR §800.16. All acronyms used in this PA are defined in Appendix A.

C. This PA negates and supersedes the 1999 PA and 1999 MOA pertaining to military training in the Marianas.

D. All signatories will be responsible for complying with the general provisions of this PA. In contrast, each of the following agencies shall be responsible for carrying out specific stipulations relating to historic resources under their jurisdiction.

1. On DoD leased land, Navy installations, and Air Force installations the DoD REP as Joint Region Marianas[1] is responsible.

2. The DoD REP, 36th Wing, and any other DoD units training within the MIRC are responsible for complying with Stipulation III.A regarding military training operations and the training constraint maps.

[1] Joint Region Marianas - Under the 2005 Base Realignment and Closure report, the establishment of a Joint Region was recommended for military installations in the Marianas. Thus, the Navy and the Air Force are in the process of becoming a "Joint Region." Military (training) operations will remain at their respective Commands but installation management responsibilities will now fall under the "Joint Region."

E. Any construction or modification of training areas as proposed within the MIRC EIS/OEIS on property of Naval Base Guam is subjected to the stipulations contained within the 2008 PA among the Commander, Navy Region Marianas, the Advisory Council on Historic Preservation, and the Guam Historic Preservation Officer Regarding Navy Undertakings on the Island of Guam. For all other areas, on Guam and the Northern Mariana Islands, the stipulations in this PA will be followed.

II. PROFESSIONAL STANDARDS

A. All surveys, testing, and mitigation regarding archaeological resources will be carried out by, or under the oversight or supervision of a person or persons meeting the professional qualification for Archaeologist found in "The Secretary of the Interior's (SOI) Historic Preservation Professional Qualification Standards" (SOI Qualification Standards), 62 Federal Register 33712.

B. All historic property surveys for historic buildings and structures will be carried out by, or under the oversight or supervision of, a person or persons meeting the professional qualifications for Historical Architect under Standard a or b found in SOI Qualification Standards, 62 Federal Register 33719 or Architectural Historian under Standard a or b found in SOI Qualification Standards, 62 Federal Register 33713-4 or Historic Landscape Architect under Standard a or b found in SOI Qualification Standards, 62 Federal Register 33720 or Historian under Standard a or b found in the SOI Qualification Standards, 62 Federal Register 33722.

C. Where Joint Region Marianas utilizes contracts that involve work governed by this PA that may affect historic properties, Joint Region Marianas will use appropriate contract performance requirements, and/or appropriate source selection criteria which shall include minimum qualifications for historic preservation experience and satisfactory prior performance, as appropriate to the nature of the work and the type of procurement, developed with the participation of professionals meeting the standards of Stipulation II.B, for projects involving historic buildings and structures, or II.A, for projects involving archaeological sites.

III. GENERAL STIPULATIONS:

A. TRAINING CONSTRAINT MAPS

1. For areas with training constraints due to the presence of historic properties, training constraint maps have been developed. These maps show the locations of off-limits or No Training (NT) areas and Limited Training (LT) areas.

    a. NT areas are to be avoided, and no training exercises shall occur within these areas.

b. LT areas are primarily designated as pedestrian traffic areas with vehicular access limited to designated roadways and/or with the use of rubber-tired vehicles. However, no pyrotechnics, demolition, or digging is allowed without prior consultation with the appropriate HPO.

2. Training constraint maps will be updated by the respective cultural resource managers (CRM) for each property based on consultation with the appropriate HPO on a yearly basis so that these maps remain current as new information becomes available through planned cultural resource studies or inadvertent finds. Areas defined as NT or LT can change based on the new data and consultation. Similarly, training activities may be eliminated, reduced, or expand based on the new data. However, any major changes to this PA must comply with Stipulation VIII.

3. Training constraint maps shall be disseminated and made available to military planners who coordinate and execute training exercises so that they are aware of the constraints.

B. TRAINING PROGRAM REVISIONS

The DoD REP, 36th Wing, and any other DoD units training within the MIRC will notify, coordinate, and consult with the appropriate HPO(s) and the NPS (if a NHL is involved) on a case-by-case basis for any new introduction of forces and maneuvers that do not comply with the general or area-specific stipulations of this PA.

IV. AGENCY- AREA – SPECIFIC STIPULATIONS

A. GUAM

1. Main Base / Waterfront Annex

Training will be limited per the Main Base training constraints map (see Appendix B).

2. Ordnance Annex

a. The appropriate CRM will verify that pop-up targets for the Sniper Range at Ordnance Annex are situated so that no historic properties are in the ballistic trajectory.

b. Training will be limited per the training constraints map for the Ordnance Annex in Appendix B.

3. Northwest Field

   a. As part of the Northwest Field Beddown Initiatives, the 36th Wing has conducted Historic American Building Survey/Historic American Engineering Record (commonly referred to as HABS/HAER) recordation and supplementary documentation of the Northwest Field runway complex and previously existing facilities as mitigation for any potential adverse effect of military training and support activities in the Northwest Field area.

   b. Any area of Northwest Field that has not been previously surveyed and involves construction or ground disturbing activities will be surveyed and inventoried for cultural resources. Any cultural resource within the affected area will be evaluated for inclusion on the NRHP. Any resource(s) determined eligible for the NRHP, which cannot be avoided, will be subjected to data recovery.

   c. Appendix B contains the Northwest Field training map. Training is currently constrained within these areas.

4. Tarague

   Training at Tarague will be confined to the existing Combat Arms Training and Maintenance (also known as CATM) range as shown in Appendix B.

5. Andersen South

   This area is designated as an unconstrained training area (see Appendix B).

B. TINIAN

1. Unai Chulu

   a. The Center Access Road (CAR): The back beach area of Unai Chulu is designated as a no training area except for the CAR. The entire length and width of the CAR is currently capped with a layer of crushed coral. The crushed coral cap is approximately 20 centimeters thick and 3 meters wide. The road cap covers the access road from the Dyckman Road intersection to the intersection with the existing beach access road that parallels the beach.

   b. Road Fencing: To keep vehicles on the CAR, fencing was installed running parallel to the road on both shoulders for the entire length of the road. Archaeological testing of Site TN-73 has revealed intact deposits lie below one meter of disturbed stratigraphy.

   c. Maintenance: The CRM designated by Joint Region Marianas will monitor the condition of the capped road and fence on a quarterly basis (if any training has occurred during that time period) by conducting a field visit and site check of the CAR and fencing per Stipulation V. Any deterioration of the road surface or the fence will be repaired.

d. To ensure vehicles and pedestrians remain on designated ingress and egress paths and comply with NT and LT constraints, the CRM designated by the Joint Region Marianas will, on a quarterly basis (if any training has occurred during that time period) conduct a field visit and site check of Unai Chulu (see Stipulation V).

e. Training will be limited per the Unai Chulu training constraints map (see Appendix B).

2. Unai Dankulo

a. Training will be limited per the Unai Dankulo training constraints map (see Appendix B).

b. To ensure vehicles and pedestrians remain on designated ingress and egress paths and comply with NT and LT constraints, the CRM designated by the Joint Region Marianas will, on a quarterly basis (if any training has occurred during that time period) conduct a field visit and site check of Unai Dankulo (see Stipulation V).

3. Unai Masalok

a. An area of the Unai Masalok has been designated a LT area (see Appendix B). In general, military training operations at Unai Masalok will consists of low density training (pedestrian traffic).

b. The CRM designated by the Joint Region Marianas will, on a quarterly basis (if any training has occurred during that time period) conduct a field visit and site check of Unai Masalok (see Stipulation V).

4. Tinian – DoD Leased Lands

a. The DOD leased lands on Tinian include the Exclusive Military Use Area (EMUA) and the Leased-Back Area (LBA). The Tinian NHL comprises a large portion of the EMUA (see Appendix B).

b. Training in the EMUA and LBA will be consistent with the Tinian constraints map as shown in Appendix B.

c. Historic Building and Structures

1. Bullet traps will be installed behind temporary targets within historic buildings and structures to stop the trajectory and ricochet of bullets. Previous field monitoring and visual inspections by the CRM designated by the Joint Region Marianas and CNMI HPO staff show that use of these bullet traps adequately mitigates any impacts that this type of activity may have had to historic buildings and structures.

2. After each exercise, shell casings and targets will be removed.

3. Baseline digital photo documentation of the building shall also be conducted to show the current state of the building. The CRM designated by the Joint Region Marianas shall continue to digitally photo-document the structure on a quarterly basis (if any training has occurred during that time period) as evidence that the bullet traps have successfully mitigated the potential adverse affect of this undertaking. These photos shall be submitted to the CNMI HPO and NPS via e-mail. A site visit by the CNMI HPO or NPS may be conducted in lieu of photo documentation as stated in Stipulation V.D.

d. Tinian National Historic Landmark[2]

1. The CRM designated by the Joint Region Marianas will ensure that there is ongoing documentation, survey, evaluation and assessment of the cumulative effects of training on the Tinian NHL, including its historic character and setting.

2. The CRM designated by the Joint Region Marianas will assess the cumulative effects and determine the appropriate actions associated with them, according to the Secretary of the Interior's Standards, in an annual report provided to the NPS and the CNMI HPO. The report will describe how the responsibilities are being carried out under this PA pertaining to the Tinian NHL.

3. The report will be submitted to the NPS and CNMI HPO, in addition to other interested parties who request a copy of this report.

[2] The DOD recognizes and acknowledges that 16 USC §470h-2(f) mandates that "[P]rior to approval of any Federal undertaking which may directly and adversely affect any National Historic Landmark, the head of the responsible Federal agency shall, to the maximum extent possible, undertake such planning and actions as may be necessary to minimize harm to such landmark." The DOD shall ensure that the military training activities included in the undertaking are carried out in a manner that is consistent with this legal mandate.

4. Upon termination of this PA under Stipulation IX or XI, the CRM designated by the DoD shall provide a report to the NPS and the CNMI HPO. This report shall summarize the following (for the time period that this PA has been in effect):

   a. The training activities that have occurred and their effects on the Tinian NHL.

   b. Steps taken to respond to those effects.

   c. List any newly identified cultural resources.

   d. NRHP eligibility evaluations completed for any newly identified cultural resources.

V. FIELD MONITORING AND REPORT SUBMISSION

A. Certain training areas will require field monitoring and report submission. See Agency-Area – Specific Stipulations (Stipulation IV).

B. Schedule: The CRM designated by the Joint Region Marianas shall conduct quarterly site checks (if any training has occurred within that time period) and shall submit a report to the appropriate HPO and NPS if applicable.

C. Field Report Contents: These reports will, at a minimum, include the following information:

   1. Digital photographs of a selection of historic properties within the affected area after completion of training exercises to show the general status of the historic properties in the area.

   2. If applicable, a description of any adverse effects that the training activities may have had on an historic property.

D. Review by the appropriate HPO: The HPO will review each report and provide the appropriate CRM with comments, if any. The HPO or the appropriate CRM may request a site visit by the appropriate HPO in lieu of photo documentation and a report.

E. See Stipulation IV.B.4.c regarding a special NHL assessment report to be submitted by the CRM designated by Joint Region Marianas to the NPS and the CNMI HPO upon the termination of this PA.

VI. DISCOVERIES AND EMERGENCIES

A. If during the performance of an undertaking, previously unknown cultural resources are discovered, the appropriate CRM shall be notified.

1. Reasonable measures to avoid or minimize impacts to the cultural resource will be undertaken.

2. Once notified, the appropriate CRM shall inspect the discovery and determine whether it is eligible for listing on the NRHP.

   a. If the discovery is not eligible for the NRHP, then the relevant agency will proceed.

   b. If it is determined that the cultural resource is eligible for the NRHP, the appropriate CRM will notify the applicable HPO via telephone, fax or e-mail, request concurrence for the determination, and document this discovery. The CRM will begin consultation with the HPO on how to mitigate the impacts or document the newly discovered historic property. If the Tinian NHL is involved, the NPS will also be notified and consulted.

B. If human burials are discovered during the performance of an undertaking, the appropriate CRM shall follow the applicable Standard Operating Procedure (commonly referred to as SOPs) specified in Appendix C. Different areas have different SOPs depending on the land managing agency and local regulations of each area.

C. In the event that natural disasters (such as typhoons or tsunamis), fires, sudden disruptions of utilities service, spill events or other emergency events occur, the particular DoD agency affected may take immediate actions to preserve life and property without having to undergo Section 106 review. However, emergency response work will take into consideration that historic properties may be affected by recovery or emergency efforts. When possible, such emergency actions will be undertaken in a manner that does not foreclose future preservation or restoration of historic properties. The appropriate CRM will notify the particular HPO by telephone of the emergency (if possible) and will follow up with written documentation if any historic properties were discovered or disturbed during the emergency events. Consultation with the appropriate HPO will be conducted as soon as practical based on the emergency circumstances.

VII. RESOLVING OBJECTIONS

A. Should any signatory to this PA object in writing regarding any actions carried out or proposed with respect to the implementation of this PA, the appropriate agency shall consult with the objecting party. All other signatories should be notified in writing that one of signatories is objecting to a specific action in this PA. The objecting party shall do the notifications.

B. If after initiating such consultation, the agency conducting the action determines that the objection cannot be resolved through consultation, it shall forward all documentation relevant to the objection to the ACHP, including the agency's proposed response to the objection.

C. Within 30 calendar days after receipt of all pertinent documentation, the ACHP shall exercise one of the following options:

1. Concur with the agency's proposed response;

2. Provide the agency with recommendations on the proposed response. The agency shall take into account such recommendations before making a final decision on the matter and proceeding accordingly;

3. Notify the agency that the objection will be referred to the ACHP membership for formal comment per 36 CFR §800.7(c). The resulting formal comment shall be taken into account by the agency in accordance with 36 CFR §800.7(c). If the ACHP has not responded within the allotted time, the agency may make a final decision on the objection and proceed accordingly.

VIII. AMENDMENT

A. Regulatory agencies (such as the Guam HPO and CNMI HPO) may propose to amend any stipulation of this PA within their area of jurisdiction. Each landowning/managing agency will have the ability to amend their portions of the PA specifically relating to any stipulation regarding the management of historic properties on their installation(s).

B. The amendment process starts when a signatory notifies the other signatories of this PA that it wishes to amend this agreement. A written notice must be sent to all signatories by the agency that wishes to amend the PA (or a particular portion of the PA). The requests should include the proposed amendments and the reasons for proposing them. The parties affected by these proposed amendments shall consult to consider the proposed changes to this PA.

C. No amendment shall take effect until it has been agreed upon and executed by all signatories affected by the amendment.

IX. TERMINATION

A. Regulatory agencies (such as the Guam HPO and CNMI HPO) may propose to terminate any stipulation of this PA within their area of jurisdiction only after complying with Stipulation VII. Each landowning/managing agency will have the ability to terminate their portions of the PA specifically relating to any stipulation regarding the management of cultural resources on their property only after complying with Stipulation VII.

B. The termination process starts when an agency provides in writing to other signatories of this PA, that it wishes to terminate this agreement, or a portion of the agreement applicable to them. A written notice must be sent to all signatories by the agency that wishes to terminate the PA (or their portion of the PA). The written notice must explain in detail the reasons for the proposed termination. The signatories will consult during a 30-calendar-day consultation period to seek agreement on amendments or other actions that would avoid termination. The 30-day consultation period starts when all parties have received written notification that an agency is requesting termination. If the signatory proposing the termination does not withdraw the proposal by the end of the 30-day consultation period and a longer period of arbitration is not agreed to by all signatories, then the PA or portion of the PA will be terminated.

C. In the event of full termination of this PA, all agencies will comply with 36 CFR §800 with regard to all individual undertakings. In the event that only a portion of the PA is terminated, then the remainder of the PA and the applicable stipulations will remain in effect and the PA will be amended to reflect this change per Stipulation VIII.

X. ANTI-DEFICIENCY ACT

A. The Anti-Deficiency Act, 31 U.S.C. §1341, prohibits federal agencies from incurring an obligation of funds in advance of or in excess of available appropriations. Accordingly, the parties agree that any requirement for obligation of funds arising from the terms of this agreement shall be subject to the availability of appropriated funds for that purpose, and that this agreement shall not be interpreted to require the obligation or expenditure of funds in violation of the Anti-Deficiency Act.

B. If compliance with the Anti-Deficiency Act alters or impairs a specific DoD agency's ability to implement the stipulations of this PA, the DoD Agency shall consult with the signatories. If an amendment is necessary, then Stipulation VIII shall be followed.

XI. DURATION

This PA shall become effective upon execution by all signatories and shall remain in effect for a period of 10 years unless terminated prior to that in accordance with Stipulation IX.

EXECUTION AND IMPLEMENTATION of this PA evidences that DOD REP, Joint Region Marianas, and the 36th Wing have afforded the Guam HPO, CNMI HPO, ACHP, and the NPS an opportunity to comment on the undertaking and its effects on historic properties in the Marianas, and have taken into account the effects of military training in the Marianas.

Each of the undersigned certifies that they have full authority to bind the party that they represent for purposes of entering into this agreement.

SIGNATORIES

THE DEPARTMENT OF DEFENSE REPRESENTATIVE
JOINT REGION MARIANAS

By: D Biesel Date: 8/22/09

D. T. BIESEL
Rear Admiral, U.S. Navy
Department of Defense Representative Guam, Commonwealth of the Northern Mariana Islands, Federated States of Micronesia and Republic of Palau;
Commander, Joint Region Marianas

COMMANDER, 36TH WING

By: Date: 17 JUN 09

PHILIP M. RUHLMAN
Brigadier General, USAF
Commander, 36th Wing

SIGNATORIES (continued)

GUAM HISTORIC PRESERVATION OFFICER

By: ______________________ Date: 10-2-09

JOSEPH W. DUENAS
Director
Department of Parks, Recreation & Historic Preservation

THE COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS

HISTORIC PRESERVATION OFFICER

By: ______________________ Date: 10/30/09

PEDRO (ROY) SABLAN
Director
Commonwealth of the Northern Mariana Islands Historic Preservation Office

INVITED SIGNATORIES

NATIONAL PARK SERVICE

By: Rory D. Westberg Date: 12-11-09

RORY D. WESTBERG
Acting Regional Director
Pacific West Region, National Park Service

APPENDIX A

ACRONYMS & ABBREVIATIONS

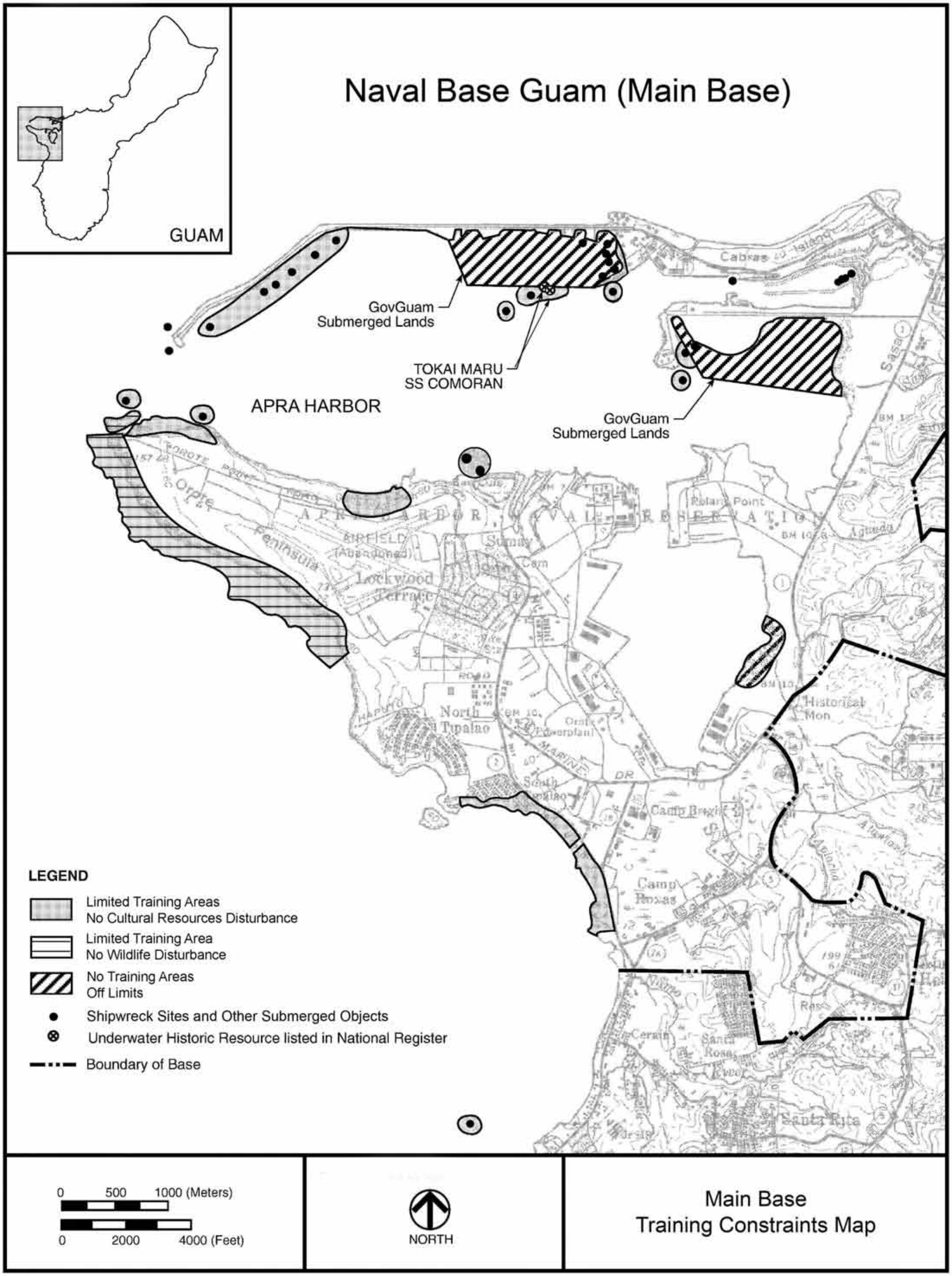
ACRONYMS & ABBREVIATIONS

36th Wing	Commander, 36th Wing
ACHP	Advisory Council on Historic Preservation
CAR	Center Access Road
CATM	Combat Arms Training and Maintenance
CFR	Code of Federal Regulations
CNMI	Commonwealth of the Northern Mariana Islands
CNRM	Commander, Navy Region Marianas
CRM	Cultural Resource Manager
DoD	Department of Defense
DoD REP	DoD Representative Guam, Commonwealth of the Northern Marianas, Federated States of Micronesia and Republic of Palau
EIS	Environmental Impact Statement
EMUA	Exclusive Military Use Area
HABS	Historic American Building Survey
HAER	Historic American Engineering Record
HPO	Historic Preservation Officer
LT	Limited Training
MIRC	Mariana Islands Range Complex
MLA	Military Leaseback Area
MOA	Memorandum of Agreement
NHL	National Historic Landmark
NT	No Training
OEIS	Overseas Environmental Impact Statement
PA	Programmatic Agreement
SOI	Secretary of the Interior
SOP	Standard Operating Procedures
Tinian NHL	Tinian Landing Beaches, Ushi Point Field, and North Field, Tinian Island National Historic Landmark
U.S.C.	United States Code

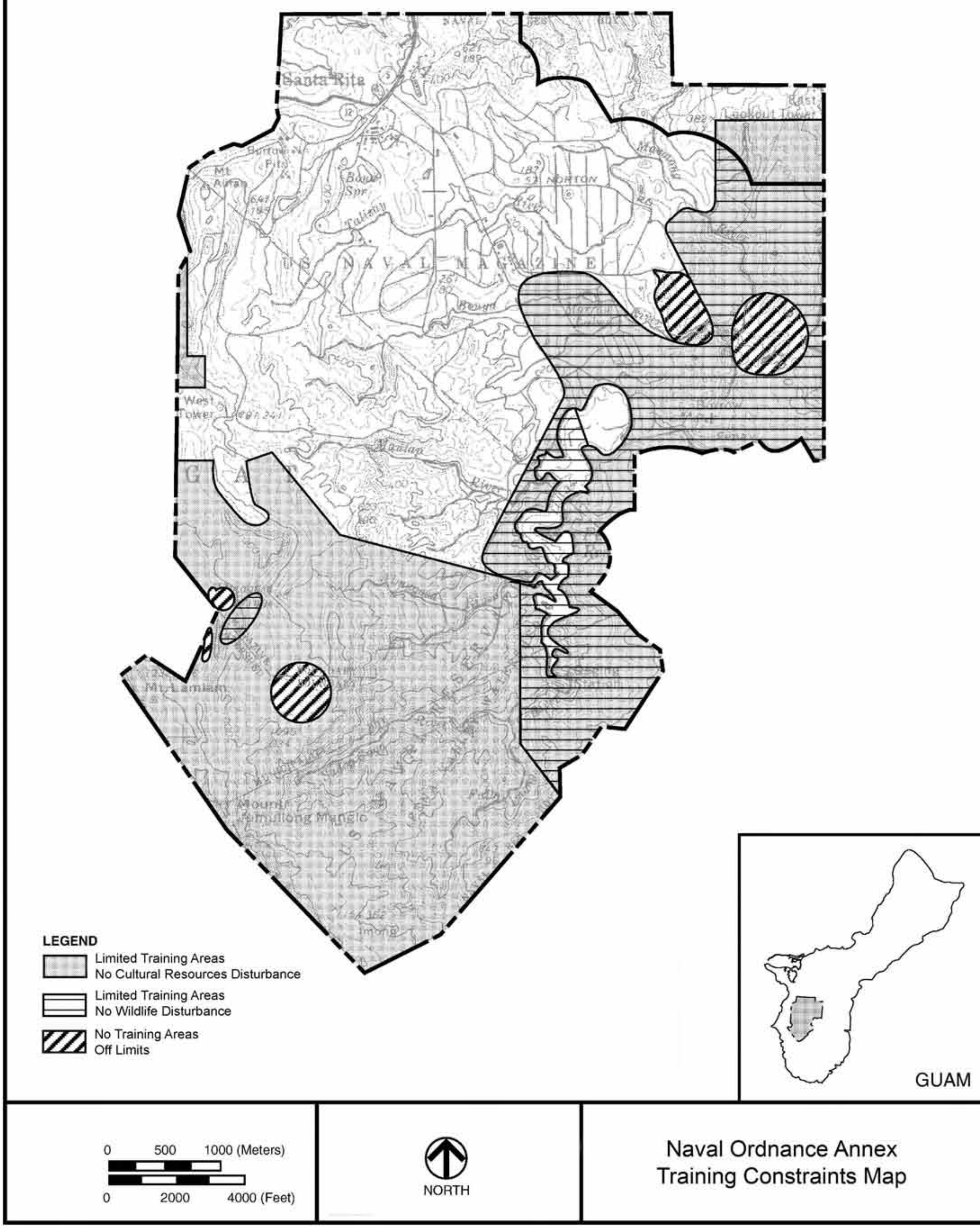
APPENDIX B

TRAINING AND
TRAINING CONSTRAINT
MAPS

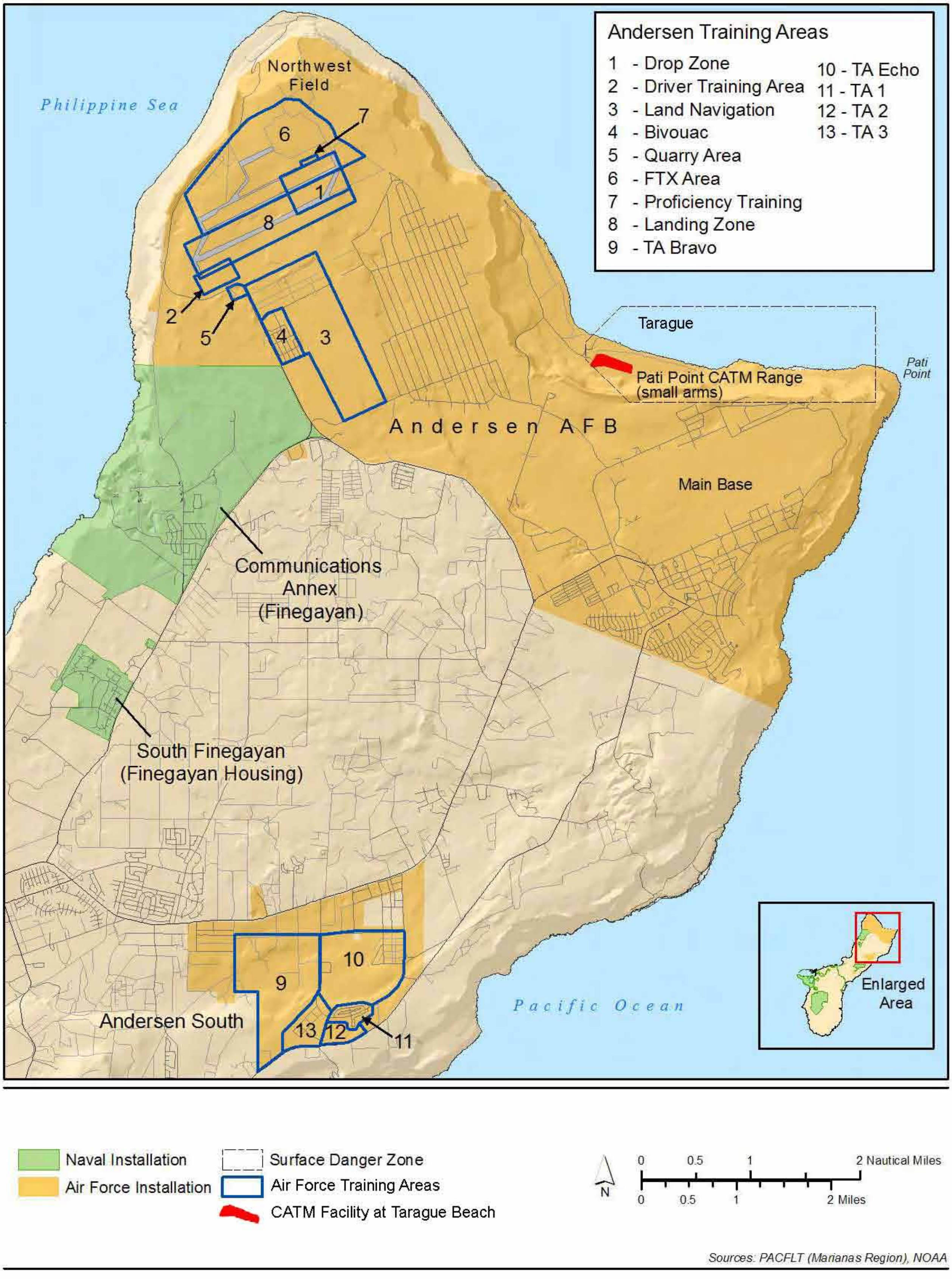
ISLAND OF GUAM


Naval Base Guam (Main Base)
GUAM
GovGuam
Submerged Lands
TOKAI MARU
SS COMORAN
APRA HARBOR
GovGuam
Submerged Lands
LEGEND
Limited Training Areas
No Cultural Resources Disturbance
Limited Training Area
No Wildlife Disturbance
No Training Areas
Off Limits
Shipwreck Sites and Other Submerged Objects
Underwater Historic Resource listed in National Register
Boundary of Base
0 500 1000 (Meters)
0 2000 4000 (Feet)
NORTH
Main Base
Training Constraints Map

Naval Ordnance Annex

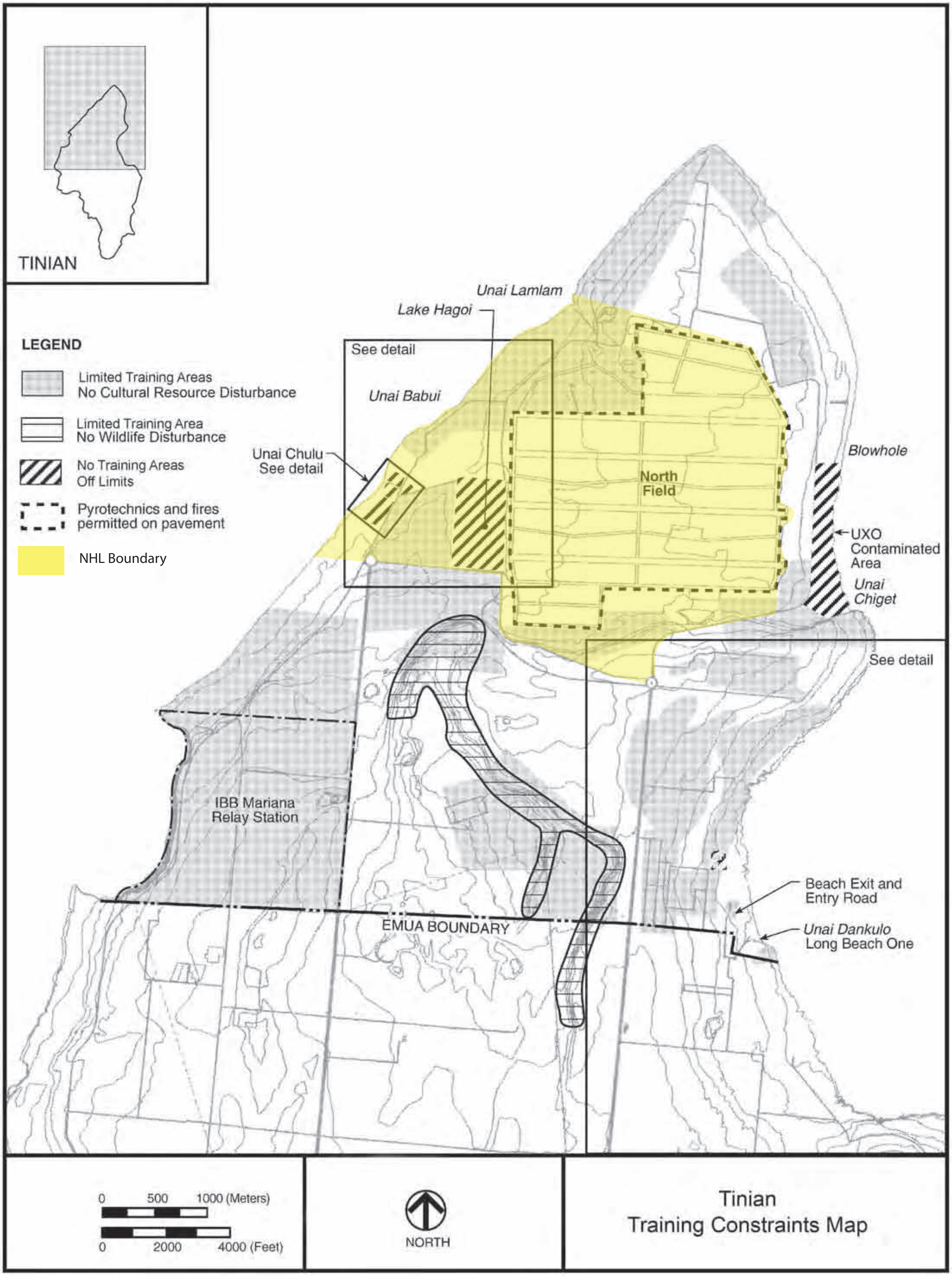


Naval Ordnance Annex
Training Constraints Map

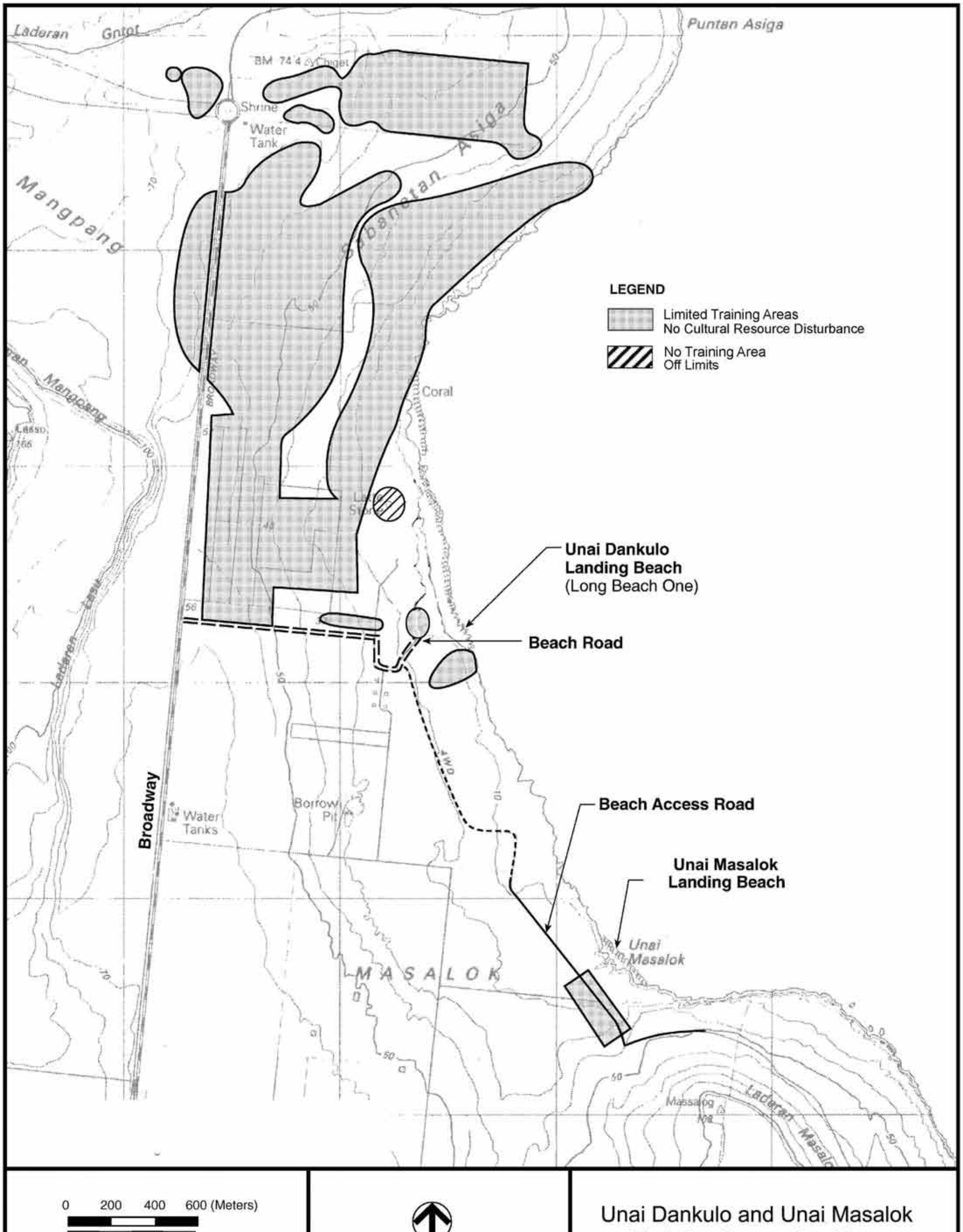


Air Force Training Areas (Northwest Field, Tarague, Andersen South).

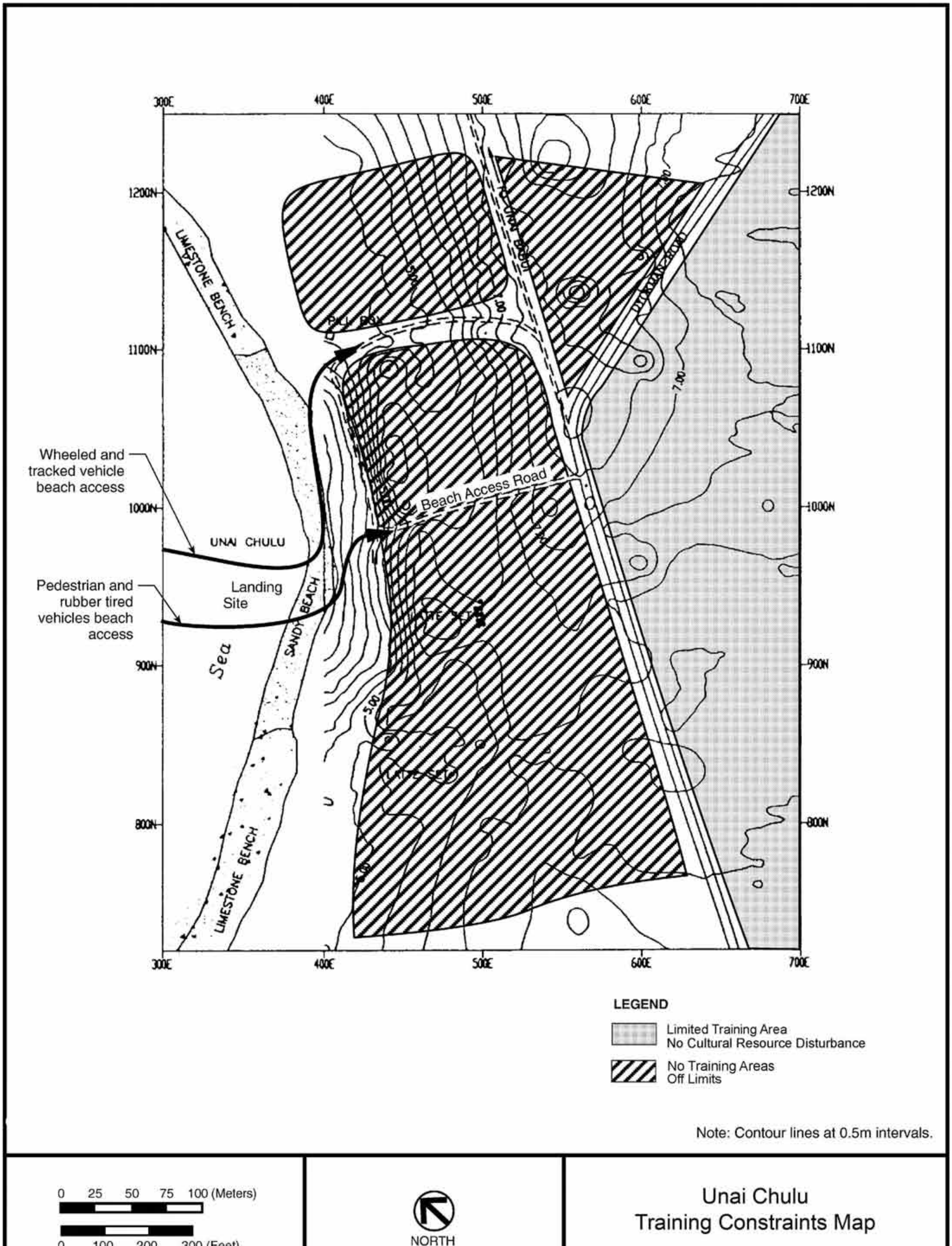
ISLAND OF TINIAN



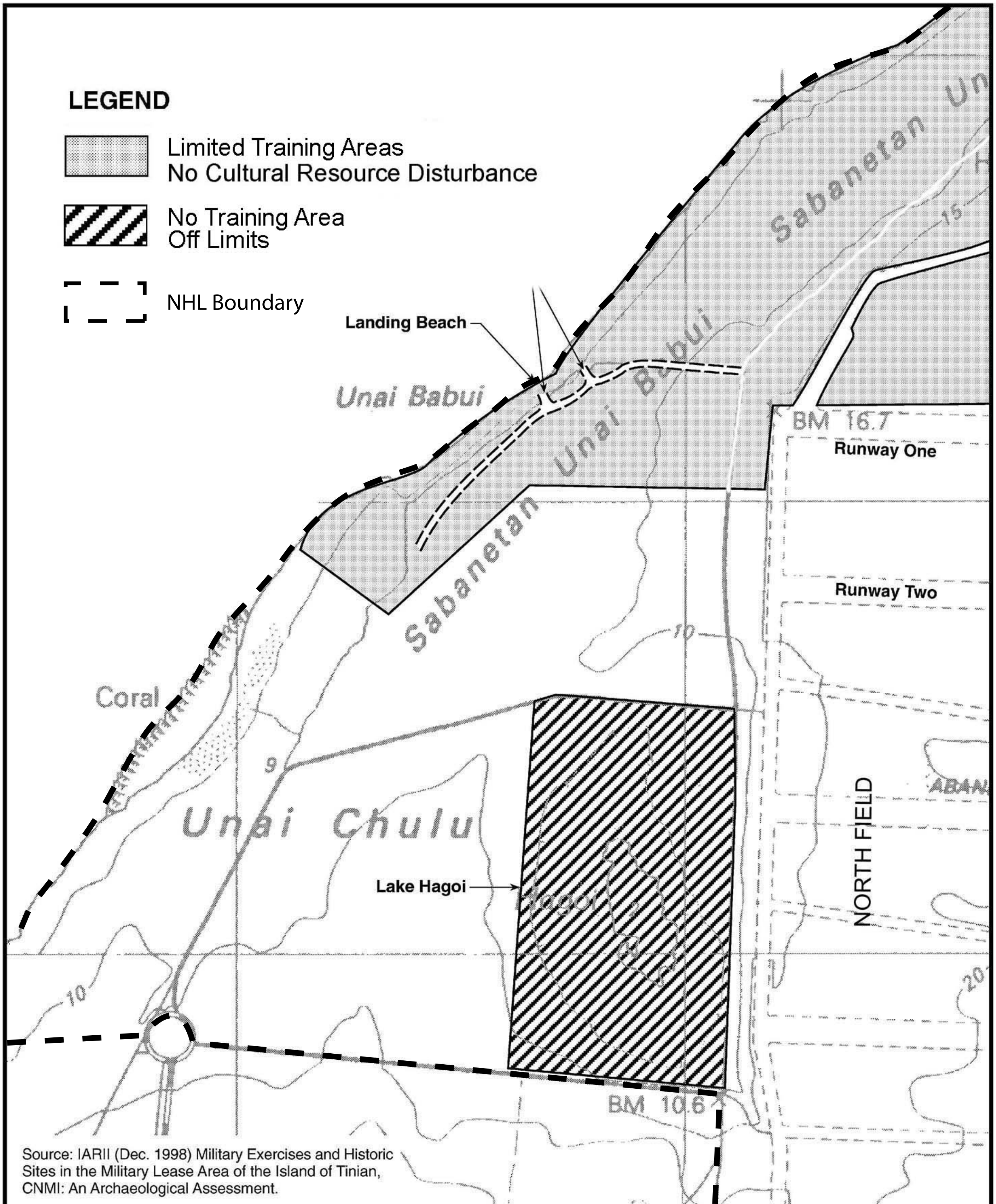
Tinian
Training Constraints Map



Unai Dankulo and Unai Masalok
Training Constraints Map



Unai Chulu
Training Constraints Map



Unai Babui & Lake Hagoi Training Constraints Map

APPENDIX C

STANDARD OPERATING PROCEDURES
FOR THE INADVERTENT DISCOVERY OF HUMAN BURIALS

ISLAND OF GUAM

NAVY STANDARD OPERATING PROCEDURE
REGARDING THE INADVERTENT DISCOVERY OF HUMAN REMAINS ON GUAM

PURPOSE: This SOP provides uniform guidelines in the event that human remains are inadvertently discovered or disturbed during the course of any action, undertaking, or activity (including those caused by natural occurrences such as erosion) on Navy-retained lands on Guam. Inadvertent discovery refers to the unintentional excavation or discovery of human remains.

ETHICS: Any human remains regardless of ethnicity or time of deposition shall be treated with respect and dignity.

REFERENCE: National Historic Preservation Act, 36 CFR Part 800; Archaeological Resources Protection Act; Certain aspects of the Native American Graves Protection and Repatriation Act and the Guam Department of Parks and Recreation General Guidelines for Archaeological Burials were also incorporated into this SOP.

RESPONSIBILITY: Primary responsibility for carrying out this SOP lies with the Navy's cultural resource manager under Commander, Navy Region Marianas (CNRM). These procedures should be briefed to all on-site managers and supervisors who are carrying out work that could result in inadvertent discovery of remains on Navy property or during Navy sponsored projects.

STANDARD OPERATING PROCEDURES
REGARDING THE INADVERTENT DISCOVERY OF
HUMAN REMAINS ON GUAM

<u>STEP I</u> – INITIAL DISCOVERY

If human skeletal remains (or remains thought to be human) are found during a Navy project or on Navy retained lands on Guam, the following procedures shall be followed:

1. The remains shall be protected from the elements and the area around the discovery shall be secured. CNRM security personnel and cultural resource manager should be notified immediately.
2. If human remains were uncovered during a Navy construction project, then the contracting officer associated with the specific project shall be notified per the contract clause referencing these procedures. A stop work order for the area within the immediate vicinity of the find shall be issued by the contracting officer, if appropriate. The contracting officer shall be notified of all subsequent consultations regarding the remains

<u>STEP II</u> PRELIMINARY IDENTIFICATION

CNRM cultural resource manager shall determine if the skeletal remains are animal or human. This shall be done through a professional trained in the identification of human remains (such as an archaeologist, physical anthropologist, forensic specialist) and such professional shall examine the remains and make a determination as to whether they are human. If the skeletal remains are identified as human, then proceed to Step III.

<u>STEP III</u> IDENTIFICATION - AGE OF DEPOSITION (TIME PERIOD) & ETHNICITY

If possible, the age of deposition (time period) and ethnicity of the remains shall be determined based on skeletal morphology, context, and associated artifacts by (or under the supervision of) an archaeologist meeting federal qualifications set forth in 36 CFR 61, Appendix A. This determination shall be made as soon as possible, taking into account specific circumstances regarding the discovery of the remains. The following steps shall be undertaken during the identification phase:

<u>Modern Remains</u>

If the skeletal remains are found to be human and are modern, then CNRM security personnel and Naval Criminal Investigative Services (NCIS) will take over the investigation.

World War II Remains

If the skeletal remains are found to be human and are from World War II (WWII), then the following procedures shall be followed:

1. If there is reason to believe that the remains are from WWII and are of the indigenous origin (Charmorro) or of any other civilian present on Guam at the time, then the Community/Public Affairs office shall be notified and involved in the consultation process.
2. If there is reason to believe that the remains are of U.S. military personnel, then the Joint POW/MIA Accounting Command (JPAC) shall be notified and will take over the case.
3. If there is reason to believe that the remains are Japanese from World War II, the Consulate General of Japan (CGJ), Agana, Guam, shall be notified and consulted with as to the disposition of the remains.
4. A courtesy call will be made to the Guam [State] Historic Preservation Office (SHPO) to inform them that human skeletal remains from WWII time period were uncovered. However, human remains from this time period are usually not considered as archaeological in nature and other agencies such as JPAC or CGJ have jurisdiction over those matters.

Depending on the preliminary determination by the agencies as to whether the remains are of recent, historic, or pre-contact deposition, the following steps shall be taken:

Remains Older than WWII (Historic and Prehistoric)

If the skeletal remains are found to be human and older than 50 years (and are not associated with WWII), then following procedures shall be followed:

1. The cultural resource manager shall notify the SHPO within three working days of the identification that the skeletal remains are human and are historic or prehistoric in nature.
2. If requested, the CNRM cultural resource manager shall arrange for a site visit by a SHPO representative.
3. The cultural resource manager shall consult with the SHPO and follow Section II and III of the Policy Guidance in the Guam Department of Parks and Recreation General Guidelines for Archaeological Burials.
4. If any other organization or agency comes forward and expresses an interest in participating in the consultation process, they must submit a written request expressing their desire to participate in the consultation process and explain how they are culturally affiliated with the human remains. Their comments will be considered in the overall decision making process.
5. If the remains are encountered during project construction, CNRM shall determine the feasibility of project alternatives that will avoid disturbance of the remains or whether disinterment is necessary. If a mass burial is indicated, preservation in place shall be the preferred alternative. The results of the consultation shall be placed on file at CNRM environmental office and JPAC shall be notified.

Undetermined Remains

If a determination as to the age of deposition of the remains or the ethnicity of the remains cannot be determined, the procedures below shall be followed:

1. The SHPO will be notified and consulted with. Based on the consultation, a decision will be made to either preserve the remains *in situ* or to remove them for further analysis in hopes that the age of deposition and ethnicity can eventually be determined so that the appropriate protocols can be followed.

2. If it is determined that the skeletal remains and any associated artifacts will be exhumed, then the remains should be documented by (or under the supervision of) a qualified archaeologist.

3. Tests involving damage to the skeletal material are highly discouraged and will not be performed by the Navy. However, should it be necessary, performance of radiocarbon dating on any associated charcoal, midden, or artifacts may be conducted at the discretion of the Navy in consultation with the SHPO in order to determine age of deposition. The results of these tests, if any, shall be presented in the report by the recording professional. This report shall be submitted to the CNRM cultural resource manager and the SHPO as a record of the study.

4. If additional tests were conducted, another attempt to determine age of deposition and determine the ethnicity of the skeletal remains will be made based on the results. If a determination can be made on the age of deposition or ethnicity, then the disposition of the human remains will be conducted according to appropriate protocols outlined previously.

5. If a professional(s) not associated with the Navy, meeting the qualifications set forth in 36 CFR 61 Appendix A, seeks to analyze the skeletal remains they shall submit a written request to the CNRM cultural resource manager. The CNRM cultural resource manager shall notify the SHPO of the request and will follow the procedures outlined in the Research Guidelines section of the Guam Department of Parks and Recreation General Guidelines for Archaeological Burials. The applicant shall be notified within 30 days of submission of the Research Design whether it has been accepted or rejected. The cost of the tests and report preparation shall be borne by the applicant. A copy of the results and findings shall be provided to the Navy and the SHPO within six months after the tests are conducted. The remains shall be curated at the laboratory of the researcher until plans for reburial have been made.

6. If the age of deposition or ethnicity of the human remains cannot be determined, then the CNRM cultural resource manager, in consultation with the SHPO, shall curate the remains and any associated artifacts in the event that further information may come to light or rebury the remains. A record of the consultation process shall be placed on file at CNRM environmental office and at the SHPO.

STEP IV DISPOSITION

CNRM shall follow Sections II and III of the Policy Guidance in the Guam Department of Parks and Recreation General Guidelines for Archaeological Burials when dealing with the disposition of human remains older than WWII. Reiterated below are procedures tailored specifically to burials found on Navy property on Guam using the Department of Parks and Recreation General Guidelines for Archaeological Burials as a general guideline.

1. If the remains are found eroding out of the soil, the Navy, in consultation with the SHPO, shall decide whether the remains can be preserved in place or whether the remains would be severely damaged by leaving them *in situ***.** The results of the decision-making process shall be placed on file at the CNRM environmental office.

2. If the remains are exposed during a project, and the project can be redesigned to avoid the remains, or the remains can be left in place then the following steps shall be taken: The remains and any associated artifacts shall be recorded *in situ* by an individual meeting the qualifications set forth in 36 CFR 61.9 using standard archeological procedures set forth in 48 CFR 44720. Every effort shall be made to determine the number of individuals and the age, sex, and ethnicity of the remains. The documentation and a record of the location of the remains shall be kept on file at CNRM environmental office. A copy shall be provided to the SHPO.

3. If the project cannot be redesigned to avoid disturbing the remains the following steps shall be followed:

   (a) The remains and any associated artifacts shall be removed by an archeologist meeting the professional qualifications set forth in 36 CFR 61.9**,** using standard archeological procedures set forth in 48 CFR 44720.

   (b) A report of the excavation techniques and findings, along with a photographic record shall be submitted to CNRM within 30 days of disinterment. The documentation shall be kept on file at CNRM and a copy provided to the HPO; any associated artifacts shall be temporarily curated at the contractor's laboratory until the final disposition of the remains is determined.

4. If remains have to be moved, then through consultation with the SHPO it will be determined by CNRM that the human remains may be reburied elsewhere. COMAVMARIANAS will follow Section IV(A)(1 and 4) or Section IV(B) of the Guam Department of Parks and Recreation General Guidelines for Archaeological Burials if determined appropriate and funds are available. The documentation and a record of the location of the remains shall be kept on file at the CNRM environmental office. A copy shall be provided to the SHPO.

AIR FORCE (36TH WING) STANDARD OPERATING PROCEDURE FOR THE INADVERTENT DISCOVERY OF HUMAN REMAINS

PURPOSE: This SOP provides uniform guidelines in the event that human remains are inadvertently disturbed during the course of any action, undertaking, or activity at Andersen AFB (including those caused by natural occurrences such as erosion). Inadvertent discovery refers to the unintentional discovery of human remains during the course of any operations.

REFERENCE: National Historic Preservation Act, 36 CFR Part 800; Archaeological Resources Protection Act; DoD Directive 4710.1; DoD Instruction 4715.3

RESPONSIBILITY: Primary responsibility for carrying out this SOP lies with on-site managers of the undertaking and the Andersen AFB Cultural Resource Manager (CRM). A copy of this SOP should be provided to all on-site managers and supervisors who are carrying out work that could result in inadvertent discovery of remains. A copy should also be provided to Law Enforcement, 36 SFS.

PROCEDURES.

1. Upon discovery of unanticipated archaeological remains, the individual making the discovery should notify the on-site manager or person in charge of the action, undertaking, or activity. The on-site manager should immediately halt the action, undertaking, or activity in the vicinity of the discovery.

2. The on-site manager should ensure that a reasonable effort is made to secure the area and protect the archaeological resource from damage (including vandalism). This might include cordoning the area and covering exposed items with a tarp or similar material.

3. The on-site manager should notify Andersen AFB law enforcement personnel immediately. Security personnel should inspect the remains to ensure that they are not of recent origin.

4. If the remains are not of recent origin, the on-site manager should contact the Andersen AFB CRM to report the nature, location, and circumstances of the inadvertent discovery.

5. The CRM should carry out the following actions, if necessary:

    A. arrange for an evaluation by a professional archaeologist to determine if the remains are human or non-human, and if human, to evaluate the origin, nature, and ethnicity (if possible) of the human remains. A determination of whether the inadvertent discovery constitutes a "historic property" under the NHPA should also be made; if so, then Section 106 proceedings are also called into play.

    B. if the remains are human, notify the Guam HPO immediately.

C. in consultation with the Guam HPO, the CRM should ensure that the remains are properly treated until appropriate disposition of the remains has taken place. The Guam HPO should also be consulted as to appropriate disposition protocols.

6. The CRM will make a tracking report of the inadvertent discovery for inclusion in the annual report of historic preservation activities on the installation.

7. Prior to resuming the action, undertaking, or activity, the Andersen AFB CRM should ensure that associated cultural resources discovered by this process are protected and/or adverse effects are mitigated. If associated cultural resources are protected, the CRM should ensure that they will not be further impacted by continuing the activity.

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STANDARD OPERATING PROCEDURE
FOR THE INADVERTENT DISCOVERY OF HUMAN REMAINS
WITHIN THE COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS

PURPOSE: This Standard Operating Procedure (SOP) provides uniform guidelines in the event that human remains are inadvertently discovered during the course of any Navy action, undertaking, or activity (including those caused by natural occurrences such as erosion) or on Navy property or Department of Defense (DoD) leased lands within the Commonwealth of the Northern Mariana Islands (CNMI).

ETHICS: Any human remains regardless of ethnicity or time of deposition shall be treated with respect and dignity.

REFERENCES: National Historic Preservation Act, 36 CFR Part 800; Archaeological Resources Protection Act; Native American Graves Protection and Repatriation Act and the CNMI Historic Preservation Office's (HPO) Procedures for the Treatment of Human Remains in the Commonwealth of the Northern Mariana Islands (May 2000) were also incorporated into this SOP.

RESPONSIBILITY: Primary responsibility for carrying out this SOP lies with the Navy's cultural resource manager under Commander, Navy Region Marianas (CNRM). These procedures should be briefed to all on-site managers and supervisors who are carrying out work that could result in inadvertent discovery of remains on Navy property or DoD leased property.

DEFINITIONS: In this SOP, human remains are defined as whole or partial human skeletal remains including dentition. Human skeletal remains that have been transformed or utilitzed as artifacts (tools, implements, decoration, jewelry, etc.) are excluded from this definition. These items shall be treated as artifacts. The term "inadvertent discovery" refers to the unintentional excavation or discovery of human remains.

STANDARD OPERATING PROCEDURES
FOR THE INADVERTENT DISCOVERY OF HUMAN REMAINS
WITHIN THE COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS

STEP I – INITIAL DISCOVERY

If human skeletal remains (or remains thought to be human) are found during a Navy project or on Navy-retained or DoD leased lands within CNMI, the procedures below shall be followed:

1. The remains shall be protected from the elements and the area around the discovery shall be secured. Security personnel and the Navy's cultural resource manager (CRM) should be notified immediately.
2. If the remains are found during a Navy sponsored construction project or on Navy retained-lands or DoD leased land, then work in the immediate vicinity shall be halted until the situation is properly evaluated. If this project is tied to a construction project, then the contracting officer associated with the specific project shall be notified per the contract clause referencing these procedures. A stop work order for the area within the immediate vicinity of the find shall be issued by the contracting officer, if appropriate. The contracting officer shall be notified of all subsequent consultations regarding the remains.

STEP II PRELIMINARY IDENTIFICATION

The CRM shall determine if the skeletal remains are animal or human. If the CRM does not have a background or training in osteology, the identification should be done through a professional trained in the identification of human remains (such as an archaeologist, physical anthropologist, forensic specialist, medical examiner, or M.D.) and such professional shall examine the remains and make a determination as to whether they are human. If the skeletal remains are identified as human, then proceed to Step III.

STEP III IDENTIFICATION - AGE OF DEPOSITION (TIME PERIOD) & ETHNICITY

If possible, the age of deposition (time period) and ethnicity of the remains shall be determined based on skeletal morphology, burial context, and associated artifacts. This identification should be conducted by (or under the supervision of) an archaeologist that meets the federal qualifications set forth by the Secretary of the Interior in 36 CFR 61, Appendix A. This determination shall be made as soon as possible, taking into account specific circumstances regarding the discovery of the remains.

The following steps shall be undertaken during the identification phase:

Modern Remains

If the skeletal remains are found to be human and are modern, then Navy security personnel and the Naval Criminal Investigative Service will take over the investigation.

World War II Remains

If the skeletal remains are found to be human and are from World War II (WWII), then the following procedures shall be followed:

1. In all cases of WWII period human remains, the Navy's Community/Public Affairs office shall be notified.
2. If there is reason to believe that the human remains are of Chamorro descent and from WWII, then the CNMI HPO will be notified since the CNMI Department of Culture and Community Affairs has designated the CNMI HPO as the agency that handles civilian remains from WWII discovered within CNMI. The CNMI HPO will be consulted with as to how the remains will be repatriated.
3. If there is reason to believe that the remains are from WWII and are civilians of Carolinian descent, then the Carolinian Affairs (CA) office will be notified and will be consulted with as to how the remains will be repatriated.
4. If there is reason to believe that the remains are of U.S. military personnel from WWII, then the Joint POW/MIA Accounting Command (JPAC) shall be notified and will take over the investigation.
5. If there is reason to believe that the remains are Japanese civilians from WWII, the Saipan Consular Office of Japan (COJ) shall be notified and will be consulted with as to how the remains will be repatriated.
6. If there is reason to believe that the remains are Korean civilians from WWII, the Republic of Korea Consulate General (ROKCG) in Guam shall be notified and will be consulted with as to how the remains will be repatriated.
7. The CNMI HPO will be notified (in the form of a phone call) to inform them that human skeletal remains were discovered and are believed to be from the WWII time period. The CNMI HPO is the keeper of records regarding all human remains disinterred in CNMI from WWII. However, since human remains from this time period are under the jurisdiction of other agencies such as CA office, JPAC, COJ, ROKCG , the Navy will put these agencies in touch with the CNMI HPO. If the agencies mentioned above decide to that they want the human remains exhumed, a record of the context, associated objects, and photograph and sketch the remains will be submitted to the HPO SHPO after the remains are disinterred.

Depending on the preliminary determination as to whether the remains are of recent, historic, or pre-contact deposition, the following steps shall be taken:

Remains Older than WWII (Historic and Prehistoric)

If the skeletal remains are found to be human and older than 50 years (and are not associated with WWII), then following procedures shall be followed:

1. CRM shall notify the CNMI HPO within five working days of the identification that the skeletal remains are human and are historic or prehistoric in nature.
2. If requested, the CRM shall arrange for a site visit by a CNMI HPO representative.
3. If possible, the CRM should identify the ethnic affiliation (Chamorro or Carolinian) of the human remains in consultation with the CNMI HPO.[1]
4. If any other organization or agency comes forward and expresses an interest in participating in the consultation process, they must submit a written request expressing their desire to participate in the consultation process and explain how they are culturally affiliated with the human remains. The CRM will assess this request along with the CNMI HPO. Their comments will be considered in the overall decision making process.
5. If the remains are encountered during project construction, CRM shall determine the feasibility of project alternatives that will avoid disturbance of the remains or whether disinterment is necessary. If a mass burial is indicated, preservation is the preferred alternative. The results of the consultation shall be placed on file at CNRM environmental office

Undetermined Remains

If a determination as to the age of deposition of the remains or the ethnicity of the remains cannot be determined, the following procedures shall be followed:

1. The CNMI HPO will be notified and consulted with. Based on the consultation, a decision will be made to either preserve the remains *in situ* or to remove them for further analysis in hopes that the age of deposition and ethnicity can eventually be determined so that the appropriate protocols can be followed.
2. If it is determined that the skeletal remains and any associated artifacts will be excavated, then they should be documented by (or under the supervision of) a qualified archaeologist.
3. Tests involving damage to the skeletal material are highly discouraged and will not be performed by the Navy. However, should it be necessary, performance of radiocarbon dating on any associated charcoal, midden, or artifacts may be conducted at the discretion of the Navy in consultation with the CNMI HPO in order to determine age of deposition. The results of these tests, if any, shall be presented in the report by the recording professional. This report shall be submitted to the CNRM environmental office and the CNMI HPO as a record of the study.
4. If additional studies are conducted, another attempt to determine age of deposition and determine ethnicity of the skeletal remains will be made based on the results. If a determination can be made on the age of deposition or ethnicity, then the disposition of the human remains will be conducted according to appropriate protocols outlined previously.

[1] Although not likely, but if Native American, Native Alaskan, or Native Hawaiian remains are encountered, then CNRM shall follow the procedures outlined in the Native American Graves Protection and Repatriation Act.

5. If a professional(s) not associated with the Navy, meeting the qualifications set forth in 36 CFR 61 Appendix A, seeks to analyze the skeletal remains they shall submit a written request to the CRM. The CRM shall notify the CNMI HPO of the request. A research design acceptable to both the CRM and the CNMI HPO will be required in order to conduct analyses on human remains recovered from Navy managed lands. In addition, the applicant shall fill out and submit to the CNMI HPO, a curation agreement form. The applicant shall be notified within 30 days of submission of the Research Design whether it has been accepted or rejected. The cost of the tests and report preparation shall be borne by the applicant. A copy of the results and findings shall be provided to the CRM and CNMI HPO within six months after the tests are conducted. The remains shall be curated at the laboratory of the researcher until plans for reburial have been made.
6. If the age of deposition or ethnicity of the remains cannot be determined and exhumation is necessary, then the Navy in consultation with the HPO shall curate the remains and any associated artifacts in the event that further information may come to light or rebury the remains. A record of the consultation process shall be placed on file at CNRM environmental office and at the CNMI HPO.

<u>STEP IV</u> DISPOSITION

Reiterated below are procedures tailored specifically to disposition of human remains found on Navy property or DoD leased land within CNMI using the Section V (Class I and II) of the CNMI HPO's Procedures for the Treatment of Human Remains in the Commonwealth of the Northern Mariana Islands (May 2000) as a general guideline. These procedures apply to prehistoric and historic human remains. The disposition of human remains from WWII or modern origin will be primarily handled by other entities and agencies as mentioned in STEP III.

Disposition of pre-historic and historic human remains:

1. If human remains are discovered eroding out of sediments, then the Navy, in consultation with the CNMI HPO, shall decide whether the remains can be preserved in place or whether the remains should be removed. The results of the decision-making process shall be placed on file at CNRM environmental office. The CRM shall carry out the procedures agreed upon during the consultation process.

2. If the remains are exposed during a project, and the project can be redesigned to avoid the remains, or the remains can be left *in situ* without impacts to the project, then the following steps shall be taken:
    a. The location and description of the remains and any associated artifacts shall be recorded *in situ* by an individual meeting the qualifications set forth in 36 CFR 61.9 using standard archeological procedures set forth in 48 CFR 44720.
    b. Every effort shall be made to determine the number of individuals and the age, sex, and ethnicity of the remains. The documentation and a record of the location of the remains shall be kept on file at CNRM environmental office. A copy shall be provided to the CNMI HPO.

3. If the project cannot be redesigned to avoid disturbing the remains the following steps shall be followed:

a. The remains and any associated artifacts shall be removed by an archeologist meeting the professional qualifications set forth in 36 CFR 61.9**,** Appendix A, using standard archeological procedures set forth in 48 CFR 44720. If the Navy or contractor seeks to curate the artifacts for a short time before turning over the artifacts to the CNMI HPO, then an artifact loan agreement form needs to filled out and submitted to the CNMI HPO.

b. A report of the excavation techniques and findings, along with a photographic record and sketches shall be submitted to CRM within 180 days of disinterment. The documentation shall be kept on file at CNRM environmental office and a copy will be provided to the HPO; any associated artifacts shall be temporarily curated at the contractor's laboratory until the final disposition of the remains is determined.

4. If remains have to be moved, then through consultation with the CNMI HPO it will be determined by CRM that the human remains may be reburied elsewhere. The CRM will consult with the CNMI HPO as to the appropriate location. The documentation and a record of the location of the remains shall be kept on file at CNRM environmental office a copy shall be provided to the CNMI HPO.

<u>STEP V.</u> CULTURAL ACCESS

Any requests for access to the burial sites should be submitted to CRM in writing. The agency or organization must show how their organization is culturally associated with the remains in order for their request to be considered a legitimate cultural access request. If the Navy determines that the agency or organization has a legitimate cultural access request, then they Navy will arrange a date and time for them to access the site taking into account current Navy security and training schedules. Site visit protocols require the visitors be escorted by a Navy representative at all times, that the visitors conduct themselves in a respectable manner, and follow all Navy rules and regulations while on the installation. Any behavior otherwise, and the individual(s) will be escorted off the installation or even restricted from entering again. Persons may be denied access if they do not pass the Navy’s security clearance procedures. However, every effort will be made to accommodate legitimate cultural access requests. Access requests shall be placed on file at CNRM environmental office will be reported to the CNMI HPO on a yearly basis.