NAVFAC Atlantic Biological Resource Services

Contract: N62470-08-D-1008; Task Order No. KB03

September 30, 2013

Final Marine Resource Assessment for the Japan and Mariana Archipelagos Volume I: Chapters 1-5

Prepared for:
NAVFAC Pacific
Acquisitions (ACQ32)
258 Makalapa Drive, Suite 100
Pearl Harbor, HI 96860-3134

Prepared by:
Tetra Tech, Inc.
2200 Wilson Blvd., Suite 400
Arlington, VA 22201

NAVFAC Atlantic Biological Resource Services

Contract # N62470-08-D-1008; Task Order KB03

Final Marine Resource Assessment for the Japan and Mariana Archipelagos

September 30, 2013

Tetra Tech, Inc.
2200 Wilson Blvd., Suite 400
Arlington, VA 22201

TABLE OF CONTENTS

LIST OF FIGURES.....xv
LIST OF TABLES.....xxi
LIST OF ACRONYMS AND ABBREVIATIONS.....xxiii

1.0 INTRODUCTION.....1-1
1.1 STATEMENT OF PURPOSE AND NEED.....1-1
1.2 LOCATION OF MRA STUDY AREA.....1-1
1.1.1 Open Ocean Waters of the MRA Study Area.....1-5
1.1.2 Coastal Waters of the MRA Study Area.....1-5
1.3 REPORT ORGANIZATION.....1-17
1.4 REFERENCES.....1-19

2.0 APPLICABLE LAWS AND LEGISLATION.....2-1
2.1 INTRODUCTION.....2-1
2.2 FEDERAL RESOURCE LAWS.....2-1
2.2.1 National Environmental Policy Act.....2-1
2.2.2 Rivers and Harbors Appropriation Act.....2-2
2.2.3 Submerged Lands Act.....2-2
2.2.4 Outer Continental Shelf Lands Act.....2-2
2.2.5 Marine Mammal Protection Act.....2-2
2.2.6 Endangered Species Act.....2-3
2.2.7 Migratory Bird Treaty Act.....2-4
2.2.8 Coral Reef Conservation Act.....2-5
2.2.9 Magnuson-Stevens Fishery Conservation and Management Act.....2-5
2.2.10 National Fishing Enhancement Act.....2-6
2.2.11 Sikes Act.....2-7
2.2.12 Coastal Zone Management Act.....2-7
2.2.13 Marine Protection, Research, and Sanctuaries Act.....2-8
2.2.14 National Marine Sanctuaries Act.....2-8
2.2.15 National Invasive Species Act.....2-8
2.2.16 Clean Water Act.....2-9
2.2.17 Marine Plastic Pollution Research and Control Act.....2-9
2.2.18 Marine Debris Research, Prevention, and Reduction Act.....2-9
2.2.19 Comprehensive Environmental Response, Compensation, and Liability Act.....2-10
2.2.20 Oil Pollution Act.....2-10
2.2.21 Harmful Algal Bloom and Hypoxia Research and Control Act.....2-10
2.2.22 Estuary Restoration Act.....2-10
2.2.23 National Historic Preservation Act.....2-11
2.2.24 Antiquities Act.....2-11
2.2.25 National Wildlife Refuge System Improvement Act.....2-11
2.2.26 Historic Sites Act.....2-12
2.2.27 Abandoned Shipwreck Act.....2-12
2.2.28 Archaeological Resources Protection Act.....2-12
2.3 EXECUTIVE ORDERS AND PRESIDENTIAL PROCLAMATIONS.....2-12
2.3.1 Executive Order 11990–Protection of Wetlands.....2-12
2.3.2 Executive Order 12114–Environmental Effects Abroad of Major Federal Actions.....2-13
2.3.3 Executive Order 12962–Recreational Fisheries.....2-13
2.3.4 Executive Order 13089–Coral Reef Protection.....2-13
2.3.5 Executive Order 13112–Invasive Species.....2-14
2.3.6 Executive Order 13158–Marine Protected Areas.....2-14
2.3.7 Executive Order 13186–Responsibilities of Federal Agencies to Protect Migratory Birds.....2-14
2.3.8 Executive Order 13547–Stewardship of the Ocean, Our Coasts, and the Great Lakes.....2-14

2.3.9 Presidential Proclamation 8335–Establishment of the Marianas Trench Marine National Monument ... 2-15
2.4 DEPARTMENT OF DEFENSE ENVIRONMENTAL COMPLIANCE ... 2-15
2.5 AT-SEA COMPLIANCE ... 2-16
2.6 INTERNATIONAL ENVIRONMENTAL CONVENTIONS, TREATIES, AND ORGANIZATIONS ... 2-16
2.6.1 International Convention for the Prevention of Pollution from Ships ... 2-16
2.6.2 United Nations Convention on the Law of the Sea ... 2-17
2.6.3 International Seabed Authority ... 2-17
2.6.4 London Convention ... 2-18
2.6.5 International Convention for the Regulation of Whaling ... 2-18
2.6.6 Convention on Biological Diversity ... 2-18
2.6.7 Convention on the Conservation of Migratory Species of Wild Animals ... 2-18
2.6.8 Convention on International Trade in Endangered Species of Wild Fauna and Flora ... 2-19
2.7 REFERENCES ... 2-20
3.0 METHODOLOGY ... 3-1
3.1 INTRODUCTION ... 3-1
3.2 OVERVIEW OF THE MRA UPDATE PROCESS ... 3-1
3.3 GEOGRAPHIC FOCUS ... 3-1
3.4 SPECIES SELECTION CRITERIA ... 3-1
3.4.1 Marine Mammals ... 3-1
3.4.2 Reptiles ... 3-2
3.4.3 Seabirds ... 3-2
3.4.4 Marine Vegetation ... 3-2
3.4.5 Invertebrates ... 3-2
3.4.6 Fishes ... 3-2
3.4.7 Marine Protected Areas ... 3-3
3.5 LITERATURE AND DATA SEARCH ... 3-3
3.6 DATA CONFIDENCE ... 3-4
3.7 SPATIAL DATA ... 3-4
3.8 ECOSYSTEM TERMS AND CHARACTERISTICS CONSIDERED IN THE MRA ... 3-7
3.8.1 Ecosystem Scale ... 3-7
3.8.2 Biogeography ... 3-9
3.8.3 Ecosystem Integrity ... 3-17
3.8.4 Ecosystem Disturbance ... 3-25
3.9 REFERENCES ... 3-31
4.0 OCEANOGRAPHY ... 4-1
4.1 INTRODUCTION ... 4-1
4.2 CLIMATE/WEATHER ... 4-1
4.2.1 Seasons and Storms ... 4-1
4.2.2 El Niño-Southern Oscillation ... 4-5
4.2.3 Pacific Decadal Oscillation ... 4-8
4.2.4 Climate Change ... 4-8
4.3 MARINE GEOLOGY ... 4-9
4.3.1 Bathymetry and Physiography ... 4-9
4.3.2 Substrate ... 4-25
4.3.3 Geologic Processes ... 4-29
4.3.4 Tsunami ... 4-32
4.4 PHYSICAL OCEANOGRAPHY ... 4-34
4.4.1 Surface Currents and Circulation ... 4-34
4.4.2 Subsurface Currents and Water Masses ... 4-44
4.4.3 Oceanic Fronts ... 4-47
4.5 CHEMICAL OCEANOGRAPHY ... 4-47
4.5.1 Water Column Characteristics ... 4-47

4.5.2 Chemical Cycles *4-53*
4.6 BIOLOGICAL OCEANOGRAPHY 4-54
4.6.1 Primary Production *4-54*
4.6.2 Secondary Production *4-65*
4.6.3 Harmful Algal Blooms *4-66*
4.6.4 References *4-68*
5.0 MARINE MAMMALS 5-1
5.1 INTRODUCTION 5-1
5.1.1 Global Distribution and Preferred Habitat *5-1*
5.1.2 Biology, Life History, and Behavior *5-4*
5.1.3 Global Threats and Management *5-5*
5.2 SPECIES LIST AND STATUS 5-6
5.3 NORTH PACIFIC RIGHT WHALE (*EUBALAENA JAPONICA*) 5-13
5.3.1 Description *5-13*
5.3.2 Status and Management *5-13*
5.3.3 Population and Abundance *5-13*
5.3.4 Biology, Ecology, and Behavior *5-14*
5.3.5 Habitat and Distribution *5-15*
5.3.6 Species-specific Threats *5-17*
5.4 OMURA'S WHALE (*BALAENOPTERA OMURAI*) 5-21
5.4.1 Description *5-21*
5.4.2 Status and Management *5-21*
5.4.3 Population and Abundance *5-21*
5.4.4 Biology, Ecology, and Behavior *5-21*
5.4.5 Habitat and Distribution *5-22*
5.4.6 Species-specific Threats *5-23*
5.5 HUMPBACK WHALE (*MEGAPTERA NOVAEANGLIAE*) 5-27
5.5.1 Description *5-27*
5.5.2 Status and Management *5-27*
5.5.3 Population and Abundance *5-27*
5.5.4 Biology, Ecology, and Behavior *5-28*
5.5.5 Habitat and Distribution *5-32*
5.5.6 Species-specific Threats *5-34*
5.6 COMMON MINKE WHALE (*BALAENOPTERA ACUTOROSTRATA*) 5-39
5.6.1 Description *5-39*
5.6.2 Status and Management *5-39*
5.6.3 Population and Abundance *5-40*
5.6.4 Biology, Ecology, and Behavior *5-40*
5.6.5 Habitat and Distribution *5-42*
5.6.6 Species-specific Threats *5-43*
5.7 BRYDE'S WHALE (*BALAENOPTERA BRYDEI/EDENI*) 5-47
5.7.1 Description *5-47*
5.7.2 Status and Management *5-47*
5.7.3 Population and Abundance *5-47*
5.7.4 Biology, Ecology, and Behavior *5-48*
5.7.5 Habitat and Distribution *5-49*
5.7.6 Species-specific Threats *5-51*
5.8 SEI WHALE (*BALAENOPTERA BOREALIS*) 5-57
5.8.1 Description *5-57*
5.8.2 Status and Management *5-57*
5.8.3 Population and Abundance *5-57*
5.8.4 Biology, Ecology, and Behavior *5-58*
5.8.5 Habitat and Distribution *5-59*
5.8.6 Species-specific Threats *5-60*

5.9 FIN WHALE (*BALAENOPTERA PHYSALUS*) 5-67
5.9.1 Description 5-67
5.9.2 Status and Management 5-67
5.9.3 Population and Abundance 5-67
5.9.4 Biology, Ecology, and Behavior 5-68
5.9.5 Habitat and Distribution 5-69
5.9.6 Species-specific Threats 5-71
5.10 BLUE WHALE (*BALAENOPTERA MUSCULUS*) 5-75
5.10.1 Description 5-75
5.10.2 Status and Management 5-75
5.10.3 Population and Abundance 5-75
5.10.4 Biology, Ecology, and Behavior 5-76
5.10.5 Habitat and Distribution 5-77
5.10.6 Species-specific Threats 5-79
5.11 GRAY WHALE (*ESCHRICHTIUS ROBUSTUS*) 5-83
5.11.1 Description 5-83
5.11.2 Status and Management 5-83
5.11.3 Population and Abundance 5-83
5.11.4 Biology, Ecology, and Behavior 5-84
5.11.5 Habitat and Distribution 5-86
5.11.6 Species-specific Threats 5-87
5.12 SPERM WHALE (*PHYSETER MACROCEPHALUS*) 5-91
5.12.1 Description 5-91
5.12.2 Status and Management 5-91
5.12.3 Population and Abundance 5-92
5.12.4 Biology, Ecology, and Behavior 5-92
5.12.5 Habitat and Distribution 5-94
5.12.6 Species-specific Threats 5-97
5.13 PYGMY SPERM WHALE (*KOGIA BREVICEPS*) 5-103
5.13.1 Description 5-103
5.13.2 Status and Management 5-103
5.13.3 Population and Abundance 5-103
5.13.4 Biology, Ecology, and Behavior 5-103
5.13.5 Habitat and Distribution 5-104
5.13.6 Species-specific Threats 5-106
5.14 DWARF SPERM WHALE (*KOGIA SIMA*) 5-109
5.14.1 Description 5-109
5.14.2 Status and Management 5-109
5.14.3 Population and Abundance 5-109
5.14.4 Biology, Ecology, and Behavior 5-109
5.14.5 Habitat and Distribution 5-110
5.14.6 Species-specific Threats 5-111
5.15 CUVIER'S BEAKED WHALE (*ZIPHIUS CAVIROSTRIS*) 5-117
5.15.1 Description 5-117
5.15.2 Status and Management 5-117
5.15.3 Population and Abundance 5-117
5.15.4 Biology, Ecology, and Behavior 5-118
5.15.5 Habitat and Distribution 5-119
5.15.6 Species-specific Threats 5-120
5.16 BLAINVILLE'S BEAKED WHALE (*MESOPLODON DENSIROSTRIS*) 5-127
5.16.1 Description 5-127
5.16.2 Status and Management 5-127
5.16.3 Population and Abundance 5-127
5.16.4 Biology, Ecology, and Behavior 5-127

5.16.5 Habitat and Distribution 5-129
5.16.6 Species-specific Threats 5-130
5.17 BAIRD'S BEAKED WHALE (*BERARDIUS BAIRDII*) 5-133
5.17.1 Description 5-133
5.17.2 Status and Management 5-133
5.17.3 Population and Abundance 5-133
5.17.4 Biology, Ecology, and Behavior 5-133
5.17.5 Habitat and Distribution 5-134
5.17.6 Species-specific Threats 5-135
5.18 LONGMAN'S BEAKED WHALE (*INDOPACETUS PACIFICUS*) 5-139
5.18.1 Description 5-139
5.18.2 Status and Management 5-139
5.18.3 Population and Abundance 5-139
5.18.4 Biology, Ecology, and Behavior 5-139
5.18.5 Habitat and Distribution 5-140
5.18.6 Species-specific Threats 5-141
5.19 HUBBS' BEAKED WHALE (*MESOPLODON CARLHUBBSI*) 5-145
5.19.1 Description 5-145
5.19.2 Status and Management 5-145
5.19.3 Population and Abundance 5-145
5.19.4 Biology, Ecology, and Behavior 5-145
5.19.5 Habitat and Distribution 5-146
5.19.6 Species-specific Threats 5-147
5.20 GINKGO-TOOTHED BEAKED WHALE (*MESOPLODON GINKGODENS*) 5-151
5.20.1 Description 5-151
5.20.2 Status and Management 5-151
5.20.3 Population and Abundance 5-151
5.20.4 Biology, Ecology, and Behavior 5-151
5.20.5 Habitat and Distribution 5-152
5.20.6 Species-specific Threats 5-153
5.21 STEJNEGER'S BEAKED WHALE (*MESOPLODON STEJNEGERI*) 5-157
5.21.1 Description 5-157
5.21.2 Status and Management 5-157
5.21.3 Population and Abundance 5-157
5.21.4 Biology, Ecology, and Behavior 5-157
5.21.5 Habitat and Distribution 5-158
5.21.6 Species-specific Threats 5-159
5.22 ROUGH-TOOTHED DOLPHIN (*STENO BREDANENSIS*) 5-163
5.22.1 Description 5-163
5.22.2 Status and Management 5-163
5.22.3 Population and Abundance 5-163
5.22.4 Biology, Ecology, and Behavior 5-164
5.22.5 Habitat and Distribution 5-165
5.22.6 Species-specific Threats 5-166
5.23 COMMON BOTTLENOSE DOLPHIN (*TURSIOPS TRUNCATUS*) 5-171
5.23.1 Description 5-171
5.23.2 Status and Management 5-171
5.23.3 Population and Abundance 5-172
5.23.4 Biology, Ecology, and Behavior 5-172
5.23.5 Habitat and Distribution 5-175
5.23.6 Species-specific Threats 5-177
5.24 LONG-BEAKED COMMON DOLPHIN (*DELPHINUS CAPENSIS*) 5-185
5.24.1 Description 5-185
5.24.2 Status and Management 5-185

5.24.3 Population and Abundance *5-185*
5.24.4 Biology, Ecology, and Behavior *5-185*
5.24.5 Habitat and Distribution *5-186*
5.24.6 Species-specific Threats *5-187*
5.25 SHORT-BEAKED COMMON DOLPHIN (*DELPHINUS DELPHIS*) 5-191
5.25.1 Description *5-191*
5.25.2 Status and Management *5-191*
5.25.3 Population and Abundance *5-192*
5.25.4 Biology, Ecology, and Behavior *5-192*
5.25.5 Habitat and Distribution *5-193*
5.25.6 Species-specific Threats *5-194*
5.26 PANTROPICAL SPOTTED DOLPHIN (*STENELLA ATTENUATA*) 5-199
5.26.1 Description *5-199*
5.26.2 Status and Management *5-199*
5.26.3 Population and Abundance *5-199*
5.26.4 Biology, Ecology, and Behavior *5-200*
5.26.5 Habitat and Distribution *5-201*
5.26.6 Species-specific Threats *5-203*
5.27 SPINNER DOLPHIN (*STENELLA LONGIROSTRIS*) 5-209
5.27.1 Description *5-209*
5.27.2 Status and Management *5-209*
5.27.3 Population and Abundance *5-210*
5.27.4 Biology, Ecology, and Behavior *5-210*
5.27.5 Habitat and Distribution *5-211*
5.27.6 Species-specific Threats *5-213*
5.28 STRIPED DOLPHIN (*STENELLA COERULEOALBA*) 5-219
5.28.1 Description *5-219*
5.28.2 Status and Management *5-219*
5.28.3 Population and Abundance *5-219*
5.28.4 Biology, Ecology, and Behavior *5-220*
5.28.5 Habitat and Distribution *5-221*
5.28.6 Species-specific Threats *5-222*
5.29 FRASER'S DOLPHIN (*LAGENODELPHIS HOSEI*) 5-229
5.29.1 Description *5-229*
5.29.2 Status and Management *5-229*
5.29.3 Population and Abundance *5-229*
5.29.4 Biology, Ecology, and Behavior *5-230*
5.29.5 Habitat and Distribution *5-230*
5.29.6 Species-specific Threats *5-231*
5.30 RISSO'S DOLPHIN (*GRAMPUS GRISEUS*) 5-235
5.30.1 Description *5-235*
5.30.2 Status and Management *5-235*
5.30.3 Population and Abundance *5-235*
5.30.4 Biology, Ecology, and Behavior *5-236*
5.30.5 Habitat and Distribution *5-237*
5.30.6 Species-specific Threats *5-238*
5.31 PACIFIC WHITE-SIDED DOLPHIN (*LAGENORHYNCHUS OBLIQUIDENS*) 5-241
5.31.1 Description *5-241*
5.31.2 Status and Management *5-241*
5.31.3 Population and Abundance *5-241*
5.31.4 Biology, Ecology, and Behavior *5-241*
5.31.5 Habitat and Distribution *5-243*
5.31.6 Species-specific Threats *5-244*
5.32 NORTHERN RIGHT WHALE DOLPHIN (*LISSODELPHIS BOREALIS*) 5-247

5.32.1 Description ... 5-247
5.32.2 Status and Management ... 5-247
5.32.3 Population and Abundance ... 5-247
5.32.4 Biology, Ecology, and Behavior ... 5-247
5.32.5 Habitat and Distribution ... 5-249
5.32.6 Species-specific Threats ... 5-249
5.33 MELON-HEADED WHALE (*PEPONOCEPHALA ELECTRA*) ... 5-253
5.33.1 Description ... 5-253
5.33.2 Status and Management ... 5-253
5.33.3 Population and Abundance ... 5-253
5.33.4 Biology, Ecology, and Behavior ... 5-254
5.33.5 Habitat and Distribution ... 5-255
5.33.6 Species-specific Threats ... 5-257
5.34 PYGMY KILLER WHALE (*FERESA ATTENUATA*) ... 5-263
5.34.1 Description ... 5-263
5.34.2 Status and Management ... 5-263
5.34.3 Population and Abundance ... 5-263
5.34.4 Biology, Ecology, and Behavior ... 5-263
5.34.5 Habitat and Distribution ... 5-264
5.34.6 Species-specific Threats ... 5-266
5.35 FALSE KILLER WHALE (*PSEUDORCA CRASSIDENS*) ... 5-271
5.35.1 Description ... 5-271
5.35.2 Status and Management ... 5-271
5.35.3 Population and Abundance ... 5-271
5.35.4 Biology, Ecology, and Behavior ... 5-272
5.35.5 Habitat and Distribution ... 5-273
5.35.6 Species-specific Threats ... 5-274
5.36 KILLER WHALE (*ORCINUS ORCA*) ... 5-281
5.36.1 Description ... 5-281
5.36.2 Status and Management ... 5-282
5.36.3 Population and Abundance ... 5-282
5.36.4 Biology, Ecology, and Behavior ... 5-282
5.36.5 Habitat and Geographic Range ... 5-285
5.36.6 Species-specific Threats ... 5-287
5.37 SHORT-FINNED PILOT WHALE (*GLOBICEPHALA MACRORHYNCHUS*) ... 5-291
5.37.1 Description ... 5-291
5.37.2 Status and Management ... 5-291
5.37.3 Population and Abundance ... 5-292
5.37.4 Biology, Ecology, and Behavior ... 5-292
5.37.5 Habitat and Distribution ... 5-293
5.37.6 Species-specific Threats ... 5-295
5.38 INDO-PACIFIC BOTTLENOSE DOLPHIN (*TURSIOPS ADUNCUS*) ... 5-301
5.38.1 Description ... 5-301
5.38.2 Status and Management ... 5-301
5.38.3 Population and Abundance ... 5-301
5.38.4 Biology, Ecology, and Behavior ... 5-301
5.38.5 Habitat and Distribution ... 5-303
5.38.6 Species-specific Threats ... 5-305
5.39 FINLESS PORPOISE (*NEOPHOCAENA PHOCAENOIDES*) ... 5-309
5.39.1 Description ... 5-309
5.39.2 Status and Management ... 5-309
5.39.3 Population and Abundance ... 5-310
5.39.4 Biology, Ecology, and Behavior ... 5-310
5.39.5 Habitat and Distribution ... 5-312

5.39.6 Species-specific Threats *5-313*
5.40 DALL'S PORPOISE (*PHOCOENOIDES DALLI*) 5-317
5.40.1 Description *5-317*
5.40.2 Status and Management *5-317*
5.40.3 Population and Abundance *5-318*
5.40.4 Biology, Ecology, and Behavior *5-318*
5.40.5 Habitat and Distribution *5-320*
5.40.6 Species-specific Threats *5-321*
5.41 NORTHERN FUR SEAL (*CALLORHINUS URSINUS*) 5-325
5.41.1 Description *5-325*
5.41.2 Status and Management *5-325*
5.41.3 Population and Abundance *5-325*
5.41.4 Biology, Ecology, and Behavior *5-326*
5.41.5 Habitat and Distribution *5-328*
5.41.6 Species-specific Threats *5-329*
5.42 SPOTTED SEAL (*PHOCA LARGHA*) 5-333
5.42.1 Description *5-333*
5.42.2 Status and Management *5-333*
5.42.3 Population and Abundance *5-333*
5.42.4 Biology, Ecology, and Behavior *5-333*
5.42.5 Habitat and Distribution *5-335*
5.42.6 Species-specific Threats *5-336*
5.43 DUGONG (*DUGONG DUGON*) 5-339
5.43.1 Description *5-339*
5.43.2 Status and Management *5-339*
5.43.3 Population and Abundance *5-339*
5.43.4 Biology, Ecology, and Behavior *5-340*
5.43.5 Habitat and Distribution *5-342*
5.43.6 Species-specific Threats *5-345*
5.44 REFERENCES 5-349
6.0 REPTILES 6-1
6.1 INTRODUCTION 6-1
6.1.1 Global Distribution and Preferred Habitat *6-1*
6.1.2 Biology, Life History, and Behavior *6-2*
6.1.3 Global Threats and Management *6-3*
6.2 SPECIES LIST AND STATUS 6-4
6.3 GREEN SEA TURTLE (CHELONIA MYDAS) 6-5
6.3.1 Description *6-5*
6.3.2 Status and Management *6-6*
6.3.3 Population and Abundance *6-6*
6.3.4 Biology, Ecology, and Behavior *6-7*
6.3.5 Habitat and Distribution *6-9*
6.3.6 Species-specific Threats *6-14*
6.4 HAWKSBILL SEA TURTLE (ERETMOCHELYS IMBRICATA) 6-21
6.4.1 Description *6-21*
6.4.2 Status and Management *6-21*
6.4.3 Population and Abundance *6-21*
6.4.4 Biology, Ecology, and Behavior *6-22*
6.4.5 Habitat and Distribution *6-23*
6.4.6 Species-specific Threats *6-26*
6.5 LOGGERHEAD SEA TURTLE (CARETTA CARETTA) 6-29
6.5.1 Description *6-29*
6.5.2 Status and Management *6-29*
6.5.3 Population and Abundance *6-29*

6.5.4 Biology, Ecology, and Behavior ... 6-30
6.5.5 Habitat and Distribution ... 6-31
6.5.6 Species-specific Threats ... 6-33
6.6 OLIVE RIDLEY SEA TURTLE (LEPIDOCHELYS OLIVACEA) ... 6-37
6.6.1 Description ... 6-37
6.6.2 Status and Management ... 6-37
6.6.3 Population and Abundance ... 6-37
6.6.4 Biology, Ecology, and Behavior ... 6-38
6.6.5 Habitat and Distribution ... 6-39
6.6.6 Species-specific Threats ... 6-41
6.7 LEATHERBACK SEA TURTLE (DERMOCHELYS CORIACEA) ... 6-45
6.7.1 Description ... 6-45
6.7.2 Status and Management ... 6-45
6.7.3 Population and Abundance ... 6-45
6.7.4 Biology, Ecology, and Behavior ... 6-46
6.7.5 Habitat and Distribution ... 6-48
6.7.6 Species-specific Threats ... 6-50
6.8 SALTWATER CROCODILE (CROCODYLUS POROSUS) ... 6-53
6.8.1 Description ... 6-53
6.8.2 Status and Management ... 6-53
6.8.3 Population and Abundance ... 6-53
6.8.4 Biology, Ecology, and Behavior ... 6-53
6.8.5 Habitat and Distribution ... 6-54
6.8.6 Species-specific Threats ... 6-54
6.9 REFERENCES ... 6-55
7.0 SEABIRDS ... 7-1
7.1 INTRODUCTION ... 7-1
7.1.1 Global Distribution and Preferred Habitat ... 7-1
7.1.2 Biology, Life History, and Behavior ... 7-1
7.1.3 Global Threats and Management ... 7-2
7.2 SPECIES LIST AND STATUS ... 7-3
7.2.1 Migratory Bird Treaty Act ... 7-4
7.2.2 U.S. Fish and Wildlife Service Birds of Conservation Concern ... 7-4
7.3 SHORT-TAILED ALBATROSS (*PHOEBASTRIA ALBATRUS*) ... 7-6
7.3.1 Description ... 7-6
7.3.2 Status and Management ... 7-6
7.3.3 Population and Abundance ... 7-7
7.3.4 Biology, Ecology, and Behavior ... 7-7
7.3.5 Habitat and Distribution ... 7-9
7.3.6 Species-specific Threats ... 7-17
7.4 TAXONOMIC GROUPS ... 7-18
7.4.1 Albatrosses, petrels, shearwaters, and storm-petrels (order Procellariiformes) ... 7-18
7.4.2 Boobies, cormorants, frigatebirds, and tropicbirds (order Pelecaniformes) ... 7-20
7.4.3 Tropicbirds (order Phaethontiformes) ... 7-21
7.4.4 Phalaropes, Gulls, Noddies, Terns, Skua, and Jaegers (order Charadriiformes) ... 7-22
7.5 REFERENCES ... 7-25
8.0 MARINE INVERTEBRATES ... 8-1
8.1 INTRODUCTION ... 8-1
8.2 SPECIES LIST AND STATUS ... 8-2
8.3 PROPOSED CORAL SPECIES ... 8-4
8.3.1 Description ... 8-4
8.3.2 Status and Management ... 8-5
8.3.3 Population and Abundance ... 8-5

8.3.4 Biology, Ecology, and Behavior *8-5*
8.3.5 Habitat and Distribution *8-7*
8.3.6 Threats *8-8*
8.4 ACROPORIDAE PROPOSED CORALS 8-10
8.4.1 Description *8-10*
8.4.2 Biology, Ecology, and Behavior *8-10*
8.4.3 Family-specific Threats *8-11*
8.5 AGARICIDAE PROPOSED CORALS 8-15
8.5.1 Description *8-15*
8.5.2 Habitats and Distribution *8-15*
8.5.3 Family-specific Threats *8-16*
8.6 EUPHYLLIDAE PROPOSED CORALS 8-17
8.6.1 Family-specific Threats *8-17*
8.7 FAVIIDAE PROPOSED CORALS 8-17
8.7.1 Family-specific Threats *8-17*
8.8 MILLEPORIDAE PROPOSED CORALS 8-18
8.8.1 Family-specific Threats *8-18*
8.9 MUSSIDAE PROPOSED CORALS 8-19
8.9.1 Family-specific Threats *8-19*
8.10 PECTINIIDAE PROPOSED CORALS 8-20
8.10.1 Family-specific Threats *8-20*
8.11 POCILLOPORIDAE PROPOSED CORALS 8-21
8.11.1 Description *8-21*
8.11.2 Biology, Ecology, and Behavior *8-21*
8.11.3 Family-specific Threats *8-21*
8.12 PORITIDAE PROPOSED CORALS 8-23
8.12.1 Description *8-23*
8.12.2 Biology, Ecology, and Behavior *8-23*
8.12.3 Family-specific Threats *8-23*
8.13 TAXONOMIC GROUPS 8-25
8.14 FORAMINIFERA, RADIOLARIANS, CILIATES (PHYLUM PROTOZOA) 8-26
8.15 SPONGES (PHYLUM PORIFERA) 8-26
8.16 HYDROIDS AND JELLYFISH (PHYLUM CNIDARIA) 8-27
8.17 FLATWORMS (PHYLUM PLATYHELMINTHES) 8-27
8.18 RIBBON WORMS (PHYLUM NEMERTEA) 8-27
8.19 ROUND WORMS (PHYLUM NEMATODA) 8-28
8.20 SEGMENTED WORMS (PHYLUM ANNELIDA) 8-28
8.21 BRYOZOANS (PHYLUM ECTOPROCTA) 8-28
8.22 SQUID, BIVALVES, SEA SNAILS, CHITONS (PHYLUM MOLLUSCA) 8-28
8.23 SHRIMP, CRAB, LOBSTER, BARNACLES, COPEPODS (PHYLUM ARTHROPODA) 8-29
8.24 SEA STARS, SEA URCHINS, SEA CUCUMBERS (PHYLUM ECHINODERMATA) 8-29
8.25 REFERENCES 8-31
9.0 FISH 9-1
9.1 INTRODUCTION 9-1
9.1.1 Global Distribution and Preferred Habitat *9-1*
9.1.2 Fishes of the Japan Archipelago *9-2*
9.1.3 Fishes of the Mariana Archipelago *9-3*
9.1.4 Global Threats and Management *9-4*
9.2 SPECIES LIST AND STATUS 9-6
9.3 SCALLOPED HAMMERHEAD SHARK (*SPHYRNA LEWINI*) 9-7
9.3.1 Description *9-7*
9.3.2 Status and Management *9-7*
9.3.3 Population and Abundance *9-8*
9.3.4 Biology, Ecology, and Behavior *9-8*

9.3.5 Habitat and Distribution ... 9-9
9.3.6 Species-specific Threats ... 9-10
9.4 KNIFETOOTH SAWFISH (ANOXYPRISTIS CUSPIDATA) ... 9-10
9.4.1 Description ... 9-10
9.4.2 Status and Management ... 9-11
9.4.3 Population and Abundance ... 9-11
9.4.4 Biology, Ecology, and Behavior ... 9-11
9.4.5 Habitat and Distribution ... 9-12
9.4.6 Species-specific Threats ... 9-13
9.5 HUMPHEAD WRASSE (CHEILINUS UNDULATUS) ... 9-13
9.5.1 Description ... 9-13
9.5.2 Status and Management ... 9-13
9.5.3 Population and Abundance ... 9-14
9.5.4 Habitat and Distribution ... 9-14
9.5.5 Species-specific Threats ... 9-15
9.6 TAXONOMIC GROUPS ... 9-15
9.7 REFERENCES ... 9-27
10.0 MANAGED SPECIES AND ESSENTIAL FISH HABITAT ... 10-1
10.1 INTRODUCTION ... 10-1
10.2 WESTERN PACIFIC REGIONAL FISHERIES MANAGEMENT COUNCIL ... 10-5
10.3 THREATS TO ESSENTIAL FISH HABITAT ... 10-5
10.4 ESSENTIAL FISH HABITAT TYPES AND HABITAT AREAS OF PARTICULAR CONCERN ... 10-5
10.5 ESSENTIAL FISH HABITAT DESIGNATIONS ... 10-9
10.5.1 Bottomfish Management Unit ... 10-10
10.5.2 Pelagic Management Unit ... 10-19
10.5.3 Crustacean Management Unit ... 10-25
10.5.4 Coral Reef Ecosystem Management Unit – Currently Harvested Coral Reef Taxa ... 10-33
10.5.5 Coral Reef Ecosystem Management Unit – Currently Harvested Aquarium Taxa/Species ... 10-66
10.5.6 Coral Reef Ecosystem Management Unit – Potentially Harvested Coral Reef Taxa ... 10-76
10.6 REFERENCES ... 10-107
11.0 MARINE HABITATS ... 11-1
11.1 INTRODUCTION ... 11-1
11.2 ESTUARIES ... 11-3
11.2.1 Description ... 11-3
11.2.2 Distribution ... 11-4
11.2.3 Conditions and Stressors ... 11-6
11.3 MANGROVES AND SALT MARSHES ... 11-6
11.3.1 Description ... 11-6
11.3.2 Distribution ... 11-8
11.3.3 Condition and Stressors ... 11-11
11.4 INTERTIDAL HABITATS (MUDFLATS, ROCKY SHORES, AND SANDY BEACHES) ... 11-15
11.4.1 Description ... 11-15
11.4.2 Distribution ... 11-17
11.4.3 Conditions and Stressors ... 11-20
11.5 SEAGRASS BEDS ... 11-20
11.5.1 Description ... 11-20
11.5.2 Distribution ... 11-22
11.5.3 Conditions and Stressors ... 11-27
11.6 KELP BEDS ... 11-27
11.6.1 Description ... 11-27
11.6.2 Distribution ... 11-28
11.6.3 Condition and Stressors ... 11-29
11.7 CORAL REEFS ... 11-29

11.7.1 Description ... 11-29
11.7.2 Distribution ... 11-31
11.7.3 Conditions and Stressors ... 11-73
11.8 ARTIFICIAL HABITATS (ARTIFICIAL REEF, SHIPWRECKS, OIL AND GAS PLATFORMS, FISH AGGREGATING DEVICES) ... 11-83
11.8.1 Description ... 11-83
11.8.2 Distribution ... 11-83
11.8.3 Conditions and Stressors ... 11-85
11.9 SUBMARINE CANYONS ... 11-89
11.9.1 Description ... 11-89
11.9.2 Distribution ... 11-89
11.9.3 Conditions and Stressors ... 11-89
11.10 CHEMOSYNTHETIC COMMUNITIES ... 11-89
11.10.1 Description ... 11-89
11.10.2 Distribution ... 11-91
11.10.3 Conditions and Stressors ... 11-97
11.11 DEEP CORAL COMMUNITIES ... 11-98
11.11.1 Description ... 11-98
11.11.2 Distribution ... 11-98
11.11.3 Conditions and Stressors ... 11-100
11.12 SEAMOUNTS ... 11-100
11.12.1 Description ... 11-100
11.12.2 Distribution ... 11-101
11.12.3 Conditions and Stressors ... 11-103
11.13 DEEP OCEAN TRENCHES ... 11-103
11.13.1 Description ... 11-103
11.13.2 Distribution ... 11-103
11.13.3 Conditions and Stressors ... 11-104
11.14 ABYSSAL PLAINS AND OTHER DEEP SOFTBOTTOM HABITAT ... 11-104
11.14.1 Description ... 11-104
11.14.2 Distribution ... 11-104
11.14.3 Conditions and Stressors ... 11-105
11.15 REFERENCES ... 11-107
12.0 MARINE PROTECTED AREAS ... 12-1
12.1 INTRODUCTION ... 12-1
12.2 MARINE PROTECTED AREAS OF THE JAPAN ARCHIPELAGO ... 12-2
12.3 MARINE PROTECTED AREAS OF THE MARIANA ARCHIPELAGO ... 12-8
12.4 MARINE PROTECTED AREAS OF THE CAROLINE ISLANDS ... 12-23
12.5 REFERENCES ... 12-29
13.0 HUMAN USES AND STRESSORS ... 13-1
13.1 FISHERIES (COMMERCIAL, RECREATIONAL, SUBSISTENCE) ... 13-1
13.1.1 Description ... 13-1
13.1.2 Status and Management ... 13-13
13.1.3 Distribution of Operations ... 13-22
13.2 RECREATION AND TOURISM ... 13-24
13.2.1 Description ... 13-25
13.2.2 Status and Management ... 13-26
13.2.3 Distribution of Operations ... 13-28
13.3 NAVIGABLE WATERWAYS AND COMMERCIAL SHIPPING ... 13-35
13.3.1 Description ... 13-35
13.3.2 Status and Management ... 13-35
13.3.3 Distribution of Operations ... 13-36
13.4 MARITIME BOUNDARIES: TERRITORIAL WATERS, CONTIGUOUS ZONE, AND EXCLUSIVE ECONOMIC ZONE ... 13-41
13.4.1 Description ... 13-41

13.4.2 Status and Management *13-44*
13.4.3 Distribution of Operations *13-47*
13.5 OIL AND GAS 13-47
13.5.1 Description *13-47*
13.5.2 Status and Management *13-48*
13.5.3 Distribution of Operations *13-48*
13.6 REFERENCES 13-49
14.0 LIST OF PREPARERS 14-1
15.0 GLOSSARY 15-1

This Page Intentionally Left Blank

LIST OF FIGURES

Figure 1-1: Location of the Marine Resource Assessment Study Area and Key Open Ocean Features in the North Pacific Ocean 1-3
Figure 1-2: Location of the Marine Resource Assessment Study Area 1-7
Figure 1-3: Location of the Japan Archipelago Portion of the Marine Resource Assessment Study Area 1-11
Figure 1-4: Location of the Mariana Archipelago Portion of the Marine Resource Assessment Study Area 1-12
Figure 1-5: Navy Managed Lands and Operating Sites on Guam 1-15
Figure 3-1: Ecological Processes Plotted as a Function of Space and Time 3-8
Figure 3-2: Three-dimensional Representation of the Continental Margin and Abyssal Zone 3-10
Figure 3-3: Biogeographic Classification Systems in the North Pacific 3-13
Figure 3-4: Biogeographic Classification Systems in the MRA Study Area 3-15
Figure 3-5: Conceptual Diagram of Ecosystem Characteristics and Interactions 3-17
Figure 3-6: Simplified Conceptual Marine Food Web 3-21
Figure 4-1: Bathymetry of the North Pacific Ocean 4-13
Figure 4-2: Bathymetry of the MRA Study Area 4-14
Figure 4-3: Three-dimensional View of the Bathmetry of the Japan Archipelago Portion of the MRA Study Area .. 4-15
Figure 4-4: Three-dimensional View of the Mariana Archipelago Portion of the MRA Study Area 4-16
Figure 4-5: Depth Zones of the North Pacific Ocean 4-17
Figure 4-6: Depth Zones of the MRA Study Area 4-18
Figure 4-7: Banks, Guyots, and Seamounts in the North Pacific Ocean 4-19
Figure 4-8: Banks, Guyots, and Seamounts in the MRA Study Area 4-20
Figure 4-9: Trenches, Basins, and Abyssal Plains in the North Pacific Ocean 4-21
Figure 4-10: Trenches, Basins, and Abyssal Plains in the MRA Study Area 4-22
Figure 4-11: Volcanic Activity in the North Pacific Ocean 4-23
Figure 4-12: Volcanic Activity in the MRA Study Area 4-24
Figure 4-13: Distribution of Dominant and Subdominant Bottom Types in the MRA Study Area 4-27
Figure 4-14: Distribution of Sediment Types in the MRA Study Area 4-28
Figure 4-15: Surface Circulation of the North Pacific Ocean Highlighting the Extent of the North Pacific Subtropical Gyre 4-37
Figure 4-16: Circulation and Sea Surface Temperature in the North Pacific Ocean 4-38
Figure 4-17: Regional Surface Circulation of the Kuroshio, Tsushima, and Oyashio Current 4-39
Figure 4-18: Simplified Schematic of Thermohaline Circulation in the North Pacific Ocean 4-45
Figure 4-19: Average Monthly Sea Surface Temperature in the North Pacific Ocean 4-51
Figure 4-20: Average Monthly Sea Surface Temperature in the MRA Study Area 4-52
Figure 4-21: Average Monthly Net Primary Production in the North Pacific Ocean 4-59
Figure 4-22: Average Monthly Net Primary Production in the MRA Study Area 4-60
Figure 4-23: Average Monthly Surface Chlorophyll a Concentration in the North Pacific Ocean 4-61
Figure 4-24: Average Monthly Surface Chlorophyll a Concentration in the MRA Study Area 4-62
Figure 4-25: Hydrothermal Vents, Cold Seeps, and Whale Skeletons in the North Pacific Ocean 4-63
Figure 4-26: Hydrothermal Vents, Cold Seeps, and Whale Skeletons in the MRA Study Area 4-64
Figure 5-1: Sightings of All Marine Mammals in the Mariana Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented. 5-11
Figure 5-2: Survey Effort for All Marine Mammal Sightings in the Mariana Portion of the MRA Study Area 5-12
Figure 5-3: Geographic Range of the North Pacific Right Whale in the North Pacific Ocean 5-19
Figure 5-4: Geographic Range of the North Pacific Right Whale in the MRA Study Area 5-20

Figure 5-5: Geographic Range of the Omura's Whale in the North Pacific Ocean 5-25
Figure 5-6: Geographic Range of the Omura's Whale in the MRA Study Area 5-26
Figure 5-7: Geographic Range of the Humpback Whale in the North Pacific Ocean 5-37
Figure 5-8: Geographic Range of the Humpback Whale in the MRA Study Area 5-38
Figure 5-9: Geographic Range of the Common Minke Whale in the North Pacific Ocean 5-45
Figure 5-10: Geographic Range of the Common Minke Whale in the MRA Study Area 5-46
Figure 5-11: Geographic Range of Bryde's Whale in the North Pacific Ocean 5-53
Figure 5-12: Geographic Range of Bryde's Whale in the MRA Study Area 5-54
Figure 5-13: Sightings of the Bryde's Whale in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented. 5-55
Figure 5-14: Geographic Range of the Sei Whale in the North Pacific Ocean 5-63
Figure 5-15: Geographic Range of the Sei Whale in the MRA Study Area 5-64
Figure 5-16: Sightings of the Sei Whale in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented. 5-65
Figure 5-17: Geographic Range of the Fin Whale in the North Pacific Ocean 5-73
Figure 5-18: Geographic Range of the Fin Whale in the MRA Study Area 5-74
Figure 5-19: Geographic Range of the Blue Whale in the North Pacific Ocean 5-81
Figure 5-20: Geographic Range of the Blue Whale in the MRA Study Area 5-82
Figure 5-21: Geographic Range of the Gray Whale in the North Pacific Ocean 5-89
Figure 5-22: Geographic Range of the Gray Whale in the MRA Study Area 5-90
Figure 5-23: Geographic Range of the Sperm Whale in the North Pacific Ocean 5-99
Figure 5-24: Geographic Range of the Sperm Whale in the MRA Study Area 5-100
Figure 5-25: Sightings of the Sperm Whale in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented. 5-101
Figure 5-26: Geographic Range of the Pygmy Sperm Whale in the North Pacific Ocean 5-107
Figure 5-27: Geographic Range of the Pygmy Sperm Whale in the MRA Study Area 5-108
Figure 5-28: Geographic Range of the Dwarf Sperm Whale in the North Pacific Ocean 5-113
Figure 5-29: Geographic Range of the Dwarf Sperm Whale in the MRA Study Area 5-114
Figure 5-30: Sightings of the Dwarf Sperm Whale in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented. 5-115
Figure 5-31: Geographic Range of Cuvier's Beaked Whale in the North Pacific Ocean 5-123
Figure 5-32: Geographic Range of Cuvier's Beaked Whale in the MRA Study Area 5-124
Figure 5-33: Sightings of the Cuvier's Beaked Whale in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented. 5-125
Figure 5-34: Geographic Range of Blainville's Beaked Whale in the North Pacific Ocean 5-131
Figure 5-35: Geographic Range of Blainville's Beaked Whale in the MRA Study Area 5-132
Figure 5-36: Geographic Range of Baird's Beaked Whale in the North Pacific Ocean 5-137
Figure 5-37: Geographic Range of Baird's Beaked Whale in the MRA Study Area 5-138
Figure 5-38: Geographic Range of Longman's Beaked Whale in the North Pacific Ocean 5-143
Figure 5-39: Geographic Range of Longman's Beaked Whale in the MRA Study Area 5-144
Figure 5-40: Geographic Range of Hubb's Beaked Whale in the North Pacific Ocean 5-149
Figure 5-41: Geographic Range of Hubb's Beaked Whale in the MRA Study Area 5-150
Figure 5-42: Geographic Range of the Gingko-toothed Beaked Whale in the North Pacific Ocean 5-155
Figure 5-43: Geographic Range of the Gingko-toothed Beaked Whale in the MRA Study Area 5-156
Figure 5-44: Geographic Range of Stejneger's Beaked Whale in the North Pacific Ocean 5-161
Figure 5-45: Geographic Range of Stejneger's Beaked Whale in the MRA Study Area 5-162

Figure 5-46: Geographic Range of the Rough-toothed Dolphin in the North Pacific Ocean 5-167
Figure 5-47: Geographic Range of the Rough-toothed Dolphin in the MRA Study Area 5-168
Figure 5-48: Sightings of the Rough-toothed Dolphin in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented. 5-169
Figure 5-49: Geographic Range of the Common Bottlenose Dolphin in the North Pacific Ocean 5-181
Figure 5-50: Geographic Range of the Common Bottlenose Dolphin in the MRA Study Area 5-182
Figure 5-51: Sightings of the Common Bottlenose Dolphin in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented. 5-183
Figure 5-52: Geographic Range of the Long-beaked Common Dolphin in the North Pacific Ocean 5-189
Figure 5-53: Geographic Range of the Long-beaked Common Dolphin in the MRA Study Area..... 5-190
Figure 5-54: Geographic Range of the Short-beaked Common Dolphin in the North Pacific Ocean 5-197
Figure 5-55: Geographic Range of the Short-beaked Common Dolphin in the MRA Study Area..... 5-198
Figure 5-56: Geographic Range of the Pantropical Spotted Dolphin in the North Pacific Ocean..... 5-205
Figure 5-57: Geographic Range of the Pantropical Spotted Dolphin in the MRA Study Area 5-206
Figure 5-58: Sightings of the Pantropical Spotted Dolphin in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented. 5-207
Figure 5-59: Geographic Range of the Spinner Dolphin in the North Pacific Ocean 5-215
Figure 5-60: Geographic Range of the Spinner Dolphin in the MRA Study Area..... 5-216
Figure 5-61: Sightings of the Spinner Dolphin in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented. 5-217
Figure 5-62: Geographic Range of the Striped Dolphin in the North Pacific Ocean 5-225
Figure 5-63: Geographic Range of the Striped Dolphin In the MRA Study Area 5-226
Figure 5-64: Sightings of the Striped Dolphin in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented. 5-227
Figure 5-65: Geographic Range of Fraser's Dolphin in the North Pacific Ocean 5-233
Figure 5-66: Geographic Range of Fraser's Dolphin in the MRA Study Area..... 5-234
Figure 5-67: Geographic Range of Risso's Dolphin in the North Pacific Ocean 5-239
Figure 5-68: Geographic Range of Risso's Dolphin in the MRA Study Area 5-240
Figure 5-69: Geographic Range of the Pacific White-sided Dolphin in the North Pacific Ocean..... 5-245
Figure 5-70: Geographic Range of the Pacific White-sided Dolphin in the MRA Study Area 5-246
Figure 5-71: Geographic Range of the Northern Right Whale Dolphin in the North Pacific Ocean 5-251
Figure 5-72: Geographic Range of the Northern Right Whale Dolphin in the MRA Study Area..... 5-252
Figure 5-73: Geographic Range of the Melon-headed Whale in the North Pacific Ocean 5-259
Figure 5-74: Geographic Range of the Melon-headed Whale in the MRA Study Area 5-260
Figure 5-75: Sightings of the Melon-headed Whale in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented. 5-261
Figure 5-76: Geographic Range of the Pygmy Killer Whale in the North Pacific Ocean 5-267
Figure 5-77: Geographic Range of the Pygmy Killer Whale in the MRA Study Area 5-268
Figure 5-78: Sightings of the Pygmy Killer Whale in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented. 5-269
Figure 5-79: Geographic Range of the False Killer Whale in the North Pacific Ocean 5-277
Figure 5-80: Geographic Range of the False Killer Whale in the MRA Study Area 5-278
Figure 5-81: Sightings of the False Killer Whale in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented. 5-279
Figure 5-82: Geographic Range of the Killer Whale in the North Pacific Ocean..... 5-289
Figure 5-83. Geographic Range of the Killer Whale in the MRA Study Area 5-290

Figure 5-84: Geographic Range of the Short-finned Pilot Whale in the North Pacific Ocean 5-297
Figure 5-85: Geographic Range of the Short-finned Pilot Whale in the MRA Study Area 5-298
Figure 5-86: Sightings of the Short-finned Pilot Whale in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented. 5-299
Figure 5-87: Geographic Range of the Indo-Pacific Bottlenose Dolphin in the North Pacific Ocean 5-307
Figure 5-88: Geographic Range of the Indo-Pacific Bottlenose Dolphin in the MRA Study Area 5-308
Figure 5-89: Geographic Range of the Indo-Pacific Finless Porpoise in the North Pacific Ocean 5-315
Figure 5-90: Geographic Range of the Indo-Pacific Finless Porpoise in the MRA Study Area 5-316
Figure 5-91: Geographic Range for Dall's Porpoise in the North Pacific Ocean 5-323
Figure 5-92: Geographic Range for Dall's Porpoise in the MRA Study Area 5-324
Figure 5-93: Geographic Range of the Northern Fur Seal in the North Pacific Ocean 5-331
Figure 5-94: Geographic Range of the Northern Fur Seal in the MRA Study Area 5-332
Figure 5-95: Geographic Range of the Spotted Seal in the North Pacific Ocean 5-337
Figure 5-96: Geographic Range of the Spotted Seal in the MRA Study Area 5-338
Figure 5-97: Geographic Range for the Dugong in the North Pacific Ocean 5-347
Figure 5-98: Geographic Range for the Dugong in the MRA Study Area 5-348
Figure 6-1: Geographic Range and Location of Nesting Beaches of the Green Sea Turtle in the North Pacific Ocean 6-15
Figure 6-2: Locations and Density of the Green Sea Turtle Nesting Beaches in the MRA Study Area 6-16
Figure 6-3: Locations and Density of the Green Sea Turtle Nesting Beaches in Saipan 6-17
Figure 6-4: Locations and Density of the Green Sea Turtle Nesting Beaches in Tinian 6-18
Figure 6-5: Locations and Density of the Green Sea Turtle Nesting Beaches in Rota 6-19
Figure 6-6: Locations and Density of the Green Sea Turtle Nesting Beaches in Guam 6-20
Figure 6-7: Geographic Range and Location of Nesting Beaches of the Hawksbill Sea Turtle in the North Pacific Ocean 6-27
Figure 6-8: Locations and Density of the Hawksbill Sea Turtle Nesting Beaches in Palau 6-28
Figure 6-9: Geographic Range and Location of Nesting Beaches of the Loggerhead Sea Turtle in the North Pacific Ocean 6-35
Figure 6-10: Locations and Density of the Loggerhead Sea Turtle Nesting Beaches in Japan 6-36
Figure 6-11: Geographic Range and Location of Nesting Beaches of the Olive Ridley Sea Turtle in the North Pacific Ocean 6-43
Figure 6-12: Geographic Range and Location of Nesting Beaches of the Leatherback Sea Turtle in the North Pacific Ocean 6-51
Figure 7-1: Geographic Range of the Short-tailed Albatross in the North Pacific Ocean 7-11
Figure 7-2: Geographic Range of the Short-tailed Albatross in the MRA Study Area 7-15
Figure 10-1: Fishery Management Councils in the Pacific Ocean 10-3
Figure 10-2: Essential Fish Habitat for Egg and Larval Lifestages of Bottomfish Designated for the Mariana Archipelago 10-15
Figure 10-3: Essential Fish Habitat for Juvenile and Adult Lifestages of Bottomfish Designated for Guam 10-16
Figure 10-4: Essential Fish Habitat for Juvenile and Adult Lifestages of Bottomfish Designated for Tinian and Saipan 10-17
Figure 10-5: Essential Fish Habitat for Juvenile and Adult Lifestages of Bottomfishes Designated for Farallon de Medinilla 10-18
Figure 10-6: Essential Fish Habitat for Lifestages of Pelagic Fishes Designated for the Mariana Archipalego 10-23
Figure 10-7: Essential Fish Habitat for Eggs and Larval Lifestages of Crustaceans (Excluding Deepwater Shrimp) Designated for the Mariana Archipelago 10-29

Figure 10-8: Essential Fish Habitat for Juvenile and Adult Lifestages of Crustaceans Designated for Guam 10-30
Figure 10-9: Essential Fish Habitat for Juvenile and Adult Lifestages of Crustaceans Designated for Tinian and Saipan 10-31
Figure 10-10: Essential Fish Habitat for Juvenile and Adult Lifestages of Crustaceans Designated for Farallon de Medinilla 10-32
Figure 10-11: Essential Fish Habitat for Lifestages of the Currently Harvested Coral Reef Taxa Designated for the Mariana Archipelago 10-37
Figure 10-12: Essential Fish Habitat for Juvenile and Adult Lifestages of the Currently Harvested Coral Reef Taxa Designated for Guam 10-38
Figure 10-13: Essential Fish Habitat for Juvenile and Adult Lifestages of Flagtails and Mullets of the Currently Harvested Coral Reef Taxa Designated on Guam in the Mariana Archipelago 10-39
Figure 10-14: Essential Fish Habitat for Adult Lifestages of Rudderfishes of the Currently Harvested Coral Reef Taxa Designated on Guam in the Mariana Archipelago 10-40
Figure 10-15: Essential Fish Habitat for Juvenile and Adult Lifestages of the Currently Harvested Coral Reef Taxa Designated for Tinian and Saipan 10-41
Figure 10-16: Essential Fish Habitat for Juvenile and Adult Lifestages of Flagtails and Mullets of the Currently Harvested Coral Reef Taxa Designated on Tinian and Saipan in the Mariana Archipelago 10-42
Figure 10-17: Essential Fish Habitat for Adult Lifestages of Rudderfishes of the Currently Harvested Coral Reef Taxa Designated on Tinian and Saipan in the Mariana Archipelago 10-43
Figure 10-18: Essential Fish Habitat for Juvenile and Adult Lifestages of the Currently Harvested Coral Reef Taxa Designated for Farallon de Medinilla 10-44
Figure 10-19: Essential Fish Habitat for Juvenile and Adult Lifestages of the Flagtails and Mullets Currently Harvested Coral Reef Taxa Designated on Farallon de Medinilla in the Mariana Archipelago 10-45
Figure 10-20: Essential Fish Habitat for Adult Lifestages of Rudderfishes of the Currently Harvested Coral Reef Taxa Designated on Farallon de Medinilla in the Mariana Archipelago 10-46
Figure 10-21: Essential Fish Habitat for Lifestages of the Potentially Harvested Coral Reef Taxa Designated for the Mariana Archipelago 10-81
Figure 11-1: Distribution of Mangrove and Seagrass Communities in Saipan and Tinian 11-13
Figure 11-2: Distribution of Mangrove and Seagrass Communities in Guam 11-14
Figure 11-3: Live Cover of Coral Reef Habitats Around the Japan Archipelago 11-47
Figure 11-4: Live Cover of Coral Reef Habitats of the Izu Islands, Bōsō Peninsula, and Izu Peninsula 11-48
Figure 11-5: Live Cover of Coral Reef Habitats of the (A) Osumi Islands, (B) Kyūshū, and (C) the Tokara Islands .. 11-49
Figure 11-6: Live Cover of Coral Reef Habitats of the Okinawa Islands 11-50
Figure 11-7: Subtidal Reef Morphology of Pagan 11-51
Figure 11-8: Benthic Substratum of Pagan 11-52
Figure 11-9: Live Cover of Coral Reef Habitats of Pagan 11-53
Figure 11-10: Subtidal Reef Morphology of Farallon de Medinilla 11-54
Figure 11-11: Benthic Substratum of Farallon de Medinilla 11-55
Figure 11-12: Live Cover of Coral Reef Habitats of Farallon de Medinilla 11-56
Figure 11-13: Subtidal Reef Morphology of Saipan and Northern Tinian 11-57
Figure 11-14: Benthic Substratum of Saipan and Northern Tinian 11-58
Figure 11-15: Live Cover of Coral Reef Habitats of Saipan and Northern Tinian 11-59
Figure 11-16: Subtidal Reef Morphology of Tinian 11-60
Figure 11-17: Benthic Substratum of Tinian 11-61
Figure 11-18: Live Cover of Coral Reef Habitats of Tinian 11-62
Figure 11-19: Subtidal Reef Morphology of Aguijan 11-63
Figure 11-20: Benthic Substratum of Aguijan 11-64

Figure 11-21: Live Cover of Coral Reef Habitats of Aguijan 11-65
Figure 11-22: Reef Morphology of Rota 11-66
Figure 11-23: Benthic Substratum of Rota 11-67
Figure 11-24: Live Cover of Coral Reef Habitats in Rota 11-68
Figure 11-25: Subtidal Reef Morphology of Guam 11-69
Figure 11-26: Benthic Substratum of Guam 11-70
Figure 11-27: Live Cover of Coral Reef Habitats of Guam 11-71
Figure 11-28: Integrated Local Threats to Coral Reefs in the Northern Pacific Ocean 11-81
Figure 11-29: Integrated Local Threats to Coral Reefs in the MRA Study Area 11-82
Figure 11-30: Distribution of Artificial Habitats of the Japan Archipelago (Including Shipwrecks for the Entire Area and Fish Aggregating Devices for Okinawa Island Only) 11-87
Figure 11-31: Distribution of Artificial Reefs, Shipwrecks, and Fish Aggregating Devices in the Mariana Archipleago 11-88
Figure 11-32: Distribution of Chemosynthetic Communities in the Japan Archipelago (Including Cold Seeps and Hydrothermal Vent Habitats) 11-95
Figure 12-1: Map of the Mariana Arc of Fire National Wildllife Refuge and the Mariana Trench Marine National Monument 12-15
Figure 12-2: Map of the Protected Areas in Saipan 12-19
Figure 12-3: Map of the Protected Areas in Rota 12-20
Figure 12-4: Map of the Protected Areas in Guam 12-21
Figure 12-5: Marine Protected Areas and Marine Managed Areas in Palau 12-27
Figure 13-1: Exclusive Economic Zones in the North Pacific Ocean 13-3
Figure 13-2: Exclusive Economic Zones of MRA Study Area 13-4
Figure 13-3: Harbors and Boat Ramps on Guam 13-11
Figure 13-4: Annual Estimated Commercial Fish Landings for Commonwealth of the Northern Mariana Islands . 13-17
Figure 13-5: Annual Boat-Based Total Landings for Guam (1982-2011) 13-19
Figure 13-6: Annual Estimated Commercial Landings for Guam 13-20
Figure 13-7: Popular Dive Sites Within (A) Guam, (B) Rota, and (C) Saipan 13-33
Figure 13-8: Major Japanese Ports and Cargo Volumes for 2002 13-37
Figure 13-9: Shipping Lanes in the MRA Study Area 13-39
Figure 13-10: A 3-Dimentional Depiction of the U.S. Maritime Boundaries 13-41

LIST OF TABLES

Table 1-1: Coastal Waters of the MRA Study Area 1-2
Table 1-2: Population of the Northern Mariana Islands and Guam 1-10
Table 3-1: Common Marine Zonation by Depth 3-9
Table 3-2: Example Ecosystem Services 3-25
Table 4-1: Average Number of Landfalling Tropical Cyclones in the Western North Pacific During El Niño, La Niña, and Neutral Years 4-4
Table 4-2: Most Damaging Tsunamis to Impact Japan 4-34
Table 5-1: Marine Mammals with Possible or Confirmed Presence in the MRA Study Area 5-7
Table 6-1: Status of Sea Turtles in the MRA Study Area 6-5
Table 6-2: Summary of Worldwide Hawksbill Nesting Trends 6-22
Table 7-1: ESA-Listed Seabird Species Found in the MRA Study Area 7-3
Table 7-2: Migratory Bird Treaty Act Species and Birds of Conservation Concern that Occur within the MRA Study Area 7-4
Table 7-3: Descriptions and Examples of Major Taxonomic Groups of Seabirds within the MRA Study Area 7-18
Table 8-1: Coral Species Proposed for ESA Listing in the MRA Study Area 8-2
Table 8-2: Acroporidae Corals Habitat and Range 8-12
Table 8-3: Agariciidae Corals Habitat and Range 8-16
Table 8-4: Euphyllidae Corals Habitat and Range 8-17
Table 8-5: Faviidae Corals Habitat and Range 8-18
Table 8-6: Milleporidae Corals Habitat and Range 8-19
Table 8-7: Mussidae Corals Habitat and Range 8-20
Table 8-8: Pectiniidae Corals Habitat and Range 8-21
Table 8-9: Pocillopora Corals Habitat and Range 8-22
Table 8-10: Poritidae Corals Habitat and Range 8-24
Table 8-11: Major Taxonomic Groups of Marine Invertebrates in the MRA Study Area 8-25
Table 9-1: Status and Presence of ESA-Listed Fish Species Found in the MRA Study Area 9-7
Table 9-2: Major Taxonomic Groups of Marine Fishes within the MRA Study Area 9-17
Table 10-1: Essential Fish Habitat and Habitat Areas of Particular Concern in the MRA Study Area 10-7
Table 10-2: Bottomfish Management Unit Species Essential Fish Habitat Designations 10-13
Table 10-3: Pelagic Management Unit Species Essential Fish Habitat Designations 10-21
Table 10-4: Crustacean Management Unit Species Essential Fish Habitat Designations 10-27
Table 10-5: Coral Reef Ecosystem Currently Harvested Management Unit Species Essential Fish Habitat Designations 10-35
Table 10-6: Coral Reef Ecosystem Currently Harvested Aquarium Management Unit Species Essential Fish Habitat Designations 10-67
Table 10-7: Coral Reef Ecosystem Potentially Harvested Management Unit Species Essential Fish Habitat Designations 10-77
Table 11-1: Types of Marine Habitats in the MRA Study Area 11-1
Table 11-2: Hydrothermal Vent Communities in the Japan Archipelago 11-92
Table 11-3: Cold Seep Communities in the Japan Archipelago 11-93
Table 12-1: Institutional and Management Framework for Marine Protected Areas in Japan 12-2
Table 12-2: Marine Protected Areas of the Japan Archipelago 12-4
Table 12-3: Institutional and Management Framework from Marine Protected Areas in the Mariana Archipelago 12-8
Table 12-4: Marine Protected Areas of the Mariana Archipelago 12-10

Table 12-5: Summary of Applicable Information from the Constitutional Division of Environmental Responsibilities and other Programs in the Federated States of Micronesia 12-23
Table 12-6: Marine Protected Areas of the Caroline Islands 12-26
Table 13-1: Commonwealth of the Northern Mariana Islands Commercial Fishery Landings 13-16
Table 13-2: Guam Commercial Fishery Landings 13-18
Table 13-3: Dive Sites on Izu Peninsula 13-29
Table 13-4: The Maritime Boundaries and their Seaward and Jurisdictional Extents 13-43
Table 13-5: Timeline Detailing the Establishment of U.S. Jurisdiction and Maritime Boundaries 13-45

LIST OF ACRONYMS AND ABBREVIATIONS

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

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

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

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

1.0 INTRODUCTION

The U.S. Department of the Navy's (Navy) U.S. Commander Pacific Fleet Activities (COMPACFLT) contracted preparation of this Marine Resource Assessment (MRA) to update data and information on marine resources encompassing the open ocean, deep sea, and coastal areas associated with the Japan/Okinawa Complexes Operating Area (OPAREA) and Mariana Islands Training and Testing Area (MITT). The MRA provides comprehensive and up-to-date descriptions of the marine environment and biology, ecology, status, and condition of marine mammals, marine reptiles, seabirds, invertebrates, fish, marine habitats, and other marine resources in coastal and open ocean areas where Navy training activities occur. Two separate MRAs were prepared in the year 2005 for the Japan/Okinawa Complexes OPAREA and the Mariana Islands Range Complex (U.S. Department of the Navy 2005a, b). This MRA covers additional areas in the vicinity of the original Study Areas.

1.1 STATEMENT OF PURPOSE AND NEED

This MRA was developed to maintain a comprehensive and state-of-knowledge compilation of data and information on marine resources that inhabit open ocean and coastal waters within the MRA Study Area for the Japan and Mariana Archipelagos (the MRA Study Area). This MRA includes a discussion of the physical environment, habitats (coastal and oceanic), and protected species present in the MRA Study Area. Also addressed in this assessment are essential fish habitat (EFH) designations, commercial and recreational fisheries, and other areas of interest (e.g., marine managed areas [MMA], self contained underwater breathing apparatus [SCUBA] diving sites, and oil and gas structures).

Section 4.1.1 of Department of Defense (DoD) Instruction 4715.3 (1996),"Environmental Conservation Program," states that "all DoD conservation programs shall work to guarantee continued access to our land, air, and water resources for realistic military training and testing while ensuring that natural and cultural resources are sustained in a healthy condition for scientific research, education, and other compatible uses by future generations." The marine resources information assembled in this MRA will serve as a baseline from which the Navy may evaluate its operations and potential impacts of these operations on the marine environment, while maintaining the requirement of instilling dedication to the obligations of sound resource stewardship in trained and ready forces. This assessment will contribute to the Fleet's integrated long-range planning process, and is an important component of the Fleet's ongoing compliance with U.S. federal mandates that aim to protect and manage resources in the marine environment. All species and habitats potentially affected by the Navy's maritime exercises and protected by U.S. federal or state legislation are considered in this assessment.

1.2 LOCATION OF MRA STUDY AREA

The MRA Study Area encompasses open ocean and coastal waters of the Japan and Mariana Archipelagos as well as the western portion of the Caroline Islands. Open ocean areas of the MRA Study Area cover portions of these oceanographic features: the North Central Pacific Gyre, Kuroshio Current, East China Sea, and Philippine Sea (Figure 1-1). Coastal waters of the MRA Study Area cover portions of the Japan Archipelago, the Commonwealth of the Northern Mariana Islands (CNMI), U.S Territory of Guam (Guam), the western portion of the Federated States of Micronesia (FSM), and the Republic of Palau (Palau) (Table 1-1). The MRA does not include information on airspace, land, or terrestrial resources within range complexes.

Table 1-1: Coastal Waters of the MRA Study Area

Jurisdiction	Archipelago/Island/Site Names
	Japan Archipelago
Government of Japan	Bōsō Peninsula, Honshū Island Izu Peninsula, Honshū Island Izu Islands Kyūshū Island Ōsumi Islands Tokara Archipelago Okinawa Island, Kerama Islands, Kume Island, and Daito Islands
	Mariana Archipelago
Commonwealth of the Northern Mariana Islands	Pagan Farallon de Medinilla Saipan Tinian Aguijan Rota
U.S. Territory of Guam	Guam • Apra Harbor • Haputo Ecological Reserve Area • Ritidian Unit • Orote Peninsula Ecological Reserve Area • Agat Bay • Talofofo Bay
	Caroline Islands
Federated States of Micronesia	Yap
Republic of Palau	Palau

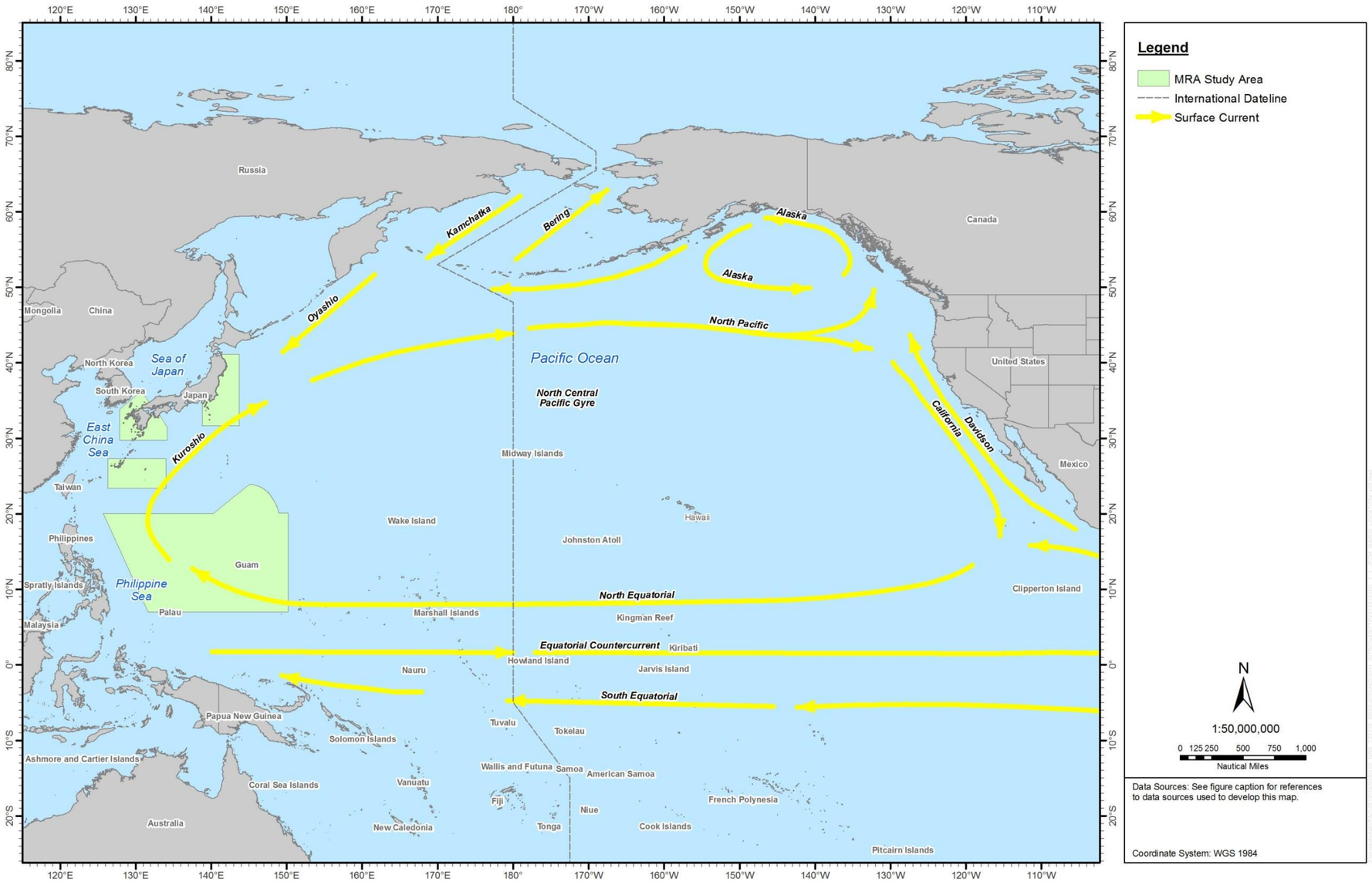

Figure 1-1: Location of the Marine Resource Assessment Study Area and Key Open Ocean Features in the North Pacific Ocean
Sources: Bell (2009); National Oceanic and Atmospheric Administration (2013).

This Page Intentionally Left Blank

1.1.1 Open Ocean Waters of the MRA Study Area

The MRA Study Area includes portions of open ocean waters of four oceanographic features: the North Central Pacific Gyre, Kuroshio Current, East China Sea, and Philippine Sea (Figure 1-2).

NORTH CENTRAL PACIFIC GYRE. A portion of the open ocean waters of the MRA Study Area is located within the southwestern portion of the North Central Pacific Gyre. The North Central Pacific Gyre is located at the center of the North Pacific Ocean. The North Central Pacific Gyre is the planet's largest circulation pattern—encompassing 200 million square kilometers (km^2) of ocean. It is bounded to the north by the North Pacific Current, to the east by the California Current, to the south by the North Equatorial Current, and to the west by the Kuroshio Current.

KUROSHIO CURRENT. A portion of the open ocean waters of the MRA Study Area is located in the Kuroshio Current. The Kuroshio Current extends from the Philippines to Japan's northernmost island, Hokkaidō (Aquarone and Adams 2009). The Kuroshio Current encompasses a surface area of approximately 1.3 million km^2.

EAST CHINA SEA. A portion of the open ocean waters of the MRA Study Area is located in the East China Sea. The East China Sea borders China, Taiwan, Japan, and the Korean peninsula (Heileman and Tang 2009). The East China Sea encompasses a surface area of approximately 775,000 km^2.

PHILIPPINE SEA. A portion of the open ocean waters of the MRA Study Area is located in the Philippine Sea. The Philippine Sea encompasses an area of approximately 5 million km^2. The Philippine Sea is bounded by the Philippines to the southwest; Palau, Yap, and Ulithi to the southeast; the Marianas, including Guam, Saipan, and Tinian, to the east; the Bonin and Iwo Jima Islands to the northeast; the Japanese islands of Honshū, Shikoku, and Kyūshū to the north; the Ryukyu Islands to the northwest; and Taiwan to the extreme west.

1.1.2 Coastal Waters of the MRA Study Area

The MRA Study Area includes portions of coastal waters in the Japan and Mariana Archipelagos and Caroline Islands (Table 1-1; Figure 1-2). Marine resources are described at the archipelago, island, and site levels, depending on the specifity of the data and information available for the particular geographic location. The coastal waters of the MRA Study Area surround land areas with different levels of human and natural hazard activity that could pose different levels of ecological stress on marine resources.

This Page Intentionally Left Blank

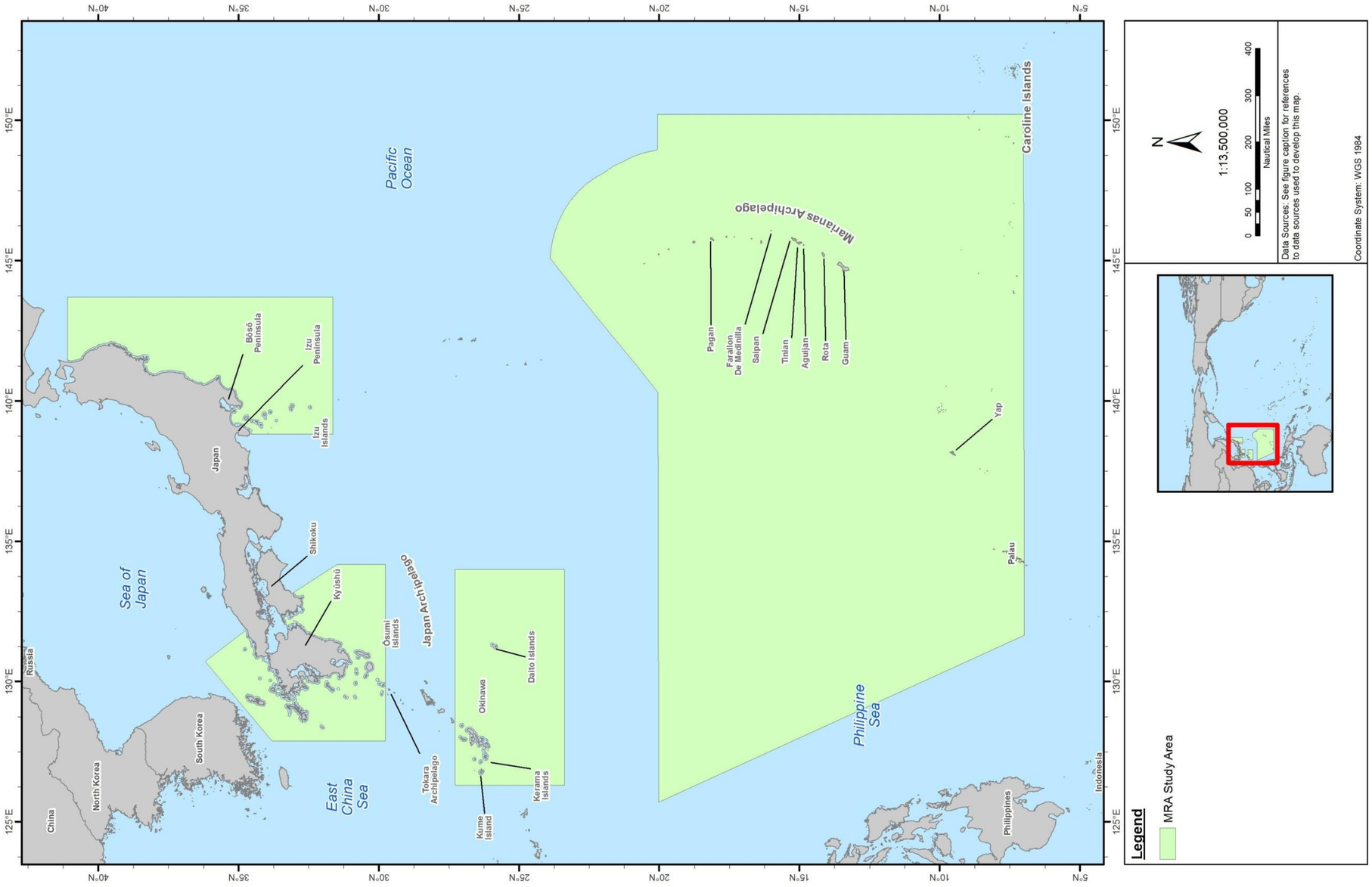

Figure 1-2: Location of the Marine Resource Assessment Study Area
Source: Bell (2009).

This Page Intentionally Left Blank

JAPAN ARCHIPELAGO. The MRA Study Area encompasses coastal waters along portions of northeastern portion of Honshū Island, Kyūshū Island, and Okinawa (Figure 1-3). Japan is an island nation that contains four major islands and approximately 7,000 smaller islands that arc just east of the Asian continent. The country is located in the western North Pacific Ocean and borders the Sea of Japan and the East China Sea. The bow-shaped archipelago is over 3,800 kilometers (km) long, with total land area approximating 380,000 km^2. Specific groups of islands of the Japan Archpelago are highlighted in this MRA where data and information are available. These islands include:

Bōsō Peninsula, Izu Peninsula, and Izu Islands. Coastal waters of the MRA Study Area include the northeastern portion of Honshū Island from the Bōsō Peninsula (excluding Tōkyō Bay) and extending to the southern tip of the Izu Peninsula. The Bōsō Peninsula is east of Tōkyō Bay. The Izu Peninsula is between Sagami Bay and Suruga Bay. The Izu Islands lie offshore of Honshū Island along 140 °E and 35° – 33°N, and belong to the Metropolis of Tōkyō. Honshū is the seventh largest island in the world, and Tōkyō, the capital city of Japan, lies on the eastern coast along Tōkyō Bay. Honshū is the largest of the Japanese islands, with an area of 230,500 km^2, or 60 percent (%) of Japan's total land area. Both Naval Air Facility Atsugi and Yokosuka Naval Complex are located on the eastern coast of Honshū, south of Tōkyō.

Kyūshū Island, Ōsumi Islands, and Tokara Archipelago. Coastal waters of the MRA Study Area include Kyūshū Island and Ōsumi Islands and Tokara Archipelago. The third largest Japanese island, Kyūshū (35,640 km^2), is located west of Shikoku and southwest of Honshū Islands. The COMPACFLT Sasebo installations and facilities are concentrated along the Sasebo Harbor on Kyūshū.

Okinawa Island, Kerama Islands, Kume Island, and Daito Islands. Coastal waters of the MRA Study include the Okinawa Island and neighboring islands including Iheya, Izena, Aguni, Tonaki, Kume, and Kerama Islands, and offshore Daito Islands. These islands are part of the Ryukyu archipelago, which arcs from the southern tip of Kyūshū through the Western Pacific Ocean, stretching toward Taiwan. The northern islands of the chain are governed by Kagoshima Prefecture, whereas the southern islands, including the island of Okinawa, are governed by Okinawa Prefecture. Okinawa Prefecture is one of the 47 self-governing units within Japan designed as the administrative rule in each section for the nation, a concept similar to that of city and state in the United States. Although Okinawa Prefecture accounts for a very small portion (1,176 km^2, 0.6%) of Japan's total land area, these islands lie within the closest geographical proximity to Southeast Asia and are crucial to exchanges between nations. Because of its proximity to potential trouble spots in the Pacific, Okinawa has been favored to serve as a location at which the military could deploy forces in the event of a global conflict (Fuqua 2001). In 1952, the San Francisco Peace Treaty officially recognized Okinawa as a U.S. possession, but soon after, the land was returned to Japanese control. Both nations have since agreed upon mutual sharing of the lands in a security relationship explained, in part, by the 1960 Treaty of Mutual Cooperation and Security (Fuqua 2001). The United States and Japan developed a roadmap for realigning U.S. military troops from Okinawa to Guam in 2006. This roadmap was adjusted in 2012 (U.S. Department of the Navy 2012, May 2).

MARIANA ARCHIPELAGO. The MRA Study Area includes the coastal waters of the CNMI and Guam (Figure 1-4). CNMI was established in 1976 through a covenant between the people of the Northern Mariana Islands and the United States (Central Intelligence Agency 2012b). The CNMI is a chain of 16 islands that extends 730 km from Farallon de Pajaros in the north to Rota in the south, and encompasses a total land area of 510 km^2. The largest islands in the CNMI are Saipan, Rota, and Tinian, which account for 65% of the Commonwealth's land area and are home to 99% of its population (Table 1-2). As of the

2010 census the total population of CNMI was 53,889 (CNMI Department of Commerce 2010). The population of the CNMI decreased by 22% between 2000 and 2010 (CNMI Department of Commerce 2010; Commonwealth of the Northern Mariana Islands Department of Commerce Central Statistics Division 2001). Guam was ceded to the United States by Spain in 1898, captured by the Japanese in 1941, and retaken by the United States three years later (Central Intelligence Agency 2012a). The military installation on the island is one of the most strategically important U.S. bases in the Pacific. The Territory of Guam was created in 1949 by President Truman through the Guam Organic Act. The population of Guam increased 2.9% between the 2000 and 2010 censuses (Guam Bureau of Statistics and Plans 2012).

Table 1-2: Population of the Northern Mariana Islands and Guam

Island	Population
Saipan	48,220
Rota	2,527
Tinian	3,136
Guam	159,358

Sources: CNMI Department of Commerce (2010); Guam Bureau of Statistics and Plans (2012).

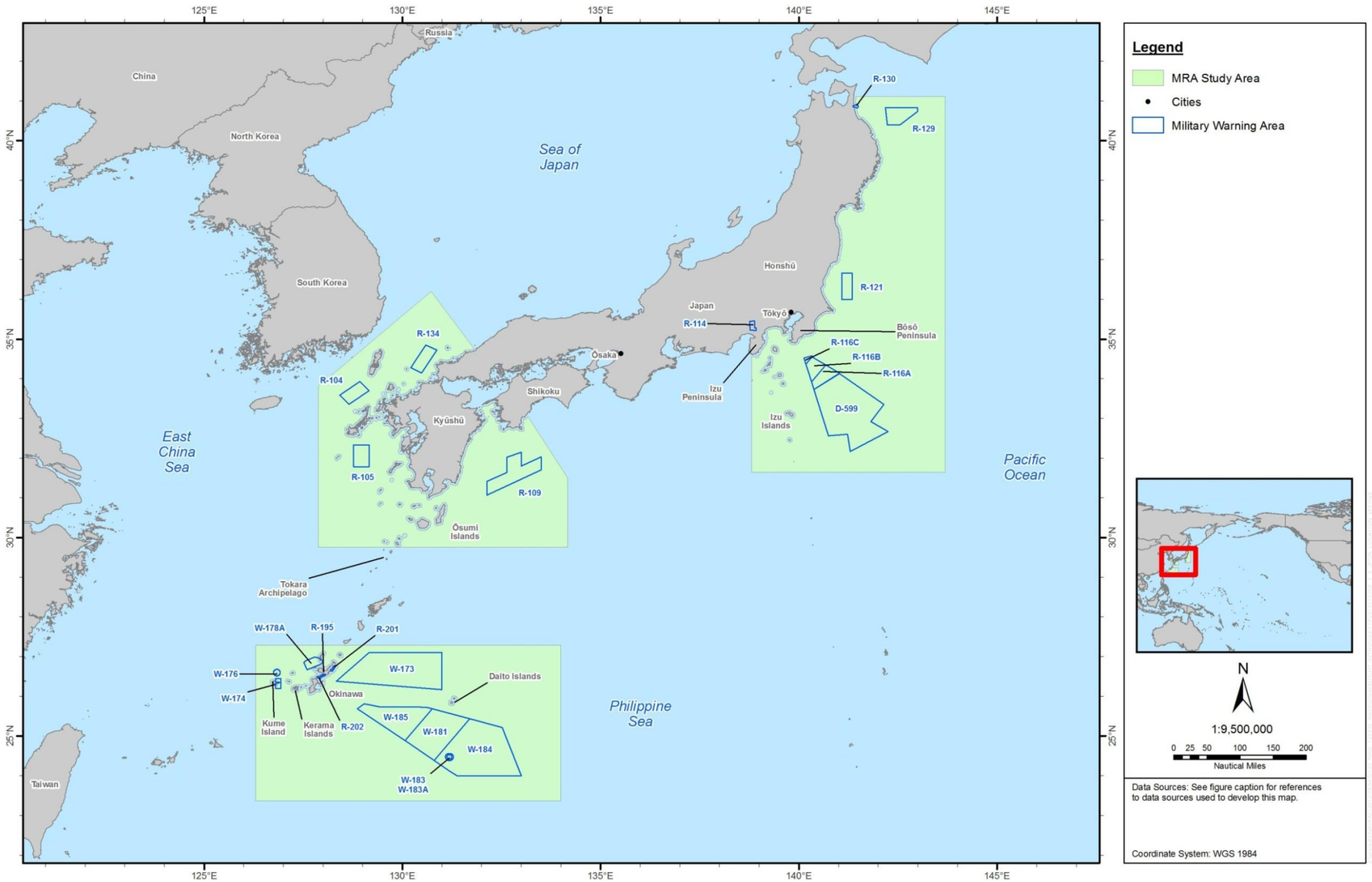

Figure 1-3: Location of the Japan Archipelago Portion of the Marine Resource Assessment Study Area
Source: U.S. Department of the Navy (2005a).

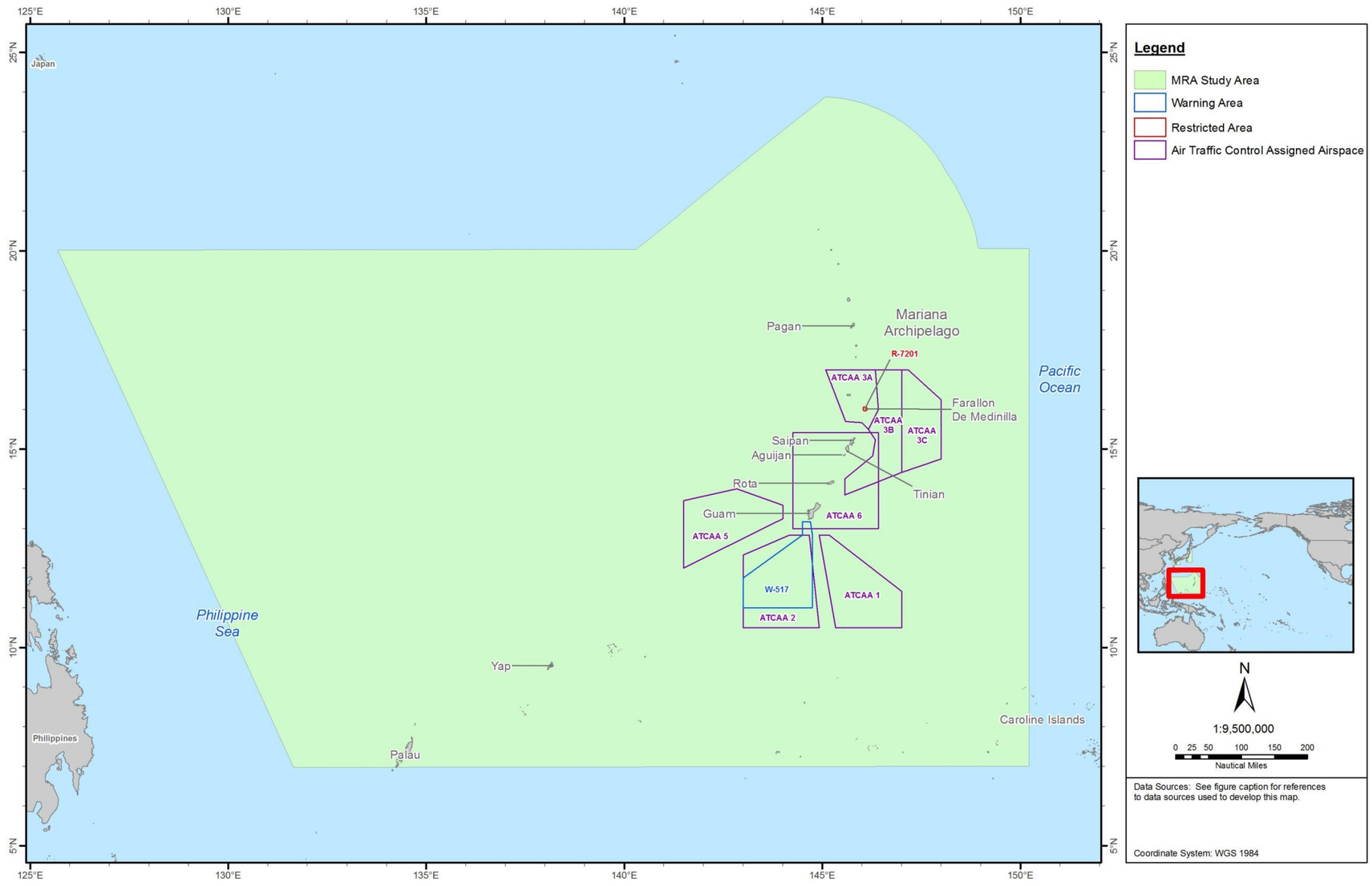

Figure 1-4: Location of the Mariana Archipelago Portion of the Marine Resource Assessment Study Area
Source: Crain (2013).

Specific islands of the Mariana Archpelago are highlighted in this MRA where data and information are available. These islands include:

Pagan. Pagan is an unihabited island with a land area of 4.8 km^2 located at latitude 18°8'N and longitude 145°48'E. Pagan has two main land masses connected by a narrow strip of land. Pagan is the 4th largest of the islands of CNMI. The maximum elevation of Pagan is 570 meters (m). The northern portion of the island is volcanically active (Bearden et al. 2005). The most recent eruption occurred in 2010 (Smithsonian National Museum of Natural History 2012).

Farallon de Medinilla. Farallon de Medinilla (FDM) is an uninhabited island with a land area of 0.81 km^2 island located at latitude 16°N and longitude 146°3.5'E. Island elevation is about 85 m above sea level and is currently leased to the U.S. military by the CNMI. The lease agreement allows U.S. military use of the island as a target range until 2075. FDM plays a special and unique role in national defense, and its environment is suitable for supporting established training requirements. Moreover, the air and sea space at FDM provides sufficient room for the many different attack profiles necessary to replicate training operations in the CNMI. FDM is the Pacific Fleet's only U.S.-controlled range available for live-fire training for forward-deployed Naval forces. The Pacific Fleet has been conducting military activities in this range since 1976 (Globalsecurity.org 2005).

Saipan. Saipan is an inhabitated island with a land area of 122 km^2 located at latitude 15° 12'N and longitude 145° 45'E. Ninety percent of the CNMI population lives on Saipan, the administrative center of the CNMI. Saipan is located in the southern portion of CNMI (Bearden et al. 2005; U.S. Department of Defense 2008). The island has diverse coral reef structures including fringing and a barrier reef system. Saipan is the largest island of the CNMI (20 km long and 9 km wide). It has a rough topography and its highest point, Mount Tagpochau (474 m high), is an extinct volcano. Saipan is located approximately 200 km north of Guam, 5,150 km west of Hawai'i, and 2,012 km east of Japan. The Port of Saipan, inaugurated in 1999, is a world-class commercial port facility and primary seaport of the CNMI that can accommodate deep draft vessels (Commonwealth Ports Authority 2004; Romero 1999).

Tinian. Tinian is an inhabitated island with a land area of 102 km^2 located at latitude 15°N and longitude 145° 38'E. The maximum elevation of Tinian is 166 m. Tinian is the second most populated island in the CNMI (Bearden et al. 2005). The U.S. military leases more than two-thirds of the island. Training on Tinian occurs within the Military Lease Area, with limited activities in Tinian Harbor.

Aguijan. Aquijan is an unihabited island with a land area of 7.3 km^2 island located at latitude 14° 52' N and longitude 145° 34' E. The maximum elevation of Aguijan is 57 m and it is surrounded by steep cliffs. Aguijan has an an islet, Naftan Rock, that the Navy formerly used as a bombing target (Bearden et al. 2005; U.S. Department of Defense 2008). Unexploded ordnance remains in the waters surrounding the islet, which is a nesting site for seabirds.

Rota. Rota is an inhabited island with a land area of 85.5 km^2 located at latitude 14°10'N and longitude 145° 14' E (Bearden et al. 2005). The maximum altitude of Rota is 496 m on Mt. Manira. Fringing reefs surround the island which is still largely undeveloped. Tourism is increasing in Rota (Pacific Islands Benthic Habitat Mapping Center 2011).

Guam. Guam is a inhabited island with a land area of 560 km^2 located at latitude 13° 28' N and longitude 144° 47' E. The highest point, Mount Lamlam, is 406 m. Northern Guam is composed of flat, uplifted limestone, while the southern half is raised volcanic material. Guam is heavily populated and is the

largest and southernmost island in the Mariana Archipelago (Porter et al. 2005). Guam is a strategic stopping point for ships and aircraft. Specific sites operated or managed by the U.S. military around Guam are highlighted in this MRA (Figure 1-5). These sites include:

Apra Harbor – Located on the western side of Guam, Apra Harbor is one of the largest protected deepwater harbors in the central Pacific Ocean. Naval Base Guam is located at the southern end of the harbor. Given its position with respect to the Far East and its recent development, the island has become a political, economic, and military stronghold of national and international significance (Globalsecurity.org 2004). The U.S. military at Guam operates in coastal waters at Apra Harbor.

Haputo Ecological Reserve Area – Located along the northwestern side of Guam, the Haputo Ecological Reserve Area is under control of the Commanding Officer, Naval Communications Area Master Station, Western Pacific (National Oceanic and Atmospheric Administration 2009).

Guam National Wildlife Refuge: Ritidian Unit – Located on the northernmost tip of Guam, the Guam National Wildlife Refuge: Ritidian Unit, formerly a specialized U.S. Naval installation, was decommissioned and is now owned by the U.S. Fish and Wildlife Service (National Oceanic and Atmospheric Administration 2009).

Orote Peninsula Ecological Reserve Area – Located along the central west coast of Guam, Orote Peninsula Ecological Reserve Area is under control of the Commanding Officer, Naval Station Guam (National Oceanic and Atmospheric Administration 2009).

Agat Bay – Located on west coast of Guam just south of the Orote Peninsula, Agat Bay stretches between two headlands, Orote Point and Facpi Point. The U.S. military at Guam operates in coastal waters at Agat Bay.

Talofofo Bay – Located on the southeast coast of Guam, Talofofo Bay is bordered on both sides by cliffs, with a dark sand beach at the end of the bay. Navy activities occur upland in the watershed fronting Talofofo Bay.

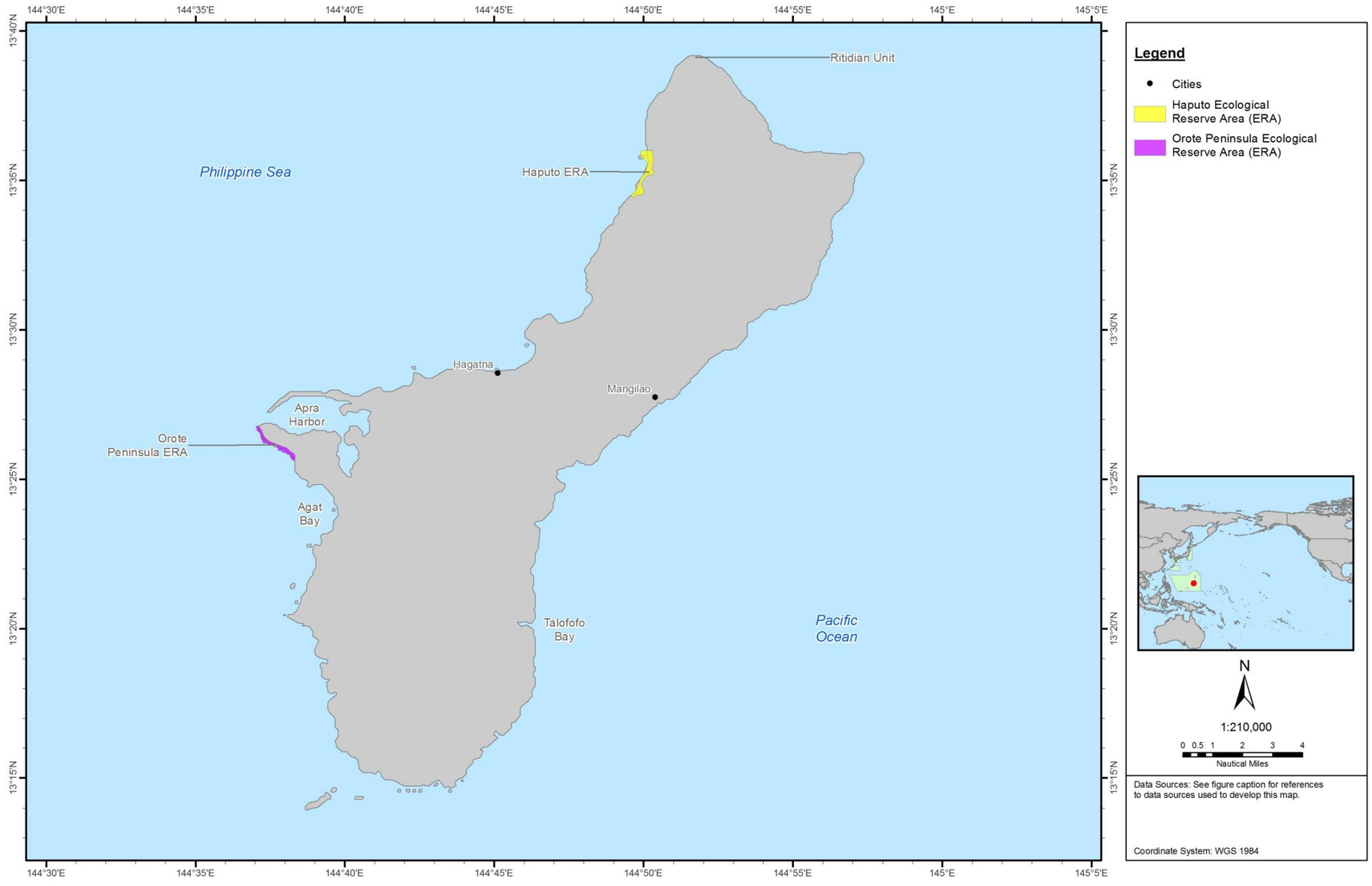

Figure 1-5: Navy Managed Lands and Operating Sites on Guam
Source: National Oceanic and Atmospheric Administration (2012).

This Page Intentionally Left Blank

CAROLINE ISLANDS. The MRA Study Area includes coastal waters of Yap, located in the western portion of the FSM and Palau (Figure 1-2). The FSM and Palau are part of the Caroline Islands, one of the longest island chains in the world (Hasurmai et al. 2005). FSM is comprised of 607 small islands that stretch 2,739 km in length from Kosrae in the east to Yap in the west (Federated States of Micronesia Visitors Board 2012a). It is located just above the equator in the Western Pacific and about 4,023 km southwest of Hawai'i. Total land area is 701 km^2. Each of the four States, Kosrae, Phonpei, Chuuk, and Yap, include high islands. All states except Kosrae also include numerous atolls. The total population of FSM is estimated at 107,000 in 2000, a 22% increase over the 1980s survey Government of the Federated States of Micronesia (2012).

The FSM and the Palau each negotiated a Compact of Free Association with the United States (Federated States of Micronesia Visitors Board 2012b) which entered into force on November 3, 1986. The Compact of Free Association provided independence for the former Pacific Islands Trust Territories from the U.S. and economic assistance, defense, and other benefits in exchange for U.S. defense and certain other operating rights. Palau formed their own government as the Republic of Palau. The districts Chuuk, Yap, Pohnpei , and Kosrae voted in a referendum to form a Federation under the Constitution of the Federated States of Micronesia in 1978 (Federated States of Micronesia Visitors Board 2012b). The Republic of Palau and FSM are members of the United Nations.

Yap. Yap is an inhabited island with a land area of 100 km^2 island located at 9° 29'N 138° 05'E. Yap has 15 associated islands and atolls (Hasurmai et al. 2005). The population of Yap was 11,200 people in 2000 (Government of the Federated States of Micronesia 2012). Currently, no military operations occur near Yap.

Palau. Palau is an inhabitated island with a land area of 459 km^2 located at 7°30' N, 134°30' E. Palau is composed of 12 inhabited islands. It is located 741 km east of Mindanao in the southern Philippines and about 1,300 km southwest of Guam (Golbuu et al. 2005). The population of Palau was 19,907 people according to the last census in 1995 (Palau Office of Planning and Statistics 2012). Currently, no military operations occur within 10 nautical miles of the island but could in the future if permission is granted.

1.3 REPORT ORGANIZATION

This MRA provides information and data on marine resources in the MRA Study Area. The content of each section of each chapter is organized to provide global and regional summaries in addition to MRA Study Area specific content on the marine resources. The MRA Study Area specific content is organized as described in Section 1.2 into open ocean and coastal waters from north to south and from island-wide to site-specific where information exists. This report is organized into 13 chapters.

- Chapter 1 provides background information including purpose of and need for the MRA and a description of the location of the MRA Study Area.
- Chapter 2 summarizes federal resource laws, executive orders and Presidential Proclamations, DoD and federal compliance requirements, and international environmental conventions, treaties, and organizations of potential relevance to Navy operations in coastal and open ocean waters.
- Chapter 3 summarizes the approach and process used to develop the content of the MRA.
- Chapter 4 provides information on the marine geology, physical oceanography, chemical oceanography, and biological oceanography within the MRA Study Area.

- Chapters 5–9 provide general information and species profiles on marine mammals (Chapter 5), marine reptiles (Chapter 6), seabirds (Chapter 7), marine invertebrates (Chapter 8), and fish (Chapter 9) within the MRA Study Area.
- Chapter 10 provides information on federally managed fisheries and essential fish habitat.
- Chapter 11 provides profiles on marine habitats within the MRA Study Area.
- Chapter 12 summarizes marine protected areas within the MRA Study Area.
- Chapter 13 summarizes selected human uses within the MRA Study Area.

1.4 REFERENCES

Aquarone, M. C. and Adams, S. (2009). X-23 Kuroshio Current LME. In K. Sherman and G. Hempel (Eds.), *The UNEP Large Marine Ecosystem Report: A Perspective on Changing Conditions in LMEs of the World's Regional Seas*. (UNEP Regional Seas Report and Studies No. 182, pp. 393-401). Nairobi, Kenya: United Nations Environmental Programme.

Bearden, C., Brainard, R., de Cruz, T., Hoeke, R., Houk, P., Holzwarth, S., et al. (2005). The state of coral reef ecosystems of the Commonwealth in the Northern Mariana Islands. In J. E. Waddell (Ed.), *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2005*. (NOAA Technical Memorandum NOS-NCCOS-11, pp. 399-441). Silver Spring, MD: NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team.

Bell, J. T. (2009, 09 December), Department of the Navy, Naval Facilities Engineering Command Atlantic. *Country Boundaries*. GIS data provided to J. Peters, Tetra Tech, Inc., Nashville, TN.

Central Intelligence Agency (2012a, Last updated 13 April 2012). Australia-Oceania: Guam. In *The World Factbook*. [Web page]. Retrieved from https://www.cia.gov/library/publications/the-world-factbook/geos/gq.html, 19 April 2012.

Central Intelligence Agency (2012b, Last updated 29 March 2012). Northern Mariana Islands. In *The World Factbook*. [Web page]. Retrieved from https://www.cia.gov/library/publications/the-world-factbook/geos/cq.html, 19 April 2012.

CNMI Department of Commerce (2010). Population of the Commonwealth of the Northern Mariana Islands by village: 2010. [Electronic fact sheet]. Retrieved from http://commerce.gov.mp/wp-content/uploads/2012/01/2010-CNMI-Census-Village-Population-Counts.pdf, 19 April 2012.

Commonwealth of the Northern Mariana Islands Department of Commerce Central Statistics Division (2001). *Saipan Population by District 1980 to 2000*. [Web page]

Commonwealth Ports Authority (2004). *Commonwealth of the Northern Mariana Islands: Port of Saipan*. [Web page], 06 May 2005.

Crain, J. (2013), Department of the Navy, Naval Facilities Engineering Command Atlantic. Warning Area Layers and Airspace. GIS Data provided to B. Agius on 16 and 17 January, Tetra Tech, Inc., Portland, ME.

Federated States of Micronesia Visitors Board (2012a). Geography. [Web page]. Retrieved from http://www.visit-fsm.org/visitors/geography.html, 20 April 2012.

Federated States of Micronesia Visitors Board (2012b). History. [Web page]. Retrieved from http://www.visit-fsm.org/visitors/history.html, 20 April 2012.

Fuqua, J. (2001). Understanding Okinawa's role in the U.S.-Japan security agreement. In *Japan Digest*, 29 July 2005.

Globalsecurity.org (2004). *Guam*. [Web page], 13 June 2005.

Globalsecurity.org (2005, Last updated 26 April 2005). *Farallon de Medinilla (FDM)*. [Web page], 13 June 2005.

Golbuu, Y., Bauman, A., Kuartei, J. and Victor, S. (2005). The state of coral reef ecosystems of Palau. In J. E. Waddell (Ed.), *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2005*. (NOAA Technical Memorandum NOS NCCOS 11, pp. 488-507). Silver Spring, MD: NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team.

Government of the Federated States of Micronesia (2012). People. [Web page]. Retrieved from http://www.fsmgov.org/info/people.html, 20 April 2012.

Guam Bureau of Statistics and Plans (2012). 2010 Guam census population counts. [Web page]. Retrieved from http://www.bsp.guam.gov/index.php?option=com_content&view=article&id=130&Itemid=100008, 20 April 2012.

Hasurmai, M., Joseph, E., Palik, S. and Rikim, K. (2005). The state of coral reef ecosystems of the Federated States of Micronesia. In J. E. Waddell (Ed.), *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2005*. (NOAA Technical Memorandum NOS NCCOS 11, pp. 387-398). Silver Spring, MD: NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team.

Heileman, S. and Tang, Q. (2009). X-22 East China Sea LME. In K. Sherman and G. Hempel (Eds.), *The UNEP Large Marine Ecosystem Report: A Perspective on Changing Conditions in LMEs of the World's Regional Seas*. (UNEP Regional Seas Report and Studies No. 182, pp. 383-392). Nairobi, Kenya: United Nations Environmental Programme.

National Oceanic and Atmospheric Administration. (2009). *Coral Reef Habitat Assessment for U.S. Marine Protected Areas: U.S. Territory of Guam*. (pp. 17) U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service Management & Budget Office.

National Oceanic and Atmospheric Administration, Marine Debris Program (2013). Marine Debris Information: Movement. [Web Page]. Retrieved from http://marinedebris.noaa.gov/marinedebris101/movement.html

National Oceanic and Atmospheric Administration, Ocean and Coastal Resource Management, National Marine Protected Areas Center. (2012). MPA Inventory Database [vector digital data]. (v3 ed.). Monterey, CA: NOAA's Ocean Service, National Marine Protected Areas Center (MPAC). Available from http://www.mpa.gov/dataanalysis/mpainventory/

Pacific Islands Benthic Habitat Mapping Center (2011, Last updated 14 November 2011). Commonwealth of Northern Mariana Islands (CNMI) and Guam. In *Data Sets*. [Web page]. Retrieved from http://www.soest.hawaii.edu/pibhmc/pibhmc_cnmi.htm, 20 July 2012.

Palau Office of Planning and Statistics (2012). Population censuses. [Web page] Bureau of Budget and Planning, Office of Planning and Statistics. Retrieved from http://www.palaugov.net/stats/PalauStats/Social/Census/Census.htm, 20 April 2012.

Porter, V., Leberer, T., Gawel, M., Gutierrez, J., Burdick, D. R., Torres, V., et al. (2005). The state of coral reef ecosystems of Guam. In J. E. Waddell (Ed.), *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2005*. (NOAA Technical Memorandum NOS NCCOS 11, pp. 442-487). Silver Spring, MD: NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team.

Romero, L. F. (1999, 3 February). CPA sets Saipan harbor inauguration. *Saipan Tribune, 9*(282).

Smithsonian National Museum of Natural History (2012). Global Volcanism Program: Pagan. In *Bulletin of the Global Volcanism Network*. [Web page]. Retrieved from http://www.volcano.si.edu/world/volcano.cfm?vnum=0804-17=, 23 April 2012.

U.S. Department of Defense. (1996). Environmental Conservation Program. (Instruction Number 4715.3). Washington, DC: Secretary of Defense.

U.S. Department of Defense, U.S. Naval Facilities Engineering Command Pacific. (2008). *Coral Reef Ecosystem and Habitat Surveys in the Mariana Archipelago: Preliminary Findings and Key Figures for the Islands of Guam, Aguijan, Tinian, Saipan, and Pagan*. (PIFSC Internal Report IR-08-014, pp. 44). Honolulu, HI: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Pacific Islands Fisheries Science Center.

U.S. Department of the Navy. (2005a). *Marine Resources Assessment for the Japan and Okinawa Complexes Operating Area* [Final report]. (Contract # N62470-02-D-9997, CTO 0028, pp. 394). Pearl Harbor, HI: Pacific Division, Naval Facilities Engineering Command. Prepared by Geo-Marine, Inc., Plano, Texas.

U.S. Department of the Navy. (2005b). *Marine Resources Assessment for the Marianas Operating Area*. (Contract # N62470-02-D-9997, CTO 0028, pp. 416). Pearl Harbor, HI: Pacific Division, Naval Facilities Engineering Command. Prepared by Geo-Marine, Inc., Plano, Texas.

U.S. Department of the Navy (2012, May 2). NEPA Planning for Guam Realignment Roadmap Adjustment [Electronic press release]. Retrieved from http://www.navy.mil/search/display.asp?story_id=66926, 14 May 2012.

This Page Intentionally Left Blank

2.0 APPLICABLE LAWS AND LEGISLATION

2.1 INTRODUCTION

This section covers laws, regulations, presidential orders, and international treaties that may have some applicability in U.S. and international waters of the MRA Study Area for the Japan and Mariana Archipelagos (the MRA Study Area) depending on the action being considered. It is important to obtain an applicability determination from assigned counsel to ensure any requirements or obligations are adequately addressed.

2.2 FEDERAL RESOURCE LAWS

The principal U.S. federal legislations that govern U.S. Department of the Navy (Navy) activities in the marine environment are the National Environmental Policy Act (NEPA), the Marine Mammal Protection Act (MMPA), the Endangered Species Act (ESA), and the Magnuson-Stevens Fishery Conservation and Management Act. This section provides an overview of federal resource laws that may be applicable depending on the action being considered.

2.2.1 National Environmental Policy Act

The NEPA of 1969 (42 U.S. Code [U.S.C.] §§ 4321-4370[f]) established U.S. policies and goals for environmental protection. The NEPA seeks to develop a balance between people and the environment, to promote efforts at preventing or eliminating damage to the environment, and to improve understanding of important ecological systems and natural resources. To achieve this, the NEPA requires that federal agencies appropriately consider environmental factors in all decisions. This includes all major federal actions—as well as state or private actions that benefit from federal funding—that occur within or may affect U.S. lands, territories, and possessions, or coastal waters.

The NEPA consists of two sections. Title I outlines a basic national charter for protection of the environment, while Title II establishes the Council on Environmental Quality (CEQ), which monitors progress toward achieving the goals set forth in Section 101 of the NEPA. The CEQ also advises the President on environmental issues and provides guidance to other federal agencies on compliance with the NEPA.

Section 102(2) of the NEPA contains "action-forcing" provisions to ensure federal agencies act according to the letter and the spirit of the law. These procedural requirements direct all federal agencies to appropriately consider environmental effects of their decision-making by evaluating the environmental impact, irreparable environmental effects, alternatives, and short-term and long-term impacts of the proposed action. Determination that a proposed action would significantly impact or possibly significantly impact the human environment triggers a NEPA requirement for federal agencies to fully consider the environmental consequences of the proposed action, usually through preparation of an Environmental Impact Statement (EIS). Section 102(2) further requires development and evaluation of alternatives to the proposed action.

Studies and/or actions requiring federal compliance should be prepared in accordance with Section 102(2)(c) of the NEPA, the CEQ regulations on implementing NEPA procedures (40 *Code of Federal Regulations* [C.F.R.] §§ 1500-1508), and Navy regulations on implementing NEPA procedures (32 C.F.R. § 775).

2.2.2 Rivers and Harbors Appropriation Act

Congress passed the Rivers and Harbors Appropriation Act of 1899 (33 U.S.C. § 403) to restrict the building of structures over or in U.S. navigable waterways. Under Section 9, no bridge, dam, dike, or causeway may be constructed without Congressional approval. Structures within a state that have been approved by the state legislature may be built with approval of the Secretary of Transportation or the Chief of the U.S. Army Corps of Engineers (USACE) and the Secretary of the Army. Section 10 prohibits construction of wharfs, piers, and jetties over or in navigable waterways without approval of Congress. The Chief of Engineers and the Secretary of the Army must approve both construction and excavation in navigable waters.

Under the Rivers and Harbors Appropriate Action, danger zones can be established by regulation for any area within which Department of Defense (DoD) operations likely will endanger its use and navigation. Naval restricted areas may be established when required for protection of life and property at a military installation.

2.2.3 Submerged Lands Act

The Submerged Lands Act (SLA) of 1953 (43 U.S.C. §§1301-1315) grants coastal states title to offshore lands within their historic boundaries as well as the rights to the natural resources on or within those lands. The right and power to manage, lease, develop, and use these lands and resources should also be established in these states. The federal government relinquishes its claims to the lands and resources, but maintains the right to regulate offshore activities for national defense, international affairs, navigation, and commerce. Under Section 54-7-620 of the Act, submerged archaeological historic property means any site, vessel, structure, object, or remains that yield or are likely to yield information of significance to scientific study of human prehistory, history, or culture, and are embedded in or on submerged lands, and have remained unclaimed for 50 years or longer. This term includes, but is not limited to, abandoned shipwrecks and their contents, as well as individual assemblages of historic or prehistoric artifacts.

2.2.4 Outer Continental Shelf Lands Act

Passed at the same time as the SLA, the Outer Continental Shelf Lands Act (OCSLA) of 1953 (43 U.S.C. §§ 1331-1356), which was substantially amended in 1978 as the OCSLA Amendments (OCSLAA) (Public Law [P.L.] 95-372), grants the federal government jurisdiction over submerged lands of the outer continental shelf from the seaward boundary of state/territorial waters to the shelf break. The primary goal of the OCSLAA is to manage oil and gas resources within the continental shelf underlying U.S. offshore waters, as well as to preserve and develop these stores for use by the United States. The Act also directs the Bureau of Ocean Energy Management (BOEM), formerly the Minerals Management Service) under the Department of the Interior, to preserve and develop offshore oil and gas in accordance with stewardship of associated marine and coastal environments, and to cancel leases if activity will result in environmental damage. The BOEM is to consult with relevant agencies when necessary, as well as undergo consistency review in accordance with the Coastal Zone Management Act (CZMA).

2.2.5 Marine Mammal Protection Act

The MMPA of 1972 (16 U.S.C. §§ 1361-1407) established a moratorium on “taking” marine mammals in U.S. waters and lands. The MMPA defines marine mammals as cetaceans (whales, dolphins, and porpoises), pinnipeds (walruses, seals, and sea lions), sirenians (manatees and dugongs), sea otters, and

polar bears. The National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) jointly administer the MMPA, each with responsibility over certain marine mammals; the NMFS is charged with managing cetaceans and pinnipeds, while the USFWS manages manatees, sea otters, and polar bears. The MMPA also prohibits importation into the United States of any marine mammal or parts or products thereof, unless for the purpose of scientific research or public display, as permitted by the Secretary of the Interior (in relation to USFWS) or the Secretary of Commerce (in relation to NMFS).

The MMPA defines taking as “harassing, hunting, capturing, killing, or attempting to harass, hunt, capture, or kill any marine mammal” (16 U.S.C. § 1362[3][13]). The MMPA was amended in 1994 to define two levels of harassment. Level A harassment is defined as any act of pursuit, torment, or annoyance that has potential to injure a marine mammal or marine mammal stock in the wild. Level B harassment is defined as any act that has potential to disturb a marine mammal or marine mammal stock in the wild by disrupting behavioral patterns, including but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering.

The definition of “harassment” in relation to military readiness and scientific research activities conducted by or on behalf of the federal government was altered in the National Defense Authorization Act (NDAA) for Fiscal Year 2004 (P.L. 108-136). Level A harassment was redefined as any act that injures or has significant potential to injure a marine mammal or marine mammal stock in the wild. Level B harassment was redefined as any act that disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns, including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering, to a point where such behavioral patterns are abandoned or significantly altered (16 U.S.C. § 1362[3][18][B]).

Section 101(a)(5)(A) of the MMPA provides a mechanism for allowing, upon request, "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 geographic region. This authorization may be given if, after notice and opportunity for public comment, the Secretary of Commerce (1) determines that total takes during a 5-year or less period will negligibly impact the affected species or stock, and (2) prescribes necessary regulations that detail methods of taking and monitoring, and requirements for reporting. The MMPA specifies that the moratorium on taking may be waived when the Secretary determines that the takes will negligibly impact the affected species or population stock. Section 101(a)(5)(A) also specifies that the Secretary has the right to deny permission to take marine mammals if, after notice and opportunity for public comment, the Secretary finds that either (1) applicable regulations regarding taking, monitoring, and reporting are not being followed; or (2) takes are, or may be, having more than a negligible impact on the affected species or stock.

2.2.6 Endangered Species Act

The ESA of 1973 (16 U.S.C. §§ 1531-1599) was established to protect and conserve threatened and endangered species and the ecosystems upon which they depend. An “endangered species” is a species in danger of extinction throughout all or a significant portion of its range. A “threatened species” is likely to become endangered within the foreseeable future throughout all or a significant portion of its range. All federal agencies are required to implement protection programs for threatened and endangered species, and to use their authority to further the purposes of the ESA. The NMFS and the USFWS jointly administer the ESA and are responsible for listing all species that are candidates for threatened or endangered status. A “candidate species” is the subject of either a petition to list or is to undergo a status review—a species for which the NMFS or USFWS has determined listing may be or is warranted

(National Marine Fisheries Service 2004). The NMFS is further charged with listing all species of concern that fall under its jurisdiction. A "species of concern" is a species for which the NMFS has some concerns regarding status and threats, but for which insufficient information is available to start the process to consider listing the species under the ESA (National Marine Fisheries Service 2004). Neither listing as candidate nor informal status such as species of concern provides protection under the ESA. Protection comes only when threatened or endangered status has been formally determined.

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

Section 4 deals with ESA designation of geographic areas as critical habitat for threatened or endangered species. Included in the habitat designation are the physical and biological features essential to conservation of a threatened or endangered species (i.e., the primary constituent elements). Designation of critical habitat affects only federal agency actions and federally funded or permitted activities. Certain military lands may be exempt from critical habitat designation. Exemption for lands other than military lands is also possible on the basis of an already established management plan. This requires a determination by the Secretary of the Interior that the management plan benefits the species for which critical habitat designation is sought (i.e., the area does not need "special management considerations or protection").

2.2.7 Migratory Bird Treaty Act

The Migratory Bird Treaty Act (MBTA) of 1918 (16 U.S.C. 703 et seq.) and the Migratory Bird Conservation Act (16 U.S.C. §§ 715–715d, 715e, 715f–715r) of 1929 are the primary acts of legislation in the United States to conserve migratory birds. These statutes implement the United States' commitment to four bilateral treaties, or conventions, for protection of a shared migratory bird resource. Current treaties are in place regarding this among the countries of Great Britain, Mexico, Canada, Japan, and the Soviet Union. The MBTA prohibits taking, killing, or possessing migratory birds or the parts, nests, or eggs of such birds, unless permitted by regulation. The species of birds protected by the MBTA appears in 50 C.F.R. 10.13, and encompass almost all avian families found in North America.

The 2003 NDAA provides that the Secretary of the Interior shall exercise his/her authority under the MBTA to prescribe regulations to exempt the Armed Forces from the incidental taking of migratory birds during military readiness activities authorized by the Secretary of Defense (SECDEF). Congress defined military readiness activities as all training and operations of the Armed Forces that relate to combat, and the adequate and realistic testing of military equipment, vehicles, weapons, and sensors for proper operation and suitability for combat use. The final rule authorizing the DoD to take migratory birds during military readiness activities was published in the *Federal Register* on February 28, 2007 (50 C.F.R. 21). The regulation specifies that the Armed Forces must confer and cooperate with USFWS on development and implementation of conservation measures to minimize or mitigate adverse effects of a military readiness activity if USFWS determines that such activity may have a "significant adverse effect" on a population of a migratory bird species.

An activity has a significant adverse effect if, over a reasonable period of time, it diminishes the capacity of a population of a migratory bird species to maintain genetic diversity, to reproduce, and to function effectively in its native ecosystem. A population is defined as "a group of distinct, coexisting, same species, whose breeding site fidelity, migration routes, and wintering areas are temporally and spatially stable, sufficiently distinct geographically (at some point of the year), and adequately described so that the population can be effectively monitored to discern changes in its status."

2.2.8 Coral Reef Conservation Act

The Coral Reef Conservation Act (CRCA) of 2000 (16 U.S.C. §§ 6401-6409) recognizes the importance of coral species in furtherance of Executive Order (EO) 13089. This Act applies U.S. waters, territories, and possessions, and any nation in free association with the United States. The CRCA seeks to advance conservation and restoration of coral reef ecosystems through application of sound science, sustainable use management, and provision of support and financing to programs and organizations in both the governmental and private sectors. Responsibility for the CRCA is vested in the Administrator of the National Oceanic and Atmospheric Administration (NOAA), which produced a national coral reef action strategy in consultation with the U.S. Coral Reef Task Force (USCRTF).

The USCRTF was established in 1998 by EO 13089 (National Oceanic and Atmospheric Administration 2005). In 2002, the USCRTF developed the U.S. Coral Reef National Action Strategy to further implement the National Action Plan as called for in the CRCA. These documents provide the guiding framework for priorities, strategies, and actions of the USCRTF and its members.

2.2.9 Magnuson-Stevens Fishery Conservation and Management Act

In 1996, the Fishery Conservation and Management Act of 1976 (16 U.S.C. §§ 1801-1882) was reauthorized, renamed the Magnuson-Stevens Fishery Conservation and Management Act, and amended by the Sustainable Fisheries Act (SFA) (P.L. 104-297) to provide for conservation and management of the fisherie. The Magnuson-Stevens Fishery Conservation and Management Act established a 200-nautical mile (nm) fishery conservation zone in U.S. waters and a network of regional Fishery Management Councils (FMC). The FMCs include federal and state officials who oversee fishing activities in the fishery management zone. Exclusive federal management authority over U.S. domestic fisheries resources is vested in the NMFS. The Act also established 10 national standards for fishery conservation and management (e.g., optimum yield, scientific information, allocations, efficiency, and costs/benefits).

The SFA created the mandate to determine essential fish habitat (EFH), defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" (16 U.S.C. § 1802[10]). The term "fish" is defined in the SFA as "finfish, mollusks, crustaceans, and all other forms of marine animals and plant life other than marine mammals and birds." The regulations for implementing EFH define "waters" as aquatic areas and their biological, chemical, and physical properties, while "substrate" refers to the associated biological communities that make these areas suitable fish habitat (50 C.F.R. § 600.10).

Habitats used at any time during at least one of the species life stages must be accounted for when describing and identifying EFH (National Marine Fisheries Service 2002). The identification must include descriptive information on the geographic range of the EFH for all life stages, along with maps of the EFH for life stages over appropriate temporal and spatial scales. Habitat requirements also must be identified, described, and mapped for all life stages of each species. The NMFS and regional FMCs

determine the species distributions by life stage and characterize associated habitats, including habitat areas of particular concern. The SFA requires federal agencies to consult with the NMFS on activities that may adversely affect EFH.

In 2002, the NMFS issued a final rule that simplified EFH regulations (National Marine Fisheries Service 2002). This final rule includes (1) clearer standards for identifying and describing EFH, such as inclusion of the geographic boundaries and a map of the EFH, as well as guidance for the FMCs to distinguish EFH from other habitats; (2) more guidance for the FMCs on evaluating the impact of fishing activities on EFH and clearer standards for deciding when FMCs should act to minimize the adverse impacts; and (3) clarification and reinforcement of the EFH consultation procedures (National Marine Fisheries Service 2002).

The SFA requires that regional FMCs describe and identify EFH for each federally managed species, minimize to the extent practicable adverse effects on such habitat caused by fishing, and identify other actions to encourage conservation and enhancement of such habitats in federal Fishery Management Plans. The SFA requires federal agencies to consult with NMFS on activities that may adversely affect EFH. For actions that affect a threatened or endangered species, its critical habitat, and its EFH, federal agencies must initiate ESA and EFH consultations. An adverse effect is any impact that reduces quality and/or quantity of EFH. Adverse effects may include direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species, and their habitat, and other ecosystem components, if such modifications reduce the quality and/or quantity of EFH. Adverse effects on EFH may result from actions occurring within EFH or outside of EFH, and may include site-specific or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 C.F.R. 600.810(a)).

The Western Pacific Regional Fisheries Management Council oversees fisheries management in the Mariana Archipelago.

2.2.10 National Fishing Enhancement Act

The National Fishing Enhancement Act (NFEA) (33 U.S.C. §§ 2101-2106) of 1984 designates the Secretaries of Commerce and the Army with lead responsibilities to encourage, regulate, and monitor development of artificial reefs in the navigable waters and waters overlying the outer continental shelf of the United States. One of the primary directives of the NFEA was to prepare a long-term National Artificial Reef Plan (NARP) (33 U.S.C. § 2103) (National Oceanic and Atmospheric Administration 2007a). Section 202 of the Act recognizes the harmful effects of overfishing on fishery resources, and proposes that properly designed, constructed, and located artificial reefs can enhance the habitat and diversity of these fishery resources. The NARP, which underwent revision in 2007, had been implemented in November 1985 to provide guidance and criteria on various aspects of artificial reef use, including types of construction materials and planning, siting, designing, permitting, installing, maintaining, and managing artificial reefs (National Oceanic and Atmospheric Administration 2007b). One of the most significant recommendations in the NARP encourages development of state-specific artificial reef plans (Gordon 1993).

A number of artificial reefs have been established within the MRA Study Area. Establishment of new artificial reefs must follow guidelines established in the NARP (National Oceanic and Atmospheric Administration 2007a).

2.2.11 Sikes Act

The Sikes Act of 1960 (16 U.S.C. § 670[a]-670[o]) directs the SECDEF to carry out a program for cooperative development and implementation of Integrated Natural Resources Management Plans (INRMP) to provide for conservation and rehabilitation of fish and wildlife resources on U.S. military installations. The INRMP integrates conservation of natural resources on military lands with military operations to ensure consistency with appropriate federal laws. The Sikes Act Improvement Act of 1997 requires an INRMP, to the extent appropriate and applicable, provide for (1) fish and wildlife management, land management, forest management, and fish and wildlife-oriented recreation; (2) fish and wildlife habitat enhancement or modification; (3) wetland protection, enhancement, and restoration, where necessary for support of fish, wildlife, or plants; (4) integration of, and consistency among, the various activities conducted under the plan; (5) establishment of specific natural resource management goals and objectives and time frames for proposed actions; (6) sustainable public use of natural resources to the extent that the use is not inconsistent with the needs of fish and wildlife resources; (7) public access to the installation necessary or appropriate for sustainable use of natural resources, subject to requirements necessary to ensure safety and military security; (8) enforcement of applicable natural resource laws; (9) no net loss in the capability of the installation's lands to support the military mission of the installation; and (10) such other activities as the military has determined appropriate.

2.2.12 Coastal Zone Management Act

The Coastal Zone Management Act (CZMA) of 1972 (16 U.S.C. §§ 1451-1466) established a voluntary national program through which U.S. states and territories can develop and implement coastal zone management plans. The NOAA, under the Secretary of Commerce, administers this Act. States and territories use coastal zone management plans "to manage and balance competing uses of and impacts to any coastal use or resource" (National Oceanic and Atmospheric Administration 2000). A coastal zone management plan must be given federal approval before the state or territory can implement the plan. The plan must include defined boundaries of the coastal zone, the uses of the area that the state or territory will regulate, a list of mechanisms to be employed to control the regulated uses, and guidelines for prioritizing the regulated uses. Currently, 34 U.S. states and territories have federally approved coastal zone management plans. These states and territories manage over 153,500 kilometers or 99.9 percent (%) of U.S. shoreline along the Atlantic, Pacific, and Arctic Oceans, as well as the Great Lakes.

The CZMA also instituted a federal consistency requirement, which restricts behaviors of federal agencies regarding state- and territory-managed coastal zones. Federal agency actions that affect any land or water use or natural resource of the coastal zone (e.g., military operations, offshore oil and gas development, dredging projects, and developments on federal lands or in protected areas) must be "consistent to the maximum extent practicable" with the enforceable policies of a state or territory's coastal management program. The federal consistency requirement was enacted as a mechanism to address coastal effects, to ensure adequate federal consideration of state and territory coastal management programs, and to avoid conflicts between states or territories and federal agencies by fostering early consultation and coordination (National Oceanic and Atmospheric Administration 2000). Within each state or territory's coastal zone management plan is a list of the federal agency activities for which consistency determinations must be prepared. Under certain circumstances, the President is authorized to exempt specific activities from the federal consistency requirement if he/she determines that these activities are of paramount interest to the United States.

2.2.13 Marine Protection, Research, and Sanctuaries Act

The Marine Protection, Research, and Sanctuaries Act (MPRSA) of 1972 (33 U.S.C. §§ 1401-1445) regulates dumping of toxic materials beyond U.S. territorial waters and provides guidelines for designation and regulation of marine sanctuaries. Titles I and II prohibit persons or vessels subject to U.S. jurisdiction from transporting any material out of the United States for the purpose of dumping it into ocean waters without a permit. The term "dumping" does not include intentional placement of devices in ocean waters or on the sea bottom when the placement occurs pursuant to an authorized federal or state program.

2.2.14 National Marine Sanctuaries Act

During the reauthorization of the MPRSA in 1992, Title III of the MPRSA was designated the National Marine Sanctuaries Act (NMSA) (16 U.S.C. §§ 1431-1445[c]). The NMSA authorizes the Secretary of Commerce to designate and manage areas of the marine environment with special national significance as national marine sanctuaries. Regulations at 15 C.F.R. Part 922 further implement the NMSA and regulate the conduct of certain activities within sanctuaries. Section 304(d) of the NMSA further requires federal agencies to consult with NOAA before taking actions, including authorization of private activities, "likely to destroy, cause the loss of, or injure a sanctuary resource." In addition, federal agencies are required to consult on proposed actions that "may affect" the resources of a national marine sanctuary. Any activities prohibited by the aforementioned regulations can be undertaken only by obtaining a permit from the National Marine Sanctuary Program.

National marine sanctuaries are established for marine areas with special conservation, recreational, ecological, historical, cultural, archaeological, scientific, educational, or aesthetic qualities. There are 13 sanctuaries in the National Marine Sanctuaries System. Local community and stakeholder involvement occurs before and during the designation of a sanctuary (National Oceanic and Atmospheric Administration 2012a, b). The National Marine Sanctuary Program develops management plans, conducts education and outreach activities, and directs scientific investigation and research programs through partnerships with local and federal agencies in order to safeguard large marine areas and the resources.

Regulations associated with each sanctuary specified at 15 C.F.R., 922. In general, within the boundaries of any sanctuary, regulations prohibit discharging or depositing any material, although specific discharge prohibitions and exceptions vary from site to site. In addition, it is prohibited to discharge or deposit any material outside a sanctuary that could subsequently enter the sanctuary and injure a resource or quality of that resource. Many of the national marine sanctuaries do not allow drilling into, dredging, or otherwise altering the seabed, although there are some exceptions. Prohibitions related to military operations are outlined after the description of each national marine sanctuary and marine national monument, although significant exemptions may apply and are noted accordingly.

2.2.15 National Invasive Species Act

The National Invasive Species Act of 1996 (16 U.S.C. §§ 4701-4751) develops guidelines for identifying ways in which non-native species enter the lands and waters of the United States, as well as methods for mitigating and monitoring invasive species and the degree to which they have or will spread. Sections 4711 et seq. particularly address aquatic invasive species. Section 4713 mandates that the DoD, in cooperation with the International Maritime Organization (IMO), develop and implement a ballast water

management program for its seagoing vessels to minimize potential for introduction of non-native species via ballast water discharge and exchange.

2.2.16 Clean Water Act

In 1977, Congress addressed heightening concern over water pollution by amending the Federal Water Pollution Control Act (FWPCA) of 1948 as the Clean Water Act (CWA) (33 U.S.C. §§ 1251-1376). For a synopsis of initiatives prior to 1977, see the USFWS Digest of Federal Resource Laws entry for the FWPCA.

The CWA took the first step toward establishing a comprehensive solution to the country's serious water pollution problems. Through standards, technical tools, and financial assistance, the CWA works toward accomplishment of two goals: (1) make U.S. waters fishable and swimmable ,and (2) eliminate contaminant discharge into such waters. Under authority of the U.S. Environmental Protection Agency (USEPA), the CWA sets water quality standards for all pollutants, requires a permit for discharge of pollutants from a point source, and funds sewage treatment plant construction. Section 319 of the CWA describes control of nonpoint source (NPS) pollution, assigning to states the responsibility to implement best management practices for control of NPS pollution. States also are granted the authority to ensure that federal activities are consistent with state programs.

In addition to regulating pollution in offshore waters, the CWA, under the amendment known as the Water Quality Act of 1987, also requires state and federal agencies to devise programs and management plans that aim to maintain the biological and chemical integrity of estuarine waters. In estuaries of national significance, NOAA is permitted to conduct water quality research in order to evaluate state and federal management efforts. Sensitive estuarine habitats, such as seagrass beds and wetlands, are protected from pollution under this Act.

2.2.17 Marine Plastic Pollution Research and Control Act

The Marine Plastic Pollution Research and Control Act (MPPRCA) of 1987, (33 U.S.C. §§ 1901-1915) regulates discharge of contaminants into the ocean. Under the MPPRCA, discharge of any plastic materials into the ocean is prohibited, including synthetic ropes, fishing nets, plastic bags, and biodegradable plastics. The discharge of floating dunnage, lining, and packing materials is prohibited in navigable waters and in areas offshore less than 25 nm from the nearest land. The Act also requires that all ocean-going U.S. flag vessels greater than 12.2 meters long, as well as all manned, fixed, or floating platforms subject to U.S. jurisdiction, maintain records of garbage discharges and disposals.

2.2.18 Marine Debris Research, Prevention, and Reduction Act

The Marine Debris Research, Prevention, and Reduction Act (MDRPRA) of 2006 established a Marine Debris Program within NOAA and the U. S. Coast Guard (USCG) to help identify, determine sources of, assess, reduce, and prevent marine debris and its adverse impacts on the marine environment and navigation safety, in coordination with non-federal entities, and for other purposes. The MDRPRA set authorized 10 million dollars for NOAA to implement the Marine Debris Program, including mapping, identification, and impact assessments, removal and prevention activities, research and development of alternatives to gear posing threats to the marine environment, and outreach activities. The MDRPRA also re-established the Interagency Marine Debris Coordinating Committee, which consists of representatives from the following federal agencies: NOAA, USACE, Navy, Department of Homeland

Security/USCG, USEPA, USFWS, Department of State, and other federal agencies or organizations with interests in ocean issues and water pollution prevention and control.

2.2.19 Comprehensive Environmental Response, Compensation, and Liability Act

In 1980 Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), which was substantially amended in 1983 (42 U.S.C. §§ 9601-9675). CERCLA establishes liability to the federal government for damage to natural resources under U.S. jurisdiction, directs the federal government to provide officials to act as trustees for natural resources, and provides funds for natural resources damage assessments. CERCLA deals specifically with hazardous waste disposal and cleanup, and provides a national contingency plan, in conjunction with the CWA, for response to oil or hazardous waste spills.

2.2.20 Oil Pollution Act

The Oil Pollution Act of 1990 (33 U.S.C. §§ 2701-2761) further increased protection of the nation's oceans. In addition to amending the CWA, this Act details new policies relating to oil spill prevention and cleanup methods. Any party responsible for a vessel, offshore facility, or deepwater port that could undergo an oil spill must maintain proof of financial responsibility for potential damage and removal costs. The Act details which parties are liable in a variety of oil spill circumstances and what damage and removal costs must be paid. The President has the authority to use the Oil Spill Liability Trust Fund to cover these costs when necessary. Justification for any fund expenditure must accord with the National Contingency Plan, which is an oil and hazardous substance pollution prevention plan established by the CWA (33 U.S.C. § 1321[d]). Federal, state, tribal, and foreign trustees must assess the natural resource damages that occur from oil spills in their trusteeships, and develop plans to restore the damaged natural resources. The Act also established the Interagency Coordinating Committee on Oil Pollution Research, whose purpose is to research and develop plans for natural resource restoration and oil spill prevention.

2.2.21 Harmful Algal Bloom and Hypoxia Research and Control Act

In response to growing harmful algal bloom (HAB) and hypoxia problems, Congress passed the Harmful Algal Bloom and Hypoxia Research and Control Act (HABHRCA) of 1998 (P.L. 105-383). This statute formed the Interagency Task Force on Harmful Algal Blooms and Hypoxia. The task force was instructed to compose a national assessment on the ecological and economic impacts of HABs, the same type of assessment for hypoxia, and a separate assessment for hypoxia in the Gulf of Mexico. These assessments include recommendations for mitigation, and detail the socioeconomic consequences of such solutions. The Act appropriates a certain amount of funds to the Secretary of Commerce to use for education, research, and monitoring needed to carry out the Act's directives. In 2000, the National Science and Technology Council Committee on Environment and Natural Resources released its National Assessment of Harmful Algal Blooms in U.S. waters (Luttenberg et al. 2000). The HABHRCA was reauthorized in 2004 with new mandates for research and vertical integration of management efforts. Ciguatera fish poisoning, caused by several species of harmful dinoflagellates, is one form of a HAB (National Oceanic and Atmospheric Administration 2012c).

2.2.22 Estuary Restoration Act

The Estuary Restoration Act of 2000 (33 U.S.C. §§ 2901-2909) established the Estuary Habitat Restoration Council, a federal interagency council ordered to develop a national estuary habitat

restoration strategy, published in 2002. Private entities propose projects to the council, which then makes recommendations to the USACE; projects are selected for implementation based on specific criteria. The federal government pays up to 65% of the project costs, excluding operation and maintenance costs. These projects are tracked in an online database developed and maintained by NOAA. The ultimate goal of the Act is to restore 1 million acres of estuary habitat by 2010.

The Estuary Restoration Act affects 30 states, the District of Columbia, Puerto Rico, Northern Mariana Islands, Virgin Islands, American Samoa, and Guam.

2.2.23 National Historic Preservation Act

The National Historic Preservation Act of 1966 (16 U.S.C. 470 et seq.) established historic preservation as a national policy, and directed the federal government to provide leadership in preserving, restoring, and maintaining the historic and cultural environment. Section 106 of National Historic Preservation Act requires federal agencies to take into account effects of their undertakings on historic properties, and afford the Advisory Council on Historic Preservation a reasonable opportunity to comment. The Act created the National Register of Historic Places, the list of National Historic Landmarks, and the State Historic Preservation Offices to help protect each state’s historical and archaeological resources. Section 110 of the Act requires federal agencies to assume responsibility for preservation of historic properties owned or controlled by them, and requires them to locate, inventory, and nominate all properties that qualify for the National Register. Agencies shall exercise caution to assure that significant properties are not inadvertently transferred, sold, demolished, substantially altered, or allowed to deteriorate.

2.2.24 Antiquities Act

The Antiquities Act of 1906 (16 U.S.C. 431) establishes the federal government as the protector of archaeological and historical sites and objects. It also mandates the government to work actively for preservation of cultural resources and for the public's access to them. This legislation has served as the basic guideline for most state regulatory legislation.

Marine National Monuments are designated by Presidential Proclamation under the Antiquities Act. The Presidential Proclamation of 2009 (January 6, 2009) established the Marianas Trench, Pacific Remote Island, and Rose Atoll Marine National Monuments. NOAA and USFWS manage these three Pacific Marine National Monuments, in addition to their co-management of the Papahanaumokuakea Marine National Monument established in 2006 (Agardy 2000; National Oceanic and Atmospheric Administration 2012a; U.S. Fish and Wildlife Service 2011). Marine National Monuments encompass almost 214,777,000 acres of small islands, reefs, and deep ocean waters (U.S. Fish and Wildlife Service 2011).

2.2.25 National Wildlife Refuge System Improvement Act

The National Wildlife Refuge System Administration Act of 1966, as amended by the National Wildlife Refuge System Improvement Act of 1997, provides the legal basis for management of the refuges. The Act establishes a unifying mission for the Refuge System, a process for determining compatible uses of refuges, and a requirement for preparing comprehensive conservation plans. USFWS oversees the National Wildlife Refuge System (NWRS). The NWRS is composed of over 540 established refuges, spanning many types of habitats. USFWS manages 177 ocean and Great Lakes refuges as a national network of lands and waters for conservation, management, and, where appropriate, restoration of the

fish, wildlife, and plant resources and their habitats. Approximately 140 to 150 refuges nationwide contain marine and estuarine habitat.

2.2.26 Historic Sites Act

The 1935 Historic Site Act (16 U.S.C. 461-467) declares as national policy the government's interest in preservation of historic sites, buildings, and objects of national significance. The Act directs the National Park Service to investigate and assess historic and archaeological sites, and provides the basis for the National Parks Service's archaeology program. The Act extends the Antiquities Act of 1906 by charging the National Parks Service with a nationwide responsibility, in no way restricted to areas owned by the federal government or impacted by the federal government’s activities.

2.2.27 Abandoned Shipwreck Act

The Abandoned Shipwreck Act of 1997 (43 U.S.C. §§ 2101- 2106) asserts the federal government's title to any abandoned shipwreck that meets the criteria for inclusion in the National Register (any shipwreck whose title has voluntarily been given up by the owner with the intent of never claiming a right or interest in the future and without vesting ownership in any other person. Such shipwrecks are ordinarily treated as abandoned after 30 days from the sinking). The Act stipulates that titles to these shipwrecks will be transferred to the appropriate states. The state has responsibility to formulate a plan to manage the wrecks that follows the guidelines established by the Advisory Council on Historic Preservation. These guidelines address the need to allow access to the sites by the general public while preserving the historic and environmental integrity of the site for scientific investigation. The Act specifically calls for establishment and management of underwater parks for the purpose of providing such protection. Under the Abandoned Shipwreck Act, the Department of the Interior and National Park Service issued guidelines in 2007 to help states manage shipwrecks in their waters.

2.2.28 Archaeological Resources Protection Act

The Archaeological Resources Protection Act of 1979 (P.L. 96-95; 16 U.S.C. 470 aa-mm), since amended four times, secures, for the present and future benefit of the American people, protection of archaeological resources and sites on public and Indian lands, and fosters increased cooperation and exchange of information among governmental authorities, the professional archaeological community, and private individuals having collections of archaeological resources and data obtained before October 31, 1979. The term “archaeological resource” means any material remains of past human life or activities of archaeological interest, as determined under uniform regulations promulgated pursuant to this Act. No item shall be treated as an archaeological resource under this regulation unless such item is at least 100 years of age.

2.3 EXECUTIVE ORDERS AND PRESIDENTIAL PROCLAMATIONS

The following subsections describe EOs and Presidential Proclamations that may be applicable in the MRA Study Area.

2.3.1 Executive Order 11990–Protection of Wetlands

EO 11990 on Protection of Wetlands (42 C.F.R. 26961) was issued in 1977 in furtherance of NEPA. The order aims to mitigate both short- and long-term effects on wetlands resulting from destruction or modification, and to limit new construction in wetlands. Federal agencies are ordered to preserve

wetlands, take specific action to minimize impacts to these, and avoid new construction where there is a practicable alternative. In taking action to minimize destruction and degradation of wetlands, agencies are ordered to consider relevant socioeconomic and ecologic factors. Pursuant to this order, the federal government implemented its policy of "no net loss" of wetlands.

2.3.2 Executive Order 12114–Environmental Effects Abroad of Major Federal Actions

EO 12114 (44 C.F.R. 1957) was issued in 1979 to further environmental objectives consistent with U.S. foreign and national security policies by extending the principles of the NEPA to the international stage. Under EO 12114, federal agencies that engage in major actions with potential to significantly affect the environment outside of U.S. jurisdiction (i.e., not on or in U.S. territorial soil or waters) must prepare or consult appropriate documents to determine the effect(s) such actions may have on the environment. These documents may include an EIS, an overseas EIS, relevant bilateral or multilateral environmental studies in which the U.S. is a participant, environmental assessments, summary environmental analyses, or any other document relevant to the issue at hand. The type of document that must be consulted or prepared depends on where the major federal action is set to occur (i.e., on the global commons or within the boundaries of a foreign nation). Certain actions, such as intelligence activities, disaster and emergency relief actions, and actions that occur in the course of an armed conflict, are exempt from this order. Such exemptions do not apply to major federal actions that significantly affect an environment not within any nation's jurisdiction, unless permitted by law. The purpose of the order is to force federal agencies to consider the effects of their actions on international and foreign environments.

2.3.3 Executive Order 12962–Recreational Fisheries

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

2.3.4 Executive Order 13089–Coral Reef Protection

EO 13089 on Coral Reef Protection (63 C.F.R. 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." This EO directs all federal agencies to protect coral reef ecosystems to the extent feasible, and instructs particular agencies to develop coordinated, science-based plans to restore damaged reefs, as well as mitigate current and future impacts on reefs, both in the United States and

around the globe (Agardy 2000). This order also establishes the interagency U.S. Coral Reef Task Force, co-chaired by the Secretary of the Interior and the Secretary of Commerce through the Administrator of NOAA.

2.3.5 Executive Order 13112–Invasive Species

EO 13112 on Invasive Species (64 C.F.R. 6183) was issued in 1999 to help prevent introduction of terrestrial and aquatic invasive species into the United States, and to address the economic, ecological, and human health problems posed by invasive species. EO 13112 builds upon the goals set forth in the National Invasive Species Act of 1996 but does not affect the obligation of the DoD to manage its seagoing vessels as mandated in 16 U.S.C. § 4713. When practicable, federal agencies are ordered to avoid actions that may introduce or spread invasive species, to mitigate the effects of invasive species, and to restore native species and habitats. In addition, a National Invasive Species Council was established for planning and management, recommendations, and facilitation of communication regarding invasive species issues. The council was also ordered to produce a National Invasive Species Management Plan, the final draft of which was issued in 2001 (National Invasive Species Council 2001).

2.3.6 Executive Order 13158–Marine Protected Areas

EO 13158 on Marine Protected Areas (MPA) [65 Federal Register (FR) 34909] of 2000 is a furtherance of EO 13089. It creates the framework for a national system of MPAs. MPAs are defined in EO 13158 as "any area of the marine environment that has been reserved by federal, state, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein." This EO strengthens governmental interagency cooperation in protecting the marine environment. It also calls for strengthening management of these existing areas, creating new ones, and preventing harm to marine ecosystems by federally approved, conducted, or funded activities (Agardy 2000). Currently, NOAA is redefining the criteria used to designate MPAs and has recently reclassified all existing MPAs as marine managed areas.

2.3.7 Executive Order 13186–Responsibilities of Federal Agencies to Protect Migratory Birds

EO 13186 on the Responsibilities of Federal Agencies to Protect Migratory Birds (66 FR 3853) was issued in 2001 to support the efforts of the MBTA and other acts. The EO directs executive departments and agencies that detrimentally affect migratory birds to increase their protection of these birds. Each department or agency must develop and implement a Memorandum of Understanding (MOU) through USFWS. The MOU must incorporate a variety of efforts set out in the order that promote conservation of migratory bird populations. These efforts include restoring migratory bird habitats and preventing pollution in environments important to migratory birds. The departments and agencies have 2 years to implement their MOUs, but the EO encourages them to implement the EO's policies immediately. Such practices can be implemented through activities already established or incorporated into new plans. The EO also formed the Interagency Council for the Conservation of Migratory Birds, which administers the EO.

2.3.8 Executive Order 13547–Stewardship of the Ocean, Our Coasts, and the Great Lakes

EO 13547 (75 FR 43023) was issued in 2010 for the stewardship of the ocean, our coasts, and the Great Lakes. This comprehensive National Ocean Policy adopts the recommendations of the Interagency Ocean Policy Task Force and directs executive agencies to implement the recommendations under the guidance of a National Ocean Council. This EO establishes a national policy to ensure protection,

maintenance, and restoration of the health of ocean, coastal, and Great Lakes ecosystems and resources; enhance sustainability of ocean and coastal economies; preserve our maritime heritage; support sustainable uses and access; provide for adaptive management to enhance our understanding of and capacity to respond to climate change and ocean acidification; and coordinate with our national security and foreign policy interests.

A draft National Ocean Policy Implementation Plan was released in January 2012 with priority strategies and activities including strengthening or establishing regional ocean partnerships to improve multi-sectoral coordination for coastal and ocean management (National Ocean Council 2012).

2.3.9 Presidential Proclamation 8335–Establishment of the Marianas Trench Marine National Monument

The Marianas Trench Marine National Monument (the "Monument") was established in January 2009 by Presidential Proclamation under authority of the Antiquities Act (16 U.S.C. 431) with the purpose of protecting the submerged volcanic areas of the Mariana Ridge; the coral reef ecosystems of the waters surrounding the islands of Farallon de Pajaros, Maug, and Asuncion in the Commonwealth of the Northern Mariana Islands (CNMI); and the Mariana Trench. The Secretaries of Commerce, through NOAA, and the Interior, manage the Monument pursuant to applicable legal authorities.

Nothing in the Proclamation or any regulation imposes limits or otherwise affects the Armed Forces' discretion to use, maintain, improve, manage, or control any property under the administrative control of a Military Department, or otherwise limits availability of such property for military mission purposes. The prohibitions required by the Proclamation do not apply to activities and exercises of the Armed Forces (including those carried out by the USCG). In the event of threatened or actual destruction of, loss of, or injury to a monument living marine resource resulting from an incident caused by a component of the DoD or the USCG, the cognizant component shall promptly coordinate with the Secretary of the Interior or Commerce to identify appropriate actions to respond to and mitigate any actual harm and where possible, restore or replace the monument resource or quality.

A multi-year, multi-agency planning process has begun to develop a Monument Management Plan for the Marianas Trench Marine National Monument. According to the proclamation, the management plans and their implementing regulations shall impose no restrictions on innocent passage in the territorial sea or otherwise restrict navigation, overflight, and other internationally recognized lawful uses of the sea, and shall incorporate the provisions of the Proclamation regarding Armed Forces actions and compliance with international law. In developing and implementing management plans and any management rules and regulations, the Secretaries are directed to involve as cooperating agencies the agencies with jurisdiction or special expertise—including the DoD, the Department of State, and other agencies through scoping in accordance with the NEPA (42 U.S.C. 4321 et seq.) and its implementing regulations, and with EO 13352 of August 26, 2004, Facilitation of Cooperative Conservation—and shall treat as a cooperating agency the Government of CNMI, consistent with these authorities.

2.4 DEPARTMENT OF DEFENSE ENVIRONMENTAL COMPLIANCE

In addition to the U.S. federal legislation that governs Navy activities in the marine environment, the Navy is required to comply with environmental requirements promulgated by department program manuals and U.S. federal policy. However, several major federal resource laws have provisions for the exemption of certain DoD activities, if necessary for national security.

2.5 AT-SEA COMPLIANCE

The Navy's Environmental and Natural Resources Program Manual (OPNAVINST 5090.1C) applies to Navy ships and floating drydocks worldwide and, as appropriate, to the boats and other craft carried by these ships (U.S. Department of the Navy 2007). Chapter 22 covers "Environmental Compliance Afloat" and lays out Navy policy for environmental stewardship and compliance for its vessels operating within U.S. waters and abroad. The chapter addresses discharge of waste, including blackwater, graywater, hazardous and medical wastes, plastics, and other trash, as well as procedures for oil spill response and ballast water control.

The Navy is required to comply with U.S. federal policy when operating within U.S. waters or on the high seas. This includes abiding by relevant international agreements to which the United States is a signatory or conforming to international agreements, if practicable, regardless of whether the United States has officially ratified the agreement. The Navy is required to assess the impacts of its actions both within U.S. waters and abroad according to the mandates of the NEPA and EO 12114. The Navy's policy is to provide for national defense in a manner consistent with federal environmental policy, and to utilize the systematic approach of the NEPA as an effective decision-making tool. To this end, NEPA processes are integrated with Navy and U.S. Marine Corps actions as early as possible to protect, enhance, and restore environmental quality within a framework consistent with the mission of the Navy, stated national policy, and security requirements.

Specifically in regard to marine mammals, Navy vessels are prohibited from deliberately harassing a marine mammal as per the requirements of MMPA. Navy policy requires vessels to report all instances of collision between a vessel and a marine mammal to the Chief of Naval Operations. Navy policy also mandates that those in authority plan and act to protect marine mammals during training and testing (U.S. Department of the Navy 2007). The Navy employs protective measures during its training and testing mitigate adverse effects on marine mammals. The Navy consults with the USFWS and NMFS on the potential of a proposed action to affect protected species and receives a Letter of Authorization and a Biological Opinion if a take might occur.

2.6 INTERNATIONAL ENVIRONMENTAL CONVENTIONS, TREATIES, AND ORGANIZATIONS

The United States is a party to several international agreements, treaties, and conventions that seek to protect the natural resources and environmental quality of the marine environment, and is a member of several international organizations with programs to protect and manage marine resources and the marine environment. Personnel conducting Navy operations outside U.S. waters need to be informed and aware of the international marine environmental agreements and programs to which the United States is party or otherwise engaged in. The most important international conventions, treaties, and organizations related to the marine environment are listed below. Except as noted otherwise, the United States is a party to, or member of, the agreement or agency described.

2.6.1 International Convention for the Prevention of Pollution from Ships

The International Convention for the Prevention of Pollution from Ships, commonly known as MARPOL, was adopted in 1973 and modified in 1978 to prevent ship pollution, and may be cited as the Act to Prevent Pollution from Ships (33 U.S.C. 1901 to 1915). Although military vessels were exempted from the Act, the U.S. Congress passed legislation in 1987 that required the Navy to comply with the international treaty. The Act has six annexes covering oil discharge, hazardous liquid control, hazardous material transport, sewage discharge, plastic and garbage disposal, and air pollution. Annex V controls

disposal of plastics and garbage into the oceans from ships. Annex VI for prevention of air pollution sets limits on sulfur oxide and nitrogen oxide emissions from ship exhausts, as well as particulate matter, and prohibits deliberate emissions of ozone-depleting substances. The Marine Pollution Prevention Act of 2008 allowed the United States to become a party to Annex VI. The Act applies to all U.S. flagged ships anywhere in the world and to all foreign flag vessels operating in navigable U.S. waters or while at a port or terminal under U.S. jurisdiction.

2.6.2 United Nations Convention on the Law of the Sea

The United Nations (UN) is responsible for numerous treaties and agencies responsible for marine environmental resource protection and management. The United Nations Convention on the Law of the Sea (UNCLOS) was adopted in 1982 and entered into force in 1994. UNCLOS defines the rights and responsibilities of nations addressing navigation and high seas access rights, territorial sea limits, economic jurisdictions, legal status of resources on the seabed beyond national jurisdiction, protection of the marine environment, conservation and management of natural resources, marine scientific research, development and transfer of marine technology, and authority or tribunal for settling disputes. The United States has signed UNCLOS; however, the Senate has yet to ratify the treaty. UNCLOS is now regarded by many as customary international law.

UNCLOS Article 147 addresses marine environmental issues in the “Area,” i.e., the ocean beyond coastal states’ jurisdiction. This article, on “Accommodation of activities in the Area and in the marine environment,” includes the following provisions: “1. Activities in the Area shall be carried out with reasonable regard for other activities in the marine environment. 2. Installations used for carrying out activities in the Area shall be subject to the following conditions: (a) such installations shall be erected, emplaced and removed solely in accordance with this Part and subject to the rules, regulations and procedures of the Authority. Due notice must be given of the erection, emplacement and removal of such installations, and permanent means for giving warning of their presence must be maintained; (b) such installations may not be established where interference may be caused to the use of recognized sea lanes essential to international navigation or in areas of intense fishing activity; (c) safety zones shall be established around such installations with appropriate markings to ensure the safety of both navigation and the installations. The configuration and location of such safety zones shall not be such as to form a belt impeding the lawful access of shipping to particular maritime zones or navigation along international sea lanes.”

2.6.3 International Seabed Authority

The International Seabed Authority (ISA) was created under UNCLOS in 1994 to oversee activities involving seabed, ocean floor, and subsoil resources within the ocean seabed beyond coastal states’ jurisdiction. The primary purpose of the ISA is to control deep sea exploration and mining in efforts to protect the marine environment from potential harmful effects.

The IMO was established in 1948 to develop and maintain international standards regulating shipping, maritime safety, environmental protection, legal concerns, international ship and port facility security, technical cooperation, and shipping efficiency. The United States and other IMO member governments have developed a number of conventions on international marine environmental protection.

2.6.4 London Convention

The London Convention of 1975, as revised by the 1996 London Protocol, prohibits all dumping at sea except for acceptable waste listed in the "revised list," for which the treaty includes generic and specific guidelines. The London Protocol to the London Convention updated the UNCLOS definition of dumping to include "any storage of wastes or other matter in the seabed and the subsoil thereof from vessels, aircraft, platforms or other man-made structures at sea; and any abandonment or toppling at site of platforms or other man-made structures at sea, for the sole purpose of deliberate disposal." Member parties can be enrolled in the London Convention, the London Protocol, or both.

2.6.5 International Convention for the Regulation of Whaling

The International Convention for the Regulation of Whaling of 1946 established the International Whaling Commission (IWC). The purpose of the Convention is to provide for conservation of whale stocks and orderly development of the whaling industry. The IWC reviews and revises as necessary the measures in the Convention that govern the conduct of whaling throughout the world. These measures include providing for the complete protection of certain species; designating specified areas as whale sanctuaries; setting limits on the numbers and size of whales that may be taken; and prescribing open and closed seasons and areas for whaling. The compilation of catch reports and other statistical and biological records is also required and the IWC encourages, coordinates, and funds whale research, and publishes the results of scientific research. The IWC members, including the United States, currently adhere to a global moratorium on taking marine mammals for commercial exploitation.

2.6.6 Convention on Biological Diversity

The Convention on Biological Diversity (CBD), adopted in 1992, entered into force in 1993 with three main goals: conservation of biological diversity, sustainable use of biodiversity, and fair and equitable sharing of benefits arising from genetic resources. The CBD recognizes that ecosystems, species, and genetic resources must be used for the benefit of humans in a way and at a rate that does not lead to long-term decline of biological diversity, employing the precautionary principle when scientific information is lacking. The CBD requires countries to develop and implement strategies for sustainable use and protection of biodiversity. The original convention contained no specific article on marine and coastal biodiversity, and this was addressed in later decisions that resulted in the "Jakarta Mandate on the Conservation and Sustainable Use of Marine and Coastal Biological Diversity," which specifies basic principles and thematic areas and a multi-year CBD work program on marine and coastal biological diversity. The United States is not a party to the CBD.

2.6.7 Convention on the Conservation of Migratory Species of Wild Animals

The Convention on the Conservation of Migratory Species of Wild Animals (CMS) was established to conserve terrestrial, marine, and avian migratory species throughout their range. Migratory species threatened with extinction are listed in CMS Appendix I, and members work to strictly protect these animals, conserve or restore their habitat, mitigate obstacles to migration, and control other factors that might endanger them. Migratory species that need or would significantly benefit from international co-operation are listed in the CMS Appendix II. The CMS acts as a framework convention. Governments develop more specific formal Agreements or less formal instruments, such as MOUs, adapted to the requirements of particular animals and regions. The United States is not a party to the CMS, but is a part of the MOU covering Indian Ocean and South East Asian marine turtles.

2.6.8 Convention on International Trade in Endangered Species of Wild Fauna and Flora

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) was established to control the international movement of wild plants and animals, alive or dead, whole or parts thereof to assure that the pressures of international trade do not contribute to endangerment of the listed species. CITES does not provide protection for the habitat of species or how a species is used within a country; it controls only international movement of the species. If a species is in danger of extinction, the treaty can impose a ban on commercial trade of the listed species. These species are listed on Appendix I of the treaty, which is used by many countries as their endangered species list. If a species might have population level concerns, the species is listed on Appendix II; commercial trade in species on this list is allowed but must be documented and is closely monitored. Many countries consider Appendix II a list of threatened species.

2.7 REFERENCES

Agardy, T. (2000). Key steps taken to preserve the U.S.'s marine heritage. *Issues in Science and Technology, 17*(1), 26. Retrieved from http://www.issues.org/17.1/update.htm#

Gordon, W. R., Jr. (1993). *Atlantic Coast Marine Artificial Reef Habitat: Program and Policy Guidelines for Comprehensive Statewide Planning and Management*. (Special Report No. 31, pp. 87) The Atlantic States Marine Fisheries Commission.

Luttenberg, D., Sellner, K., Anderson, D. and Turgeon, D. (2000). *National Assessment of Harmful Algal Blooms in US Waters*. (pp. 47). Washington, DC: National Science and Technology Council, Committee on Environment and Natural Resources.

National Invasive Species Council. (2001). *Meeting the Invasive Species Challenge: National Invasive Species Management Plan*. (pp. 80). Washington, DC: National Invasive Species Council.

National Marine Fisheries Service (2002). Magnuson-Stevens Act Provisions; Essential Fish Habitat (EFH). [Final rule]. *Federal Register, 67*(12), 2343-2383.

National Marine Fisheries Service (2004). Endangered and threatened species;establishment of species of concern list, addition of species to species of concern list, description of factors for identifying species of concern, and revision of candidate species list under the endangered species act. *Federal Register, 69*(73), 19975-19979.

National Ocean Council. (2012). *Draft National Ocean Policy Implementation Plan*. (pp. 115). Available from http://www.whitehouse.gov/sites/default/files/microsites/ceq/national_ocean_policy_draft_implementation_plan_01-12-12.pdf

National Oceanic and Atmospheric Administration (2000, 8 December). Coastal Zone Management Act federal consistency regulations. [Final rule]. *Federal Register, 65*(237), 77124-77175.

National Oceanic and Atmospheric Administration. (2007a). *National Artificial Reef Plan (as Amended): Guidelines for Siting, Construction, Development, and Assessment of Artificial Reefs*. (pp. 51) U.S. Department of Commerce and National Oceanic and Atmospheric Administration.

National Oceanic and Atmospheric Administration (2012a). Marine National Monument Program. [Web page]. Retrieved from http://www.fpir.noaa.gov/MNM/mnm_index.html, 22 March 2012.

National Oceanic and Atmospheric Administration (2012b). Similar to National Marine Sanctuaries, Marine National Monuments designated to protect areas of the marine environment. [Web page]. Retrieved from http://oceanservice.noaa.gov/facts/marine-monument.html, 22 March 2012.

National Oceanic and Atmospheric Administration, Center for Sponsored Coastal Ocean Research (2012c). Caribbean and Pacific Island regions harmful algal blooms. [Web page]. Retrieved from http://www.cop.noaa.gov/stressors/extremeevents/hab/current/Carib_reg_08.aspx, 28 March 2012.

National Oceanic and Atmospheric Administration, National Centers for Coastal Ocean Science. (2005). *A Biogeographic Assessment of the Channel Islands National Marine Sanctuary: A Review of Boundary Expansion Concepts for NOAA's National Marine Sanctuary Program*. (NOAA Technical Memorandum NOS NCCOS 21, pp. 215). Silver Spring, MD: National Oceanic and Atmospheric Administration. Prepared by NCCOS's Biogeography Team in cooperation with the National Marine Sanctuary Program.

National Oceanic and Atmospheric Administration, National Centers for Coastal Ocean Science. (2007b). *A Biogeographic Assessment off North/Central California: In Support of the National Marine Sanctuaries of Cordell Bank, Gulf of the Farallones and Monterey Bay. Phase II - Environmental Setting and Update to Marine Birds and Mammals*. (NOAA Technical Memorandum NOS NCCOS 40, pp. 240). Silver Spring, MD: National Oceanic and Atmospheric Administration. Prepared by NCCOS's Biogeography Branch, R.G. Ford Consulting, Oikonos Ecosystem Knowledge and in cooperation with the National Marine Sanctuary Program.

U.S. Department of the Navy. (2007). *Environmental and Natural Resource Program Manual*. (OPNAVINST 5090.1C). Washington, DC: Department of the Navy.

U.S. Fish and Wildlife Service (2011, Last updated 30 March 2011). Marine National Monuments. [Web page]. Retrieved from http://www.fws.gov/marinenationalmonuments/, 22 March 2012.

This Page Intentionally Left Blank

3.0 METHODOLOGY

3.1 INTRODUCTION

This Marine Resource Assessment (MRA) was developed to maintain a comprehensive and state-of-knowledge compilation of data and information on marine resources in open ocean and coastal waters where Navy training and testing activities occur. The MRA describes habitats, species, and oceanographic conditions in these areas. This section discusses the methods used and factors considered in updating the MRA.

3.2 OVERVIEW OF THE MRA UPDATE PROCESS

The MRA update process consists of the following steps: (1) review existing MRA content, (2) search for and review new literature and data on resources in MRA Study Area for the Japan and Mariana Archipelagos (the MRA Study Area), (3) update existing content in the MRA, (4) manage references using the bibliographic management tool EndNote®X5, and (5) acquire and manage spatial data in a Geographic Information System database. This MRA update was programmed for completion in two phases. Steps 1 through 4 were completed in September 2012. Step 5 was initiated in November 2012 and completed in May 2013.

3.3 GEOGRAPHIC FOCUS

The MRA Study Area described in Chapter 1 was the geographic focus of this MRA update. MRA content from previous MRAs (U.S. Department of the Navy 2005a, b, 2011) was reviewed and incorporated as relevant to the MRA Study Area. The MRA Study Area includes open ocean and coastal waters of the Japan and Mariana Archipelagos and Caroline Islands.

3.4 SPECIES SELECTION CRITERIA

The MRA provides lists and profiles of species in the MRA Study Area. Species profiles are provided only for threatened, endangered, and candidate species protected by the Endangered Species Act (ESA) and species protected by the Marine Mammal Protection Act (MMPA). In addition to detailed species profiles, the following supplemental information is included where appropriate:

1. List of National Marine Fisheries Service (NMFS) Species of Concern
2. List of U.S. Fish and Wildlife Service (USFWS) Birds of Conservation Concern
3. List of Migratory Bird Treaty Act listed species
4. List of federally managed species under the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA)
5. Description of resources grouped by marine ecosystem zonation

The following sections provide an overview of the species selection process and foundational resources used to develop species profiles for each resource group.

3.4.1 Marine Mammals

This taxonomic group is unique in that all species are protected by the MMPA, and a few are listed as either endangered or threatened under the ESA, as well. A relatively low number of marine mammal species (approximately 130 species) are extant worldwide. The distribution and status of marine

mammal species in the MRA Study Area were based on a number of foundational resources (Jefferson, Webber, and Pitman 2008; National Marine Fisheries Service 2011) as well as the most current literature. Scientific and common names were based on Jefferson, Webber, and Pitman (2008). Marine mammal species protected by endangered species laws in other countries are listed if found in the MRA Study Area.

3.4.2 Reptiles

Only seven species of sea turtles are extant worldwide. Similar to marine mammals, the sea turtle species are protected by U.S. legislation; in addition, six of the seven sea turtles are listed as either endangered or threatened under the ESA. The distribution and status of sea turtles in the MRA Study Area were based on a number of foundational resources (National Marine Fisheries Service 2012b; The Archie Carr Center for Sea Turtle Research 2012; The SWoT Team 2012) as well as most current literature. Other than sea turtles, only saltwater crocodiles inhabit a portion of the MRA Study Area. A detailed species profile is provided for five species of sea turtles and one species of crocodile occurring within the MRA Study Area.

3.4.3 Seabirds

Seabirds encompass a diverse group of avian species comprising 15 families, with approximately 300 species occurring worldwide. Seabird species included in the MRA represent seabirds whose distribution overlaps the MRA Study Area and whose habitat associations, during either the breeding or non-breeding season, are pelagic or beyond the intertidal zone (e.g., nearshore) based on maps and profiles provided by Birdlife International (BirdLife International 2012) and current literature. These criteria limit the seabird species in this MRA to species that inhabit areas within marine waters where naval operations may be conducted. Considerable debate occurs regarding species taxonomy and nomenclature. Taxonomy and nomenclature for the MRA follows the Birdlife International Checklist (BirdLife International 2012) and the North American Classification Committee of the American Ornithologists' Union (North American Classification Committee 2012). Seabirds currently listed as either endangered, threatened, or candidate species under the ESA, and whose range of distribution and habitat association occurs within the MRA Study Area, are discussed in species profiles.

3.4.4 Marine Vegetation

No ESA-protected marine plant species occur within the MRA Study Area and therefore are not addressed in this MRA.

3.4.5 Invertebrates

Detailed species profiles are provided for invertebrates currently listed as either endangered or threatened under the ESA, and whose range of distribution falls within the MRA Study Area. Candidate coral species are discussed in group profiles based on Brainard et al. (2011).

3.4.6 Fishes

Detailed species profiles are provided for fish species currently listed as either endangered, threatened, or candidate species under the ESA, and whose distribution falls within the MRA Study Area. Fish species that occur in U.S. waters were named according to the American Fisheries Society standard nomenclature (Nelson et al. 2004). In addition to species-specific reports and literature, fish species

profiles developed by NMFS and FishBase were used to provide information on each species. NMFS provides profiles for most marine and anadromous fishes listed under the ESA (National Marine Fisheries Service 2012a). FishBase is an online fish database providing additional species-level information—including estimated distributions, environmental tolerance limits, life history characteristics, and photos (Froese and Pauly 2012).

3.4.7 Marine Protected Areas

Marine Protected Areas (MPAs) in the MRA Study Area were compiled from the United States and international databases (National Marine Protected Areas Center 2006, 2011). The National Marine Protected Areas Center maintains a database of MPAs in the United States based on a Marine Protected Areas Classification System, which provides definitions and qualifications for the various terms within Executive Order 13158 (National Marine Protected Areas Center 2006). Six criteria are used to describe the key features of most MPAs, as follows:

- Primary conservation focus
- Level of protection
- Permanence of protection
- Constancy of protection
- Ecological scale of protection
- Restrictions on extraction

MPAs in the Japan Archipelago were compiled from MPA Global database, an existing on-line list of MPAs world-wide. All MPAs listed hold a “designated” status, meaning the site is formally designated under national legislation or international convention (MPA Global 2012).

3.5 LITERATURE AND DATA SEARCH

Data represented in this study were identified and acquired using a range of methods. Data and information sources were evaluated for need, relevance, quality, and constraints on use/distribution. Need for new data acquisition was determined by examining the existing data repository for similar data, and collaboration within the project. Relevance and quality were determined through a multi-step expert review that included contractor and Navy experts. This same multi-step process evaluated constraints on use/distribution of the data initially based on public statements associated with the data. Communication with contacts for data designated for acquisition through free download or special delivery was documented; this verified permission to use the data and any constraints that would apply to that use. All data sets were cited in the project bibliographic records, and contact information and history for each acquired or requested data set were maintained as part of the permanent project record.

In many cases, previously used data sources were evaluated to determine if updated data or larger extents were available. Evaluation of these prior sources and bibliographic citations often led to related data sets, some of which were acquired to augment the previous base layers. Recommendations from internal experts and external collaborators provided important sources of data as well. Many of these sources conveyed direct points of contact or explicit online links to useful data. Finally, keyword searches of the Internet, often through data clearinghouse portals, identified additional data sets for evaluation.

Thorough and systematic searches for relevant scientific literature were conducted. Electronic literature searches were conducted using the Marine Biological Laboratory of Woods Hole Oceanographic Institution (WHOI) On-Line Library, which includes librarian-assisted retrieval of their entire hardcopy collection, as well as access to a wide range of electronic journals and databases—including Elsevier's Science Direct, the Institute for Scientific Information (ISI) Web of Science, Cambridge Abstract's Aquatic Sciences, and Fisheries Abstracts. Topic-specific searches were conducted through various websites, including the Archie Carr Sea Turtle Bibliography database, Birdlife International's species profiles and reference lists, USFWS species information, and the Bird of North America Online Database. In addition, general internet searches occurred through the Google and Google Scholar web search engines to identify other reports not recognized through the previous database searches.

Resource leads familiar with seminal literature on each subject and professional relationships with relevant researchers across the world facilitated a highly effective search process of the above databases. Resource leads reviewed titles and abstracts from these searches to determine the value of information for the MRA. Full papers were assigned to individual authors tasked with developing the text for the various subsections of this report. Results of these searches were managed using bibliographic software for ease of recall for inclusion in the document. Information relevant to the distribution and abundance of marine resources in the MRA Study Area was extracted and integrated into the narrative of relevant sections. Topic leads with a strong background on the subject compiled information, prepared each chapter, and conducted final technical review.

3.6 DATA CONFIDENCE

In all cases, data sources were sought as close to the primary producers of the data as possible. Where possible, data search and acquisition focused on government or international agency sources, as these were deemed likely to offer the highest degree of quality and confidence. Some specialized data were available only from research organizations, non-governmental organizations, or commercial providers. The decision to include data from these organizations in the project was determined by considering data need, data quality, cost, and constraints on use. Quality was assessed by initially evaluating the reputation of the data providers and later by reviewing associated documentation and the data. In order to maintain the accuracy of the data included in the MRA, units of measure were maintained as reported in the data source.

3.7 SPATIAL DATA

The geographical representation of marine resources in the Study Area is a constituent of this MRA. The data and information accumulated for this project were obtained from various sources including written literature and electronic databases, both published electronically and often provided through the Internet. Key components of the geographic methodology; software, data structure, data sources, and metadata are outlined below:

SOFTWARE. A geographic information system (GIS) provides the ability to visualize multiple data layers and analyze the spatial relationships between them. For this MRA, Environmental Systems Research Institute, Inc.'s (ESRI) ArcGIS® (versions 9.3.1 and 10.0) GIS software was used to create, store, manipulate, analyze, and display the spatial data and information accumulated for the Study Area.

DATA STRUCTURE. All applicable GIS data that fits in to the Navy Data Model (NDM), version 3.01, for was put into a NDM personal geodatabase (i.e., RestrictedArea, NaturalResourceSurvey and DocksAndWarfsP_NDM feature classes). The NDM does not include raster data or large scale, biological

or oceanographic vector GIS data.The remaining structure of the GIS data used in each map is accomplished through file management using a set of ESRI geodatabases organized by MRA chapter topic. Individual ArcMap document (mxd) files were made for each GIS-based figure in each chapter, and include content as directed by the team resource leads. In addition, two ArcGIS 3D Analyst documents (sxd) are provided, which were created and utilized for 3D maps of the study area. All figures were exported in the jpeg file format with a naming convention following chapter and figure number, and are included in a separate folder for reference. Towards the conclusion of the task, all data described above will be loaded onto the Navy Environmental Information Management System (EIMS). Itemized details of the structure of the data are:

Geodatabase Structure and Associated Data

- Navy Data Model Geodatabase (version 3.01), in ArcGIS version 9.3.1with FGDC metadata
- Vector data in Personal Geodatabases, ArcGIS version 9.3.1, with FGDC metadata
- Raster data in File and Personal Geodatabases, ArcGIS version 9.3.1, with FGDC metadata
- ArcScene documents (SXD), ArcGIS version 10
- Map documents (MXD), ArcGIS version 9.3.1
- MXD and SXD exports in jpeg format

Data stored on Environmental Information Management System (EIMS):

- The address for the EIMS home page is: https://eims3.sscno.nmci.navy.mil/welcome/
- "EIMS is a Geographic Information System (GIS)-based toolset designed to provide the Navy with a more effective and efficient means of fulfilling its regulatory compliance obligations by leveraging existing data and technologies. EIMS supports environmental planning, natural resources management and encroachment issues for Navy range and OPAREA events. "
- EIMS is an official U.S. Navy Website and requires appropriate access clearance

DATA SOURCES. The geographic locations of important marine resources in the Study Area were derived from four types of sources:

Downloaded. Geographic information was downloaded from the internet in tabular, shapefile, or geodatabase format, and as appropriate, converted into a geodatabase feature class and imported into the MRA geodatabase structure. An example of a downloaded data source would be the U.S. Marine Protected Areas Inventory Geodatabase used in Chapter 12 maps of the MRA.

Created. Geographic information was created by scanning or obtaining a digital version of a source map, digitizing the features with ArcGIS, and storing them within a new feature class in the MRA geodatabase structure. An example of a created data source would be polygon feature classes representing marine mammal geographic range, as digitized from *Marine Mammals of the World* and used in Chapter 5 maps of the MRA.

Purchased. Geographic information was purchased from an academic expert source with specifc modeling output in GIS format. Purchased datasets and metadata are stored in the MRA geodatabase structure. An example of a purchased dataset would be seabed substrates raster datasets, as modeled

from the dbSEABED system, by the Institute of Arctic and Alpine Research (INSTAAR) at the University of Colorado Boulder, and used in Chapter 4 maps of the MRA.

Navy Provided. Geographic information was provided by Navy, either from prior MRA GIS deliverables or by posting GIS information into the MRA project folder on EIMS. Where applicable, feature classes are stored in the MRA geodatabase structure, or where whole geodatabases and metadata were provided by Navy, they were left intact to preserve their integrity. An example of a Navy provided dataset would be regulated and special use airspace area feature classes as used in Chapter 1 maps of the MRA. An example of a Navy provided geodatabase would be the HDR, Inc. Marine Species Monitoring geodatabase accomplished under task KB08 in December 2011.

Once the marine resource data were imported and stored in respective geodatabases, maps were created containing geographic layers of either individual or combined data. Maps within this MRA display a scale in nautical miles. However, it should be noted that the majority of GIS layers created for this project are stored in the unprojected World Geodetic System (WGS) of 1984 (WGS 84) geographic coordinate system, which uses decimal degree latitude and longitude coordinates. As such, appropriate map projections should be employed on the data and carefully considered when calculations such as distance and area are warranted. The maps contained in the MRA should not be used for measurement purposes.

METADATA. Federal Geographic Data Committee (FGDC) Compliant Metadata was prepared in ArcGIS 9.3 for created data sources, and for purchased data sources, when it was absent from the purchase. Metadata from downloaded or Navy-provided data sources was left as is to preserve integrity of the content prepared by the source's author.

The source(s) for GIS data layers presented in the figures can be found in the GIS metadata for each layer. Sources for each map are referenced in the figure caption. All references for map source data or information may be found in the literature cited for the section in which the map appears. Reference for data sources used to create the basemaps are listed below.

- **Countries**. NGA, January 2001 and Bell, J. T. (2009, 09 December), Department of the Navy, Naval Facilities Engineering Command Atlantic. *Country Boundaries*. GIS data provided to J. Peters, Tetra Tech, Inc., Nashville, TN.
- **Cities.** ESRI, 2004, World Cities, ESRI® Data & Maps, Redlands, California, USA, 2004
- **U.S. States.** USGS 2007 and Department of the Navy. 2007. Marine Resources Assessment for the AUTEC Operating Area. Naval Facilities Engineering Command, Atlantic, Norfolk, Virginia. Contract N62470-02-D-9997, CTO 0034. Prepared by Geo-Marine, Inc., Hampton, Virginia
- **Hawaii State Boundary.** Department of the Navy. 2005. Hawaii. Marine Resources Assessment for the Hawaiian Islands Operating Area. Naval Facilities Engineering Command, Pacific Division, Pearl Harbor, Hawaii. Contract N62470-02-D-9997, CTO 0026. Prepared by Geo-Marine, Inc., Plano, Texas.
- **MRA Study Area.** Department of the Navy. 2005. Study Area. Marine Resources Assessment for the Japan and Okinawa Complexes Operating Area. Naval Facilities Engineering Command, Pacific Division, Pearl Harbor, Hawaii. Contract N62470-02-D-9997, CTO 0028. Prepared by Geo-Marine, Inc., Plano, Texas.

Hanser, S. (2012, 18 June), Department of the Navy, Naval Facilities Engineering Command. MITT Study Area. GIS Data (shapefiles) provided to K. Courtney, Tetra Tech, Inc., Honolulu, HI.

- **International Dateline:** Department of the Navy. 2005. Marine Resources Assessment for the Southern California Operating Area. Naval Facilities Engineering Command, Pacific Division, Pearl Harbor, Hawaii. Contract N62470-02-D-9997, CTO 0025. Prepared by Geo-Marine, Inc., Plano, Texas.

3.8 ECOSYSTEM TERMS AND CHARACTERISTICS CONSIDERED IN THE MRA

As part of the MRA update process, ecosystem characteristics are considered in describing resources in the MRA Study Area. The term ecosystem comprises the biotic (living) community and the (abiotic) nonliving physical environment. An ecosystem can be described as a geographically specified system of organisms, their environment, and the processes that control their dynamics (National Oceanic Atmospheric Administration 2010). Ecosystem characteristics are described in terms of ecosystem structure, function, and services. Humans, as an integral part of the ecosystem, derive numerous benefits from ecosystem services in ways that often negatively impact the ecosystem structure and function (Lovins, Lovins, and Hawken 1999). Preserving ecosystem structure and function sustains these benefits for the long term. This section introduces some of the more important attributes of ecosystems, with particular attention to terms and characteristics.

3.8.1 Ecosystem Scale

Ecosystems are insensitive to scale: a single cell may be an ecosystem for two populations of pathogens within the cell, or an entire ocean (or perhaps the globe) may be an ecosystem for wide ranging global marine mammal or fish populations (e.g., certain whales and tuna species) (Levin 1992). This range of scales means that ecosystems are nested such that smaller systems are embedded within larger systems. The scale of an ecosystem is often not biologically derived, but instead depends on the spatial and temporal extent of the system dynamics that are to be studied and influenced by management (Sissenwine and Murawaski 2004), as depicted in (Figure 3-1). Because marine ecosystems are difficult to manage at multiple scales (Levin 1992), ecosystems are often discussed at regional (or larger) scales aligned with governmental, economic, or political boundaries. Additional information on marine ecosystems, their characteristics, and federal policy pertaining to marine ecosystems is accessible on the websites of National Oceanic and Atmospheric Administration (large marine ecosystems), U.S. Environmental Protection Agency (marine ecosystems), The White House (National Ocean Policy), and NMFS (marine ecosystems).

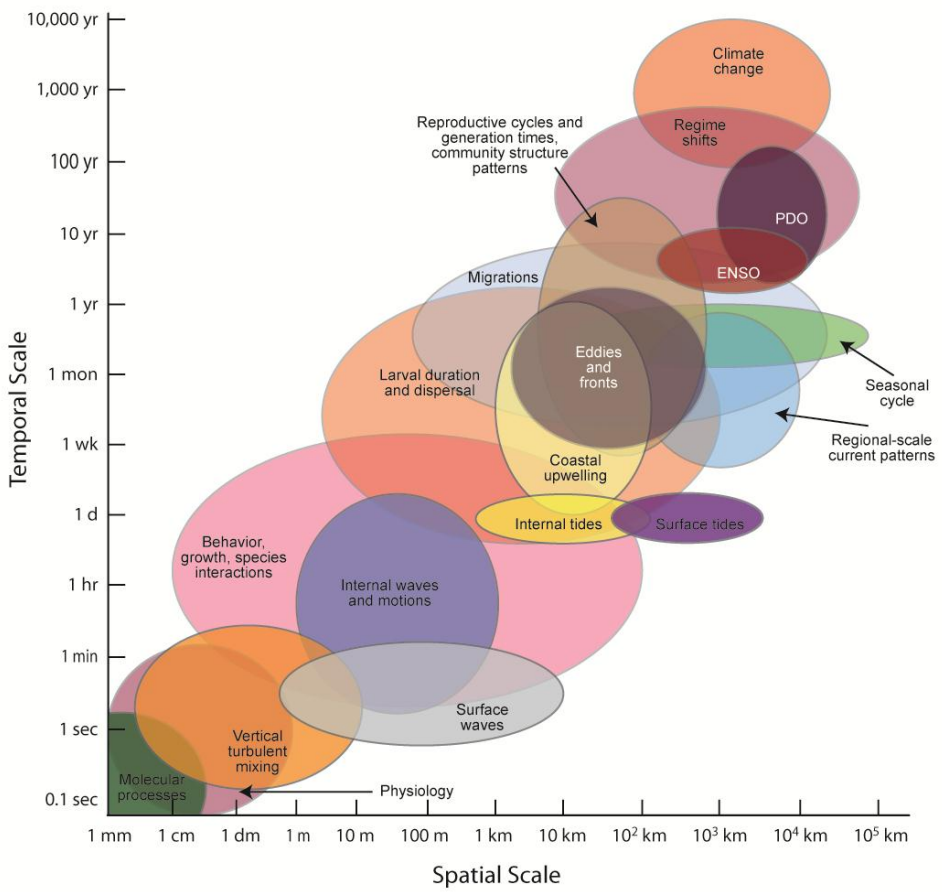

Figure 3-1: Ecological Processes Plotted as a Function of Space and Time
Source: Redrawn from Carr et al. (2011)[1] (PDO = Pacific Decadal Oscillation, ENSO = El Niño/Southern Oscillation).

[1] Frontiers in Ecology and the Environment by Ecological Society of America Copyright 2010. Reproduced with permission of ECOLOGICAL SOCIETY OF AMERICA in the format "other book" via Copyright Clearance Center.

3.8.2 Biogeography

Biogeography is the study of the spatial distribution of species or populations, essentially mapping species in their ecological context. Humans are important components of many ecosystems, and anthropogenic influences are detectable in all marine ecosystems (Halpern et al. 2008; Vitousek et al. 1997). Because many marine ecosystems are nested subunits of some larger marine zonation (Goreau 1959), biogeographic classification systems provide a structure that allows meaningful comparisons. This is somewhat analogous to nested watersheds/subwatersheds of terrestrial systems. Water depth is the primary factor affecting marine biogeography and zonation schemes because many physical and geochemical properties (e.g., light, temperature, water motion, certain water quality attributes, etc.) vary as a function of depth (Goreau 1959; Longhurst and Harrison 1989). Commonly used marine zones are defined in (Table 3-1), and a subset of those are shown in Figure 3-2.

Table 3-1: Common Marine Zonation by Depth

Depth in feet (ft.) and meters (m)	Geologic Zones	Benthic Zones	Pelagic Zones	Light
High–low tide	Shore	Intertidal	Epipelagic	Photic
Low tide–260 ft. (80 m)	Continental shelf	Subtidal (Upper neritic)		
260–656 ft. (80–200 m)		Lower neritic		
656–2624 ft. (200–800 m)	Continental slope	Bathyal	Mesopelagic	Aphotic
2624–9,840 ft. (800–3,000 m)			Bathypelagic	
9,840–13,100 ft. (3,000–4,000 m)	Continental rise			
13,300–21,320 ft. (4,000–6,500 m)	Abyssal zone	Abyssal	Abyssalpelagic	
> 21,320 ft. (> 6,500 m)	Deep ocean trenches	Hadal	Hadalpelagic	

Notes:
ft. = feet
m = meters

Superimposed on depth-dependent zonation are a host of other environmental and political attributes that further refine the biogeographic extent of the ecosystems under study. Common examples of biogeographic properties are:

- Latitude (polar, temperate, subtropical, tropical)
- Bottom type (mud, sand, rock, reef)
- Light penetration (photic-aphotic zone transition occurs around 650 feet (ft.) [200 meters (m)], but varies with water clarity)
- Biogeochemical properties (salinity, oxygen concentration, carbonate saturation, gas solubility)
- Political boundaries (territorial seas, Exclusive Economic Zones, fishery management areas, MPAs)

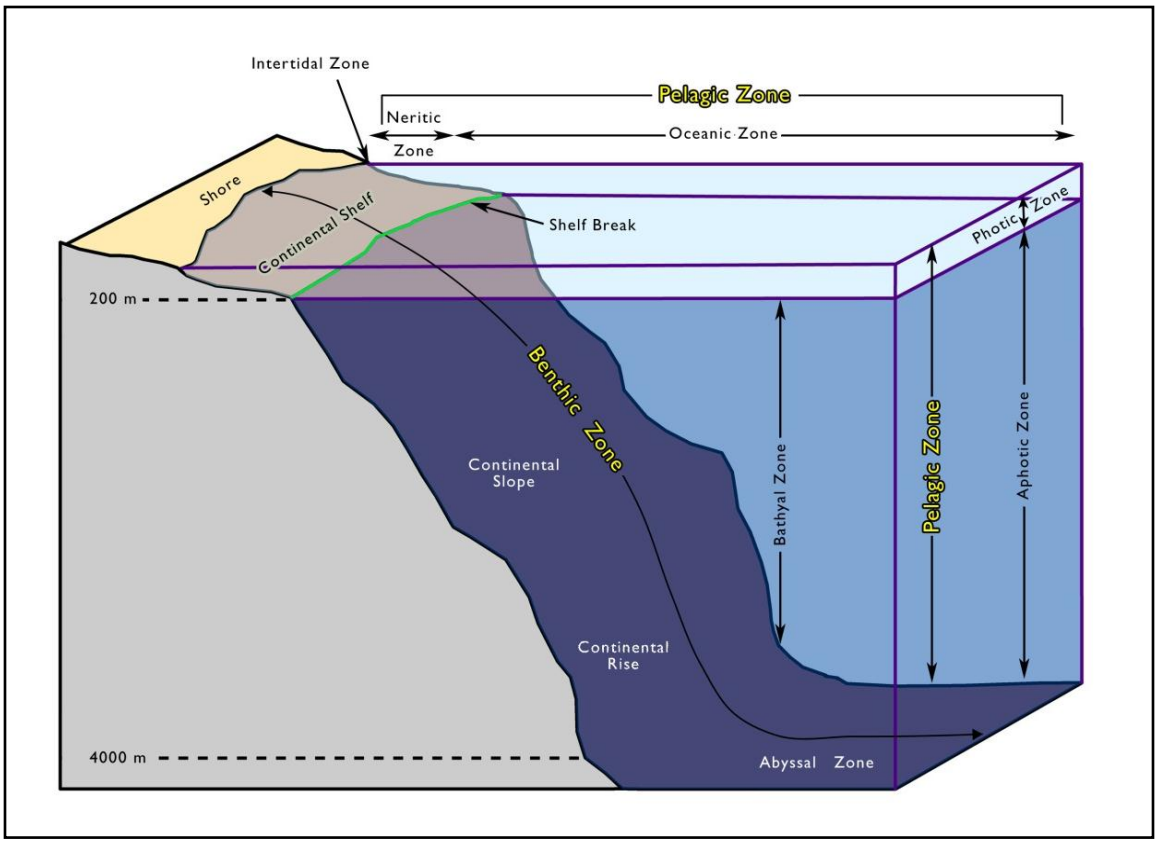

Figure 3-2: Three-dimensional Representation of the Continental Margin and Abyssal Zone

These and other properties result in a large degree of flexibility in the definitions of ecosystems, biogeographic provinces, and ecoregions. Because the quantitative aspects of ecological sciences require exact definitions of the ecosystem boundaries, much consideration is given to biogeographic zonation and the choice of biogeographic classification systems at the start of every ecological study (Levin 1992).

Common marine biogeographic classification systems include the Marine Ecoregions of the World (Spalding et al. 2007b), Large Marine Ecosystems (LME) (Sherman and Hempel 2009) (United Nations Educational Scientific and Cultural Organization 2009), and the Global Open Ocean and Deep Seabed. All of these derive purely from natural biogeographic properties, both theoretical and empirical. The merits and shortcomings of biogeographic classification systems are openly debated (Costello 2009; Longhurst 2007). The marine biogeographic classification systems in the North Pacific located within and adjacent to the MRA Study Area are shown in Figure 3-3 and Figure 3-4.

The Marine Ecoregions of the World biogeographic classification system covers all coastal and shelf waters and associated seabed out to the 650-ft. (200-m) isobath, roughly equivalent to the edge of the continental shelf (Spalding et al. 2007b). This system has a nested three-tiered hierarchy based on physical and biogeography, including taxonomic configurations, evolutionary history, patterns of dispersal, and isolation.

The development of the LME classification began in the mid-1980s as a spatial planning tool to address trans-boundary management issues such as fish and fisheries, pollution, productivity, socioeconomics,

and governance (Duda and Sherman 2002). LMEs are described as "relatively large areas of ocean space of approximately [77,220 square miles (mi.^{2})] 200,000 square kilometers (km^2) or greater," characterized by distinct "(1) bathymetry, (2) hydrography, (3) productivity, and (4) trophic relationships" (National Oceanic Atmospheric Administration 2010). The LME concept for ecosystem-based management (Duda and Sherman 2002) and its five-module approach—(1) productivity, (2) fish and fisheries, (3) pollution and ecosystem health, (4) socioeconomics, and (5) governance—have been applied to 16 international projects in Africa, Asia, Latin America, and Eastern Europe (Duda and Sherman 2002). The LME classification has been advocated by the Council on Environmental Quality's Interagency Ocean Policy Task Force (The White House Council on Environmental Quality 2010, 51) as a marine spatial framework for regional coordination and planning in the United States.

The Global Open Oceans and Deep Seabed marine biogeographic classification system addresses open oceans and deep seabeds with an emphasis on areas beyond national jurisdiction, and was developed to complement the Marine Ecoregions of the World biogeographic classification system's coverage of nearshore areas (United Nations Educational Scientific and Cultural Organization 2009). The Global Open Oceans and Deep Seabed system divides the open ocean into provinces that are distinguished by unique environmental characteristics based on temperature, depth and primary productivity; and the deep seabed provinces are classified by depth zones.

Another way to describe areas seaward of those already defined by a biogeographic classification system is to subdivide the area based on major oceanographic features such as gyres and major currents. Unlike Global Open Oceans and Deep Seabed provinces, these open ocean areas are not characterized by depth. For the purposes of this MRA, open ocean areas of MRA Study Area were based on major oceanographic features. Some of these features coincide with biogeographic regions such as the North Central Pacific Gyre Global Open Ocean and Deep Sea province and the Kuroshio and East China Sea Large Marine Ecosystems (Longhurst 1998; United Nations Educational Scientific and Cultural Organization 2009).

This Page Intentionally Left Blank

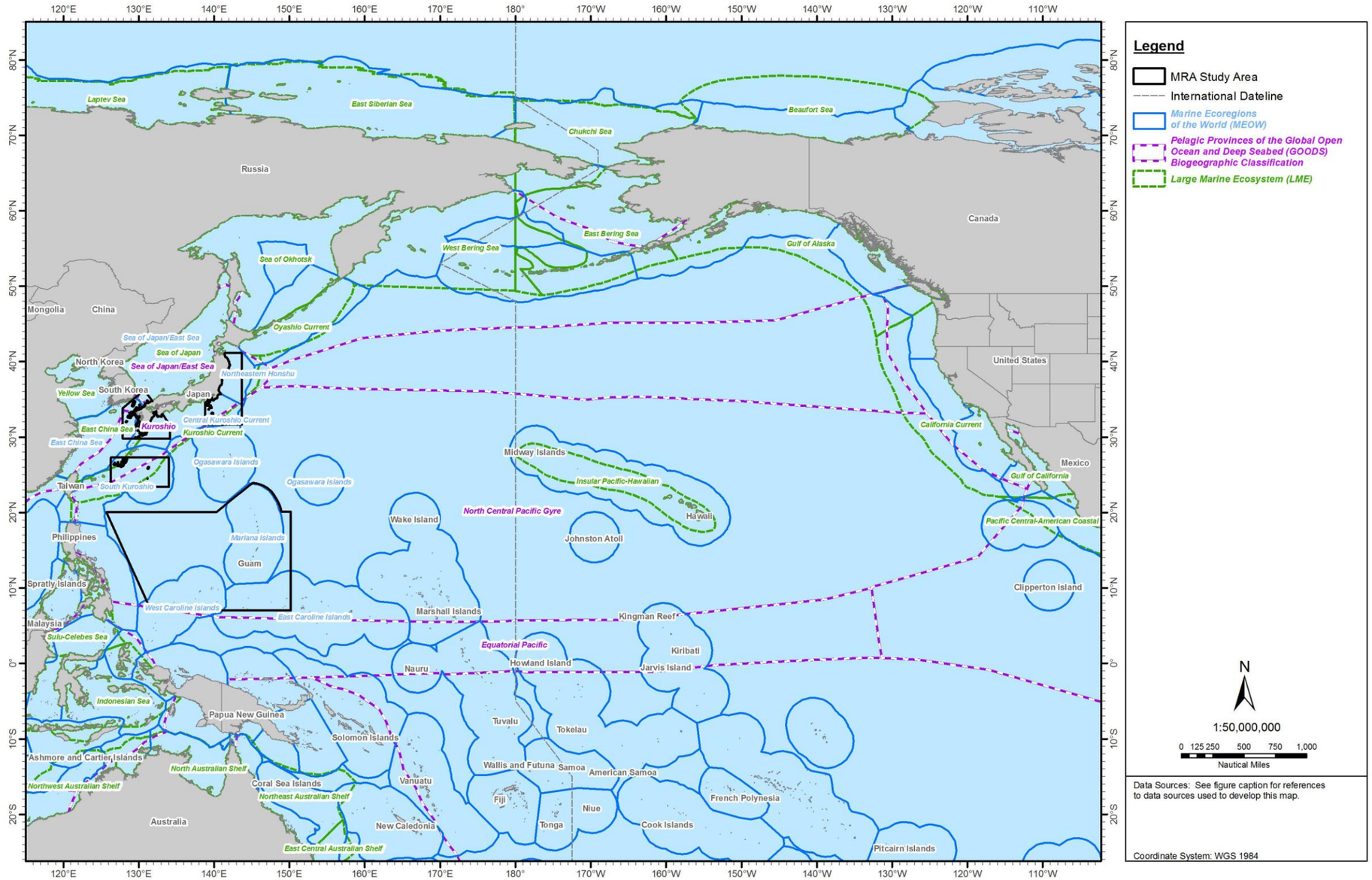

Figure 3-3: Biogeographic Classification Systems in the North Pacific
Sources: National Oceanic and Atmospheric Administration (2002); Spalding (2009); Spalding et al. (2007a).

This Page Intentionally Left Blank

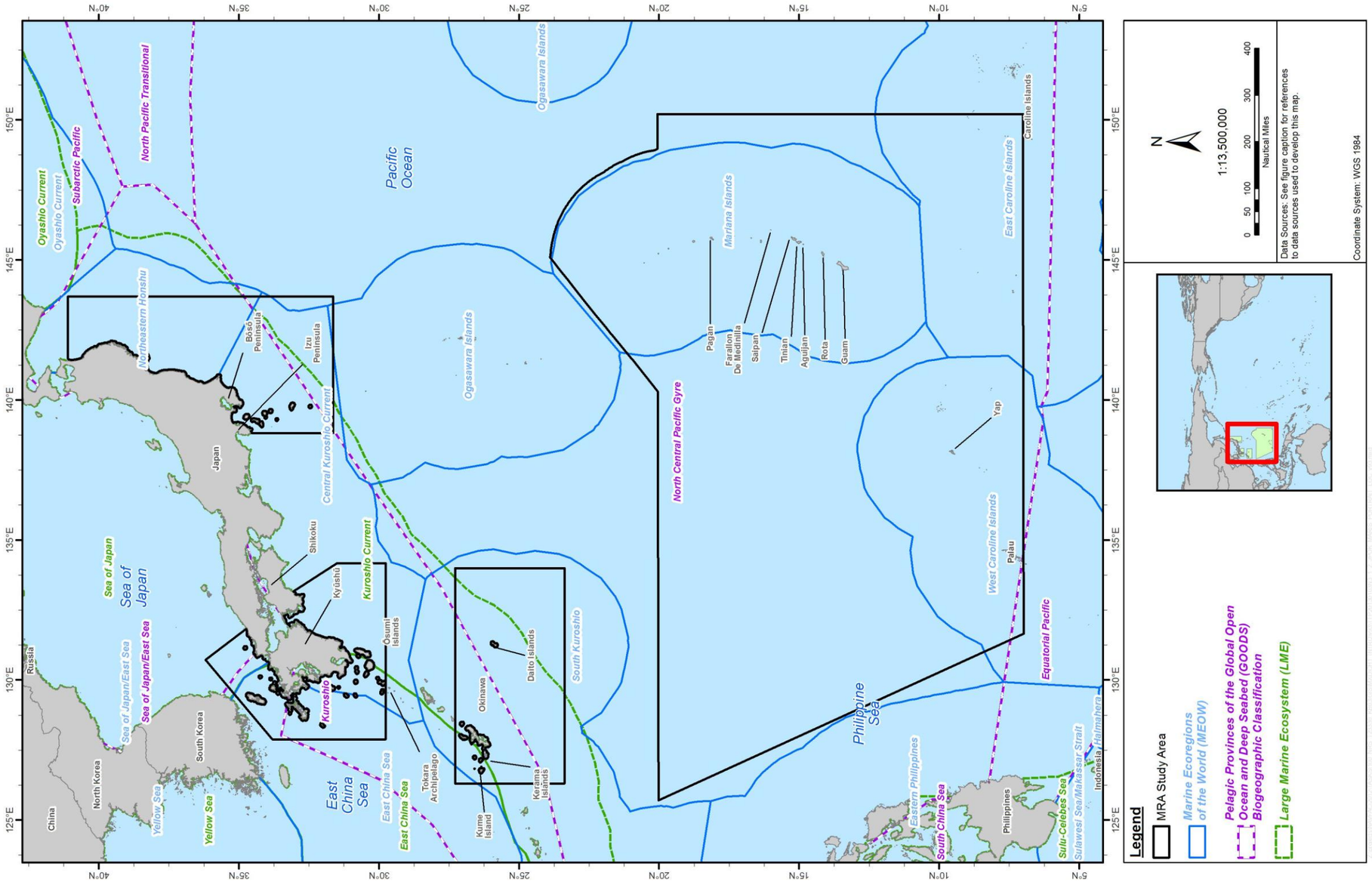

Figure 3-4: Biogeographic Classification Systems in the MRA Study Area

Sources: National Oceanic and Atmospheric Administration (2002); Spalding (2009); Spalding et al. (2007a).

This Page Intentionally Left Blank

3.8.3 Ecosystem Integrity

Ecological studies generally focus on some combination of three categories, none of which is discrete: ecosystem structure, ecosystem function, and ecosystem services (Figure 3-5). The descriptive and quantitative framework superimposed on these three categories is ecosystem integrity, a quality of ecosystems that is independent of scale. Ecosystem integrity is "the [ecosystem's] capability of supporting and maintaining a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats of the region" (Karr and Dudley 1981). Mathematically, ecosystem integrity is a function of redundancy, resistance, and resilience (Bellwood, Hoey, and Choat 2003; Holling 1996; Hughes et al. 2003). Redundancy signifies the number of different populations that play the same key role in the ecosystem. Resistance is the magnitude of change required to shift an ecosystem away from its pre-disturbance or "native" state. Resilience refers to the capacity for a disturbed ecosystem to return to its state prior to disturbance (Holling 1996).

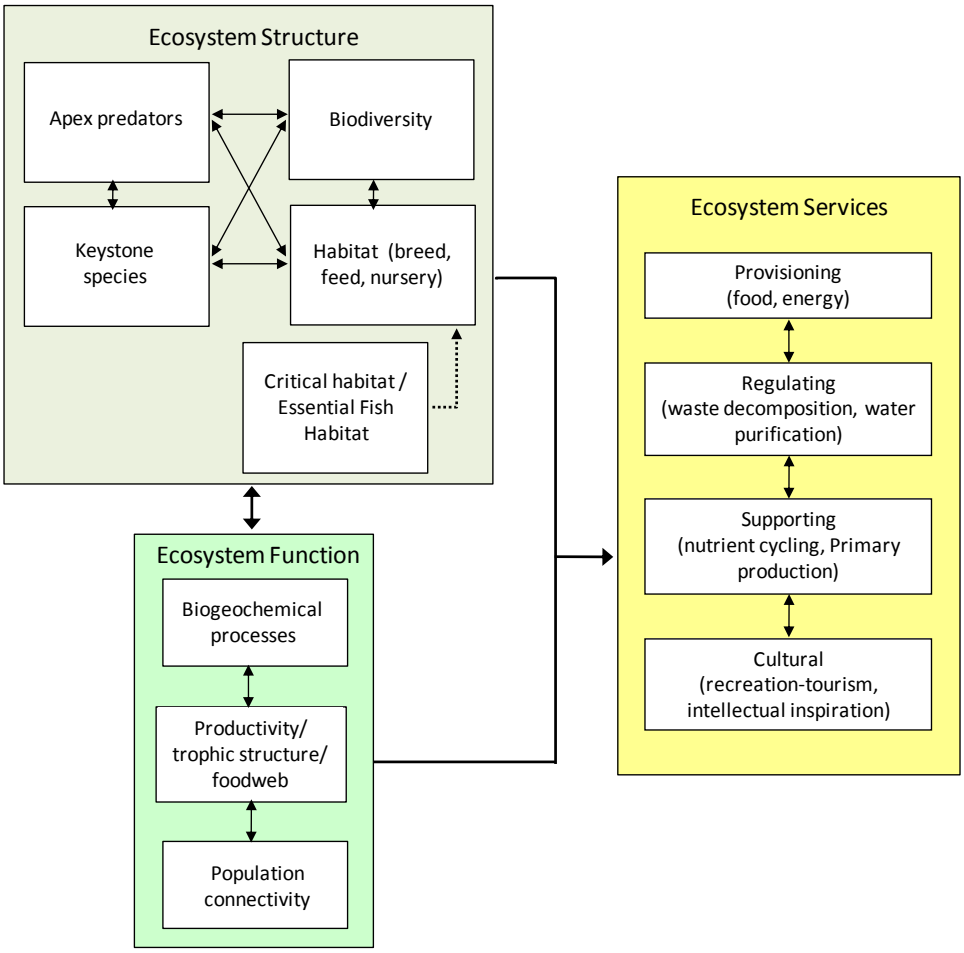

Figure 3-5: Conceptual Diagram of Ecosystem Characteristics and Interactions

Ecosystem Structure. Ecosystem structure is defined as the organization and linkages between biotic and abiotic features that combine to create a distinctive ecological unit. Ecosystem structure is a key concept in the science of ecology because it provides a framework or hierarchy to organize interacting biogeographic layers. Key properties used to characterize ecosystem structure (Figure 3-5) include

biodiversity, apex predators, keystone species, and habitats (including essential fish habitat (EFH), critical habitat, and other important habitats such as nurseries or breeding grounds) (Paine 1969, 1995).

Marine ecosystems do not occur in isolation (Jones et al. 2010). Even distant marine habitats can be linked by the ecological relationships and oceanographic processes that transport nutrients, food, larvae, sediments, and pollutants throughout the ocean (Cowen and Sponaugle 2009; Jones et al. 2010; Morgan and Fisher 2010; Weersing and Toonen 2009). Most marine species move between habitats as they complete their life cycles, or daily or seasonally as adults for feeding and mating (Hammerschlag and Serafy 2010). Many seamounts are populated by individuals that arrived as larvae among the plankton delivered by deep-sea currents (Lavelle and Mohn 2010; Shank 2010), and some communities of the abyssal plain may be sustained only by individuals exported from other habitats (Rex et al. 2005). Occurrence of many habitat types in complex patchworks increases the biodiversity of a given ecosystem by offering benefits to both predators and prey (Tuya et al. 2010).

Biodiversity can be described in terms of genetic, species, ecosystem, or functional diversity. Biodiversity is most commonly described in terms of species diversity, and particularly in terms of species richness (the number of species in a given habitat) (Hooper et al. 2005). Biodiversity is positively related to ecosystem productivity when considered at regional scales (Chase and Leibold 2002), and each species, regardless of its size, has an important role in the ecosystem. Greater species diversity helps ecosystems withstand and recover from disturbance events (Worm et al. 2006). Biodiversity plays an important role in maintaining ecosystem function (Duffy 2002; Hooper et al. 2005; Loreau et al. 2001). The benefits of biodiversity are easiest to conceptualize by the “portfolio effect”, where individual species have diminished influence because ecosystem integrity is distributed over a variety of functionally redundant species (Duffy 2002; Worm et al. 2006). Rare and endangered taxa—including endangered, threatened, and endemic species (species that occur only in a particular area)—are particularly noteworthy in characterizing biodiversity within an ecosystem. If an ecosystem has a large number of endangered, threatened, or endemic species, the ecosystem’s biodiversity less stable and ecosystem integrity is at higher risk of rapid change (Loreau et al. 2001).

Apex predators in the most generic sense are top non-specialist predators that have no predators of their own (Ritchie and Johnson 2009). Marine apex predators are at the top trophic level (Figure 3-6), but the top level is often occupied by several other apex predators that prey upon each other, as well as upon animals that occupy lower trophic levels (Sandin et al. 2008). Because apex predators are not specialists, many exert a stabilizing influence on ecosystems, preying on the most accessible species as other species recover (Ritchie and Johnson 2009). This influence has follow-on impacts through lower trophic levels, and removal of apex predators has cascading impacts throughout ecosystems (Baum and Worm 2009).

Keystone species play a critical and disproportionally important role in an ecosystem (Paine 1969). The classic terrestrial example of a keystone species is the beaver, which is solely responsible for converting stream ecosystems into pond ecosystems. The classic marine example is the removal of the sea otter from the west coast of the U.S. Released from predation by otters, their principal prey, sea urchins, exploded and sea urchins nearly eliminated their own primary food source, giant kelp. The loss of habitat formed by kelp dramatically changed the seascape of the American west coast (Estes, Duggins, and Rathbun 1989). Displacing or removing a population of keystone species usually results in the re-organization of the ecosystem and sometimes results in its collapse (Jackson et al. 2001; Keller et al. 2009).

Habitat in a generic sense is the biogeochemical environment in which a particular organism completes its life cycle (U.S. Environmental Protection Agency 2011b). The habitat for a seagrass species, turtle grass (*Thalassia testudinum*), is very well-illuminated, coarse-grained sandy bottom, with moderate-energy waters that are high in salinity and relatively high in temperature (Zieman, Fourqurean, and Iverson 1989). Defining habitat becomes more complex for motile organisms than for sessile plants and animals. A migratory organism may require three distinct habitat types for its lifecycle (e.g., origin habitat, destination habitat, and the corridor between these). The most complex scenario involves organisms that require distinct habitats for different life stages. For example, the adult mangrove snapper (*Lutjanus griseus*) lives on reefs and hardbottom, it reproduces in the open ocean, its larvae develop in estuaries, and juveniles mature in seagrass (South Atlantic Fishery Management Council 1998). Most habitats are defined in terms of their dominant seafloor features; but for some pelagic organisms, their habitat is defined in terms of a particular volume of water such as the Sargasso Sea or mesopelagic zone.

This Page Intentionally Left Blank

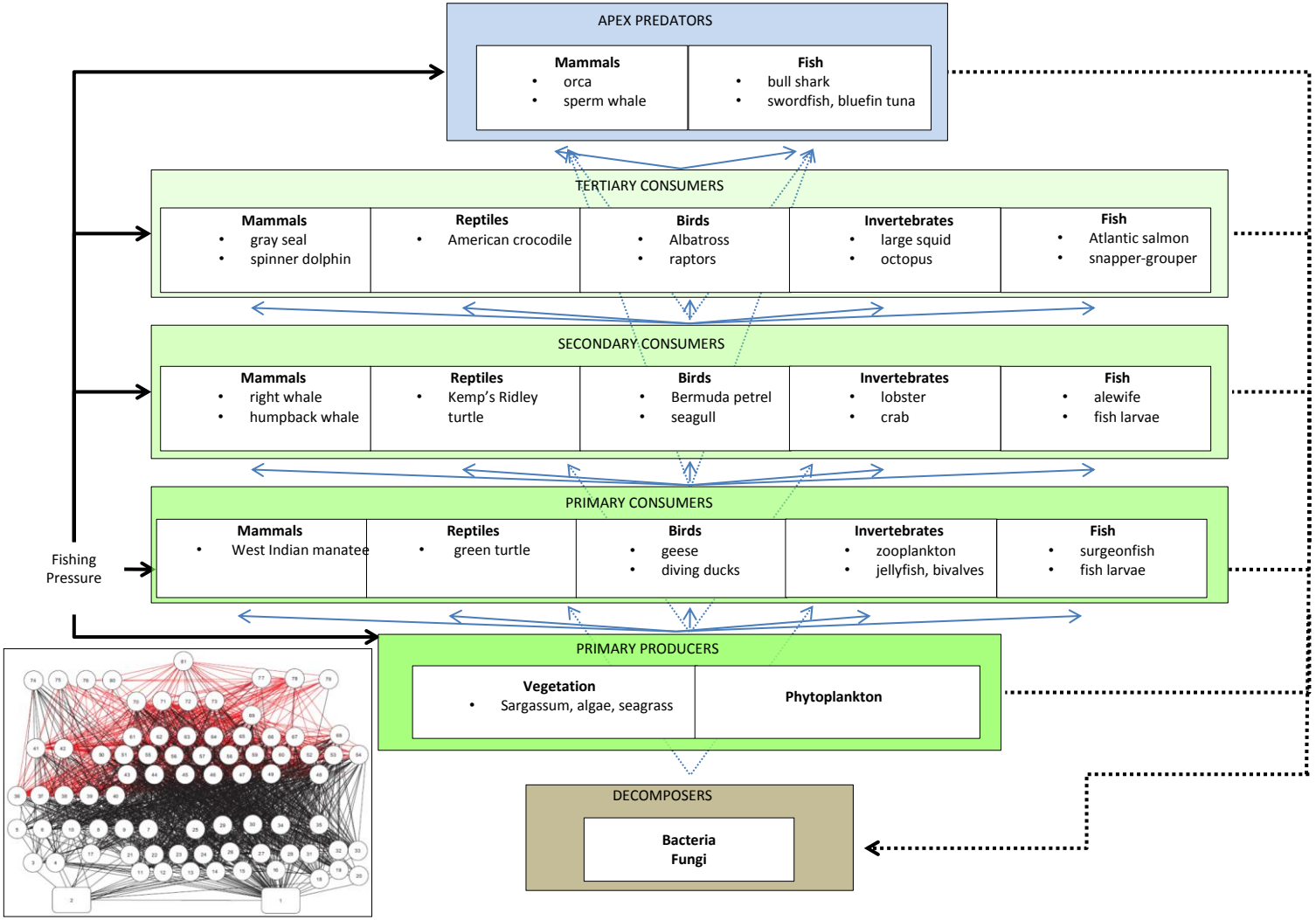

Figure 3-6: Simplified Conceptual Marine Food Web

Source: Link (2002). Inset lower left: Simplified real-world food web for the northwest Atlantic used for quantitative studies.

This Page Intentionally Left Blank

Regulatory definitions of habitat are sometimes particular to a species or group of species that have special needs for regulation. EFH is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" (National Marine Fisheries Service 2002). Critical Habitat pertains to species listed as threatened or endangered under the ESA, and is defined as "the specific areas within the geographical area occupied by the species, at the time it is listed on which are found those physical or biological features: (1) essential to the conservation of the species and (2) which may require special management considerations or protection" (United States Fish and Wildlife Service 2010).

Ecosystem Function. Ecosystem function is a process-based aspect of the science of ecology, aimed at quantifying interactions in terms of inputs and exports at various levels of ecosystems. The overall functioning of an ecosystem is complex and involves many factors relating to the chemical, physical, and biological components of the system (Figure 3-5). Ecosystem function can be defined as the interactions between organisms and the physical environment, as well as intraspecific and interspecific interactions of the biota (De Leo and Levin 1997). Key aspects of ecosystem function are biogeochemical cycling and storage, productivity and trophic dynamics, bioaccumulation/biomagnification, population connectivity, and ecosystem variability and resilience (Duffy 2002; World Resources Institute 2005).

Biogeochemical cycling and storage describes the path a chemical takes as it moves through biological organisms and abiotic areas (Allen and Fulton 2009). Nutrients, organic matter, and inorganic matter, whether dissolved or suspended, enters the sea from land-based sources (e.g., estuaries and streams), sea-based sources (e.g., mid-ocean ridges), and air-borne sources (aeolian transport and deposition) (Karr and Dudley 1981). These chemicals are cycled through the marine environment by primary producers, consumers, and decomposers in neritic and oceanic environments and are subsequently released back into the water column or stored in sediments and reefs (Doney 2010; World Resources Institute 2005).

Productivity and trophic dynamics describe the inputs and exports of energy through a marine ecosystem (Figure 3-6) (Longhurst and Harrison 1989). Specific levels in food webs are termed trophic levels, deriving from a Greek reference to feeding. The three most elementary trophic levels are producers (e.g., plants), consumers (e.g., herbivores, carnivores, and omnivores), and decomposers. Primary producers include plants and algae that inhabit the photic zone and chemosynthetic biota that inhabit deep sea hydrothermal ecosystems. Primary production is defined as the amount of inorganic carbon synthesized into organic matter in a fixed volume of water using the energy derived from solar radiation or chemical reactions over a given period of time (e.g., milligrams [mg] of organic carbon per cubic meter [m^3]per day) (Thurman 1997). Intensity and quality of light, availability of nutrients, and seawater temperature all influence primary productivity (Valiela 1995). Because natural boundaries created by bathymetry, ocean currents and fronts, and upwelling all influence the biomass and biodiversity of plankton, continental shelves and upwelling systems contribute almost half of the global ocean's primary production (Pauly and Christensen 1995). Consumers include herbivores that eat plants, carnivores that eat animals, and omnivores that eat both plants and other animals. Decomposers (detritivores) consume and break down dead plant and animal material and wastes, and release it again as energy and nutrients into the ecosystem for recycling. Food webs may be simple chains or form complex linkages between different trophic levels (Figure 3-6). Productivity is independent of scale or trophic level and is frequently defined as the quantity of organic carbon exported from the system, or removed by fishing (Doney 2010; Levin 1992).

Population connectivity describes the rate of genetic exchange among subpopulations of marine organisms, in particular the spatial and temporal scales over which marine populations are connected by larval dispersal (Cowen et al. 2002; Cowen et al. 2007). Many marine organisms produce larvae that are transported in the water column both vertically and horizontally. Populations of some species may be connected by larval transport on scales of hundreds to thousands of kilometers from the larval origin (Cowen and Sponaugle 2009); whereas endemic populations result from zero population connectivity. While most marine populations are connected across different habitats, many are connected across ecosystems as well. The terms subpopulation or local population are equivalent to a metapopulation, which is defined as spatially separated populations of the same species that interact in some way (Cowen et al. 2007).

Variability and resilience also shape ecosystem structure and function. Variability may be caused by climatic, oceanographic, and biogeochemical features that vary over space and time (such as daily, monthly, seasonal, and decadal) (Figure 3-1). Among other things this includes extreme events such as El Niño and anthropogenic climate change (Rosenzweig et al. 2008). Resilience refers to the ability of an ecosystem to absorb change and variation without transforming into a fundamentally different state (Holling 1996).

Ecosystem Services. Ecosystem services represent the benefits human populations derive directly or indirectly from ecosystem functions (Costanza et al. 1997; Lovins, Lovins, and Hawken 1999). These services can be categorized as provisioning, regulating, supporting, and social/cultural (Figure 3-5 and Table 3-2). Attempts to monetize the natural systems providing an ecosystem service can be as simplistic as the food-value of a fishery, and as complex as the value of oxygen production and carbon sequestration performed by phytoplankton. Within ecosystem services, the concept of redundancy is extremely important. While redundant food supplies exist for many fisheries, there is no excess oxygen generating capacity to replace phytoplankton, which is estimated to produce approximately half of the oxygen in the atmosphere (National Aeronautics and Space Administration 2005; National Geographic 2004). The economic principles employed in assigning value to ecosystem services would, in this example, place a very high value on phytoplankton relative to fisheries because of no practical alternative to their oxygen generating services (Costanza et al. 1997).

An ecosystem approach to management (e.g., Council on Environmental Planning or Coastal and Marine Spatial Planning) requires consideration of ecosystem structure, function, and services (Christensen et al. 1996; Mengerink, Schempp, and Austin 2009; World Resources Institute 2005). Humans, as an integral part of the ecosystem, derive numerous benefits from ecosystem services in ways that often negatively impact the ecosystem structure and function (Lovins, Lovins, and Hawken 1999). Preserving ecosystem structure and function, therefore, sustains these services for the long term (Bennett, Peterson, and Gordon 2009; Granek et al. 2010; Pendleton 2008).

Table 3-2: Example Ecosystem Services

Provisioning	Regulating	Supporting	Social/Cultural
Fisheries Coastal tourism Maritime industry Genetic resources Biochemicals, natural medicines	Climate regulation Erosion control Water purification and waste treatment Carbon sequestration (linked to primary production)	Nutrient cycling Primary production (linked to carbon sequestration) Storm protection	Cultural/maritime heritage resources Spiritual and religious values Knowledge systems Aesthetic values Recreation Education values

Adapted from World Resources Institute (2005).

Many marine management plans, including the new National Ocean Policy (The White House 2010) integrate the concepts and techniques of ecosystem services into their ecosystem-based planning and monitoring processes. For example, in the Gulf of Maine, coastal development and fishing stressors have the greatest impact on ecosystem services while military stressors have approximately 80 percent (%) less impact (Altman et al. 2011). Such information is used to prioritize mitigation efforts (Mengerink, Schempp, and Austin 2009).

3.8.4 Ecosystem Disturbance

Ecosystems can be disturbed by factors that affect (1) the physical environment, (2) ecosystem function (biogeochemical processes, productivity/foodwebs, or population connectivity), or (3) any individual aspect of ecosystem structure (e.g., apex predators, keystone species, EFH, biodiversity, habitat, critical habitat) (Sutherland et al. 2006) (Figure 3-5). Individual stressors may affect one or many components of the ecosystem. Synergistic interactions of stressors, which individually would have no impact, may also affect one or many components of the ecosystem (Hughes and Connell 1999). Ecosystems can be disturbed beyond their range of natural variation if redundancy, resistance, or resilience is compromised (Bellwood, Hoey, and Choat 2003; Holling 1996; Hughes et al. 2003). The following sub sections describe some of the more important stressors to ecosystems (Crain et al. 2009). As with much of ecology, these factors are interlinked and not easily defined in isolation (Crain et al. 2009; Karl, Melillo, and Peterson 2009).

Pollution. Chemical pollution includes both synthetic chemicals and excess nutrients. Both have measurable effects on ecosystems (Halpern et al. 2008). Nutrient pollution, principally concentrated near major coastal population centers and major rivers, is linked to inadequate treatment of surface water and wastewater. While point sources such as sewerage pipes are easily identified and managed, nonpoint sources such as fertilizer runoff are more damaging and more difficult to manage through policy (Sutherland et al. 2006; Vitousek et al. 1997). Synthetic or man-made pollutants are those chemical pollutants that either absolutely or principally does not occur in nature. For example, polychlorinated biphenyls do not exist in nature, while mercury exists in nature but is principally liberated by the burning of coal. Chemical pollutants sometimes have immediate effects, but ecosystem effects generally occur only after the pollutants are concentrated by the process of bioaccumulation. Classes of pollutants most likely to cause ecosystem disturbance via bioaccumulation are metals, plastics, persistent organic pollutants (e.g., many pesticides and fire retardants), and endocrine-disruptors (Pews Oceans Commission 2003; Teuten et al. 2009).

Physical pollution, or marine debris, includes a variety of things such as plastics, glass, metal and derelict fishing gear. The predominant type of marine debris is plastics which make up 60–80% of all marine debris (Derraik 2002). Marine debris enters the marine environment via storm drains, rivers, and accidental spills at sea while fishing gear is abandoned or lost at sea. Land-based pollution can be minimized by campaigns to encourage recycling, the proper disposal of trash, and the implementation of regulations by local governments (e.g., Los Angeles, California) to reduce the amount of trash entering storm drains (California Ocean Protection Council 2008). The City of Los Angeles Stormwater Program installed catch basin screen covers and netting systems to capture debris before it enters waterways that empty into the ocean (City of Los Angeles Department of Public Works, The Watershed Protection Division, and Stormwater Program 2012).

Concentrations of floating marine debris occur in all of the major oceans of the world. In the North Pacific Ocean there are two so-called 'garbage patches' which are areas with a large concentration of marine debris, one in the Eastern Pacific and one in the Western Pacific (National Oceanic and Atmospheric Administration, NOAA Marine Debris Program, and Office of Response and Restoration 2012). The eastern garbage patch is between Hawai'i and California and the western garbage patch is off the coast of Japan. In addition, there is a concentration of marine debris north of the Hawaiian Islands in the Subtropical Convergence Zone, a highly productive area of the ocean (Pichel et al. 2007). Debris from the tsunami that hit Japan in March of 2011 is expected to contribute to these existing concentrations of marine debris or wash ashore the Hawaiian Islands and the west coast of the United States.

Pollution has noteworthy impacts on humans via impaired ecosystem services. Obvious impacts include impaired recreational use; the so-called "fishable/swimmable" goals that motivated much of the Clean Water Act (Karr and Dudley 1981; Sherman and Hempel 2009). Somewhat more subtle are hazards associated with consuming contaminated marine life, for example restricting tuna consumption because of mercury contamination (Pews Oceans Commission 2003). Elements of both chemical and physical pollution are combined in the case of plastics pollution. Plastic debris contains some chemical toxicants but also attracts and concentrates other chemical toxicants from the surrounding water (Teuten et al. 2009). This debris acts worsen the impact of chemical pollution by facilitating bioaccumulation of many chemicals.

Bioaccumulation, biomagnification, and bioconcentration. Bioaccumulation is the net buildup of substances (e.g., chemicals or metals) in an organism directly from contaminated water, air, or sediment through the gills/lungs or skin, or from consuming food containing the substance (Newman 1998; U.S. Environmental Protection Agency 2011a). The net buildup of a substance only from an exposure medium such as water is referred to as bioconcentration (Newman 1998; U.S. Environmental Protection Agency 2011a). Bioaccumulation and bioconcentration occur within trophic levels (at the individual level) when substances are taken up by organisms faster than they can be broken down (metabolized) and eliminated; as a result, these substances build up in the tissues. The increase in concentration of these substances between trophic levels (lower to higher trophic level) is biomagnification (Newman 1998; U.S. Environmental Protection Agency 2011a). Biomagnification is a result of the process of bioaccumulation and bioconcentration in prey species that results in higher concentrations of contaminants in the predators that eat them (Newman 1998; U.S. Environmental Protection Agency 2011b).

Biomagnification poses serious risks to all organisms in the marine food web, but particularly to apex predators (e.g., marine mammals and humans) because apex predators accumulate toxins from all of

the trophic interactions below them (Sherman and Hempel 2009). Apex predators often exhibit toxin concentrations many orders of magnitude greater than the toxin concentration in seawater. For example, some whales contain biomagnified toxin concentrations that are millions of times greater than the toxin concentration in seawater (Ross et al. 2000).

Bioaccumulation dynamics differ widely among toxins, species, and sometimes between sexes of the same species (Luoma and Rainbow 2005; Wang and Rainbow 2008). This process can occur at any life stage from embryo to adult (Jeffree et al. 2006; Newman 1998), and in some cases, substances may be transmitted from parent to offspring (Ohji, T., and Miyazaki 2006). The potential impacts of contaminant bioaccumulation and biomagnification by organisms include food contamination, population decline due to mortality, developmental abnormalities, breeding loss, and behavioral changes that may cause shifts in the species composition of communities (keystone species) and changes in the marine ecosystem (Dallinger et al. 1987; Newman 1998). Given that other factors contribute to ecosystem changes (e.g., pollutants and global climate change), the impact of a single substance on the ecosystem is difficult to interpret. In only a few cases has relationship been established between bioaccumulation of toxic substances and the long term impacts of such build-up (Kudo and Miyahara 1991; Paasivirta 2000).

Properties that are essential for substances to bioaccumulate are: (1) resistance to elimination (e.g., water-soluble, with resistance to excretion, or fat-soluble), (2) stability in water and organisms, and (3) low toxicity so that intermediate members of the food web are not eliminated (Clarkson 1995). Several chemicals with the potential to bioaccumulate (e.g., explosives, metals, combustible chemicals, and plastics) are introduced to the marine environment by Navy training and testing activities.

Occurrences and fates of chemicals from plastics in the marine environment are well documented (Mackintosh et al. 2004; Morét-Ferguson et al. 2010; Staples et al. 1998; Staples et al. 1997). Plastics attract hydrophobic pollutants and effectively concentrate them (Staples et al. 1997). Two common types of toxic chemicals in plastics are phthalates and bisphenol-A. Phthalates do not biomagnify but they persist longer in seawater than in freshwater (Kang, Aasi, and Katayama 2007; Mackintosh et al. 2004). Bisphenol-A is slightly to moderately toxic, and has low potential to bioaccumulate or biomagnify in aquatic organisms (Staples et al. 1998). Endocrine disrupters such as phthalates and bisphenol-A mimic or inhibit natural hormones or alter the function of the endocrine system (Crisp et al. 2005). Endocrine disrupters can alter an organism's growth, metabolism, and reproduction at extremely low concentrations depending on the species and the chemical (Kang, Aasi, and Katayama 2007).

Habitat Disturbance. A habitat is the environmental area or footprint occupied or used by a particular species. Habitats highlighted in this ecosystem approach include EFH designated under the MSFCMA, critical habitats designated under the ESA, and other important habitats such as foraging, breeding, and nursery areas (South Atlantic Fishery Management Council 1998). Habitat loss is commonly linked to physical disturbances, principally associated with coastal development and trawling, and with disturbances to habitat forming organisms (e.g., seagrass, oysters, corals). Losses of habitats have significantly affected structures and functions of ecosystems by removing shelter, feeding, and breeding grounds (Balmford et al. 2002; Mengerink, Schempp, and Austin 2009; National Oceanic Atmospheric Administration 2010). A survey of activities in a 93,000 km^2 ecosystem determined that habitat was the most important component of the area's ecosystem services, and was highly vulnerable to human impacts. The same study concluded that military stressor sources ranked low among all ecosystem stressors (16th of 21) (Altman et al. 2011).

Overfishing. Overfishing and overharvesting causes profound changes in trophic dynamics. These changes degrade an ecosystem directly or decrease its resistance to future disturbance (Baum and Worm 2009). Because most fish harvested for food in the ocean are predators (contrasting with terrestrial systems where most food-animals are herbivores), the effects of overfishing predators can cascade down through food webs, affecting all trophic levels (Pauly et al. 1998). Obvious examples of industrial overfishing are the New England cod fishery and the whaling industry, both of which were enabled by technological advances and inadequate regulatory constraints (Jackson et al. 2001; Pauly et al. 1998; Roman and Palumbi 2003). Somewhat less obvious are examples of preindustrial overfishing. The green sea turtle population and Hawaiian monk seal populations were severely depleted shortly after European exploration of the "new world" and even before this some marine mammal species were hunted to near extinction by aboriginal populations (Jackson 1997, 2008; Jackson et al. 2001; Kittinger et al. 2011). Steller's sea cow (*Hydrodamalis gigas*), for example, was severely depleted by pre-industrial aboriginal human populations, and with the addition of hunting by Europeans its remnant population was driven to extinction by 1768 (Estes, Duggins, and Rathbun 1989).

Climate Change. Global climate change is already having measurable impacts on species and ecosystems (Hoegh-Guldberg and Bruno 2010; Hughes et al. 2011). The most important driver of climate change is increased atmospheric carbon dioxide (principally from burning fossil fuels), trapping heat that would otherwise be radiated out to space (Karl, Melillo, and Peterson 2009). The principal substressors of climate change are temperature increase, changed weather patterns, ocean acidification, and sea-level rise (Brierley and Kingsford 2009; Hoegh-Guldberg and Bruno 2010). Ecological consequences of temperature increase range from direct effects of heat stress, such as coral bleaching (Hoegh-Guldberg and Bruno 2010), to altered seasonal cues for reproduction or migration (Przeslawski et al. 2008), to radical alteration of upwelling and oceanic circulation patterns (Intergovernmental Panel on Climate Change 2007b). Changed weather patterns are likely to alter wind-driven currents, to increase the intensity and frequency of storms resulting in direct damage and erosion, and more intense flood-drought cycles in terrestrial systems will increase coastal sedimentation (Brierley and Kingsford 2009). Linked with temperature increase, changed weather patterns are likely to movement and intensity of open-ocean fronts such as those that define the North Pacific Transition (Roessig et al. 2004).

Ocean acidification is a concerning substressor of climate change (Orr et al. 2005), in part because it will have broad-spectrum impacts on the physiology of all marine biota, and in part because there are no natural or anthropogenic processes that could reverse acidification on timescales shorter than centuries (Brierley and Kingsford 2009). "Alkalinity decrease" is the more proper term than "acidification" for pH values greater than 7.0 (mean oceanic pH was 8.07 in 2010) (Pelejero, Calvo, and Hoegh-Guldberg 2010); but semantics aside, the concentration of hydrogen ions is increasing due to anthropogenic impacts. Briefly, as atmospheric carbon dioxide dissolves in seawater it forms carbonic acid. The chemical relationships between pH and the three principal forms of carbon dioxide in seawater (dissolved carbon dioxide gas, carbonic acid, and carbonate ion) are somewhat complex. Their equilibrium concentrations vary as a function of temperature, depth, atmospheric carbon dioxide concentration, and salinity (Intergovernmental Panel on Climate Change 2007b; Pelejero, Calvo, and Hoegh-Guldberg 2010). The key issue is the concentration of carbonate ion in seawater because this chemical equilibrium point determines whether marine organisms' shells and bones can be formed of aragonite (a stronger form of calcium carbonate with ultraviolet-protective properties) (Reef, Kaniewska, and Hoegh-Guldberg 2009), of calcite (a weaker form of calcium carbonate that requires more metabolic effort to maintain), or whether these skeletal structures will spontaneously dissolve (Fine and Tchernov 2007; Guinotte, Buddemeier, and Kleypas 2003; Pelejero, Calvo, and Hoegh-Guldberg 2010). Ocean acidification also has impacts on olfactory and auditory sensation in fish and

invertebrates (Bell, Johnson, and Hobday 2011; Munday et al. 2009), on coral calcification (De'ath, Lough, and Fabricius 2009), and on the skeletons of plankton and the planktonic larvae of many important marine invertebrates (Przeslawski et al. 2008).

Finally, sea level rise is already occurring and the global mean sea level is expected to be approximately 0.6 to 2.0 m higher in 2100 than it was in 2000 though the magnitude of sea level rise in specific localities will vary considerably across the globe (Brierley and Kingsford 2009; Intergovernmental Panel on Climate Change 2007b). The actual magnitude of sea level rise in the last three decades generally aligns with the worst-case predictive models (Intergovernmental Panel on Climate Change 2007b). Coastal systems, especially inter-tidal habitats like salt marsh and mangroves will be radically altered by sea level rise. Rising sea level will push the inter-tidal zone landwards, and these habitats could potentially re-establish in the new location unless it is already occupied by anthropogenic structures (e.g., roads and cities) (Pendleton 2008). Coral reefs could be negatively impacted by sea level rise in some circumstances (Hoegh-Guldberg and Bruno 2010) but, on balance, sea level rise alone is a positive impact on coral reefs (Buddemeier and Smith 1988). One of the most important ecological consequences of sea level rise is the human response to rising sea levels. Displaced from low-lying areas, agricultural lands will need to be reestablished by converting other terrestrial habitats to agricultural uses (Intergovernmental Panel on Climate Change 2007a; Pendleton 2008). Similarly, the ecological costs of defending coastal cities against rising sea levels include further alteration of hydrology (e.g., levees and dykes), removal of beaches and coastal systems (e.g., by installation of seawalls), and the ecological costs of producing the concrete and steel needed to construct these defenses (Hawken, Lovins, and Lovins 1999; Intergovernmental Panel on Climate Change 2007b, c).

Removal of Keystone Species/Apex Predators. As discussed in Section 3.8.3, apex predators reside at the top of the food chain, and adults typically have no predators of their own within the ecosystem. Removal of these animals is a result of overfishing and other disturbances. Apex predators play an important role in the ecosystem in maintaining prey species populations, as well as “mesopredators,” or smaller predators (Baum and Worm 2009; Oregon State University 2009). Apex predators keep small predator populations balanced, thereby maintaining abundance of important prey populations (Ritchie and Johnson 2009). Removal of apex predators significantly impacts ecosystem structure and function (Jackson et al. 2001; Sandin et al. 2008). For example, once released from predatory control, the cownose ray population increased eight-fold and caused collapse of the bay scallop population, its principal prey (Baum and Worm 2009).

A keystone species has a disproportionate impact on its environment relative to its biomass (Paine 1995). These species affect many other organisms in an ecosystem and help to determine the types and numbers of various other species in a community. Removal of keystone species results in changes in the structure and function of an ecosystem, or ecosystem collapse (Jackson et al. 2001; Mills, Soulé, and Doak 1993).

Ecological Extinction. Ecological extinction is defined as “the reduction of a species to such low abundance that, although it is still present in the community, it no longer interacts significantly with other species” (Estes, Duggins, and Rathbun 1989). This term differs from the terms extinction and extirpation. Extinction is defined as the complete, global, disappearance of a species. Extirpation, or local extinction, is defined as the disappearance of a species from part of its range (Estes, Duggins, and Rathbun 1989). Ecological extinction occurs at spatial scales that are relevant to an entire population (i.e., throughout ecosystems, throughout their range, or globally) (Jackson et al. 2001; Nichols, Seminoff, and Etnoyer 2009). Species that are listed as “threatened” or “endangered” are usually ecologically

extinct. While the species is still present, ecologically extinct populations no longer perform the ecological functions, or provide the ecosystem services, of the nondepleted population (Jackson et al. 2001; Sala and Knowlton 2006). Nevertheless, ecologically extinct species may still have viable populations, and recovery may be possible. Therefore, the loss of individuals from an ecologically extinct population will further impact the species. However, follow-on consequences to the ecosystem are unlikely because nearly all possible ecosystem impacts occurred as the population was becoming ecologically extinct.

Biodiversity Loss. Biodiversity loss impacts ecosystem resilience, degrades ecosystem services (Costanza et al. 1997), and depresses the rate of evolution, decreasing the stability of the ecosystem (Worm et al. 2006). Reductions in the effective population size of organisms reduce overall genetic diversity, and more broadly, reductions of populations eliminate redundancy in trophic systems. Most anthropogenic stressors lead to biodiversity loss either directly (e.g., by trawling or overfishing) or indirectly (e.g., by pollution or bioaccumulation) (Vitousek et al. 1997; Worm et al. 2006).

Biological Invasions. Biological invasions occur when a species colonizes a habitat that it has not colonized before. Naturally occurring invasions are relatively infrequent and often involve only local or regional dispersal in numbers that are too small to sustain a population in the new habitat (Ricciardi and Simberloff 2009). Invasions attributed to human activities such as the accidental transport of fouling organisms on ship hulls and in ballast water, and the increase in international shipping, have increased tremendously (Carlton and Cohen 2003). Invasive species often cause destructive changes in ecosystem structure and function, and their impacts seem to be irreversible (Molnar et al. 2008). The invasive Pacific oyster (*Crassostrea gigas*), for example, can displace native species and destroy habitat (Molnar et al. 2008).

3.9 REFERENCES

Allen, J. I. and Fulton, E. A. (2009). Top-down, bottom-up or middle-out? Avoiding extraneous detail and over-generality in marine ecosystem models. *Progress In Oceanography, 84*(1-2), 129-133. doi:10.1016/j.pocean.2009.09.016

Altman, I., Blakeslee, A. M., Osio, G. C., Rillahan, C. B., Teck, S. J., Meyer, J. J., et al. (2011). A practical approach to implementation of ecosystem-based management: a case study using the Gulf of Maine marine ecosystem. *Frontiers in Ecology and the Environment, 9*(3), 183-189. doi:10.1890/080186

Balmford, A., Bruner, A., Cooper, P., Costanza, R., Farber, S., Green, R. E., et al. (2002, August 9, 2002). Economic Reasons for Conserving Wild Nature. *Science, 297*(5583), 950-953. doi:10.1126/science.1073947

Baum, J. K. and Worm, B. (2009). Cascading top-down effects of changing oceanic predator abundances. *Journal of Animal Ecology, 78*(4), 699-714. doi:10.1111/j.1365-2656.2009.01531.x

Bell, J. D., Johnson, J. E. and Hobday, A. J. (2011). *Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change*. Noumea, New Caledonia: Secretariat of the Pacific Community.

Bellwood, D. R., Hoey, A. S. and Choat, J. H. (2003). Limited functional redundancy in high diversity systems: Resilience and ecosystem function on coral reefs. *Ecology Letters, 6*(4), 281-285. doi:10.1046/j.1461-0248.2003.00432.x

Bennett, E. M., Peterson, G. D. and Gordon, L. J. (2009). Understanding relationships among multiple ecosystem services. *Ecology Letters, 12*(12), 1394-1404. doi:10.1111/j.1461-0248.2009.01387.x

BirdLife International (2012). BirdLife international data zone. [Web page]. Retrieved from http://www.birdlife.org/datazone/info/taxonomy, 27 February 2012.

Brainard, R. E., Birkeland, C., Eakin, C. M., McElhany, P., Miller, M. W., Patterson, M., et al. (2011). *Status Review Report of 82 Candidate Coral Species Petitioned Under the U.S. Endangered Species Act*. (NOAA Technical Memorandum NMFS-PIFSC-27, pp. 530 + Appendix) U.S. Department of Commerce. Available from http://www.nmfs.noaa.gov/stories/2012/05/docs/full_doc_corals_status_review_report.pdf

Brierley, A. S. and Kingsford, M. J. (2009). Impacts of climate change on marine organisms and ecosystems. *Current Biology, 19*, R602–R614. doi:10.1016/j.cub.2009.05.046

Buddemeier, R. W. and Smith, S. V. (1988). Coral reef growth in an era of rapidly rising sea level: predictions and suggestions for long-term research. *Coral Reefs, 7*(1), 51-56. doi:10.1007/bf00301982

California Ocean Protection Council. (2008). *An Implementation Strategy for the California Ocean Protection Council Resolution to Reduce and Prevent Ocean Litter*. (pp. 28). Available from http://www.opc.ca.gov/webmaster/ftp/pdf/opc_ocean_litter_final_strategy.pdf

Carlton, J. T. and Cohen, A. N. (2003). Episodic global dispersal in shallow water marine organisms: the case history of the European shore crabs *Carcinus maenas* and *C-aestuarii*. *Journal of Biogeography, 30*(12), 1809-1820.

Carr, M. H., Woodson, C. B., Cheriton, O. M., Malone, D., McManus, M. A. and Raimondi, P. T. (2011). Knowledge through partnerships: integrating marine protected area monitoring and ocean observing systems. *Frontiers in Ecology and the Environment, 9*, 342–350. doi:10.1890/090096 Retrieved from http://www.esajournals.org/doi/abs/10.1890/090096

Chase, J. M. and Leibold, M. A. (2002). Spatial scale dictates the productivity-biodiversity relationship. *Nature, 416*(6879), 427-430. doi:10.1038/416427a

Christensen, N. L., Bartuska, A. M., Brown, J. H., Carpenter, S., D'Antonio, C., Francis, R., et al. (1996). The report of the Ecological Society of America committee on the scientific basis for ecosystem management. *Ecological Applications, 6*(3), 665-691.

City of Los Angeles Department of Public Works, The Watershed Protection Division and Stormwater Program (2012). *Pollution Abatement*. [Web page]. Retrieved from http://www.lastormwater.org/Siteorg/program/poll_abate/pollabate.htm, 03 April 2012.

Clarkson, T. W. (1995). Environmental contaminants in the food chain. *The American Journal of Clinical Nutrition, 61*(3), 682S-686S. Retrieved from http://www.ajcn.org/content/61/3/682S.abstract

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., et al. (1997). The value of the world's ecosystem services and natural capital. *Nature, 387*(6630), 253-260. doi:10.1038/387253a0

Costello, M. J. (2009). Distinguishing marine habitat classification concepts for ecological data management. *Marine Ecology Progress Series, 397*, 253-268. doi:10.3354/meps08317

Cowen, R. K., Gawarkiewicz, G., Pineda, J., Thorrold, S. and Werner, F. (2002). *Population Connectivity in Marine Systems. Report of a Workshop to Develop Science Recommendations for the National Science Foundation*. (pp. 23). Durango, CO.

Cowen, R. K., Gawarkiewicz, G., Pineda, J., Thorrold, S. R. and Werner, F. E. (2007). Population connectivity in marine systems: an overview. *Oceanography, 20*(3), 14-21.

Cowen, R. K. and Sponaugle, S. (2009). Larval dispersal and marine population connectivity. *Annual Review of Marine Science, 1*(1), 443-466. doi:10.1146/annurev.marine.010908.163757

Crain, C. M., Halpern, B. S., Beck, M. W. and Kappel, C. V. (2009). Understanding and managing human threats to the coastal marine environment. In R. S. Ostfeld and W. H. Schlesinger (Eds.), *The Year in Ecology and Conservation Biology, 2009* (pp. 39-62). Oxford, UK: Blackwell Publishing. doi:10.1111/j.1749-6632.2009.04496.x

Crisp, T. M., Clegg, E. D., Cooper, R. L., Wood, W. P., Anderson, D. G., Baetcke, K. P., et al. (2005). Environmental endocrine disruption: An effects assessment and analysis. *Environmental Health Perspectives, 106*(1), 11-56.

Dallinger, R., Prosi, F., Segner, H. and Back, H. (1987). Contaminated food and uptake of heavy metals by fish: a review and a proposal for further research. *Oecologia, 73*(1), 91-98. doi:10.1007/bf00376982

De'ath, G., Lough, J. M. and Fabricius, K. E. (2009). Declining coral calcification on the great barrier reef. *Science, 323*(5910), 116-119. doi:10.1126/science.1165283

De Leo, G. A. and Levin, S. (1997). The multifaceted aspects of ecosystem integrity. *Conservation Ecology, 1*(1), 3. Retrieved from http://www.consecol.org/vol1/iss1/art3/

Derraik, J. G. B. (2002). The pollution of the marine environment by plastic debris: A review. *Marine Pollution Bulletin, 44*(9), 842-852. doi:10.1016/S0025-326X(02)00220-5

Doney, S. C. (2010). The growing human footprint on coastal and open-ocean biogeochemistry. *Science, 328*(5985), 1512-1516. doi:10.1126/science.1185198

Duda, A. M. and Sherman, K. (2002). A new imperative for improving management of large marine ecosystems. *Ocean & Coastal Management, 45*(11-12), 797-833. doi:10.1016/S0964-5691(02)00107-2

Duffy, J. E. (2002). Biodiversity and ecosystem function: the consumer connection. *Oikos, 99*, 201-219.

Estes, J. A., Duggins, D. O. and Rathbun, G. B. (1989). The ecology of extinctions in kelp forest communities. *Conservation Biology, 3*(3), 252-264. Retrieved from http://www.scopus.com/inward/record.url?eid=2-s2.0-0024879831&partnerID=40&md5=7292a63664a8f3d9ba847142aa89a278

Fine, M. and Tchernov, D. (2007). Scleractinian coral species survive and recover from decalcification. *Science, 315*(5820), 1811. doi:10.1126/science.1137094

Froese, R. and Pauly, D. e. (2012). FishBase. [Web page]. Retrieved from www.fishbase.org, 30 March 2012.

Goreau, T. F. (1959). The ecology of Jamaican coral reefs 1. Species composition and zonation. *Ecology, 40*(1), 67-90. doi:10.2307/1929924

Granek, E. F., Polasky, S., Kappel, C. V., Reed, D. J., Stoms, D. M., Koch, E. W., et al. (2010). Ecosystem services as a common language for coastal ecosystem-based management. *Conservation Biology, 24*(1), 207-216. doi:10.1111/j.1523-1739.2009.01355.x

Guinotte, J. M., Buddemeier, R. W. and Kleypas, J. A. (2003). Future coral reef habitat marginality: temporal and spatial effects of climate change in the Pacific basin. *Coral Reefs, 22*(4), 551-558. doi:10.1007/s00338-003-0331-4

Halpern, B., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., D'Agrosa, C., et al. (2008). A global map of human impact on marine ecosystems. *Science, 319*(5865), 948-952. doi:10.1126/science.1149345

Hammerschlag, N. and Serafy, J. E. (2010). Nocturnal fish utilization of a subtropical mangrove-seagrass ecotone. *Marine Ecology, 31*(2), 364-374. doi:10.1111/j.1439-0485.2009.00337.x

Hawken, P., Lovins, A. B. and Lovins, L. H. (1999). Climate: Making sense and making money. In *Natural Capitalism: Creating the Next Industrial Revolution*

(pp. 234-259). Boston: Little, Brown and Co. Retrieved from http://www.natcap.org/sitepages/pid20.php.

Hoegh-Guldberg, O. and Bruno, J. F. (2010). The impact of climate change on the world's marine ecosystems. *Science, 328*(5985), 1523-1528. doi:10.1126/science.1189930

Holling, C. S. (1996). Surprise for science, resilience for ecosystems, and incentives for people. *Ecological Applications, 6*(3), 733-735. Retrieved from http://www.jstor.org/stable/2269475

Hooper, D. U., Chapin, F. S., III, Ewel, J. J., Hector, A., Inchausti, P., Lavorel, S., et al. (2005). Effects of biodiversity on ecosystem functioning: A consensus of current knowledge. *Ecological Monographs, 75*(1), 3-35. doi:10.1890/04-0922

Hughes, T. P., Baird, A. H., Bellwood, D. R., Card, M., Connolly, S. R., Folke, C., et al. (2003). Climate change, human impacts, and the resilience of coral reefs. *Science, 301*(5635), 929-933.

Hughes, T. P., Bellwood, D. R., Baird, A. H., Brodie, J., Bruno, J. F. and Pandolfi, J. M. (2011). Shifting base-lines, declining coral cover, and the erosion of reef resilience: Comment on Sweatman et al. (2011). *Coral Reefs, 30*(3), 653-660. doi:10.1007/s00338-011-0787-6

Hughes, T. P. and Connell, J. H. (1999). Multiple stressors on coral reefs: A long-term perspective. *Limnology and Oceanography, 44*, 932-940. Retrieved from http://www.scopus.com/scopus/inward/record.url?eid=2-s2.0-0032933347&partnerID=40

Intergovernmental Panel on Climate Change. (2007a). *Climate Change 2007 Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Core Writing Team, R. K. Pachauri and A. Reisinger (Eds.). (pp. 104). Geneva, Switzerland. Available from http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm

Intergovernmental Panel on Climate Change. (2007b). *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden and C. E. Hanson (Eds.). (978 0521 70597-4, pp. 976). Cambridge, UK: Cambridge University Press. Available from http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg2_report_impacts_adaptation_and_vulnerability.htm

Intergovernmental Panel on Climate Change. (2007c). *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* B. Metz, O. R. Davidson, P. R. Bosch, R. Dave and L. A. Meyer (Eds.). (978-0-521-70598-1, pp. 852). United Kingdom and New York, NY: Cambridge University Press. Available from http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg3_report_mitigation_of_climate_change.htm

Jackson, J. B. C. (1997). Reefs since Columbus. *Coral Reefs, 16*(SUPPL. 1).

Jackson, J. B. C. (2008). Ecological extinction and evolution in the brave new ocean. *Proceedings of the National Academy of Sciences of the United States of America, 105*(SUPPL. 1), 11458-11465.

Jackson, J. B. C., Kirby, M. X., Berger, W. H., Bjorndal, K. A., Botsford, L. W., Bourque, B. J., et al. (2001). Historical overfishing and the recent collapse of coastal ecosystems. *Science, 293*(5530), 629-637. doi:10.1126/science.1059199

Jefferson, T. A., Webber, M. A. and Pitman, R. L. (2008). *Marine Mammals of the World: A Comprehensive Guide to their Identification* (pp. 573). London, UK: Elsevier.

Jeffree, R. A., Warnau, M., Oberhansli, F. and Teyssie, J. L. (2006). Bioaccumulation of heavy metals and radionuclides from seawater by encased embryos of the spotted dogfish *Scyliorhinus canicula*. *Marine Pollution Bulletin, 52*(10), 1278-1286. doi:10.1016/j.marpolbul.2006.03.015

Jones, D. L., Walter, J. F., Brooks, E. N. and Serafy, J. E. (2010). Connectivity through ontogeny: fish population linkages among mangrove and coral reef habitats. *Marine Ecology Progress Series, 401*, 245-258. doi:10.3354/meps08404

Kang, J. H., Aasi, D. and Katayama, Y. (2007). Bisphenol A in the aquatic environment and its endocrine-disruptive effects on aquatic organisms. *Critical Reviews in Toxicology, 37*(7), 607-625. doi:10.1080/10408440701493103

Karl, T. R., Melillo, J. M. and Peterson, T. C. (Eds.). (2009). Global climate change impacts in the United States. In *Global Climate Change Impacts in the United States*. Cambridge University Press. Retrieved from www.globalchange.gov/usimpacts.

Karr, J. R. and Dudley, D. R. (1981). Ecological perspective on water quality goals. *Environmental Management, 5*(1), 55-68. Retrieved from http://www.scopus.com/inward/record.url?eid=2-s2.0-0019377764&partnerID=40&md5=f02a695a12191c9303b4a8515205ab01

Keller, B. D., Gleason, D. F., McLeod, E., Woodley, C. M., Airame', S., Causey, B. D., et al. (2009). Climate change, coral reef ecosystems, and management options for marine protected areas. *Environmental Management, 44*(6), 1069-1088. doi:10.1007/s00267-009-9346-0

Kittinger, J. N., Pandolfi, J. M., Blodgett, J. H., Hunt, T. L., Jiang, H., Maly, K., et al. (2011). Historical reconstruction reveals recovery in Hawaiian coral reefs. *PLoS ONE, 6*(10), e25460. doi:10.1371/journal.pone.0025460

Kudo, A. and Miyahara, S. (1991). A case history - Minamata mercury pollution in Japan-From loss of human lives to decontamination. *Water and Science Technology, 23*(1-3), 283-290.

Lavelle, J. W. and Mohn, C. (2010). Motion, commotion, and biophysical connections at deep ocean seamounts. *Oceanography, 23*(1), 90-103.

Levin, S. A. (1992). The problem of pattern and scale in ecology *Ecology, 73*(6), 1943-1967.

Link, J. (2002). Does food web theory work for marine ecosystems? *Marine Ecology Progress Series, 230*, 1-9. doi:10.3354/meps230001

Longhurst, A. R. (1998). Introduction. In *Ecological geography of the sea* (pp. 1-24). Burlington: Academic Press.

Longhurst, A. R. (2007). Biogeographic partition of the ocean. In *Ecological geography of the sea* (2nd ed., pp. 19-34). Burlington: Academic Press. doi:10.1016/B978-012455521-1/50003-6

Longhurst, A. R. and Harrison, W. G. (1989). The biological pump: Profiles of plankton production and consumption in the upper ocean. *Progress in Oceanography, 22*(1), 47-123.

Loreau, M., Naeem, S., Inchausti, P., Bengtsson, J., Grime, J. P., Hector, A., et al. (2001). Biodiversity and ecosystem functioning: Current knowledge and future challenges. *Science, 294*(5543), 804-808. doi:10.1126/science.1064088

Lovins, A. B., Lovins, L. H. and Hawken, P. (1999). A road map for natural capitalism. *Harvard Business Review, 77*(3), 145-158.

Luoma, S. N. and Rainbow, P. S. (2005). Why is metal bioaccumulation so variable? Biodynamics as a unifying concept. *Environmental Science & Technology, 39*(7), 1921-1931. doi:10.1021/es048947e

Mackintosh, C. E., Maldonado, J., Hongwu, J., Hoover, N., Chong, A., Ikonomou, M. G., et al. (2004). Distribution of phthalate esters in a marine aquatic food web: Comparison to polychlorinated biphenyls. *Environmental Science and Technology, 38*(7), 2011-2020. doi:10.1021/es034745r

Mengerink, K., Schempp, A. and Austin, J. (2009). *Ocean and Coastal Ecosystem-Based Management: Implementation Handbook* (pp. 169). Washington, DC: Environmental Law Institute.

Mills, L. S., Soulé, M. E. and Doak, D. F. (1993). The keystone-species concept in ecology and conservation. *Bioscience, 43*(4), 219-224. Retrieved from http://www.jstor.org/stable/1312122

Molnar, J. L., Gamboa, R. L., Revenga, C. and Spalding, M. D. (2008). Assessing the global threat of invasive species to marine biodiversity. *Frontiers in Ecology and the Environment, 6*(9), 485-492. doi:10.1890/070064

Morét-Ferguson, S., Law, K. L., Proskurowski, G., Murphy, E. K., Peacock, E. E. and Reddy, C. M. (2010). The size, mass, and composition of plastic debris in the western North Atlantic Ocean. *Marine Pollution Bulletin, 60*(10), 1873-1878. doi:10.1016/j.marpolbul.2010.07.020

Morgan, S. G. and Fisher, J. L. (2010). Larval behavior regulates nearshore retention and offshore migration in an upwelling shadow and along the open coast. *Marine Ecology Progress Series, 404*, 109-126. doi:10.3354/meps08476

MPA Global (2012). About the project. [Web page]. Retrieved from http://www.mpaglobal.org/index.php?action=aboutus, 21 March 2012.

Munday, P., Leis, J., Lough, J., Paris, C., Kingsford, M., Berumen, M., et al. (2009). Climate change and coral reef connectivity. *Coral Reefs, 28*(2), 379-395. doi:10.1007/s00338-008-0461-9

National Aeronautics and Space Administration (2005, Last updated February 23, 2008). Satellite sees ocean plants increase, coasts greening. [Web page] National Aeronautics and Space Administration, Goddard Space Flight Center. Retrieved from http://www.nasa.gov/centers/goddard/news/topstory/chlorophyll.html, 13 April 2011.

National Geographic (2004). Source of half Earth's oxygen gets little credit. [Web page] National Geographic Society. Retrieved from http://news.nationalgeographic.com/news/2004/06/0607_040607_phytoplankton.html, 13 April 2011.

National Marine Fisheries Service (2002). Magnuson-Stevens Act Provisions; Essential Fish Habitat (EFH). [Final rule]. *Federal Register, 67*(12), 2343-2383.

National Marine Fisheries Service (2011, Last updated November 15, 2011). Marine mammals. [Web page]. Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/, 16 May 2012.

National Marine Fisheries Service (2012a, Last updated February 6, 2012). Marine and anadromous fish. [Web page] NOAA Fisheries: Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/fish/, 30 March 2012.

National Marine Fisheries Service (2012b, Last updated May 10, 2012). Sea turtles. [Web page] NOAA Fisheries Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/turtles/, 16 May 2012.

National Marine Protected Areas Center. (2006). *A Functional Classification System for Marine Protected Areas in the United States*. Silver Spring, MD.

National Marine Protected Areas Center. (2011). The National System of MPAs: Analysis of National System Sites. Silver Spring, MD: Office of Ocean and Coastal Resource Management, NOAA Ocean Service. Available from http://www.mpa.gov/pdf/helpful-resources/factsheets/nss_analysis_march_2011.pdf

National Oceanic and Atmospheric Administration (2002). *Large Marine Ecosystems*. [GIS data]. Retrieved from http://www.lme.noaa.gov/index.php?option=com_content&view=article&id=177&Itemid=75

National Oceanic and Atmospheric Administration, NOAA Marine Debris Program and Office of Response and Restoration (2012, Last updated March 28, 2012). *Japan Tsunami Debris: Information and FAQs*. Retrieved from http://marinedebris.noaa.gov/info/japanfaqs.html, 04 April 2012.

National Oceanic Atmospheric Administration (2010). *Large Marine Ecosystems of the World*. [Web page]. Retrieved from http://www.lme.noaa.gov/index.php?option=com_content&view=article&id=47&Itemid=41, 06 May 2010.

Nelson, J. S., Crossman, E. J., Espinosa-Pérez, H., Findley, L. T., Gilbert, C. R., Lea, R. N., et al. (2004). Common and scientific names of fishes from the United States, Canada, and Mexico. In *American Fisheries Society Special Publication 29* (6th ed.). Bethesda, MD: American Fisheries Society.

Newman, M. C. (1998). Uptake, biotransformation, detoxification, elimination, and accumulation. In *Fundamentals of ecotoxicology* (pp. 25). Chelsea, MI: Ann Arbor Press.

Nichols, W. J., Seminoff, J. A. and Etnoyer, P. (2009). Biodiversity, function, and interconnectedness: A revolution in our understanding of marine ecosystems and ocean conservation. In R. Q. Grafton, R. Hilborn, D. Squires, M. Tait and M. Williams (Eds.), *Handbook of Marine Fisheries Conservation and Management* (pp. 43-59). Oxford University Press.

North American Classification Committee (2012). Check-list of North American birds. [Web Page]. Retrieved from http://www.aou.org/checklist/north/, 14 May 2012.

Ohji, M., T., A. and Miyazaki, N. (2006). Transfer of tributyltin from parental female to offspring in the viviparous surfperch *Ditrema temmincki*. *Marine Ecology Progress Series, 307*, 307-310.

Oregon State University (2009). Loss of top predators causing surge in smaller predators, ecosystem collapse. In *ScienceDaily*. Retrieved from http://www.sciencedaily.com//releases/2009/10/091001164102.htm, 6 May 2010.

Orr, J. C., Fabry, V. J., Aumont, O., Bopp, L., Doney, S. C., Feely, R. A., et al. (2005). Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. *Nature, 437*(7059), 681-686. doi:10.1038/nature04095

Paasivirta, J. (2000). Long-term effects of bioaccumulation in ecosystems. In B. Beek (Ed.), *Bioaccumulation – new aspects and developments* (Vol. 2J, pp. 201-233). Springer Berlin / Heidelberg. doi:10.1007/10503050_3

Paine, R. T. (1969). A Note on Trophic Complexity and Community Stability. *The American Naturalist, 103*(929), 91-93. Retrieved from http://www.jstor.org/stable/2459472

Paine, R. T. (1995). A conversation on refining the concept of Keystone species. *Conservation Biology, 9*(4), 962-964. Retrieved from http://www.jstor.org/stable/2387008

Pauly, D. and Christensen, V. (1995). Primary production required to sustain global fisheries. *Nature, 374*, 255-257.

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R. and Torres Jr, F. (1998). Fishing down marine food webs. *Science, 279*(5352), 860-863. doi:10.1126/science.279.5352.860

Pelejero, C., Calvo, E. and Hoegh-Guldberg, O. (2010). Paleo-perspectives on ocean acidification. *Trends in Ecology and Evolution, 25*(6), 332-344. doi:10.1016/j.tree.2010.02.002

Pendleton, L. H. (Ed.). (2008). *The Economic and Market Value of Coasts and Estuaries: What's At Stake?* (pp. 182) Restore America's Estuaries.

Pews Oceans Commission. (2003). *America's Living Oceans: Charting a Course for Sea Change*. . (pp. 166). Arlington, VA: Pew Oceans Commission.

Pichel, W. G., Churnside, J. H., Veenstra, T. S., Foley, D. G., Friedman, K. S., Brainard, R. E., et al. (2007). Marine debris collects within the North Pacific Subtropical Convergence Zone. *Marine Pollution Bulletin, 54*(8), 1207-1211. doi:10.1016/j.marpolbul.2007.04.010

Przeslawski, R., Ahyong, S., Byrne, M., Worheides, G. and Hutchings, P. (2008). Beyond corals and fish: The effects of climate change on noncoral benthic invertebrates of tropical reefs. *Global Change Biology, 14*, 1-23. doi:10.1111/j.1365-2486.2008.01693.x

Reef, R., Kaniewska, P. and Hoegh-Guldberg, O. (2009). Coral skeletons defend against ultraviolet radiation. *PLoS ONE, 4*(11), e7995. doi:10.1371/journal.pone.0007995

Rex, M. A., McClain, C. R., Johnson, N. A., Etter, R. J., Allen, J. A., Bouchet, P., et al. (2005). A source-sink hypothesis for abyssal biodiversity. *The American Naturalist, 165*(2), 163-178. doi:10.1086/427226

Ricciardi, A. and Simberloff, D. (2009). Assisted colonization is not a viable conservation strategy. *Trends in Ecology and Evolution, 24*(5), 248-253. doi:10.1016/j.tree.2008.12.006

Ritchie, E. G. and Johnson, C. N. (2009). Predator interactions, mesopredator release and biodiversity conservation. *Ecology Letters, 12*(9), 982-998. doi:10.1111/j.1461-0248.2009.01347.x

Roessig, J. M., Woodley, C. M., Cech Jr, J. J. and Hansen, L. J. (2004). Effects of global climate change on marine and estuarine fishes and fisheries. *Reviews in Fish Biology and Fisheries, 14*(2), 251-275. doi:10.1007/s11160-004-6749-0

Roman, J. and Palumbi, S. R. (2003). Whales before whaling in the North Atlantic. *Science, 301*(5632), 508-510. doi:10.1126/science.1084524

Rosenzweig, C., Karoly, D., Vicarelli, M., Neofotis, P., Wu, Q., Casassa, G., et al. (2008). Attributing physical and biological impacts to anthropogenic climate change. *Nature, 453*(7193), 353-357. doi:10.1038/nature06937

Ross, P. S., Ellis, G. M., Ikonomou, M. G., Barrett-Lennard, L. G. and Addison, R. F. (2000). High PCB concentrations in free-ranging Pacific killer whales, *Orcinus orca*: effects of age, sex and dietary preference. *Marine Pollution Bulletin, 40*(6), 504-515. doi:10.1016/s0025-326x(99)00233-7

Sala, E. and Knowlton, N. (2006). Global marine biodiversity trends. *Annual Review of Environment and Resources, 31*, 93-122. doi:10.1146/annurev.energy.31.020105.100235

Sandin, S. A., Smith, J. E., DeMartini, E. E., Dinsdale, E. A., Donner, S. D., Friedlander, A. M., et al. (2008). Baselines and degradation of coral reefs in the Northern Line Islands. *PLoS ONE, 3*(2), 1-11. doi:10.1371/journal.pone.0001548

Shank, T. M. (2010). Seamounts. Deep-ocean laboratories of faunal connectivity, evolution, and endemism. *Oceanography, 23*(1), 108-122.

Sherman, K. and Hempel, G. (2009). *The UNEP Large Marine Ecosystem Report: A Perspective on Changing Conditions in LMEs of the World's Regional Seas* [Electronic Version]. (UNEP Regional Seas Report and Studies No. 182). Nairobi, Kenya: United Nations Environmental Programme. Available from http://www.iwlearn.net/publications/regional-seas-reports/unep-regional-seas-reports-and-studies-no-182/

Sissenwine, M. and Murawaski, S. (2004). Moving beyond 'intelligent tinkering': advancing an ecosystem approach to fisheries. *Marine Ecology Progress Series, 274*, 291-295.

South Atlantic Fishery Management Council. (1998). *Final habitat plan for the South Atlantic region: Essential fish habitat requirements for fishery management plans of the South Atlantic Fishery Management Council*. Charleston, SC: South Atlantic Fishery Management Council. Available from http://www.safmc.net/ecosystem/EcosystemManagement/HabitatProtection/SAFMCHabitatPlan/tabid/80/Default.aspx

Spalding, M. D. (2009, 11 August), The Nature Conservancy. Global Open Oceans and Deep Sea-habitats (GOODS) Bioregional Classification: Pelagic Provinces. GIS data provided to P. Holtus, Tetra Tech, Inc., Honolulu, HI.

Spalding, M. D., Fox, H. E., Allen, G. R. and Davidson, N. (2007a). Marine Ecoregions of the World [GIS data]. (Companion publication: Spalding, M. D., Fox, H. E., Allen, G. R., Davidson, N., Ferdaña, Z. A., Finlayson, M., Halpern, B. S., Jorge, M. A., Lombana, A., Lourie, S. A., Martin, K. D., McManus, E., Molnar, J., Recchia, C. A., Robertson, J. (2007) Marine Ecoregions of the World: a bioregionalization of coast and shelf areas. BioScience 2057: 2573-2583). Arlington, VA: The Nature Conservancy (ConserveOnline). Available from http://conserveonline.org/workspaces/ecoregional.shapefile

Spalding, M. D., Fox, H. E., Allen, G. R. and Davidson, N. (2007b). Marine ecoregions of the world: A bioregionalisation of coastal and shelf areas. *Bioscience, 57*(7), 573-583.

Staples, C. A., Dome, P. B., Klecka, G. M., Oblock, S. T. and Harris, L. R. (1998). A review of the environmental fate, effects, and exposures of bisphenol A. *Chemosphere, 36*(10), 2149-2173. doi:10.1016/s0045-6535(97)10133-3

Staples, C. A., Peterson, D. R., Parkerton, T. F. and Adams, W. J. (1997). The environmental fate of phthalate esters: A literature review. *Chemosphere, 35*(4), 667-749. doi:10.1016/s0045-6535(97)00195-1

Sutherland, W. J., Armstrong-Brown, S., Armsworth, P. R., Brereton, T., Brickland, J., Campbell, C. D., et al. (2006). The identification of 100 ecological questions of high policy relevance in the UK. *Journal of Applied Ecology, 43*(4), 617-627. doi:10.1111/j.1365-2664.2006.01188.x

Teuten, E. L., Saquing, J. M., Knappe, D. R. U., Barlaz, M. A., Jonsson, S., Björn, A., et al. (2009). Transport and release of chemicals from plastics to the environment and to wildlife. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364*(1526), 2027-2045. doi:10.1098/rstb.2008.0284

The Archie Carr Center for Sea Turtle Research (2012). Archie Carr Center for sea turtle research. [Web page]. Retrieved from http://accstr.ufl.edu/, 16 May 2012.

The SWoT Team (2012). The state of the world's sea turtles. [Web page]. Retrieved from http://www.seaturtlestatus.org/, 16 May 2012.

The White House (2010). *Executive Order--Stewardship of the Ocean, Our Coasts, and the Great Lakes*. Retrieved from http://www.whitehouse.gov/the-press-office/executive-order-stewardship-ocean-our-coasts-and-great-lakes

Thurman, H. V. (1997). Primary productivity. In *Introductory Oceanography* (8th ed., pp. 377-378). Upper Saddle River, NJ: Prentice Hall.

Tuya, F., Vanderklift, M. A., Hyndes, G. A., Wernberg, T., Thomsen, M. S. and Hanson, C. (2010). Proximity to rocky reefs alters the balance between positive and negative effects on seagrass fauna. *Marine Ecology Progress Series, 405*, 175-186. doi:10.3354/meps08516

U.S. Department of the Navy. (2005a). *Marine Resources Assessment for the Japan and Okinawa Complexes Operating Area*. (Contract # N62470-02-D-9997, CTO 0028). Pearl Harbor, HI: Pacific Division, Naval Facilities Engineering Command. Prepared by Geo-Marine, Inc., Plano, Texas.

U.S. Department of the Navy. (2005b). *Marine Resources Assessment for the Marianas Operating Area*. (N62470-02-D-9997, CTO 0028). Pearl Harbor, HI: Pacific Division, Naval Facilities Engineering Command. Prepared by Geo-Marine, Inc., Plano, Texas.

U.S. Department of the Navy. (2011). *Marine Resource Assessment for Hawaii-Socal Study Area*. (NAVFAC Atlantic Biological Resource Services Contract, No. N62470–08–D–1008; Task Order KB02). Prepared for Naval Facilities Engineering Command (EV24).

U.S. Environmental Protection Agency (2011a). Ecological risk assessment - Glossary of terms. Retrieved from http://www.epa.gov/region5superfund/ecology/html/glossary.html, 23 March 2011.

U.S. Environmental Protection Agency (2011b, Last updated October 21, 2011). Waste and cleanup risk assessment glossary. Retrieved from http://toxics.usgs.gov/definitions/bioaccumulation.html, 25 March 2011.

United Nations Educational Scientific and Cultural Organization. (2009). *Global Open Oceans and Deep Seabed (GOODS) - Biogeographic Classification*. (IOC Technical Series, 84, pp. 95). Paris, France: UNESCO-IOC.

United States Fish and Wildlife Service (2010). *Endangered Species Act of 1973: As Amended through the 108th Congress*. [Web page] Department of the Interior, US Fish and Wildlife Service. Retrieved from http://www.fws.gov/endangered/laws-policies/esa.html, 05/2010.

Valiela, I. (1995). *Marine Ecological Processes* (2nd ed.). New York, NY: Springer-Verlag.

Vitousek, P. M., Mooney, H. A., Lubchenco, J. and Melillo, J. M. (1997). Human domination of Earth's ecosystems. *Science, 277*(5325), 494-499. doi:10.1126/science.277.5325.494

Wang, W. X. and Rainbow, P. S. (2008). Comparative approaches to understand metal bioaccumulation in aquatic animals. *Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology, 148*(4), 315-323. doi: 10.1016/j.cbpc.2008.04.003

Weersing, K. and Toonen, R. J. (2009). Population genetics, larval dispersal, and connectivity in marine systems. *Marine Ecology Progress Series, 393*, 1-12. doi:10.3354/meps08287

World Resources Institute, Millenium Ecosystem Assessment Board. (2005). *Ecosystems and Human Well-being: Biodiversity Synthesis*. (pp. 100). Washington, DC: World Resources Institute. Available from http://www.millenniumassessment.org/en/Synthesis.aspx

Worm, B., Barbier, E. B., Beaumont, N., Duffy, J. E., Folke, C., Halpern, B. S., et al. (2006). Impacts of biodiversity loss on ocean ecosystem services. *Science, 314*(5800), 787-790. doi:10.1126/science.1132294

Zieman, J. C., Fourqurean, J. W. and Iverson, R. L. (1989). Distribution, abundance and productivity of seagrasses and macroalgae in Florida Bay. *Bulletin of Marine Science, 44*(1), 292-311. Retrieved from http://www.scopus.com/inward/record.url?eid=2-s2.0-0024910621&partnerID=40&md5=28976eab5da8298f51beaf9eb6414d2a

4.0 OCEANOGRAPHY

4.1 INTRODUCTION

This chapter describes the oceanography of the MRA Study Area for the Japan and Mariana Archipelagos (the MRA Study Area). Climate and weather, geological features and processes, ocean currents and circulation, and ocean chemistry and biology all play important roles in the marine ecosystem of the MRA Study Area.

4.2 CLIMATE/WEATHER

The climate of the MRA Study Area ranges from temperate to tropical conditions. The MRA Study Area is prone to numerous tropical cyclones, and undergoes El Niño Southern Oscillation (ENSO) events and other manifestations of climate variability such as the Pacific Decadal Oscillation (PDO). Tropical cyclones occur in the form of tropical depressions, tropical storms, or typhoons. ENSO refers to inter-annual variations in the surface temperature and air surface pressure of the tropical Pacific Ocean (Conlan and Service 2000; Guilyardi et al. 2009). The PDO is a long-term climatic pattern with alternating warm and cool phases (Mantua and Hare 2002; Polovina et al. 1994). Global temperature change, which is affected by increased anthropogentic input of carbon dioxide and other greenhjouse gases, is resulting in changing climate and oceanographic conditions in the MRA Study Area.

4.2.1 Seasons and Storms

The MRA Study Area is characterized by distinct seasons with periods of tropical cyclone activity. A tropical depression is an organized system of clouds and thunderstorms with defined circulation patterns and maximum sustained winds of approximately 63 kilometers (km)/ hour or less (Atlantic Oceanographic and Meteorological Laboratory 2011). A tropical storm is an organized system of strong thunderstorms with a defined circulation and maximum sustained winds of 63 to 119 km/hour. A typhoon is defined as an intense tropical weather system with well-defined circulation, maximum sustained winds of 119 km/hour or higher, and a diameter that spans hundreds of kilometers over warm ocean water (Oahu Civil Defense Agency 2003; Thurman 1997). Storm surge (difference between the mean tide level and the tide level during the tropical cyclone), winds, salt stress, and heavy rainfall generated by tropical cyclones can extensively damage marine and terrestrial resources (Schlappa 2004). The storm surge and excessive rainfalls caused by tropical cyclones can cause flooding, change in nearshore salinity, erosion and sedimentation of marine resources, destruction of shoreline structures, and destruction of terrestrial and marine habitat. Strong winds and salt stress can defoliate and uproot trees, which in turn generates a pulse of debris and nutrients affecting both terrestrial and marine resources (Schlappa 2004). Heavy rainfall and subsequent flooding caused by tropical cyclones may result in changes in nearshore salinity, erosion of coastal habitats, and sedimentation (Schlappa 2004).

JAPAN ARCHIPELAGO. The climate of Japan is characterized by clear-cut temperature changes and climatic patterns that occur among the four seasons (Web Japan 2012). The Japan Archipelago is located within the Asian temperate monsoon climatic region (Isobe 1998; Web Japan 2012). This expansive region encompasses climate regimes from subtropical and humid in the south to temperate and rainy in the north. Hokkaidō, the northernmost of the main Japanese islands, undergoes a subarctic weather pattern in which the annual temperature averages 8 degrees Celsius (°C), and annual rainfall averages 115 centimeters (cm) (Web Japan 2012). When winter ends (February), cold seasonal breezes that blow from Siberia become weaker and more intermittent (Lonely Planet 2003; Web Japan 2012). Meanwhile,

low-pressure systems that reside over China migrate into the Sea of Japan and give rise to strong, warm, southerly winds that originate in the Pacific Ocean (Web Japan 2012). The first of these strong winds, the "haru ichiban," signals the arrival of spring.

Japan experiences a damp, rainy period, known as "baiu" or "tsuyu" from May until July. During this time, a high-pressure mass of cold air settles above the Okhotsk Sea north of Japan. Concurrently, a high-pressure mass of warm moist air develops over the Pacific Ocean. Where these two air masses meet, the "baiu zensen" (or rainy front), regions of warm, low-pressure air often develop, creating prolonged periods of high temperature, high humidity, and continuous rainfall from southern China to the Japanese Archipelago (U.S. Department of the Navy 1994; Web Japan 2012). Around mid-July, high-pressure systems over the Pacific Ocean dominate, and the baiu zensen is forced north, bringing the rainy period to an end. For the remainder of the summer months (through August), seasonal Pacific winds transport warm, moist air to Japan, resulting in hot weather throughout the country (JTB USA 2005; Lonely Planet 2003; Web Japan 2012).

Beginning in late summer and extending through September, Japan is often struck by typhoons (U.S. Department of the Navy 1994; Web Japan 2012). After mid-October, Japan experiences clear weather and predominantly mild temperatures (Web Japan 2012). For Okinawa, the typhoon season spans from late May through November, with peak storms in August and September (U.S. Department of the Navy 2004). Near the end of November, cold seasonal winds from the Asian continent begin to blow over Japan. These northwesterly winds pick up moisture from the Sea of Japan and drop rain or snow along the western coast of Japan (Web Japan 2012). In contrast, the eastern regions of Japan experience relatively clear conditions throughout the winter (December through February).

Along the Pacific coast of Japan from northern Honshū to Kyūshū, the climate is temperate, with hot summer months (26°C) influenced by the seasonal winds of the Pacific (U.S. Department of the Navy 1997a; Web Japan 2012). On northern tip of Honshū (Aomoi prefecture), the average daily wind speed ranges from 6–11 miles per hour (mph) and the prevailing winds are from the southwest (WeatherSpark 2012a). On the eastern side of Kyūshū (Miyasaki prefecture), the average daily wind speed ranges from 8 – 10 mph and the prevailing wind are from the west (WeatherSpark 2012c). On the western side of Kyūshū (Fuyuoka prefecture), the average daily wind speed ranges from 6–8 mph and the prevailing winds are from the southeast (WeatherSpark 2012b). Winters are cold, with average temperatures declining to 4.5°C in January (U.S. Department of the Navy 1997a). Relative humidity ranges from a low of 55 percent (%) in the winter months to approximately 80% during the rainy seasons. Precipitation (100 to 250 cm annually) typically falls during the two rainy periods (mid-June to mid-July and September through October), with snow falling only once or twice per year (U.S. Department of the Navy 1997a, b). The western side of Japan faces the Sea of Japan and experiences high levels of precipitation (rain and snow) produced by cold, humid seasonal winds from the Asian continent; these winds are impeded by the mountain ranges running along the center of the island and do not reach the eastern shores (Web Japan 2012).

The island of Kyūshū experiences a subtropical humid climate (U.S. Department of the Navy 1997b, 1998). Summer months in the region tend to be rainy and warm (up to 35°C), while winter months are moderately cool (4 to 7°C) and dry (U.S. Department of the Navy 1998). The climate is tempered by the flow of the Tsushima current along the western coast, but this influence is often offset by the northwesterly winds from the Asian mainland. Annual precipitation averages 161 cm along the northwestern coast and up to 252 cm along the southwestern coast (U.S. Department of the Navy 1997b, 1998).

The southwestern islands of Okinawa also experience a subtropical climate with average temperatures often exceeding 22°C; the region receives more than 200 cm of precipitation annually (U.S. Department of the Navy 2004; Web Japan 2012). The average daily wind speed from ranges from 9 – 10 mph and the prevailing winds are from the northeast (WeatherSpark 2012d). Approximately 60% of the rainfall occurs during May through September (U.S. Department of the Navy 2004). The local subtropical climate keeps Okinawa warm during the winter months (U.S. Department of the Navy 1997b).

The Japan Archipelago is prone to numerous seaborne natural disasters, including tropical cyclones, typhoon-induced flooding, high waves, and large tsunamis (Isobe 1998). Typhoons rank as the most expensive and deadly natural catastrophe affecting Japan, South Korea, Taiwan, and the Philippines. On average, 2.6 typhoons make landfall over Japan during summer and fall annually (Japan Meteorological Agency 2012a, b). Typhoons did not make landfall in 1984, 1986, 2000 and 2008 (Hays 2011). The record year for typhoons was 2004 in which 10 typhoons made landfall. From 1955 through 1994, 51 severe typhoons reached mainland Japan (Fujii 1998; Saunders et al. 2000). In 1959, Typhoon Vera (Isewan) created a high storm surge resulting in more than 5,000 deaths. In 1991, Typhoon Mireille damaged more than 680,000 wooden houses and caused damages that amounted to $5 billion United States (Fujii 1998). In the western Pacific, typhoon season extends from late spring through October (Limsakul et al. 2002). An analysis of tropical cyclone activity between 1977 and 2008 found that the number and intensity of tropical cyclones that made landfall in Japan increased during that period (Park et al. 2011). Increased intensity of tropical cyclones may be caused by warmer sea surface temperature (SST) and a more humid troposphere, the lowest portion of the atmosphere.

Typhoons striking Japan originate from large masses of tropical low-pressure air in the North Pacific near the U.S. Territory of Guam (Guam) between 5 degrees (°) and 20°N; the time of formation is closely related to the interannual variations of monsoons (Kadena Web Team 2005; Lander 1994; U.S. Department of the Navy 1997a; Web Japan 2012). When a typhoon begins to develop, it gradually moves north toward Taiwan and Okinawa before turning to the northeast (U.S. Department of the Navy 1997a). Annually, approximately 30 typhoons form in the Pacific, four of which reach Japan (Web Japan 2012). These typhoons threaten all of Japan because of flooding and high waves (Isobe 1998; U.S. Department of the Navy 1998). Okinawa lies in what is considered the Pacific Ocean's "Typhoon alley." Typhoon approaches to Okinawa are frequent between July and November, with the greatest numbers in August and September. However, usually only three or four storms pass close to the islands annually (Kadena Web Team 2005). The number of tropical cyclones making landfall along the western North Pacific coastlines is significantly smaller during El Niño years than during neutral years, except along the Japan and Korean Peninsula (Table 4-1) where no difference was found (Lander 1994; Saunders et al. 2000; Wu, Chang, and Leung 2004).

Table 4-1: Average Number of Landfalling Tropical Cyclones in the Western North Pacific During El Niño, La Niña, and Neutral Years

Area	June through August			September through November		
	El Niño	La Niña	Neutral	El Niño	La Niña	Neutral
Japan and Korea	3.0	2.8	2.8	1.2	0.8	1.44
China	5.1	4.8	4.9	1.7	4.0	2.8
Indochina and Thailand	1.8	1.3	1.5	1.7	3.8	2.9
Philippines	1.4	2.0	1.9	1.3	4.3	3.2

Source: Wu, Chang, and Leung (2004).

MARIANA ARCHIPELAGO. The tropical climate of the Mariana Archipelago 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°C during the day and drop to 21° to 24°C overnight (Department of Defense 1999; Eldredge 1983). January, February, and March are generally the coolest months of the year; May and June are the warmest. Throughout the year, relative humidity ranges from 65 to 75% in the afternoon and increases at night to 85 to 100%. In Guam, average monthly wind speeds range from 6.2 – 11.3 mph with an annual average wind speed of 9.1 mph (National Climatic Data Center 2008). Annual rainfall ranges from 178 to 295 cm/year (yr), with the more southerly (more tropical) islands receiving higher levels of rainfall than the more northern islands. The Mariana Archipelago experiences two distinct seasons, a dry and a rainy season, separated by brief periods of transitional weather (Department of Defense 1999; Eldredge 1983). Climatic anomalies influencing the MRA Study Area include ENSO, La Niña, and the PDO (Giese and Carton 1999; Mantua 2002; National Oceanic and Atmospheric Administration 2005a, b; Sugimoto, Kimura, and Tadokoro 2001; Trenberth 1997). Annual mean temperature in the Commonwealth of the Northern Mariana Islands is 27.7 °C (Pacific RISA 2012a), and the average annual rainfall is 127 cm/ yr. In 2007, annual mean temperature in Guam was 27.7°C (Pacific RISA 2012e), and annual rainfall totaled 203-279 cm.

During normal conditions, trade winds blowing west across the tropical Pacific pile up warm water in the west Pacific (approximately 0.5-meter [m] sea surface height [SSH] difference between Indonesia and Ecuador) (Conlan and Service 2000; National Oceanic and Atmospheric Administration 2005a, b). The equatorward flow of the eastern boundary Peru Current along the South America coastline and the easterly trade winds cause offshore transport of cool surface water (National Oceanic and Atmospheric Administration 2005b; Pickard and Emery 1982) 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 production (the rate at which the biomass of organisms changes) and higher trophic levels (including fisheries). Under these normal conditions, rainfall is scarce in the eastern Pacific and is concentrated over the warmest water in the west Pacific.

The dry season (December to June) is characterized by strong and consistent trade winds blowing from the east to northeast at 24 to 40 km/hour (Eldredge 1983; Paulay 2003). Winds are heaviest during the late morning and afternoon, and are lightest during the night. On average, less than 20% of the MRA

Study Area's rain falls during the dry season, and thunderstorms are rare (Department of Defense 1999; Eldredge 1983).

During the rainy season from July through December (also the high tropical cyclone season), the Mariana Archipelago experiences heavy winds and rains, with squalls and gales becoming more common (Department of Defense 1999; Eldredge 1983; Kubota and Wang 2009). Rain falls during more than 75% of the days. More than 60% of the annual rainfall is received during the rainy season. Tropical cyclones, however, account for only 30% of the rainfall in Guam during this period (Kubota and Wang 2009).

The Mariana Archipelago is prone to frequent and often severe tropical cyclones (Starmer et al. 2008). Tropical storms occur during humid summer months. Tropical cyclones commonly traverse the Mariana Archipelago from August to November, with the peak typhoon season extending from July through October (Elsner and Liu 2003).

Typhoons have damaged algal and coral communities of the Mariana Islands (Paulay 2003; Randall and Eldredge 1977). 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 recurrent typhoon wave damage (Paulay 2003; Schlappa 2004).

CAROLINE ISLANDS. The Federated States of Micronesia (FSM) and Republic of Palau (Palau) have a tropical climate. The average annual temperature in the FSM ranged from 26.9°C in Yap to 27.9°C in Pohnpei in 2007 (Pacific RISA 2012b). In Yap, average monthly wind speeds range from 6.4 – 10.1 mph) with an annual average wind speed of 8.0 mph (National Climatic Data Center 2008). In Palau, average monthly wind speeds range from 6.2 – 7.8 mph with an annual average wind speed of 6.8 mph (National Climatic Data Center 2008). The rainy season is from November through March. Annual rainfall ranged from 350 cm in Yap to 240 cm in Pohnpei in 2007. Although largely outside the major typhoon tracks, development of Pacific typhoons can originate in the FSM. Typhoons that have made landfall in Yap and Saipan resulting in storm surge and extreme sea levels (Chowdhury, Chu, et al. 2010).

The annual mean temperature in Palau is 28°C (Pacific RISA 2012d). Average annual rainfall in 2007 was 325 cm. The dry season is typically between February and April. Winds in Palau are typically light to moderate. Northeast trade winds are the predominant wind conditions from December to March; these decrease in April. Palau is outside the typhoon belt.

4.2.2 El Niño-Southern Oscillation

ENSO results from interannual changes in sea level pressure between the eastern and western hemispheres of the tropical Pacific (Gergis and Fowler 2009). Sea level pressure is the atmospheric pressure measured at mean sea level (MSL). During an El Niño, sea level pressure tends to be lower in the eastern Pacific and higher in the western Pacific. The opposite occurs during a La Niña. This "see-saw" in atmospheric pressure between the eastern and western tropical Pacific is called the Southern Oscillation (International Research Institute for Climate and Society 2007). A standard measure of the Southern Oscillation is the difference in sea level pressure between Tahiti and Darwin, Australia. These events can initiate large shifts in climate, atmospheric circulation, and oceanographic processes (Jacobs et al. 1994).

The North Pacific atmosphere-ocean system fluctuates with periods of 2 to 6 years in response to the southern oscillation (Nakamura, Lin, and Yamagata 1997). During normal, non-El Niño/La Niña conditions, trade winds blow west across the tropical Pacific and cause warm water to pile up in the

west Pacific (about 0.5 m SSH difference between Indonesia and Ecuador) (Conlan and Service 2000; National Oceanic and Atmospheric Administration 2005a, b). Under these normal conditions, rainfall is low in the eastern Pacific and is high over the warm waters of the western Pacific.

El Niño conditions occur when unusually high atmospheric pressure develops over the western tropical Pacific and Indian Oceans, and low sea level pressure develops in the southeastern Pacific (Conlan and Service 2000; Trenberth 1997). The trade winds weaken in the central and west Pacific; thus, the normal east to west surface water transport and upwelling along South America decreases. This decrease in turn causes the SST to increase across the mid- to eastern Pacific (Donguy et al. 1982). In the western equatorial Pacific, SST decreases (Kubota 1987) and rainfall patterns shift eastward across the Pacific, resulting in increased (and sometimes extreme) rainfall across the southern U.S. and Peru and drought in the western Pacific (Conlan and Service 2000). Historically, strong El Niño events have been documented in 1940, 1958, 1966, 1969, 1983, 1986, 1987, 1992, 1997 to 1998, 2003, 2004, 2007, and 2010 (Hayward 2000; Scripps Institution of Oceanography 2011).

The recurring El Niño pattern is one of the strongest in the ocean atmosphere system (Gergis and Fowler 2009). El Niño is associated with unusually warm ocean temperature and high air surface pressure. El Niño conditions typically last 6 to 18 months, although they can persist for longer periods of time (Barber and Chavez 1983; Durazo et al. 2001; Lynn et al. 1998; Schwing et al. 2002). Upwelling of cold, nutrient rich water along the coasts of North and South America is drastically reduced during El Niño conditions.

El Niño plays an important role in the formation of tropical cyclones across the Pacific Ocean (Fletcher et al. 2002) and in the interannual variability of rainfall associated with tropical cyclones (Kubota and Wang 2009). During the onset of an El Niño, changes in the equatorial wind patterns of the central Pacific region create a zone of high shear between the subtropical winds flowing to the east and west-flowing winds along the equator; cyclonic disturbances can develop into hurricanes in these shear zones (Fletcher et al. 2002). Under normal climatic conditions, waters of the central Pacific Ocean retain enough heat to permit formation of hurricanes but lack the necessary atmospheric disturbances for hurricane formation. However, tropical storms gradually form farther eastward during the onset of El Niño as the shear zone between eastward and westward blowing winds migrate from the western Pacific into the central Pacific region (Fletcher et al. 2002). Tropical cyclones tend to occur more in the eastern Pacific during El Niño conditions (Kubota and Wang 2009).

Recently, the El Niño Modoki event has been described that has different patterns of sea surface warming and cooling that typically described for El Niño (Ashok and Yamagata 2009; Japan Agency for Marine-Earth Science and Technology 2012). During an El Niño Modoki, increased SSTs occur in the central Pacific flanked by colder waters to the east and west (Ashok and Yamagata 2009; Weng et al. 2007). This creates a condition of atmospheric convection.

La Niña is the opposite phase of El Niño in the Southern Oscillation cycle (National Oceanic and Atmospheric Administration 2005a). La Niña events are characterized by stronger than average easterly trade winds that push the warm surface waters of the tropical Pacific to the west and enhance upwelling along the eastern Pacific coastline (Bograd et al. 2000; Schwing et al. 2000). Under these conditions and as a result of the increased upwelling along the eastern Pacific coastline, the thermocline in the western Pacific deepens and the thermocline in the eastern Pacific becomes shallower; this shift results in abnormally cold SST and low air surface pressure along the equatorial Pacific. Often with La Niña, the climatic effects are the opposite of those encountered during an El Niño warming event (higher SST in

the western equatorial Pacific, high production along Pacific upwelling coasts, and heavy rainfall in Australia and Indonesia (National Oceanic and Atmospheric Administration 2005a).

JAPAN ARCHIPELAGO. The number of tropical cyclones the make landfall in Japan and other countries riming the western North Pacific is significantly reduced during El Nino years (Trenberth 1997; Wu, Chang, and Leung 2004). In Japan, climatic shifts tend to be delayed, with maximum development of El Niño conditions occurring from September through February (Chen et al. 1998). These shifts result in a weaker than normal winter monsoon along the East Asian coast. Consequently, the climate along East Asia is warmer and wetter than normal during an El Niño winter and the ensuing spring. El Niño events shift the spawning areas of Japanese eels (*Anguilla japonica*) south reducing the likelihood of eel recruitment to coastal habitats in Japan (Kim et al. 2007).

MARIANA ARCHIPELAGO. The Mariana Archipelago 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 event, 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, the Hadley circulation (in which warm air rises from the equator and travels to the north and south, sinking at 30°) generally weakens. 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). Furthermore, typhoons in the western Pacific basin are more frequent during warm ENSO periods, although their tracks are oriented northwest and away from the Mariana Archipelago (Elsner and Liu 2003; Saunders et al. 2000). Sea level variability around the Mariana Archipelago has been found to be strongly influenced by the ENSO with low sea level occurring during El Niño and high sea level occurring during La Niña events (Chowdhury, Chu, and Schroeder 2007; Fletcher and Richmond 2010).

During La Niña, Guam experiences a deficit in rain during the dry and rainy season (86% of historical averages during the dry season and 87% of historical averages during the rainy season) (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). Guam experienced high sea levels for a period of 18 months during the 2006 to 2008 El Niño and La Niña events (Chowdhury, Barnston, et al. 2010).

CAROLINE ISLANDS. The Caroline Islands have experienced drought conditions during extreme ENSO events, especially when the El Niño condition has moved into the Western Pacific (Pacific RISA 2012b). Yap experienced high sea levels for a period of 18 months during the 2006 to 2008 El Niño and La Niña events (Chowdhury, Barnston, et al. 2010). Sea level variability around the Caroline Islands have been found to be strongly influenced by the ENSO with low sea level occurring during El Niño and high sea level occurring during La Niña events (Chowdhury, Chu, and Schroeder 2007). The distribution of skipjack in linked to large zonal displacements of the warm pool that occur during ENSO events. In the equatorial Pacific, skipjack are concentrated around 150° E during La Niña conditions and spread out to the east to 70° W during El Niño conditions (Lehodey et al. 1997).

4.2.3 Pacific Decadal Oscillation

The PDO occurs every 20 to 30 years when average temperatures of surface waters of the central and northern Pacific Ocean (20° N and poleward) shift several degrees. This oscillation affects primary production in the eastern Pacific Ocean and, consequently, affects organism abundance and distribution throughout the food chain. The PDO is linked to variability of the Aleutian Low Pressure System and is often described as a long-lived El Niño-like pattern of Pacific climate variability with both warm and cool phases (Mantua 2002; Mantua and Hare 2002; Minobe, Sako, and Nakamura 2004). However, the PDO possesses three characteristics that distinguish it from ENSO events and El Niño. First, PDO events can persist for 20 to 30 years, in contrast to the relatively short duration of the ENSO (typically up to 18 months (Hare and Mantua 2000; Mantua and Hare 2002; Minobe 1997, 1999). 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 are well understood (Mantua and Hare 2002).

Warm phases of the PDO coincide with anomalously cool and dry conditions along the western Pacific (Gordon and Giulivi 2004; Mantua and Hare 2002). SSTs in the North Pacific Ocean declined during the last warm phase of the PDO and tended to be lower than average until a shift to the cool phase of the PDO (Nakamura, Lin, and Yamagata 1997). During a positive PDO (warm phase), a large pool of cold water centers northwest of Hawaiʻi and extends to Japan (Hare 1998). SSH is also affected by the PDO; higher SSH occurs along Japan during negative (cool) phases of the PDO. The change in SSH appears to be related to changes in flow of the Kuroshio Current, which is weaker during a negative PDO. The decrease in flow from the Kuroshio Current enhances the Tsushima Current, which can affect the SSH in the Sea of Japan (Gordon and Giulivi 2004).

4.2.4 Climate Change

Climate change is believed to impact the MRA Study Area in several ways, including increased intensity of storms, increased SST, sea level rise, and ocean acidification (Intergovernmental Panel on Climate Change 2007).

The temperature in Japan has risen 1.1°C since 1898 (Ministry of Education Culture Sports Science and Technology, Japan Meteorological Agency, and Ministry of the Environment 2009). Significant temperature rise has occurred in all seasons within all four areas of Japan: Northern, Eastern, Western Japan, and Okinawa-Amami. The number of days with daily precipitation over 10 cm has increased. No clear long-term trends have been observed regarding the number of tropical cyclones or sea level rise. Increasing concentration of carbon dioxide in surface water has been observed.

Pacific Islands have experienced rising temperatures and sea levels in recent decades. Climate change projections through this century suggest increases in both air and ocean surface temperatures, increased frequency of heavy downpours, and increased rainfall during summer months (Karl, Melillo, and Peterson 2009). A 30% increase in rainfall and hotter climate is expected for the Central Equatorial Pacific. SST has increased by about 0.4°C throughout the 20th century, resulting in an increased frequency of El Niño episodes (Food and Agriculture Organization of the United Nations 2008). Global sea level rise projections range from 0.18 to 0.58 m for 2090 to 2099 relative to 1980 to 1999, and tropical cyclones are expected to increase in intensity with higher peak wind speeds and rainfall (Intergovernmental Panel on Climate Change 2007). Ocean pH has decreased by approximately 0.1 unit since the beginning of the industrial revolution as a result of absorption of increased atmospheric

carbon dioxide (Hoegh-Guldberg et al. 2009; National Research Council of the National Academies 2010). The Pacific Islands Region Climate Assessment, under preparation, will provide information regarding regional climate change relevant to the Mariana Archipelago (Pacific RISA 2012c).

4.3 MARINE GEOLOGY

Marine geology includes studies of bathymetry, submarine features, and geological processes. This section focuses on bathymetry, submarine features, and substrate of the MRA Study Area. Seismic activity and volcanism are also discussed as important geological processes in the MRA Study Area.

4.3.1 Bathymetry and Physiography

Submarine geologic features and bathymetry are major factors influencing the biology and ecology of marine life in the ocean. From the continental shelf to the deep sea abyssal plains and hadal zones, submarine geologic features influence nutrient upwelling and ocean circulation, and provide habitat for marine life. The depth of the continental shelf averages 200 m (Tomczak and Godfrey 2003; United Nations Educational Scientific and Cultural Organization 2009). The continental slope begins at the continental shelf break and falls off to the ocean floor. It is divided into marine depth zones of the upper slope (200–800 m), adjacent to the shelf break; mid-slope (about 800–1,400 m); and lower slope (1,400–4,000 m). The deep seabed is classified as bathyal (800–3,500 m), abyssal (3,500 and 6,500 m), and hadal (below 6,500 m). The abyssal plain is a relatively flat or gently sloping ocean floor that continues from the lower continental slope.

The MRA Study Area encompasses the full range of submarine geologic features, with depths from high tide to 11,033 m, the maximum depth of the Mariana Trench. The bathmetry of the MRA Study Area is shown in a series of maps including three-dimensional views and depth zones (Figure 4-1 to Figure 4-6). Isolated seamounts and clusters of seamounts, found throughout the MRA Study Area (Figure 4-7 and Figure 4-8), alter ocean flow and result in areas of enhanced localized productivity and diversity in the ocean (Lavelle and Mohn 2010). Deep sea geologic features including trenches, basins, and abyssal plains, shown in Figure 4-9 and Figure 4-10, cover large areas of the sea floor in the North Pacific Ocean and MRA Study Area. Finally, the MRA Study Area includes numerous active submarine and emergent volcanic arcs shown in Figure 4-11 and Figure 4-12. Volcanic activity associated with the MRA Study Area is further discussed in Section 4.3.3 Geological Processes.

NORTH CENTRAL PACIFIC GYRE. The North Central Pacific has numerous submarine geologic features and encompasses a range of depths from intertidal to abyssal zones (Figure 4-1 and Figure 4-5). The Hawaiian Archipelago, composed of high islands, reefs, banks, atolls, and seamounts, is the predominant geologic feature in the middle of the North Central Pacific (Polovina et al. 1994). Volcanic islands, seamounts (Figure 4-7), and atolls in this region are formed by “hot spots”—plumes of molten rock that rise from the earth’s interior (Grigg 1997). Islands are formed when a volcano reaches the sea surface. The abyssal zone of the North Central Pacific is divided into the North Central Pacific Basin, the Northeast Pacific Basin, and Northwest Pacific Basin (Figure 4-9). The Hess Rise is a large plateau that occurs to the east of the Hawai‘i Emperor Seamount Chain and the Shatsky Rise (Nemoto and Kroenke 1981). The Emperor Trough and numerous fracture zones, including the Mendocino Fracture Zone, dissect the abyssal plain of the North Central Pacific (Nemoto and Kroenke 1981).

Submarine geological features of the MRA Study Area occur along the western edge of the North Central Pacific and include areas west of the Japan Archipelago and Mariana Archipelago (Figure 4-2, Figure 4-6 Figure 4-10, and Figure 4-12). The submarine geologic features in the vicinity of the Japan Archipelago

are numerous and complex (Hashimoto 1991). The Japan Archipelago is formed from the subduction of the Pacific plate under the Asian continent forming island arcs and basins. The continental margin offshore of the Bōsō Peninsula is at a depth of 140–160 m. Well-developed submarine canyons cut through the shelf edge. The shelf off Sagami Bay ranges from 2–8 km in width with a shelf break at 110 to 103 m. The shelf break off the eastern coast of Kyūshū is 120–140 m in depth.

Submarine trenches in the vicinity of the Japan Archipelago from north to south include Kuril Trench, Japan Trench, Isu-Ogasawara Trench, Sagami Trench, Nakai Trough, and Ryukyu Trench (Figure 4-10). Associated with these trenches are the island arcs of the Kurile Islands, eastern Hokkaidō, Northwestern Japan, and Izu-Ogasawara Islands. The Nakai Trough is less than 6,000 m in depth, shallower than other trenches in the MRA Study Area. The Daito Ridges, composed of the Amami Plateau, Daito Ridge, and Okidaito Ridge, range in depth from 2,000 to 3,000 m. The depth of the Shikoko Basin is about 4,600 m.

The Mariana Islands are part of the island arc called the Mariana Ridge. The Mariana Ridge formed as active volcanoes emerged from the ocean floor over the subducting Pacific Plate (Figure 4-10 and Figure 4-12). 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). The Mariana Ridge consists of both active and extinct volcanoes (Figure 4-12). The latter are the islands of Guam, Rota, Tinian, Saipan, and Farallon de Medinilla (FDM). In general, these islands are surrounded by shallow fringing reefs with the occasional boulder breaking the water surface. Barrier reefs are present on the lee side of the islands of Guam and Saipan, and a large shoal area is 2 km north of FDM at a water depth of 36.5 m (Eldredge 1983; Randall 1979). New multichannel seismic profiles and bathymetric data have been produced that image the West Mariana Ridge and Trough (Oakley et al. 2009).

The Mariana Trench runs from approximately 11°N, 141°E to 25°N, 143°E in an arc-like pattern extending more than 2,270 km in the western North Central Pacific (Figure 4-10). 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 5,000-11,000 m, with the deepest locations southwest of Guam and becoming shallower northward. North of 14°N, the Mariana Trench shallows to a depth of less than 9 km (Fryer et al. 2003). Located within the trench is the deepest known point on the earth's seafloor, Challenger Deep (11,034 m; 11°22'N, 142°25'E), and the second deepest point, Hawaii Mapping Research Group Deep (10,732 m; 11°50'N, 144°30'E) (Fryer et al. 2003). Water mass characteristics at varying depths within the trench suggest that the waters of the Mariana Trench are not significantly different from those on the abyssal plain north of the Marshall Islands (2,000 km to the east) (Mantyla and Reid 1978).

EAST CHINA SEA. The East China Sea has two major bathymetric zones: a broad continental shelf, known as the Tunghai Shelf, and deep waters of the Okinawan Trough (Naval Environmental Prediction Research Facility 1988a). The Tunghai Shelf is part of one of the largest in the world, extending from the Yellow Sea south through the Taiwan Straits to the South China Sea and the Gulf of Tonkin. The shelf width is about 150 nautical miles at the southern boundary of the East China Sea and broadens northward near the northern boundary (near 33° N) (Naval Environmental Prediction Research Facility 1988b). Most of this shelf has depths less than 100 m, with the shelf break at 150–170 m. The Okinawa Trough extends from Taiwan to Kyūshū. A large area of the trough has depths of 1,000 m with a maximum depth of 2,700 m.

PHILIPPINE SEA. The Philippine Sea is an abyssal zone with deep basins, ridges, seamounts, and island arcs (Naval Environmental Prediction Research Facility 1988c). The West Philippine Basin, Parece Vela

Basin, and Mariana Trough are the prominent basins in the Philippine Sea (Figure 4-10). The Parece Vela Basin is a back-arc basin with a depth of approximately 5,000 m (Mrozowski and Hayes 1979). The Mariana Trough 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, Murakami, and Saito 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 that is spreading at a rate of 0.3 to 1.0 cm/yr in the northern region (Taylor and Martinez 2003; Yamazaki, Murakami, and Saito 1993).

The West Mariana Ridge is the southwestern component of the Izu-Bonin-Mariana arc system (Gardner 2010). Nearly 3,000 km long, the West Mariana Ridge resides on the eastern edge of the Philippine Sea plate. The West Mariana Ridge separates the Mariana Trough and the 5,000 m Parece Vela Basin. The West Mariana Ridge runs north-south to the east of the Parece Vela Basin, with the Mariana Trough to the east. The West Mariana Ridge merges with the Parece Vela Basin at water depths of almost 5,000 m. Several volcanic seamounts that form the West Mariana Ridge rise almost to the sea surface.

The Kyūshū-Palau ridge is approximately 2,000 km long and runs north-south through the Philippine Sea, separating the West Philippine Basin to the west and Parece Vela Basin to the east. The Kyūshū-Palau Trench runs north to south and ranges in depth from 6,800 to 8,000 m (Kobayashi 2004).

EQUATORIAL PACIFIC. The Caroline Islands span across the East and West Caroline Basins in the western Equatorial Pacific (Tomczak and Godfrey 2003). The Caroline Ridge intersects Yap Trench. The islands and submerged arcs of Palau are an extension of the Kyūshū-Palau Ridge, ranging in age from 37.7–20.1 million years. The depth of the Yap Trench ranges from 6–9 km (Japan Agency for Marine-Earth Science and Technology 2000a). The Yap Trench intersects the Palau and Mariana Trenches and is where the Philippine Sea, Pacific, and Caroline plates converge (Japan Agency for Marine-Earth Science and Technology 2000b).

This Page Intentionally Left Blank

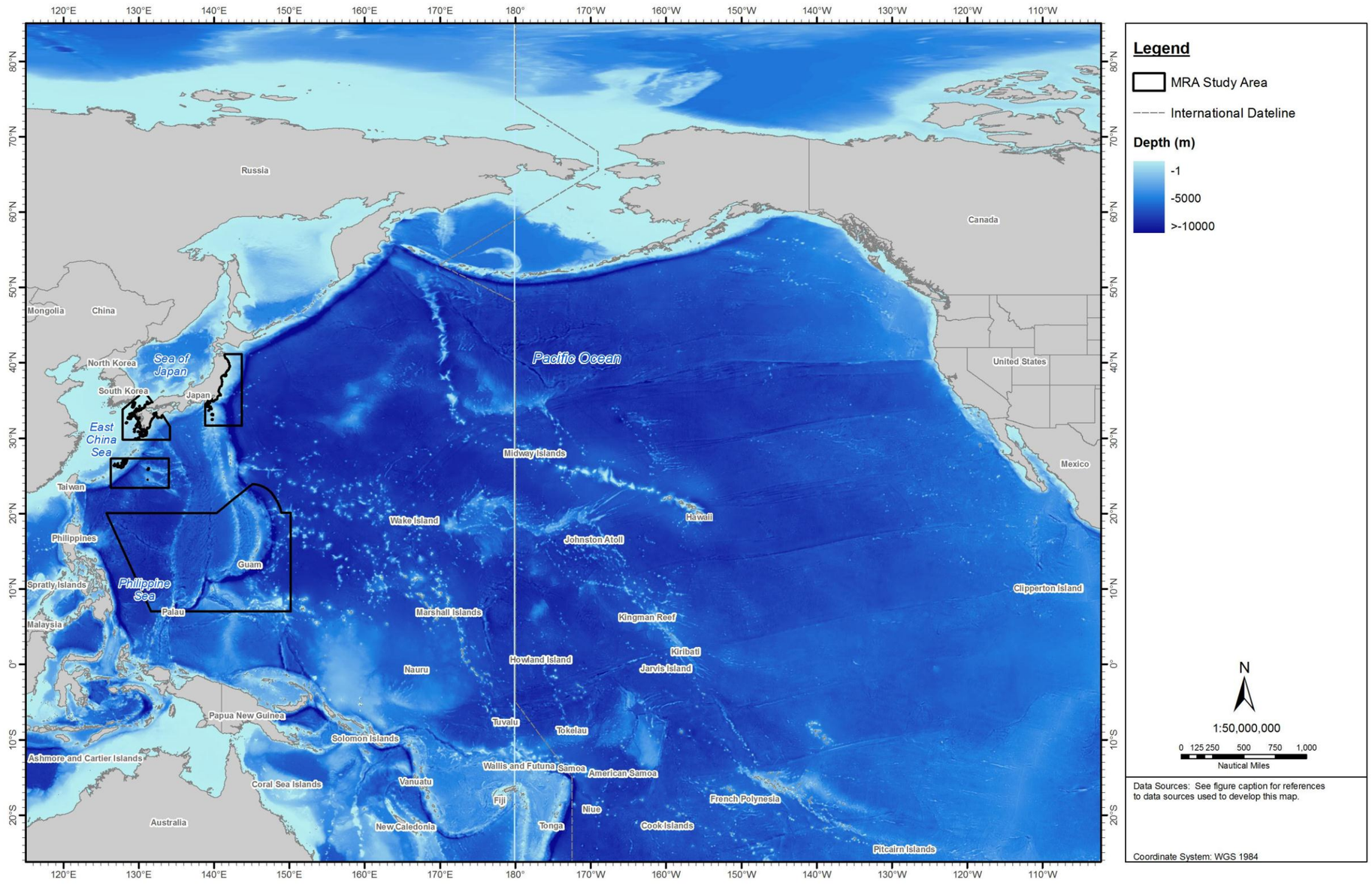

Figure 4-1: Bathymetry of the North Pacific Ocean

Sources: Intergovernmental Oceanographic Commission, International Hydrographic Organisation, and British Oceanographic Data Centre (2003) and Tetra Tech (2010).

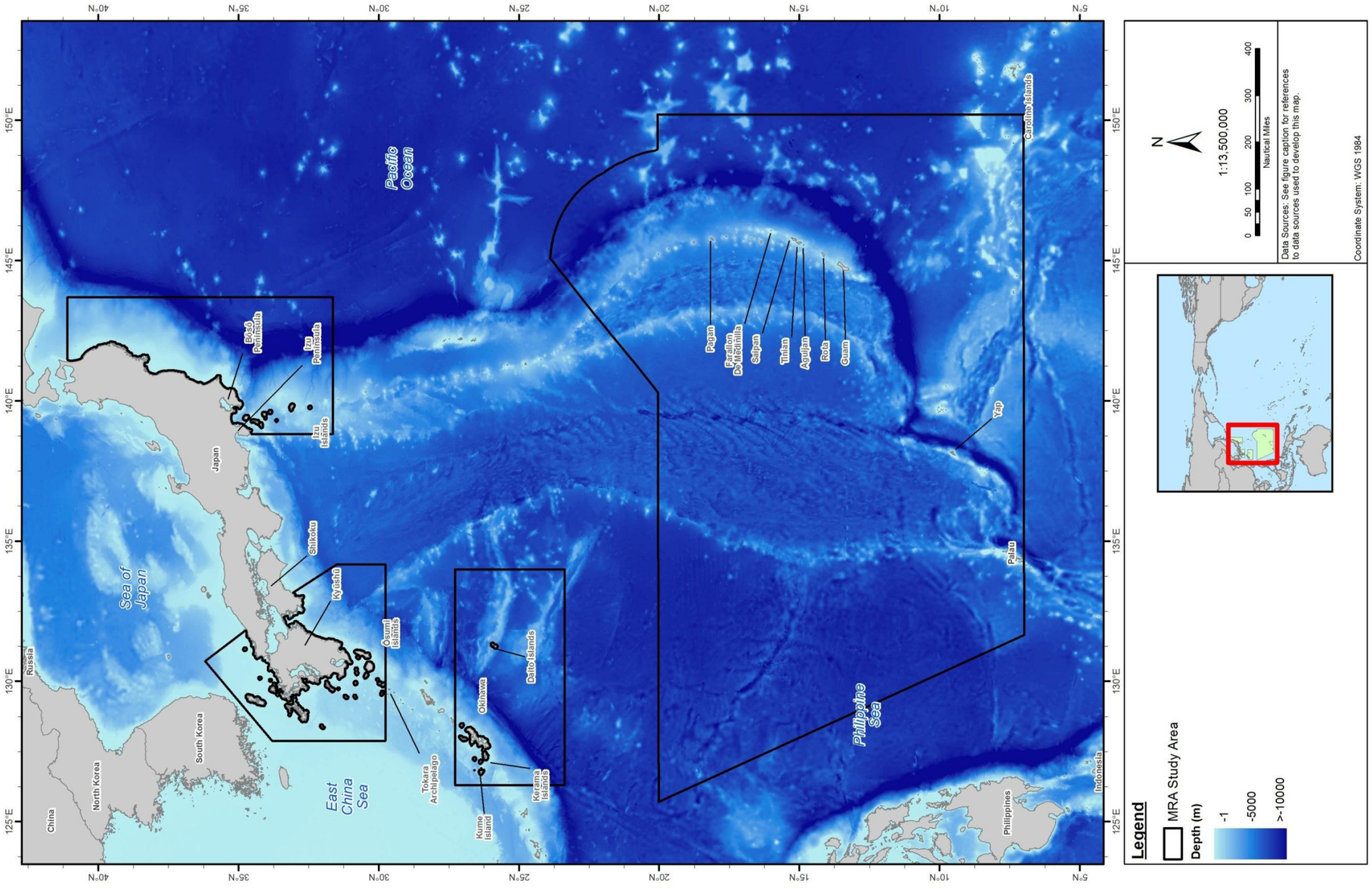

Figure 4-2: Bathymetry of the MRA Study Area

Sources: Intergovernmental Oceanographic Commission, International Hydrographic Organisation, and British Oceanographic Data Centre (2003) and Tetra Tech (2010).

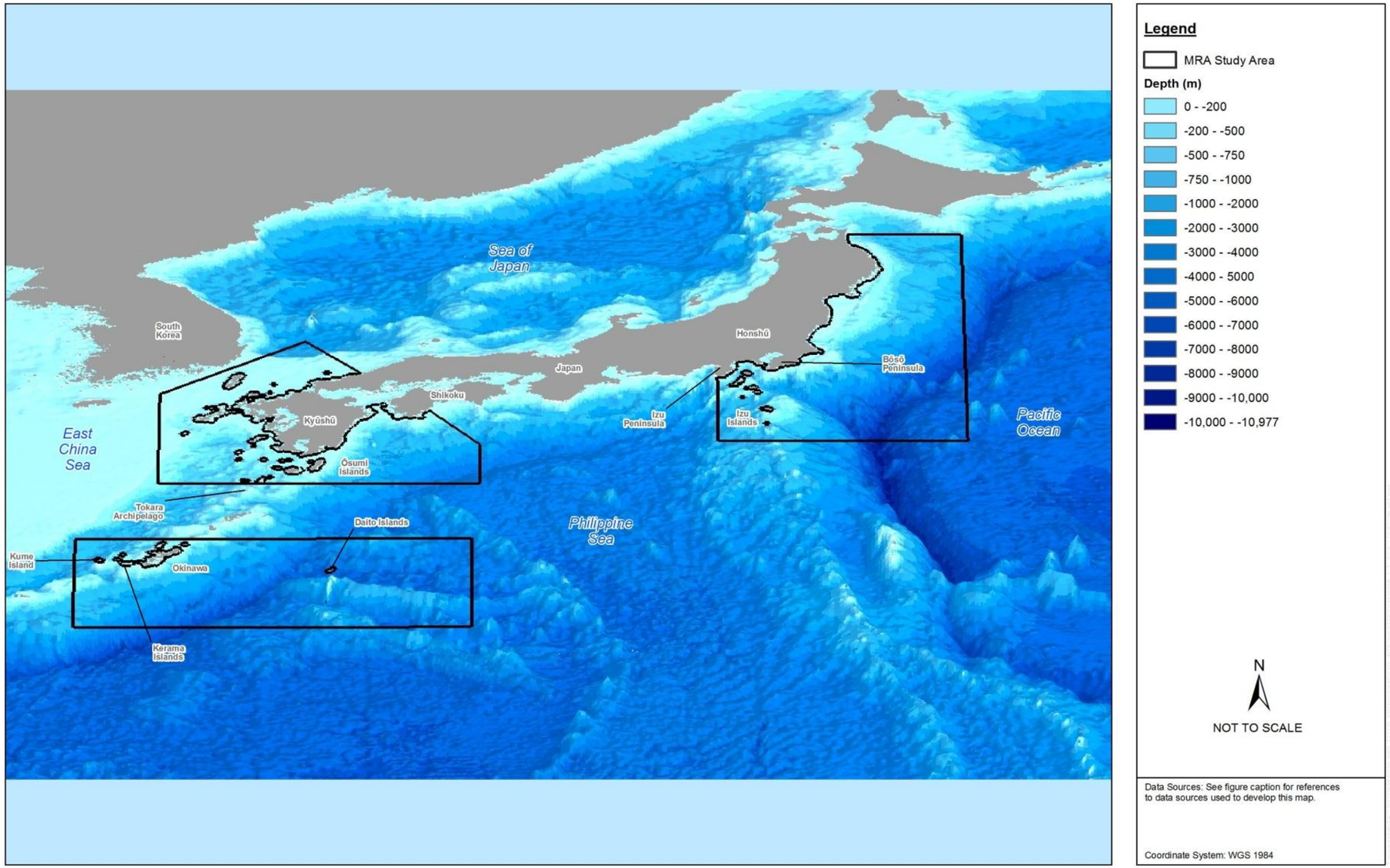

Figure 4-3: Three-dimensional View of the Bathmetry of the Japan Archipelago Portion of the MRA Study Area
Source: U.S. Department of the Navy (2005a).

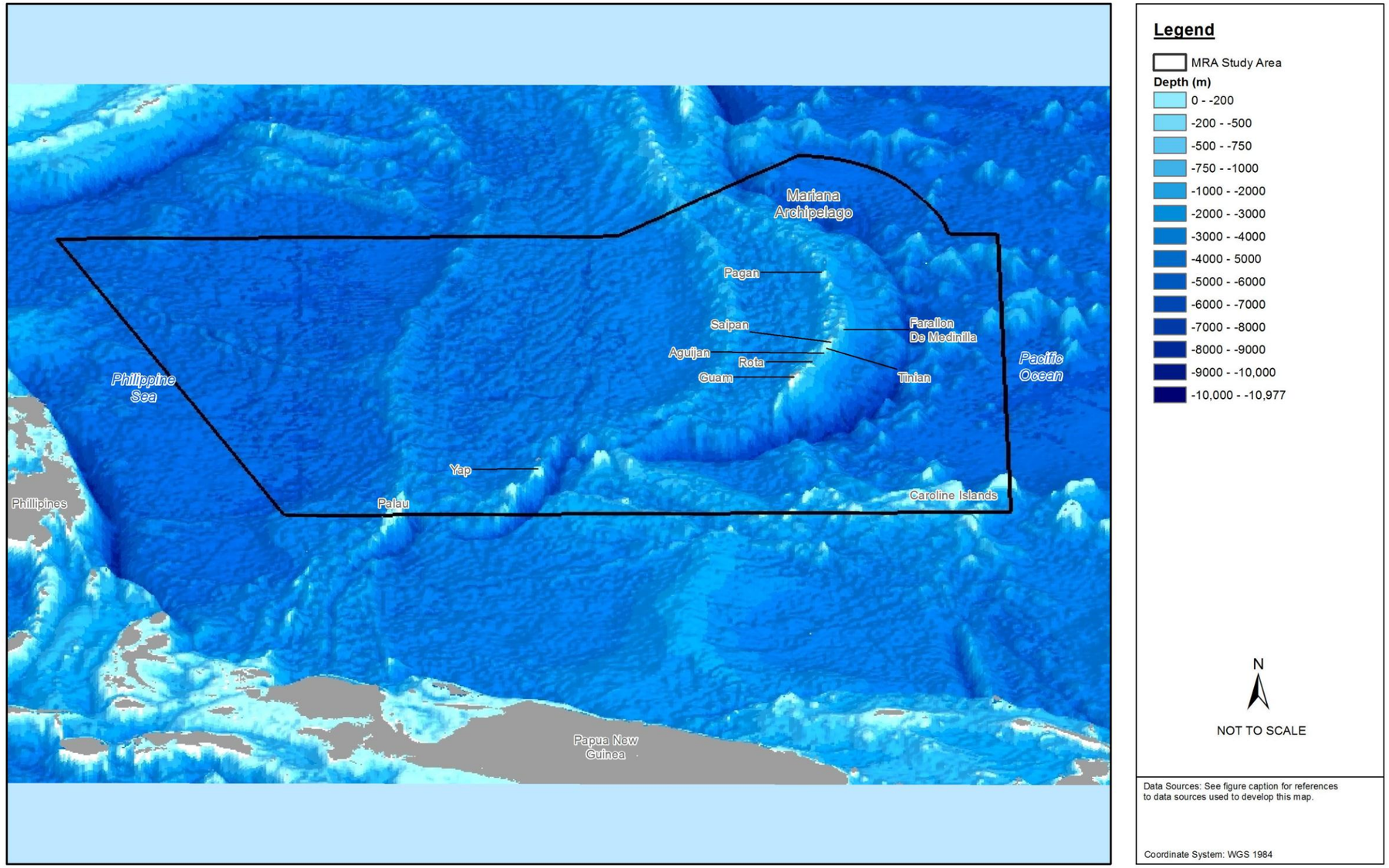

Figure 4-4: Three-dimensional View of the Mariana Archipelago Portion of the MRA Study Area
Source: U.S. Department of the Navy (2005b).

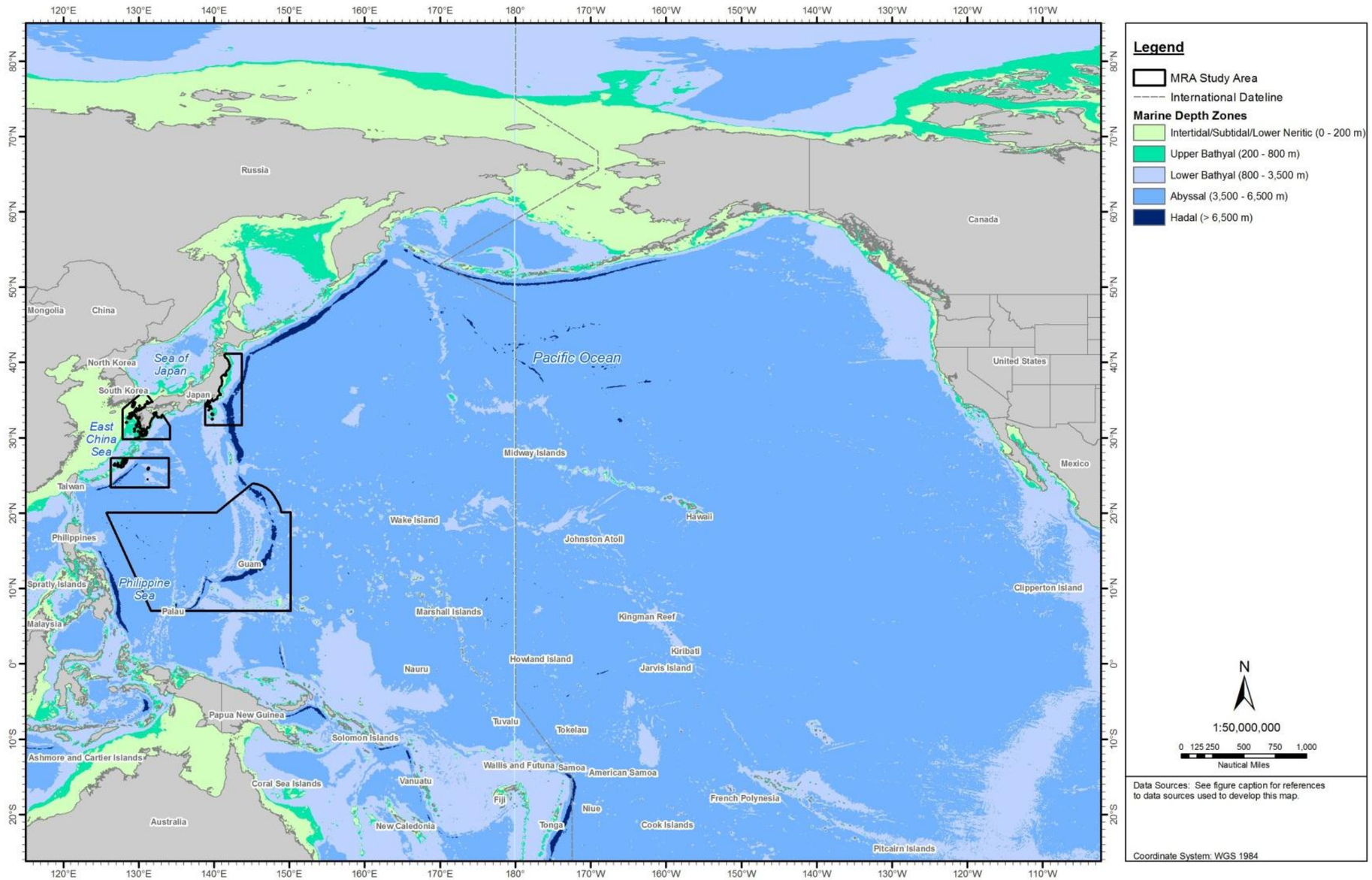

Figure 4-5: Depth Zones of the North Pacific Ocean

Sources: Intergovernmental Oceanographic Commission, International Hydrographic Organisation, and British Oceanographic Data Centre (2003) and Tetra Tech (2010).

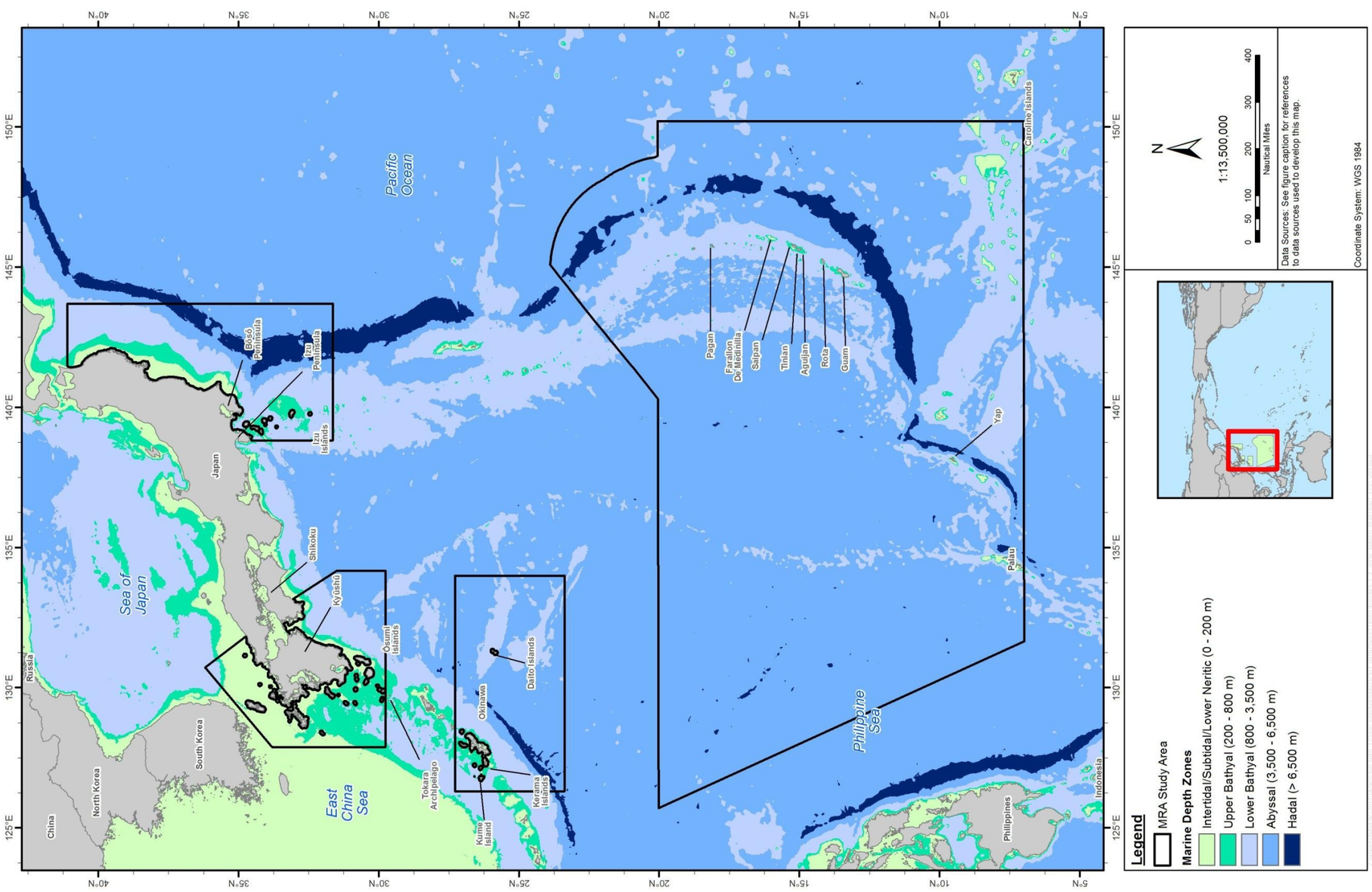

Figure 4-6: Depth Zones of the MRA Study Area

Sources: Intergovernmental Oceanographic Commission, International Hydrographic Organisation, and British Oceanographic Data Centre (2003) and Tetra Tech (2010).

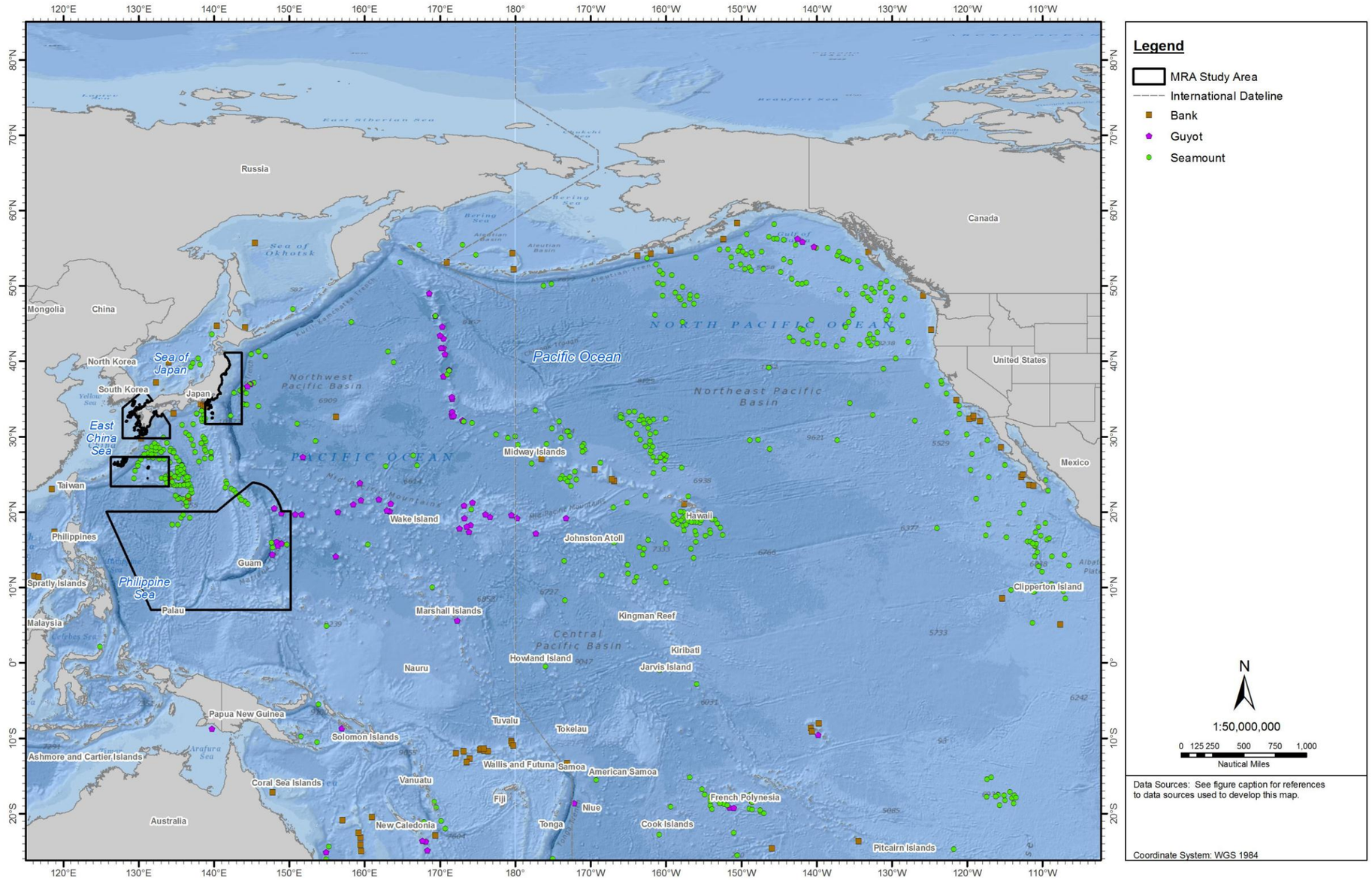

Figure 4-7: Banks, Guyots, and Seamounts in the North Pacific Ocean

Sources: Intergovernmental Oceanographic Commission, International Hydrographic Organisation, and British Oceanographic Data Centre (2003) and Tetra Tech (2010).

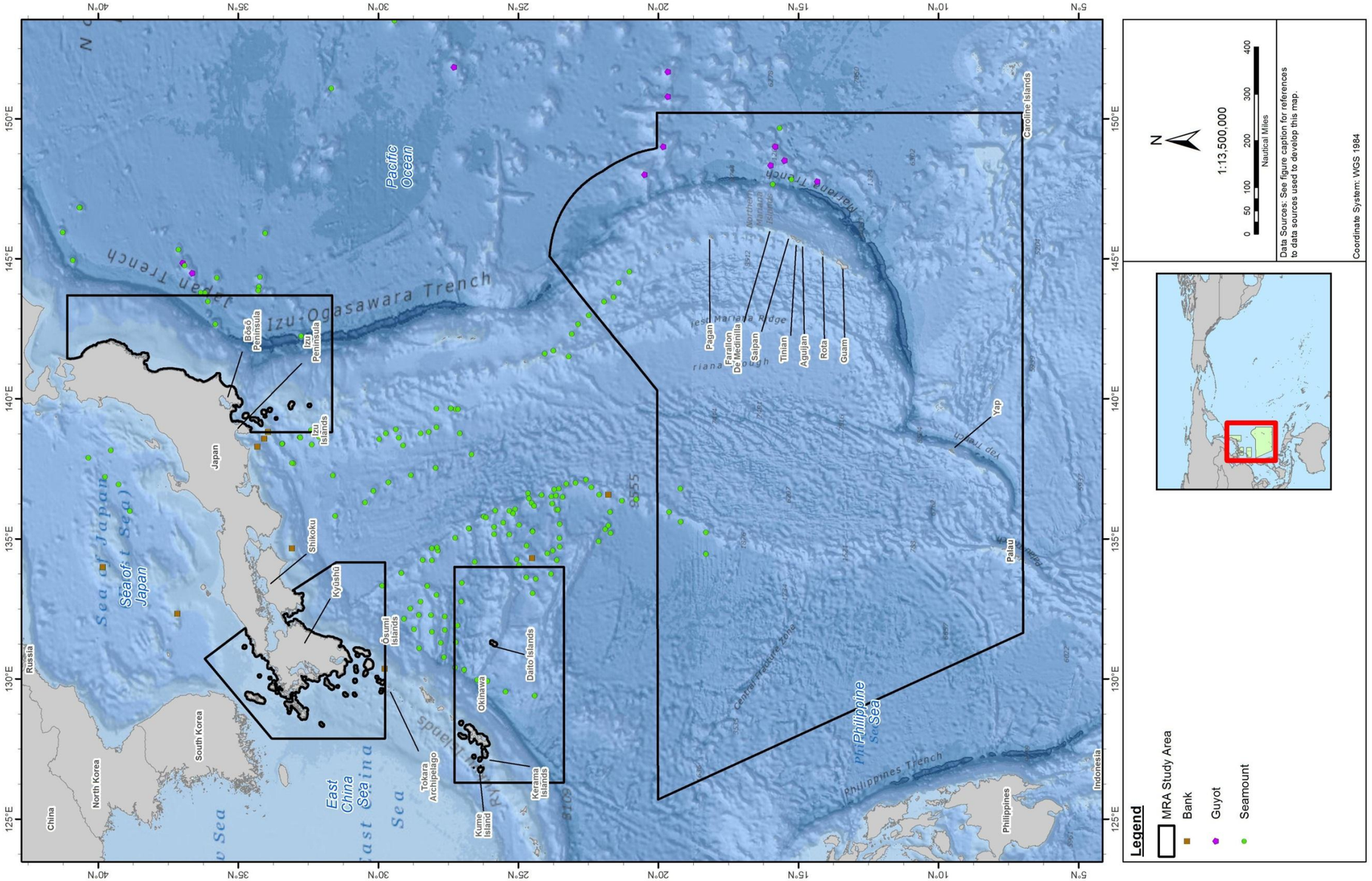

Figure 4-8: Banks, Guyots, and Seamounts in the MRA Study Area

Sources: Intergovernmental Oceanographic Commission, International Hydrographic Organisation, and British Oceanographic Data Centre (2003) and Tetra Tech (2010).

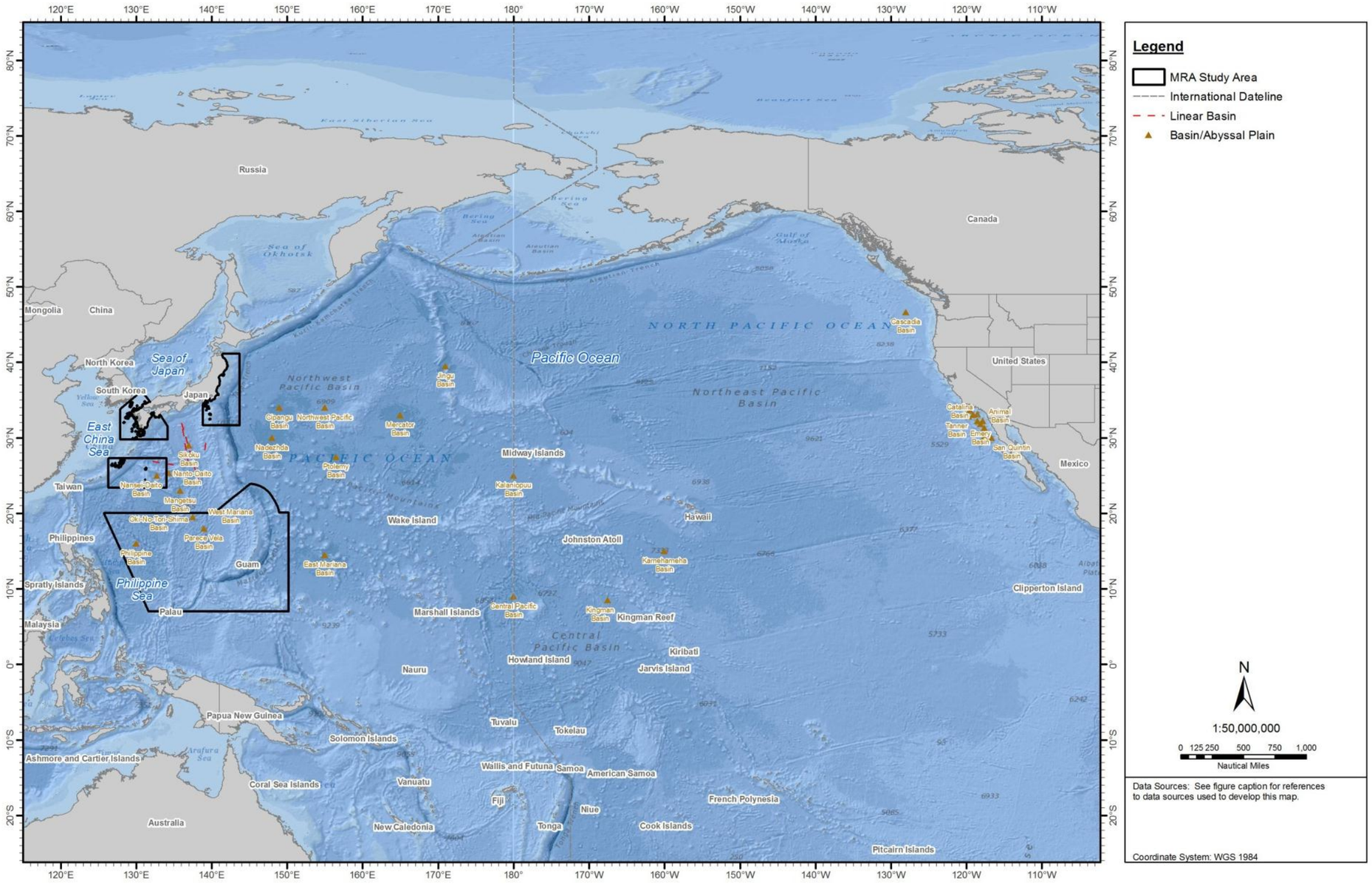

Figure 4-9: Trenches, Basins, and Abyssal Plains in the North Pacific Ocean

Sources: Intergovernmental Oceanographic Commission, International Hydrographic Organisation, and British Oceanographic Data Centre (2003) and Tetra Tech (2010).

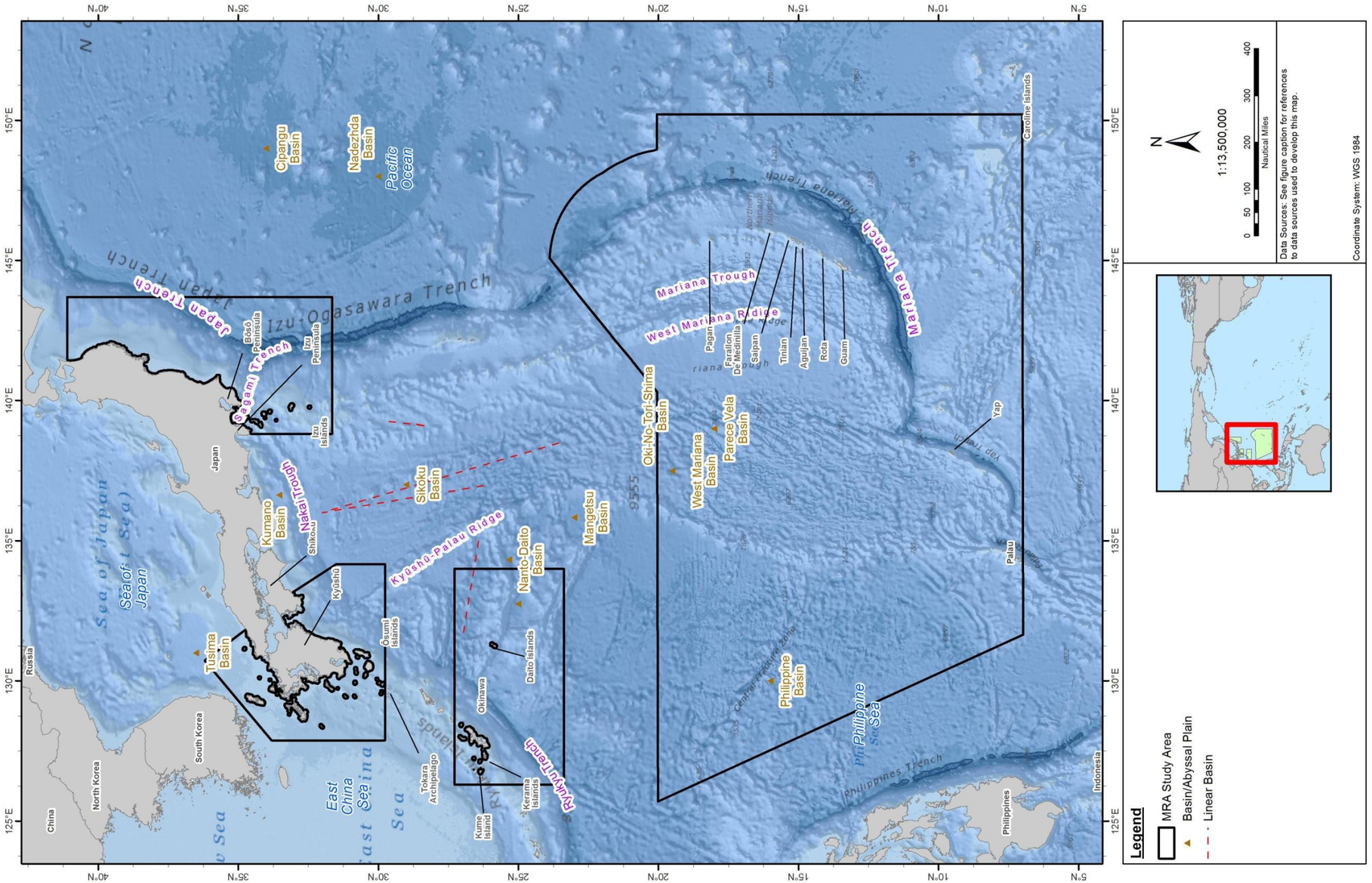

Figure 4-10: Trenches, Basins, and Abyssal Plains in the MRA Study Area

Sources: Intergovernmental Oceanographic Commission, International Hydrographic Organisation, and British Oceanographic Data Centre (2003) and Tetra Tech (2010).

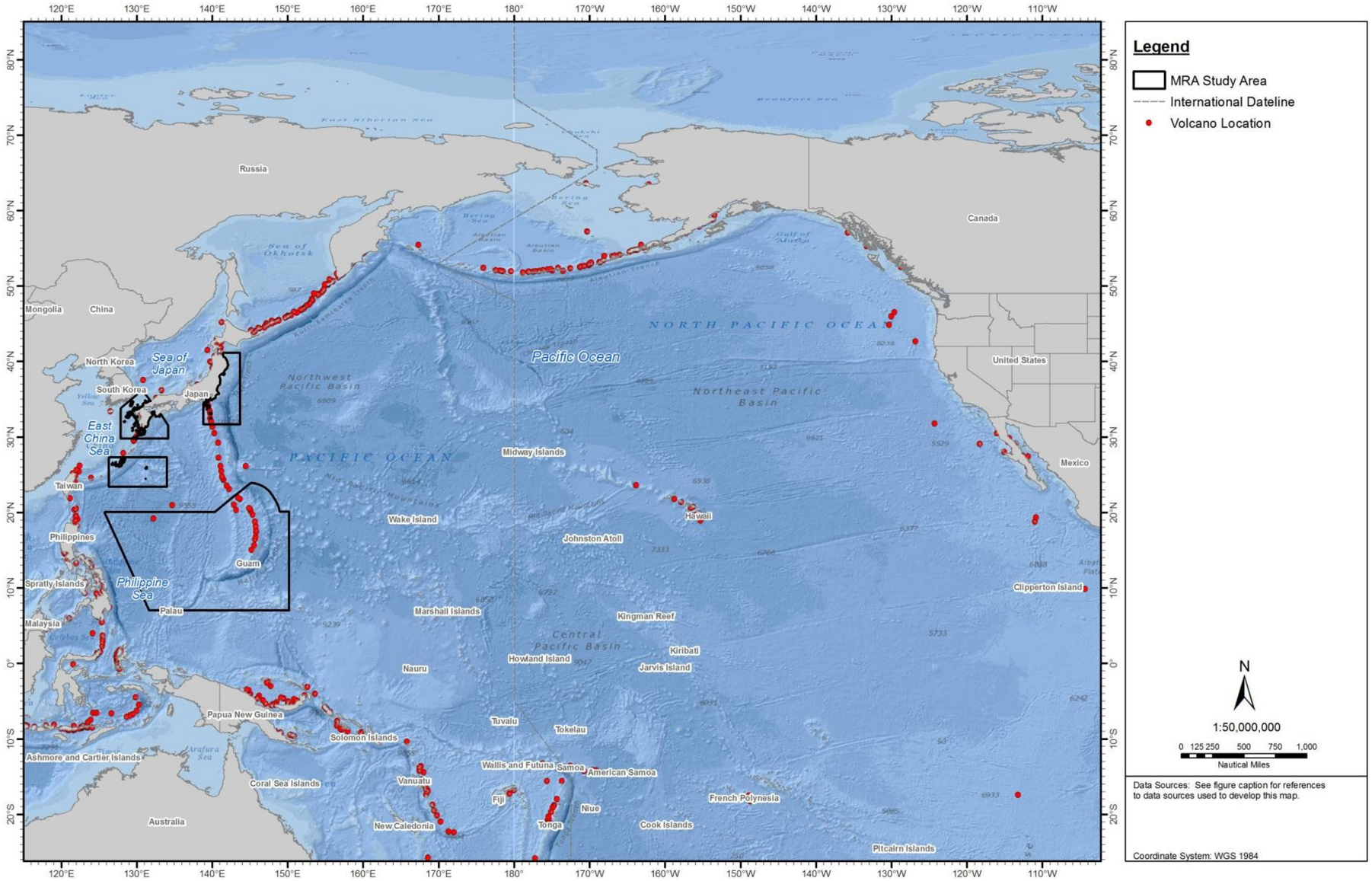

Figure 4-11: Volcanic Activity in the North Pacific Ocean
Source: National Oceanic and Atmospheric Administration (2002).

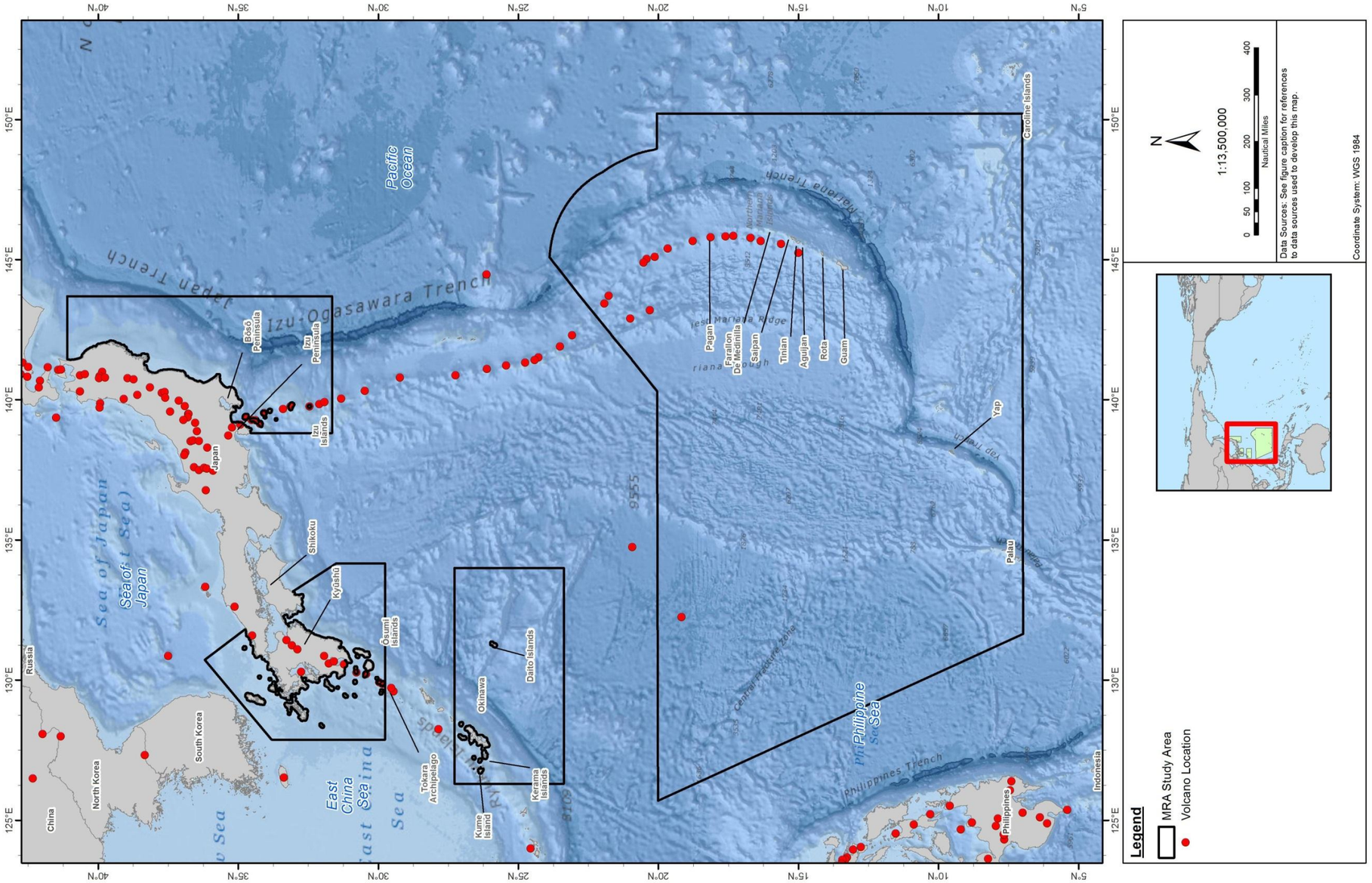

Figure 4-12: Volcanic Activity in the MRA Study Area
Source: National Oceanic and Atmospheric Administration (2002).

4.3.2 Substrate

NORTH CENTRAL PACIFIC. Sediments in the North Central Pacific are a mixture of continental and oceanic crust materials (Bailey 1993). The continental crust is made of granitic rocks, while the oceanic crust is basaltic (Castro and Huber 2007a). Sediments in the northwestern Pacific are dominated by detrital material along with notable amounts of biosiliceous and hydrogenous materials (Bailey 1993). Sediments in the Central and North Pacific include volcanic sediments, biogenic sediments, or terrigenous materials (formed on land from weathered rock) transported by winds from Asia (Nemoto and Kroenke 1981; Otosaka, Honda, and Noriki 2004; Toyoda and Masuda 1990; Uematsu, Duce, and Prospero 1985). These atmospherically transported terrigenous materials are the primary source of clay materials in the North Pacific (Uematsu, Duce, and Prospero 1985). Biogenic sediments that occur in the North Central Pacific include siliceous ooze and calcareous ooze (Nemoto and Kroenke 1981). Siliceous ooze is composed of diatom shells on the seafloor, while calcareous ooze is an accumulation of calcium carbonate shells of dead organisms on the seafloor. Calcareous ooze primarily occurs at depths less than 4,500 m in the Pacific Ocean (Toyoda and Masuda 1990). Sediments at abyssal depths of the North Pacific are primarily clay materials; however, carbonate ooze has also been found at these depths (Toyoda and Masuda 1990).

The dbSEABED (Jenkins 2012) creates unified, detailed mappings of the materials that make the seafloor integrating thousands of individual datasets of sediment samples collected by researchers throughout the world. This database was used to map the dominant and subdominant bottom types and sediment classification in the MRA Study Area (Figure 4-13 and Figure 4-14). Dominant (>66%) and subdominant (50-66%) bottom types(Figure 4-13) are assigned from visual observations of grab samples from each core. The Folk classification system (Folk 1954) uses 15 terms to describe seabed sediments (Figure 4-14).

In the Japan Archipelago, limestone sediments are often found in collaboration with reef complexes in shallow waters or on tops of seamounts (Tatsumi et al. 2000). These limestone sediments form in high-energy environments (Tatsumi et al. 2000). Most deep-sea sediments in the region are composed of silts, diatomaceous ooze, and clay; interbedded with these silts is a thin layer of volcanic ash (Jenkins et al. 2005; Kanamatsu and Matsuo 2003; McGuire and Acton 2003). Sediments associated with the trenches in the region also contain a high percentage of diatomaceous clays, silts, and ooze (Kanamatsu and Matsuo 2003; Le Pichon, Iiyama, et al. 1987a; McGuire and Acton 2003). The numerous chemosynthetic environments in this region have sediments that consist primarily of fine black or olive green mud; these sediments often have a strong sulfide odor, indicating anaerobic environments (Boulègue et al. 1987; Okada 1980). In addition to marine sediments, fine-grained minerals are transported to the sea by rivers, wind, or through episodically induced lateral transports such as turbidity currents triggered by earthquakes, storms, and floods (Aoki and Kohyama 1992). These phenomena could induce carriage of large quantities of terrestrial and marine particulate materials from the coastal region to the floor of the deep sea (Garfield et al. 1994; Heezen and Ewing 1952; Prior et al. 1987; Thunell et al. 1999).

Composition of the bottom substrate covering the seafloor surrounding the Mariana Archipelago is primarily volcanic or marine (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 that make up the fringing and barrier reefs found throughout the Mariana

Archipelago (Eldredge 1983). The Mariana Trench seafloor is composed 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).

EAST CHINA SEA. The shelf bottom consists of terrigenous sediment from the Yangtze River, with 400 million tons of sediment deposited annually (Naval Environmental Prediction Research Facility 1988a). The trough basin is composed of a combination of terrigenous muds and pelagic oozes.

PHILIPPINE SEA. Lithogenous sediments predominate in nearshore areas of the Philippine Sea (Naval Environmental Prediction Research Facility 1988c). Biosilicious ooze and mud are common south of 20°N. Calcareous ooze and marl occur north of 20°N.

EQUATORIAL PACIFIC. Thick accumulations of calcareous and siliceous ooze occur in the Equatorial Pacific as a result of the high productivity of pelagic organisms associated with oceanic upwelling along the equator (Mitchell et al. 2003).

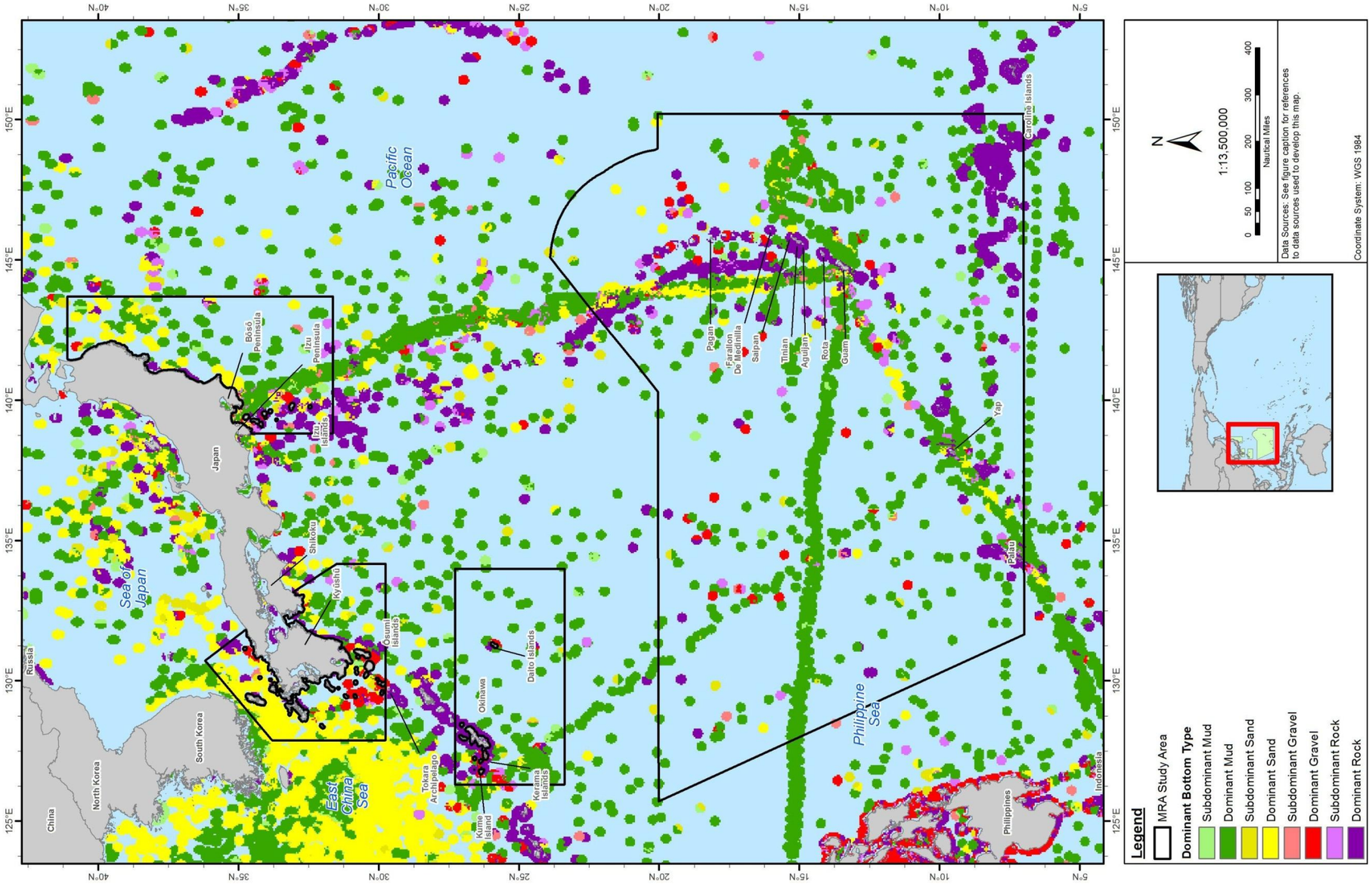

Figure 4-13: Distribution of Dominant and Subdominant Bottom Types in the MRA Study Area
Source: Jenkins (2012).

.

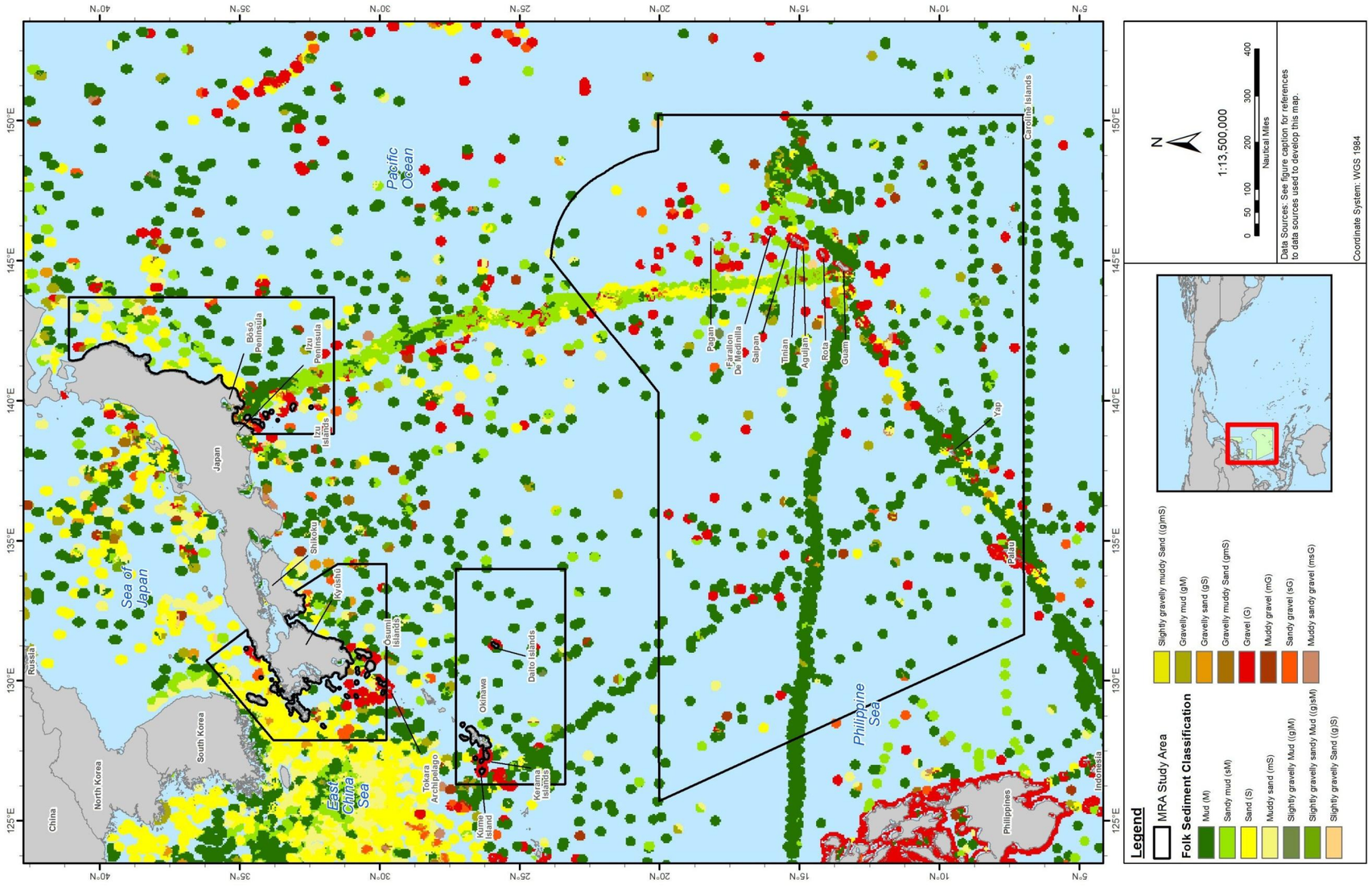

Figure 4-14: Distribution of Sediment Types in the MRA Study Area
Source: Jenkins (2012).

4.3.3 Geologic Processes

The MRA Study is dominated by dynamic geological processes including seismic activity and volcanism characteristic of active continental margins. 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 these are not associated with seismic or volcanic activity.

The North Pacific Ocean is bounded by both active and passive margins. Active continental margins are often associated with trenches, volcanism, active mountains, and seismic activity (Kennett 1982). They mark the boundaries between two converging plates and are also referred to as seismic margins. Active margins are characterized by shallow, intermediate, and deep earthquakes resulting in deformation or destruction of the earth's crust typically by subduction (Kennett 1982). Unlike passive margins, active continental margins mark the boundary between two crustal plates. As a result of the collision of the crustal plates, active margins are associated with deep oceanic trenches, formations of seamounts, seismic activity, and volcanism.

JAPAN ARCHIPELAGO. The islands of Japan mark the subduction zones of both the Pacific sea plate in the northeast and the Philippine plate in the southwest. The Pacific Plate is the oldest oceanic tectonic plate on Earth and is approximately 100 km thick; the plate is subducting under the North American Plate and under the Philippine Sea Plate at a rate of approximately 10 cm/yr (Niitsuma 2004; von Huene et al. 1982). Subduction of the Pacific Plate has resulted in creation of the Kuril Trench off the coast of Hokkaidō, the Japan Trench off of Honshū, and the Izu-Ogasawara (Izu-Bonin) Trench southeast of Japan (Niitsuma 2004; Seno 1999). The Japan Trench, approximately 800 km long, reaches a maximum depth of approximately 9,000 m (Okada 1980); it is one of the most active plate subduction zones on the planet. Along the Japan Trench, 130-million-year-old Pacific Plate material is consumed beneath the Eurasian plate (Hayashi 2004; Kopf et al. 2003). This active subduction generates many large earthquakes along the northern Japan Trench (Itou, Matsumura, and Noriki 2000). The Izu-Ogasawara (Izu-Bonin) Trench is separated from the Japan Trench in the north by the Kashima Seamount (35°50′ N, 142°40′ E) and a ridge that extends eastward from Cape Inubo, east of Tōkyō (Okada 1980; Toba and Murakami 1998). The Japan Trench, Sagimi Trench, and Izu-Ogasawara Trench intersect at the Bōsō Triple Junction, forming a trench–trench–trench type triple junction of the Pacific, Philippine Sea, and North American Plates.

The Philippine Sea Plate is subducting under the Eurasia Plate to the northwest along the Sagami Trench, Nankai Trough, and Ryukyu Trench (Ando 1975; Niitsuma 2004; Seno 1999; Seno, Stein, and Gripp 1993). The Nankai Trough is the bathymetric expression of a subduction zone where a young, thin tectonic plate (Philippine Sea Plate) has been underthrust below Japan (Le Pichon, Iiyama, Boulègue, et al. 1987; Le Pichon, Iiyama, et al. 1987a, b). Subduction in the region began approximately 10 million years ago and continues today at a rate of approximately 2–4 cm/yr (Le Pichon, Iiyama, Boulègue, et al. 1987; Le Pichon, Iiyama, et al. 1987a, b). The easternmost region of the Nankai Trough is an area of complex interaction between the Philippine Sea Plate and the Eurasia plate, resulting in a region rich in cold seep zones (Le Pichon, Iiyama, Boulègue, et al. 1987; Tsunogai, Yoshida, and Gamo 2002).

Okinawa is the exposed crest of a large, curved submarine volcanic ridge located within the Ryukyu arc system (U.S. Department of the Navy 2004). This typical trench-arc-back arc system extends in a northeast-southwest orientation approximately 1,200 km from Kyūshū, Japan, to Taiwan (Park et al. 1998). In the southern region of the Ryukyu arc system, the Philippine Sea Plate is subducting under the Eurasia Sea Plate at a rate of 5 to 7 cm/yr (Park et al. 1998).

Active trenches surround all of Japan, including Okinawa (Kasahara et al. 1998). This region is considered a seismically energetic region (U.S. Department of the Navy 1997a, 2004). More than 1,400 earthquakes with an epicenter near Tōkyō have been recorded since the late 1930s. Of these, at least 600 registered a magnitude of 4.0 to 4.9 (U.S. Department of the Navy 1997a, b). More than 1,200 earthquakes have affected western Kyūshū during the same period; of these, more than 600 were of a magnitude between 4.0 and 4.9 (U.S. Department of the Navy 1997b, 1998). This region is responsible for the destructive earthquakes and tsunamis that affect the Japanese Islands and vicinity (Rydelek and Sacks 1990). Adjacent to the Japanese Islands, on the western Pacific seafloor, the topography is dynamic, featuring seamounts and oceanic rises (Isozaki, Maruyama, and Furuoka 1990).

In general, seismic activity associated with subduction-related, plate-boundary faults is weak and aseismic (Byrne, Davis, and Sykes 1988; Davis, Suppe, and Dahlen 1983); however, subduction-zone thrusts are capable of producing some of the largest and most devastating earthquakes (Bangs et al. 2004). These large earthquakes tend to occur on a regular schedule (Rydelek and Sacks 1990); these recurrence intervals have been documented since the seventh century (Kanaori, Kawakami, and Yairi 1993; Kodaira et al. 2000). Every 100 to 124 years, almost the entire length of the Nankai Trough is ruptured by large Japanese sea quakes (magnitude greater than or equal to 7.9) (Kodaira et al. 2000). The most recent events, the 1944 Tonankai and the 1946 Nankaido earthquakes, are the best studied of the large Nankai Trough earthquakes (Ando 1975; Bangs et al. 2004; Kanamori 1972). Many large earthquakes have occurred near the northern Japan Trench area; however, no significant periodicity has yet been found for the Japan Trench (Itou, Matsumura, and Noriki 2000; Mori and Shimazaki 1984). In this region, large earthquakes (magnitude ≥7.0) have occurred recently in 1989, 1992, and 1994 (Seno 2002).

A magnitude 9.0 earthquake occurred on 11 March 2011 and generated a devastating local tsunami that struck the Pacific coast of Honshū within about 20 minutes (International Tsunami Information Center 2012). The earthquake resulted from thrust faulting between the Pacific and North America plates along the Japan Trench subduction zone. The magnitude of this earthquake far exceeded all previous events in Japan Trench in over 100 years (U.S. Geological Survey 2012).

While seismology is concerned primarily with the study of earthquakes (sudden, transient disturbances), non-transient seismic processes occur as well. Some of these processes are of great interest and practical importance. For example, continuous ground vibrations often occur at or near volcanoes (Julian 1994, 2002). Termed “volcanic tremor,” these vibrations are detected only near active volcanoes, and are often accompanied by evidence of subterranean magma motion (Julian 1994; Shimozuru, Kamo, and Kinoshita 1966). Volcanic tremor frequently precedes an eruption, although it can also occur without an associated eruption (Kubotera and Otsuka 1970). Vibrations persisting for minutes or weeks have been detected in the Nankai subduction zone where the Philippine Sea Plate subducts beneath Japan (Julian 2002).

The Japanese Islands are formed from several active volcanoes and are located within the Pacific “Ring of Fire,” one of the most volcanically active areas on the planet. Several submarine volcanoes are

located to the southeast of the Japanese Islands (Figure 4-12). The most recent eruption in the waters surrounding Japan occurred on July 3, 2005, when an undersea volcano erupted off the coast of Iwo Jima. The eruption caused a 1,000-m-high column of steam to rise from the Pacific Ocean, and was accompanied by red-tinted water and grayish mud rising from the bottom of the ocean (Associated Press 2005). The volcano, Fukutoku-Okanoba, was last known to have erupted over a period of 3 days in 1986.

MARIANA ARCHIPELAGO. The Mariana Archipelago 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 subduction of the Pacific Plate beneath the Philippine Plate, forming the Mariana Trench (Kennett 1982). The Mariana Trench is more than 2,270 km long and 114 km wide. The deepest point in the trench, Challenger Deep (11,034 m; 11°22'N, 142°25'E), is 544 km southwest of Guam at the southwestern extremity of the trench (Fryer et al. 2003).

The seafloor 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). The Mariana Trough formed when the oceanic crust in this region began to spread between the ridges as recently as 4 million years ago. Currently, the Mariana Trough is spreading at a rate of less than 1 cm/yr in the northern region, and at rates up to 3 cm/yr at the center of the trough (Yamazaki, Murakami, and Saito 1993). Distinct hydrothermal anomalies were mapped along the slow spreading (<0.5 cm/yr) sourthern portion of the Mariana Trough (Baker et al. 2005). The Mariana Archipelago is located on the Mariana Ridge, 160 to 200 km west of the Mariana Trench subduction zone.

The Mariana Archipelago is composed of 15 volcanic islands. The islands north of FDM, located on an active volcanic arc ridge axis, were formed between 1.3 and 10 million years ago (Randall 1985, 1995, 2003). The six southern islands (Guam to FDM) are on the old Mariana fore-arc ridge axis and formed about 43 million years ago (Eocene) (Birkeland 1997; Randall 1985, 2003). 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 hundred m) (U.S. Department of the Navy 2003b). Subsidence of the original volcanoes in the southern islands allowed for capping of the volcanoes by limestone. Limestone covers the northern half of Guam (limestone plateau height: 90 to 180 m above MSL), while volcanic rock and clay are exposed on the southern half of the island (Department of Defense 1999). Tinian consists of rocky shoreline cliffs and limestone plateaus with no apparent volcanic rock (Department of Defense 1999). Similar to Tinian, the uplifted limestone substrate of FDM is bordered by steep cliffs (The Environmental Company 2004). Volcanoes north of FDM have not subsided below sea level, do not have limestone caps, and remain active (Baker et al. 1996).

Guguan, Alamagan, Agrigan, Asuncion, and Farallon de Pajaros have documented volcanic activity spanning from 1883 to 1967 (Smithsonian National Museum of Natural History 2012a, b, d, f, g; U.S. Department of the Navy 2003b; U.S. Geological Survey 2005a). The first historic eruption of Anatahan (16°22'N, 145°40'E) occurred in 2003 with the most recent in 2008 (Smithsonian National Museum of Natural History 2012c). History eruptions of Pagan have occurred as early as the 17th century with the most recent eruption in 2010, and the largest recorded eruption occurred in 1981, resulting in the evacuation of the population (Smithsonian National Museum of Natural History 2012h).

Ruby Volcano and Esmeralda Bank are submarine volcanoes found northweest of Saipan and Tinian (Smithsonian National Museum of Natural History 1995, 2012e, i; U.S. Geological Survey 2005a). Ruby Volcano (15°37'N, 145°32'E), also known as Ruby Seamount, is 40.2 km northwest of Saipan and estimated to be approximately 61 m below MSL (Smithsonian National Museum of Natural History 2012i). Ruby Volcano erupted in 1966 (Johnson 1973) and then again in 1995 (Smithsonian National Museum of Natural History 2012i) as the surrounding area underwent submarine explosions, fish kills, a sulfurous odor, bubbling water, and volcanic tremors (Smithsonian National Museum of Natural History 1995). The summits of the Esmeralda Bank are from 43 to 140 m beneath the sea surface (Smithsonian National Museum of Natural History 2012e). Esmeralda Bank is a massive submarine volcano with three cones. Their summits range from 43 to 140 m beneath the sea surface.

The Mariana Archipelago undergoes numerous shallow to intermediate depth (<300 km) normal-fault events, indicating a region that is stretching (Zhang and Lay 1992), resulting in low magnitude earthquakes (U.S. Department of the Navy 2003a, b; U.S. Geological Survey 2004b). Furthermore, subduction of the Pacific Plate under the Philippine Plate causes abundant seismic activity in the MRA Study Area, with occasional intense and destructive earthquakes (magnitudes greater than 7 on the Richter scale) (Earthquake Engineering Research Institute 1993; U.S. Geological Survey 2004b, 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 and separation of the mantle (Fryer 1996). This material is less dense and rises to the surface to form seamounts (Fryer 1996; Mottl et al. 2004). Seamounts in the Study Area are of two distinct varieties: volcanoes and mud volcanoes. Volcanoes are formed along the spreading axis in the Mariana Trough where 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). Mud volcanoes are formed in a band behind the axis of the Mariana Trench. They are formed when water generated by dehydration of the subducting Pacific plate (caused by increased pressure and temperature) ascends to the mantle of the overlying crust and creates low-density rock capable of rising to the seafloor. Mud volcanoes (1) tend to have a central conduit that feeds serpentinite mud, which represents the bulk of the seamount structure (Mottl et al. 2004), and (2) host several macrofaunal communities (Fryer, Wheat, and Mottl 1999).

CAROLINE ISLANDS. The islands and submerged arcs of Palau are an extension of the Kyūshū-Palau Ridge. The Eastern Caroline Islands were formed by a hot spot between 1 and 11 million years ago. The islands show a linear progression of mean ages from 1 million years in the east (Kosrae) to 11 million years in the west (Chuuk) Keating et al. (1984).

4.3.4 Tsunami

A tsunami, Japanese for "harbor wave," is a series of waves most commonly caused by violent movements of the sea floor (Marris 2005; Natural Environment Research Council 2000). It is characterized by high speed (up to 950 km/hour), long wavelengths (up to 193 km), long periods between successive crests (varying from 5 minutes to a few hours [generally 10 to 60 minutes]), and low wave amplitude in the open ocean (less than 0.3 m) (Curtis 1998; Fletcher et al. 2002). Seafloor movements that generate tsunamis may include faulting (earthquakes), landslides, and submarine volcanic eruptions. Undersea earthquakes around the Pacific Rim, where colliding plates lead to an unusually high level of seismic activity, generate more than 80% of tsunamis worldwide (Koenig 2001; Natural Environment Research Council 2000). Most tsunamis, like the majority of earthquakes, are small

and are observed only instrumentally. Earthquakes causing tsunamis are generally characterized by slow faulting (Kanamori 1972; Kanamori and Kikuchi 1993; Polet and Kanamori 2000). Landslides may also generate tsunamis; these can originate either under the sea or above sea level (by sliding into the ocean). An example of a volcanically induced tsunami is the violent explosion of the island volcano Krakatoa in 1883; it produced tsunami waves 40 m high on the shores of Sumatra and Java. The high degree of volcanism and seismic instability in and around the Pacific Ocean has led to a long history of tsunami occurrences.

Tsunami waves are imperceptible in the open ocean; in deep water, a large tsunami wave may measure less than 0.3 m high but may span 50 to 100 km (Curtis 1998). Characteristics of tsunamis depend on water depth. For example, as water depth decreases, the speed at which a tsunami travels decreases, the wavelength between crests is shortened, and the height of the wave increases because the energy is crowded into less area (Curtis 1998). Of the 157 tsunami events were recorded globally between 1983 and 2001, all but nineteen events were in the Pacific region (Lander, Whiteside, and Lockridge 2003).

JAPAN ARCHIPELAGO. Japan is one of the most tsunami-battered islands in the Pacific Ocean (Koening 2001). Tsunamis can hit anywhere along the Japanese islands but are most common along the Pacific coast. In particular, tsunamis are frequent along the northeastern region of Honshū. Recently, a powerful tsunami was generated on 11 March 2011, from a 9.0 magnitude earthquake that reached depths of 24.4 km (International Tsunami Information Center 2012). This tsunami ranked among the 10 most devastling tsunamis in recorded history (Phillips 2011). The death toll from the earthquake and tsunami reached 13,895 people (International Tsunami Information Center 2012). Approximately 452,000 people were displaced. The impact of the natural hazards was compounded by a technological hazard. Tsunami waves damaged the Fukushima Nuclear Power Plant, resulting in the meltdown of core reactors and local emission of dangerous radiation. The World Bank estimates that it could take Japan up to 5 years to financially overcome the $235 billion damages. Since 1605, tsunamis have severely damaged various parts of Japan and caused significant death tolls (Table 4-2).

Historically, 11 of the 23 most damaging tsunamis worldwide (1600 to 1999) struck the islands of Japan (U.S. Geological Survey 2004a). Furthermore, at least four tsunamis were related to coastal volcanism; of those, two affected Hokkaidō in northern Japan (Nishimura, Miyaji, and Suzuki 1999). In 1640, after more than 1,000 years of dormancy, Mt. Komagatake, in southern Hokkaidō, erupted, and the resulting summit collapse and avalanche initiated a tsunami. Part of the avalanche flowed eastward from the summit, entered the sea, and created a large tsunami. In 1741, a tsunami struck the western coast of the Oshima peninsula. It is believed that the tsunami was initiated by volcanic eruption or landslide associated with the eruption (Nishimura, Miyaji, and Suzuki 1999). A highly destructive tsunami that hit Okushiri Island, Japan, in July 1993, damaged buildings, induced landslides, and severely damaged harbor installations; this tsunami caused a total of $600 million in damages, much of which was to harbors (Natural Environment Research Council 2000).

Table 4-2: Most Damaging Tsunamis to Impact Japan

Year	Location	Deaths
1605	Nankaido, Japan	5,000
1611	Sanriku, Japan	5,000
1703	Tokaido-Kashima, Japan	5,233
1707	Tokaido-Nankaido, Japan	30,000
1766	Sanriku, Japan	1,700
1792	Kyūshū Island, Japan	15,030
1854	Nankaido, Japan	3,000
1896	Sanriku, Japan	26,360
1923	Tokaido, Japan	2,144
1933	Sanriku, Japan	3,000
1946	Nankaido, Japan	1,977
2011	Honshū, Japan	13,895

Sources: U.S. Geological Survey (2004a) and International Tsunami Information Center (2012).

MARIANA ARCHIPELAGO. Guam has undergone only three tsunamis large enough to cause damage—in 1849, 1892, and 1993 (Lander, Whiteside, and Hattori 2002). No record of damaging tsunamis was found for the Mariana Archipelago after 1993.

CAROLINE ISLANDS. No record of damaging tsunamis was found for Palau or the FSM.

4.4 PHYSICAL OCEANOGRAPHY

4.4.1 Surface Currents and Circulation

Surface currents are horizontal movements of water primarily driven by solar heating, wind, gravity, and Coriolis effects. Wind-driven circulation dominates in the upper 100 m of the water column and therefore drives circulation over continental shelves (Hunter et al. 2007). In the northern hemisphere, the influence of the westerlies and the northeasterly trade winds on north Pacific currents produces a clockwise (anticyclonic) rotation (Tomczak and Godfrey 2003). A subarctic gyre is also present in the North Pacific as a result of the polar easterlies and the westerlies. The North Pacific Subarctic Gyre rotates counterclockwise (cyclonic rotation) (Tomczak and Godfrey 2003).

Ocean circulation of the North Central Pacific is dominated by the anticyclonic (clockwise) motion of the North Pacific Subtropical Gyre (NPSG) (Figure 4-15) (Tomczak and Godfrey 2003). Occuring between the equator and 50° N, the NPSG is bounded to the north by the North Pacific Current, to the east by the California Current, to the south by the North Equatorial Current (NEC), and to the west by the Kuroshio Current (Tomczak and Godfrey 2003). The North Pacific Current is an eastward-flowing current formed by the Kuroshio Current that flows north along the coast of Japan and by the Oyashio Current that flows south from the subarctic along the western North Pacific Ocean. (Tomczak and Godfrey 2003). The North Pacific Current bifurcates in the eastern North Pacific, at approximately 45 to 50° N, and forms the northward-flowing Alaska Current and the southward-flowing California Current (Figure 4-16). Below the NEC is the North Equatorial Counter Current (NECC).

Surface water temperatures in the North Central Pacific are largely influenced by surface circulation (Figure 4-16). Cold surface water in the North Pacific Current is carried by the California Current south along the coast of California and turns west forming the NEC. The water of the NEC further warms as it travels west just above the equator. Warm surface water from the NEC is carried by the Kuroshio Current to the north along the coast of Japan (Figure 4-17).

Climate change is expected to alter ocean circulation. The results of modeling Pacific ocean circulation using different climate scenarios suggest that, as the climate warms, the subtropical countercurrent will weaken, the Kuroshio Extension will shift northward, and the overall circulation of the subtropical gyre will slow down (Luo and Rothstein 2011).

The major surface currents of the MRA Study Area are described below. Surface currents around the Japan Archipelago include the Oyashio, Kuroshio, and Tsugaro Currents. The westward flowing NEC is the dominant flow around the Mariana Archipelago. Eastward surface current flow around the Caroline Islands is dominated by the NECC and North Equatorial Under Current.

OYASHIO CURRENT. Translated from Japanese, Oyashio means parent (oya) stream (shio) (Qiu 2001). The Oyashio is the western boundary of the subpolar gyre in the northwestern North Pacific fed by cold, nutrient-rich, upwelled waters from the western subarctic gyre (Figure 4-17) (Sakurai 2007). It originates in the Bering Sea and flows southward to the southeast coast of Hokkaidō (Kono 1997; Limsakul et al. 2002; U.S. Department of the Navy 1994). Oyashio water, one of the most productive waters of the world oceans, is cold and nutrient rich, leading to high abundance of phytoplankton and higher trophic levels (see for example Kasai et al. (1997); Taniguchi (1999).

At least two branches of the Oyashio develop along the northeastern coast of Hokkaidō (Qiu 2001; U.S. Department of the Navy 1994). The first path veers offshore and contributes to the east-north-eastward-flowing Subarctic Current along 42°N, southeast of Hokkaidō. The second path of the Oyashio Current continues southward along the east coast of Honshū (Qiu 2001).

Flow of the Oyashio Current has a well-defined annual cycle, with strong flow that spans the water column from the surface to the sea floor during winter and spring months; during the summer and fall, the Oyashio is weaker and confined to the layer shallower than 2,000 m (Qiu 2001). The southward intrusion of the Oyashio reaches, on average, a latitude of 38.7°N; however, in some years it can penetrate as far south as 37°N. Since the mid-1970s, the Oyashio Current has penetrated farther south than in previous years (Hayward 1997; Qiu 2001). Southern intrusions of the Oyashio occasionally pinch off from the main branch and form eddies. These eddies trap warm water and are gradually modified and absorbed by the surrounding cold water, soon to be replaced by another warm intrusion while colder eddies slowly sink (U.S. Department of the Navy 1994). Both long-term trends and inter-annual changes in the southward penetration of the Oyashio appear to be related to the changes in the intensity of the Aleutian low atmospheric pressure system (Hayward 1997; Qiu 2001).

KUROSHIO CURRENT. The western boundary current in the North Pacific Ocean is the Kuroshio Current (Figure 4-17). Currents flowing along the western boundaries of oceans are narrow, deep, and swift, and have speeds exceeding 3 feet (ft.)/second (s.) (1 m/s.) (Pickard and Emery 1990). The Kuroshio Current is northward flowing current, approximately 100 km wide off the coast of Japan. Average current speed ranges from 3.3 to 5.0 ft./s. (1.0 to 1.5 m/s.) (Tomczak and Godfrey 2003), and average annual mean SST is 24° C (Heileman and Tang 2009).

This Page Intentionally Left Blank

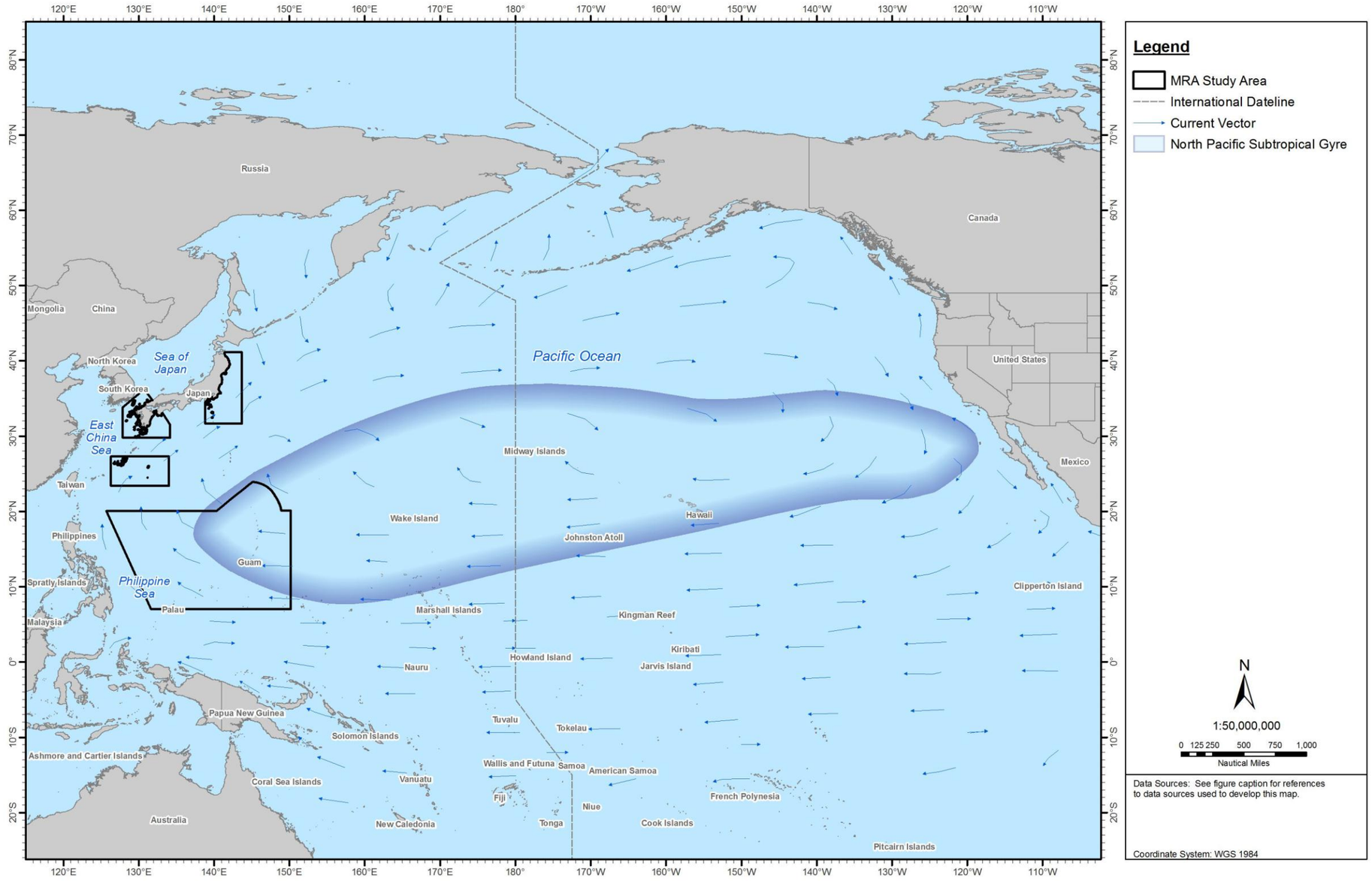

Figure 4-15: Surface Circulation of the North Pacific Ocean Highlighting the Extent of the North Pacific Subtropical Gyre
Sources: U.S. Department of the Navy (2005a, b).

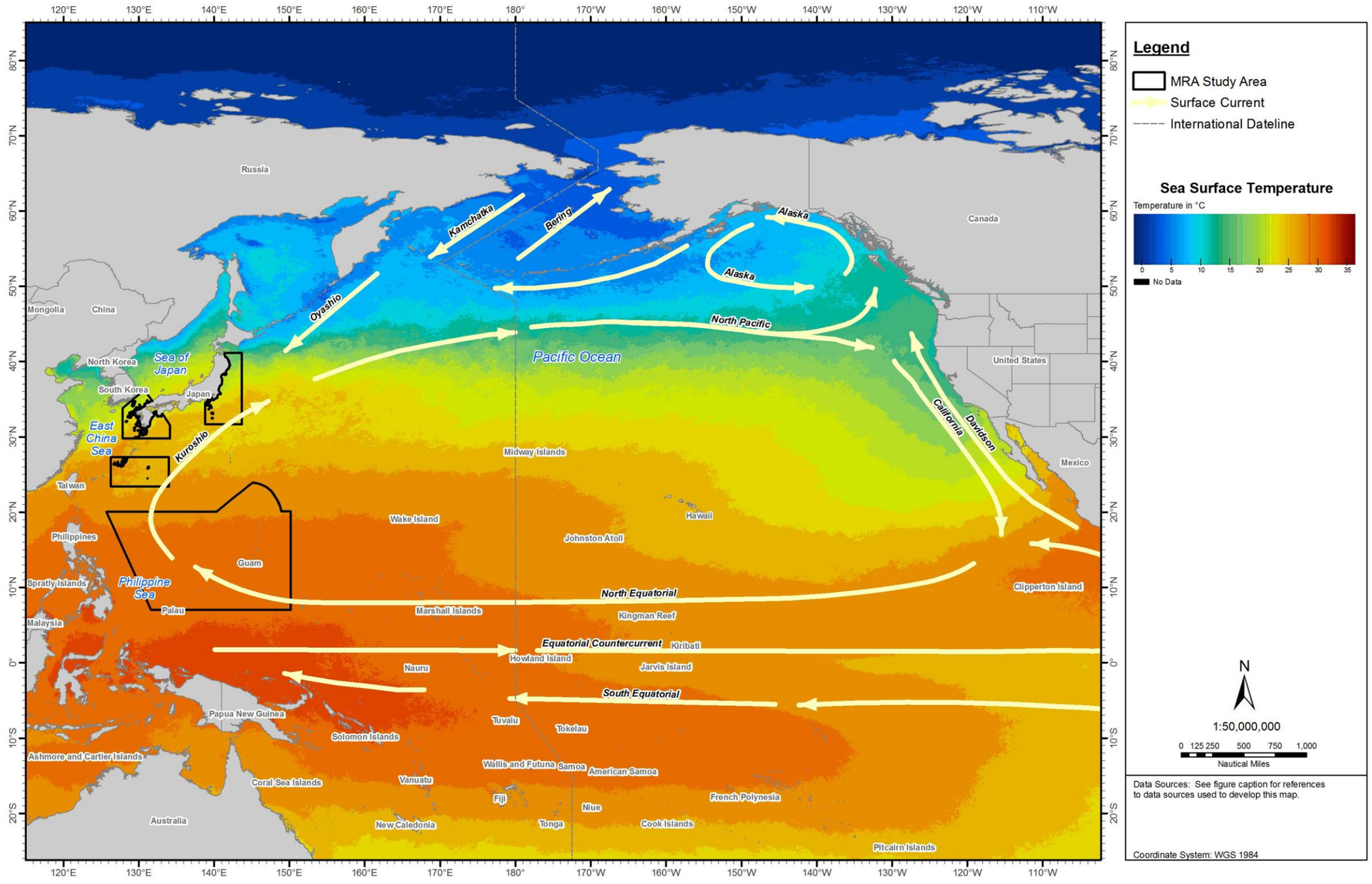

Figure 4-16: Circulation and Sea Surface Temperature in the North Pacific Ocean

Sources: National Oceanic and Atmospheric Administration (2013); Physical Oceanography Distributed Active Archive Center (2012a).

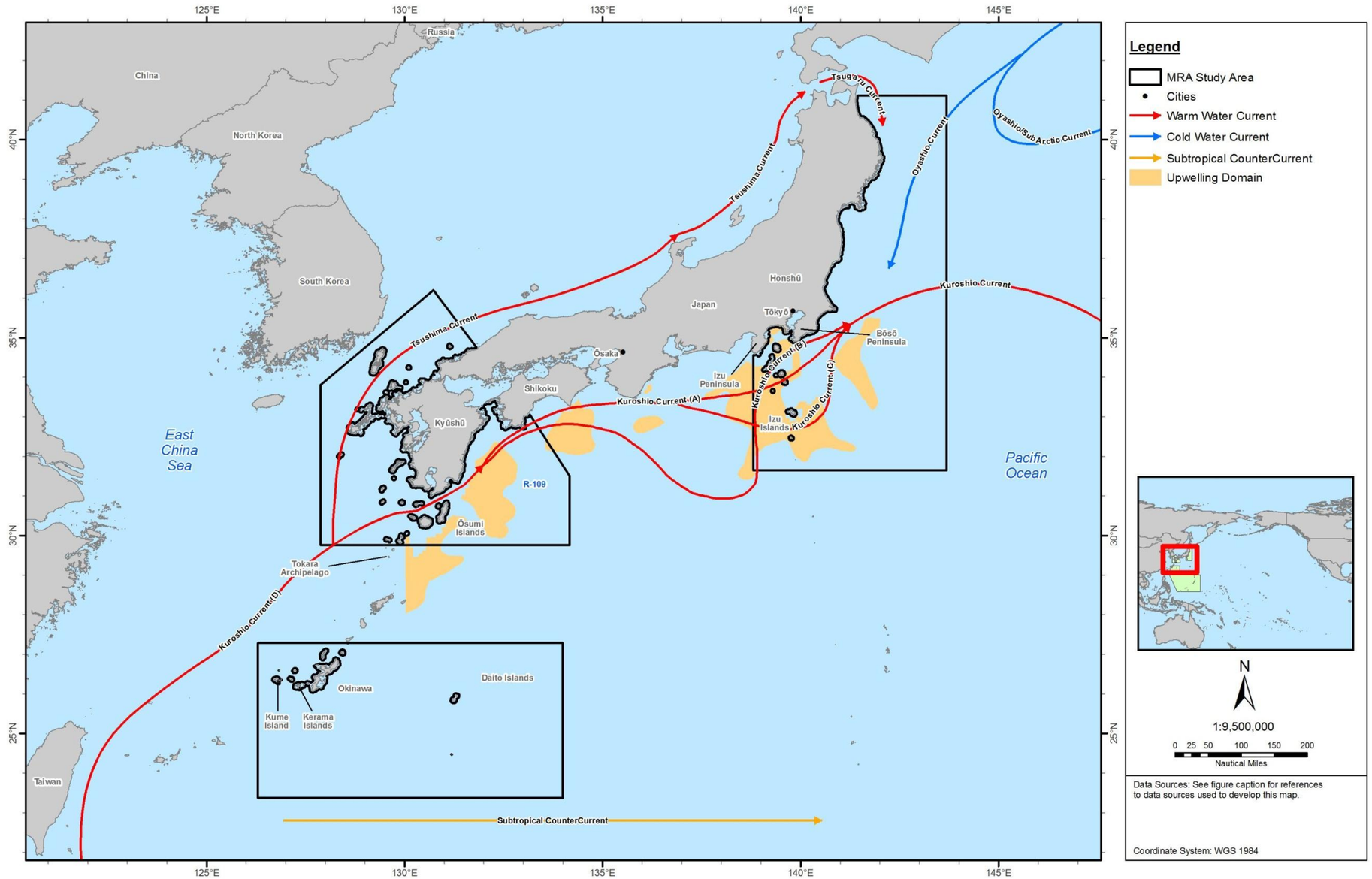

Figure 4-17: Regional Surface Circulation of the Kuroshio, Tsushima, and Oyashio Current

Sources: Furuya, Takahashi, and Nemoto (1986); Hayashi (2004); Miyazawa, Guo, and Yamagata (2004); Takahashi et al. (1980); Qiu (2001); and U.S. Department of the Navy (2005a).

This Page Intentionally Left Blank

The Kuroshio Current is a major western boundary current that begins where the NEC turns northward along the Philippines. The Kuroshio Current transports warm, low-nutrient waters northward (Tomczak and Godfrey 2003). As the Kuroshio approaches the Emperor Seamount Chains, the current forms numerous eddies and the North Pacific Current. Translated from Japanese, Kuroshio literally means black (kuro) stream (shio), referring to the dark ultramarine to cobalt blue color of its water. The "blackness" of the Kuroshio Current results from the low biological productivity of the downwelling-dominant subtropical North Pacific Ocean, because of which surface waters are devoid of detritus and other organic material (Qiu 2001). Flow of the Kuroshio also influences the global ocean climate variations and the regional climate of East Asia (Guo et al. 2003).

The Kuroshio Current originates east of the Philippine coast, where the westward flowing NEC bifurcates into the northward-flowing Kuroshio Current and the southward-flowing Mindanao Current (Qiu 2001; Qiu and Lukas 1996; U.S. Department of the Navy 1994). At the sea surface, the NEC typically bifurcates between 12 and 13°N, although this bifurcation latitude can shift from 11°N to 14.5°N inter-annually (Qiu 2001; Qiu and Lukas 1996; Toole et al. 1990). Below the sea surface, the bifurcation tends to shift northward with increasing depth because the southern limb of the subtropical gyre in the North Pacific also shifts to the north with increasing depth (Qiu 2001). In addition, the split of the NEC exhibits a seasonal fluctuation; it achieves the northernmost position in October and the southernmost position in February (Qiu and Lukas 1996). Current bifurcations near western boundaries are not uncommon and exist in other oceans as well. For example, the South Pacific South Equatorial Current (SEC) bifurcates at the Great Barrier Reef into the East Australian Current and the New Guinea Coastal Undercurrent; the SEC in the South Atlantic bifurcates at the coast of Brazil into the North Brazil Coastal Current and the southward Brazil Current (Metcalf 1968); and the SEC in the Indian Ocean bifurcates into the northward Somali Current and southward Agulhas Current (Qiu and Lukas 1996).

The Kuroshio turns eastward south of Kyūshū and flows along the southeast coasts of Honshū and Shikoku at an average speed of 1.0 to 1.5 m/s. Minimum transport (approximately 19 Sverdrup [Sv] [1 Sv = 10^6 cubic meters (m^3)/s.]) of the Kuroshio occurs in the fall when the NEC bifurcates at its seasonally northernmost latitude; maximum transport (approximately 30 Sv) occurs in the spring (Qiu 2001; Qiu and Lukas 1996). Separation of the Kuroshio from the Japan coastline occurs at approximately 140°E and 35°N; the Kuroshio then enters the open basin of the North Pacific Ocean and is renamed the Kuroshio Extension (Qiu 1995, 2001, 2002, 2003; Qiu and Kelly 1993). The Kuroshio Extension and the associated recirculation gyre form a dynamic system in a region where mesoscale and large-scale oceanic variability are the highest in the Pacific Ocean (Qiu 2002). Free from the constraint of coastal boundaries, the Kuroshio Extension is an eastward-flowing inertial jet accompanied by large-amplitude meanders and energetic warm and cold eddies (Qiu 2000, 2003; U.S. Department of the Navy 1994). The Kuroshio Extension axis is well represented by the 12°C isotherm, and the region has the highest eddy kinetic energy in the Pacific Ocean (Qiu 2002; Wyrtki, Magaard, and Hager 1976). East of the dateline, little distinction is evident between the Kuroshio Extension and the northern Subarctic Current; together, they form the broad, eastward-moving North Pacific Current (Qiu 2001, 2002).

Inter-annually, the Kuroshio Current is known for its bimodal path fluctuations (Guo et al. 2003; Qiu 2001). The "straight" path denotes the flow of the Kuroshio close to the Japan coast (Qiu 2001; Qiu and Miao 2000); the "large-meander path" signifies the detoured offshore flow of the Kuroshio. In addition to these stable paths, the Kuroshio may take a third, relatively stable path that loops southward over the Izu Ridge. This path is common during times of flow transition between meandering flow and straight flow. The large-meander path is aperiodic; once formed, both the straight and large-meander paths can persist from a year to a decade. In contrast, the transition between the meander and straight

path is rapid, often completed over a period of several months (Kawabe 1986; Qiu 2001; Qiu and Miao 2000).

Climatic effects also alter the transport of the Kuroshio. The bifurcation of the NEC into the Kuroshio and Mindanao Currents migrates to the north during El Niño years and to the south during La Niña years (Qiu and Lukas 1996). In addition, after ENSO events (within 1.5 years), transport of the NEC increases, resulting in enhanced flow of the Kuroshio and Kuroshio Extension (Qiu 2000, 2002; White and He 1986; Yamagata, Shibao, and Umatani 1985). During a positive PDO (warm-phase), transport of the Kuroshio intensifies; the negative phase of the PDO results in decreased Kuroshio flow (Gordon and Giulivi 2004).

KUROSHIO-OYASHIO CONFLUENCE REGION. The Kuroshio-Oyashio confluence region extends from the Japanese coast eastward to beyond 160°E and north to south from 37°N to 50°N (U.S. Department of the Navy 1994). These waters are formed from the interaction of three major currents. The warm Tsugaru Current flows from the Sea of Japan through the Tsugaru Strait and between Hokkaidō and Honshū, carrying warm water south along the east coast of Honshū. The cold Oyashio Current carries water from the Kuril Islands south along the east coast of Hokkaidō. The warm Kuroshio Current brings water from equatorial regions north along the east coast of Honshū, where it meets the Oyashio and Tsugaru Currents (Piatt and Gould 1994). The mixing of the water masses in the confluence region creates a highly dynamic and productive frontal system that produces an abundant resource for the fisheries off of Japan (Qu, Mitsudera, and Qiu 2001; U.S. Department of the Navy 1994).This region is an area of intense mesoscale eddy formation (Itoh and Yasuda 2010). Occurrences and behaviors of anticyclonic eddies and cyclonic eddies formed in this area relate to bottom topography, as well as variability in current flow and direction.

TSUSHIMA CURRENT. As the Kuroshio approaches the northern end of the Ryukyu chain, it splits into two branches. One branch passes along the eastern Japanese coast and the other branch passes through the Tsushima Strait entering the Sea of Japan as the Tsushima Current (Figure 4-17). The Tsushima Current is the only major warm current in the Sea of Japan (Onishi and Ohtani 1997). Velocity of current in the strait varies considerably: maximum speeds occur in the summer and fall, and minimums occur in the winter and spring (Teague et al. 2002). The Tsushima Current continues northward along the west coast of Kyūshū and Honshū; maximum summer flows are 0.8 m/s., while winter flows slow to 0.2 m/s.; speeds of 0.4 m/s. are typical throughout the remainder of the year (Lee et al. 2000; U.S. Department of the Navy 1994). Flow of the Tsushima Current is out of phase with the Kuroshio; the Tsushima Current delivers more subtropical water to the Sea of Japan when flow of the Kuroshio is weak (Gordon and Giulivi 2004). The Tsushima Current continues up the west coast of Japan and exits the Sea of Japan via the Tsugaru Strait as the Tsugaru Current. Numerous warm and cold eddies form off of the Tsushima Current as a result of the complexity of the currents in the Sea of Japan (U.S. Department of the Navy 1994). Flow of the Tsushima Current is enhanced during negative phases of the PDO and depressed during positive PDO conditions (Gordon and Giulivi 2004).

TSUGARU CURRENT. The Tsugaru Current is a branch of the Tsushima Current; it flows through the Tsugaru Strait that separates the island of Honshū to the south from Hokkaidō to the north (Figure 4-17). The mechanism responsible for formation of the Tsugaru Current from the Tsushima Current is considered an important oceanographic curiosity but remains unsolved (Onishi and Ohtani 1997). The Tsugaru Current is a shallow current that exits the strait and flows southward along the northeast coast of Honshū, resulting in a region under the influence of three distinct water masses: the Tsugaru Current, the Oyashio Current, and the Kuroshio Current (Hayashi 2004; Kojima et al. 2004; Oguma, Suzuki, and Nagata 2002). The Tsugaru Current in the strait is strong during the summer and in autumn, but almost

disappears in winter as transport decreases (Oguma, Suzuki, and Nagata 2002); transport of water from the Tsugaru Strait ranges from 1.0 to 4.1 Sv but is highly variable (Onishi and Ohtani 1997).

NORTH EQUATORIAL CURRENT. Surface currents around the Mariana Archipelago are heavily influenced by the NEC. The NEC is primarily driven by the northeast and southeast trade winds, and therefore flows westward (Figure 4-15). This current is strongest during winter, particularly in February when the trade winds are also the strongest. The NEC flows between 8° N and 15° N, with an average velocity less than 0.3 m/s. (Tomczak and Godfrey 2003; Wolanski et al. 2003). Net sea surface transport is to the west/northwest at an average speed of 0.1 to 0.2 m/s. (Uda 1970; Wolanski et al. 2003). The NEC bifurcates at the Hawaiian Islands; one branch travels north and the other continues west. The westward-flowing branch of the NEC approaches Japan and splits again, forming the southward-flowing Mindanao Current and the northward-flowing Kuroshio Current.

The Mariana Archipelago lies 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 reversals of the dominant surface current flow. In addition, the large mass of the islands within the Study Area may be capable of producing small eddies (net eastward coastal flow of several cm/s. 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 formations of these eddies have not been largely investigated throughout the MRA Study Area, existence of these eddies may explain why people lost at sea on 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).

NORTH EQUATORIAL COUNTER CURRENT. The NECC (Figure 4-15) is an eastward flowing current fed by western boundary currents of both northern and southern hemispheres (Tomczak and Godfrey 2003). Annual mean transport decreases from 45 Sv west of 135°E to 10 Sv east of the Galapagos Islands. The strength and position of the NECC vary seasonally. The NECC is located between 4 and 6°N during February through April, when the Northwest Monsoon prevents the SEC from feeding the NECC. During this period, volume transport is approximately 15 Sv and maximum speeds are below 0.2 m/s.. The NECC shifts northward to between 5°N and 10°N from May to January, when the western boundary currents of both hemispheres contribute to the flow. During this period, surface speeds range from 0.4 to 0.6 m/s..

Seasonal variations in circulation around Palau are influenced by the NECC and Mindanao Eddy (Heron, Metzger, and Skirving 2006). From December to April, circulation around Palau is northward with speeds of approximately 20 cm/s., influenced by the NECC and the Mindanao Eddy. After April, the Mindanao Eddy migrates northward and its effect on circulation surrounding Palau decreases.

EQUATORIAL UNDERCURRENT. The Equatorial Undercurrent (EUC) is the most prominent of all eastward flows at the equator (Tomczak and Godfrey 2003). The depth of the EUC varies from approximately 200 m in the west to less than 40 m in the east. This swift (1.5 m/s.) and narrow current (200 m thick and 400 km wide) extends more than 14,000 km along the equator. Volume transport of the EUC is approximately 20 Sv.

4.4.2 Subsurface Currents and Water Masses

Thermohaline circulation—also described as the ocean "conveyor belt" or meridional overturning—is the continuous circulation of water masses throughout the ocean. This cycle begins with sinking of dense waters and subsequent formation of deep water masses in the North Atlantic and Southern oceans (Dickson and Brown 1994). Water masses throughout the world's oceans are defined by their chemical and physical properties. The temperature and salinity of a water mass determine its density. Density differences cause water masses to move both vertically and horizontally. Cold, salty, dense water formed at the surface will sink, whereas warm, less salty, and less dense water will rise. These density differences are responsible for large-scale, global ocean water circulation, which plays a major role in global climate variation and transport of water, heat, nutrients, and larvae (Kawabe and Fujito 2010). A simiplifed representation of thermohaline circulation is in the North Pacific Ocean is shown in Figure 4-18. Deep cold water travels north and a shallower warmer current returns the flow to the south and west.

Deep water masses in the Pacific Ocean include Lower and Upper Circumpolar Deep Waters, Antarctic Circumpolar Current, and North Pacific Deep Water. Lower and Upper Circumpolar Deep Waters and Antarctic Intermediate Water are transported from the Antarctic Circumpolar Current to the North Pacific (Kawabe and Fujito 2010). Deep ocean circulation carries the Lower Circumpolar Deep Water westward between the East Mariana Ridge and Shatsky Rise (Kawabe et al. 2009). Upper Circumpolar Deep Water and North Pacific Deep Water are carried eastward by the return flow of deep circulation.

Intermediate water masses (residing above deep water and below surface water) include North Pacific Intermediate Water (NPIW), Pacific Central Water, and Antarctic Intermediate Water (Johnson 2008; Kawabe and Fujito 2010). NPIW is observed as a salinity minimum at depths between 300 and 800 m (Kouketsu et al. 2007). Formation of NPIW between the Kuroshio Extension and the Subartic Front east of Japan transports low-salinity and nutrient-rich water from the subpolar gyre to the intermediate waters of the North Central Pacific (Kouketsu et al. 2007). Observed changes in properties of the NPIW may explain variability observed in the North Central Pacific. The potential temperature of the NPIW core increased by 0.10 to 0.17 °C from the 1980s and 1990s to 2000s.

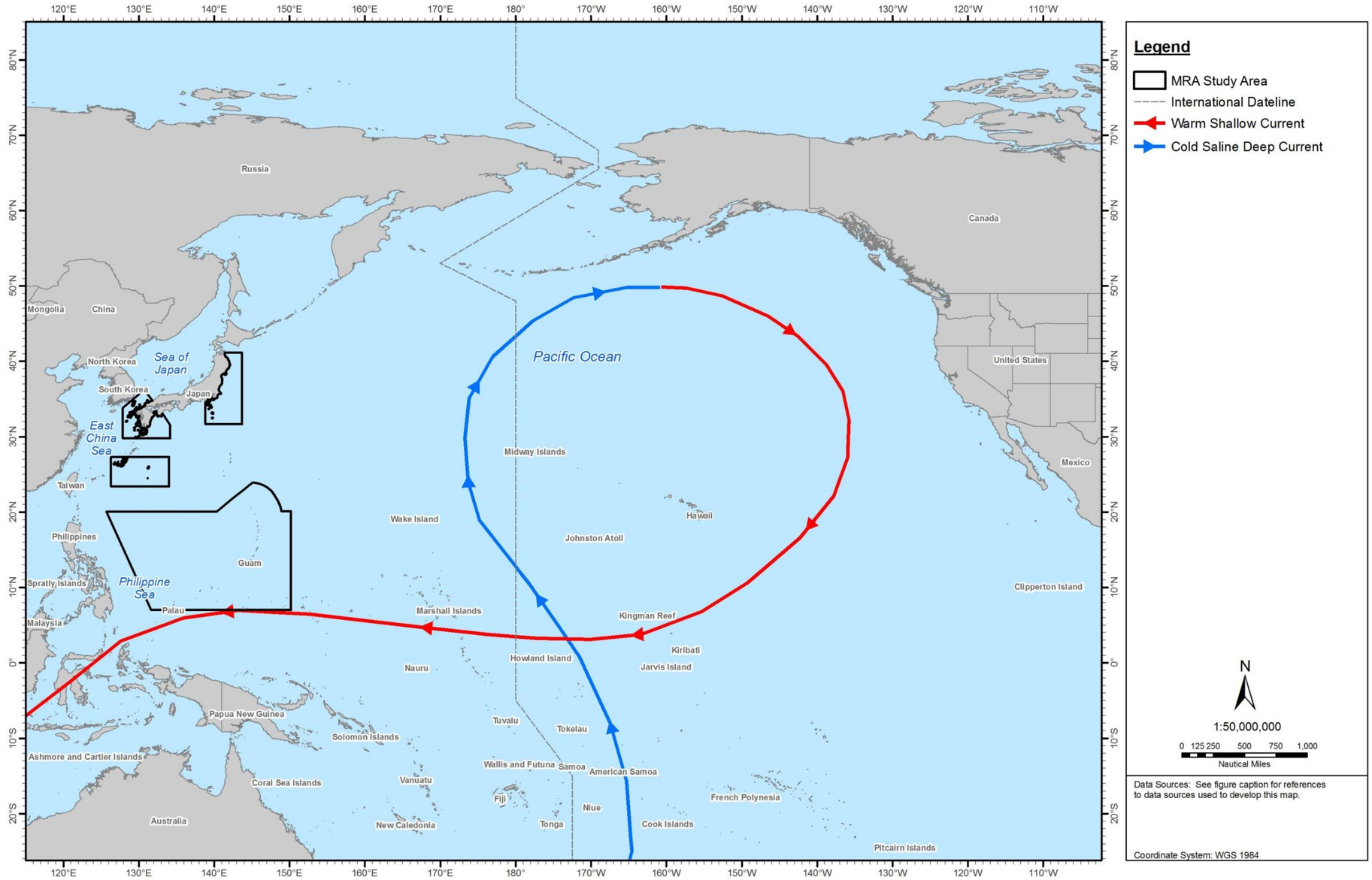

Figure 4-18: Simplified Schematic of Thermohaline Circulation in the North Pacific Ocean
Source: National Oceanic and Atmospheric Administration (2012).

This Page Intentionally Left Blank

4.4.3 Oceanic Fronts

Oceanic fronts are narrow areas of the ocean bounded by two water masses with distinct temperatures or densities, and are characterized by rapid changes in specific water properties over short distances (Belkin, Cornillon, and Sherman 2009). Oceanic fronts occur on a variety of size and temporal scales ranging from a few meters up to many thousands of kilometers, and from short-lived to year-round occurrences. Recent research on the air-sea interface suggests that SST, wind speed, and heat fluxes out of the ocean correlate positively over oceanic fronts and eddies, indicating a significant influence of the ocean on the atmosphere (Small et al. 2008). Distributions, migrations and behaviors of marine animals are influenced by oceanic fronts (Howell et al. 2010; Norcross et al. 2003; Polovina et al. 2001). Moreover, ocean fronts are often locales of increased productivity and biomass (Bost et al. 2009).

The MRA Study Area is influenced by the Subarctic Front and Subtropical Front (Norcross et al. 2003; North Pacific Marine Science Organization 2004). The Subarctic Front is at the northern boundary of the North Pacific Transition Zone and is located between 40° N and 43° N (North Pacific Marine Science Organization 2004). The Subarctic Front develops between the cold (less than 8°C), low salinity (33 parts per thousand [ppt]), productive subarctic waters in the north, and the low-nutrient subtropical waters of the central Pacific (Howell et al. 2010; North Pacific Marine Science Organization 2004). The Subtropical Front occurs at the southern boundary of the North Pacific Transition Zone between 28° and 34° N (North Pacific Marine Science Organization 2004). This front occurs between the cold, low salinity surface waters of the north and the warm, higher salinity subtropical waters from the south (North Pacific Marine Science Organization 2004).

The Transition Zone Chlorophyll Front is a feature of the North Pacific Transition Zone: cool, high chlorophyll surface water from the Alaska Gyre waters meets warm, low chlorophyll surface water from the NPSG (Polovina et al. 2001). Extending more than 4,970 miles (8,000 km) across the North Pacific, the Transition Zone Chlorophyll Front shifts seasonally north and south about 620 miles (1,000 km). During winter, the front is located at about 30 to 35° N latitude. In the summer, the front is located at about 40 to 45° N. Satellite telemetry data on movements of loggerhead turtles and detailed fisheries data for albacore tuna show that both travel along this front as they migrate across the North Pacific (Howell et al. 2010; North Pacific Marine Science Organization 2004).

The western portion of the Subarctic Front is called the Oyashio Front (Sakurai 2007). The Oyashio Front is defined by the southern boundary of the cold (2° to 8°C) Oyashio Current and the northern boundary of the warm Kuroshio Current (Tomczak and Godfrey 2003). The southern boundary of the Oyashio is located between 36° N and 40° N and 140° E and 140° W. Formation of NPIW also occurs at this front, where subpolar waters of the Oyashio Current are subducted under subtropical waters of the Kuroshio Current and are entrained in the North Central Pacific (Talley 1993).

4.5 CHEMICAL OCEANOGRAPHY

4.5.1 Water Column Characteristics

The characteristics of the water column are primarily determined by temperature and the solids and gases dissolved in it. Seawater is made up of a number of components including salts, gases, nutrients, dissolved compounds, particulate matter (solid compounds such as sand, marine organisms, and feces), and trace metals (Garrison 1999). Sea surface temperature varies with latitude, season, and depth. Sea surface temperatures are affected by atmospheric conditions and can show seasonal variation in

association with upwelling, climatic conditions, and latitude (Tomczak and Godfrey 2003). Sea surface temperature and nutrients are also influenced by long-term climatic conditions including El Niño, La Niña, the PDO, and climate change (Gergis and Fowler 2009).

Seawater is primarily composed of dissolved salts (positively charged ions and negatively charged ions). The most abundant ions in sea water are those of chlorine, sodium, calcium, potassium, magnesium, and sulfur (as sulfate). These ions make up 98% of the dissolved salts in seawater, with chloride and sodium ions making up the largest portion (85%) (Libes 1992). Concentrations of these ions (salinity) in the ocean vary according to physical processes that include addition or removal of water, precipitation, evaporation, freezing, runoff from land, and river discharges.

Salinity is defined as the total number of grams (g) of ions (dissolved salts) present in 1 kilogram (kg) of seawater (Libes 1992). Therefore, the density (mass/volume) of seawater partially depends on the amount of salts present. However, temperature also controls the density of seawater (Libes 1992). As temperature of seawater increases, density decreases; conversely, as temperature of seawater decreases, density increases. However, once the freezing point is reached, density decreases because the density of water in the solid phase (Conlan and Service 2000) is lower than of water in a liquid phase (Castro and Huber 2007a). Salts are excluded from ice when ice forms on the surface of the ocean, and the water directly under the ice is cold, salty, and therefore extremely dense. Development of a dense layer of water at the surface makes the water column unstable, and the dense water then sinks below waters with lower densities (Castro and Huber 2007a). The sinking of cold, salty water is a primary factor driving thermohaline circulation. This variation in density of seawater according to salinity and temperature (Libes 1992) leads to stratification (arrangement in layers). Typically, three density layers are present in the water column of the ocean: a surface layer (0 to 200 m), an intermediate layer (200 – 1,500 m), and a deep layer (below 1,500 m)(Castro and Huber 2007a).

The most important gases in the ocean are oxygen, carbon dioxide, and nitrogen. All three of these gases are present in the atmosphere and are readily exchanged between the ocean and the atmosphere. Oxygen minimum zones occur at bathyal depths where strong upwelling leads to high surface productivity that sinks and degrades, depleting oxygen within the water column (Levin 2003). The most extensive oxygen minimum zones are found along the eastern Pacific Ocean where upwelling occurs and where intermediate depth waters are older with a lower oxygen concentration than other water masses.

Nutrients are chemicals or elements necessary to produce organic matter. Basic nutrients include dissolved nitrogen, phosphates, and silicates. Dissolved inorganic nitrogen occurs in ocean water as nitrates, nitrites, and ammonia, with nitrates the dominant form. Solids dissolved in the ocean come primarily from rocks on land that are weathered and carried to the ocean by rivers, as well as from the air and precipitation (Stefansson and Gislason 2001).

Trace metals also occur in the surface, intermediate and deep layers of the ocean. Trace metals are elements in the marine environment at concentrations less than 0.05 micromoles (µmol)/kg (Libes 1992). Trace metals in the marine environment include lead, aluminum, chromium, manganese, copper, zinc, and iron. These metals are introduced into seawater by river runoff, anthropogenic inputs, winds, hydrothermal vents, and transport of volcanic ash (Libes 1992). However, dissolved iron and other metals adsorb onto particles or precipitate into oxides, and are removed from seawater by scavenging in the water column onto particulate matter or by sinking to the seafloor (Langmann et al. 2010; Libes 1992). Therefore, while trace metals are found throughout the water column, their distributions are

individually controlled by supply and removal processes, in addition to physical mixing and advection in ocean basins (Bruland, Orians, and Cowen 1994).

Some trace metals, particularly iron, are biologically important (Coale et al. 1998; Coale et al. 1996; Langmann et al. 2010); availability of iron affects primary production in the marine environment. Iron is introduced to the marine environment primarily by rivers, wind-driven transport from continents, hydrothermal vents, and from volcanic eruptions (Langmann et al. 2010; Libes 1992). Iron is a limiting factor for growth of phytoplankton in high-nutrient, low-chlorophyll surface water, including surface waters of the north and equatorial Pacific Ocean (Coale et al. 1998; Coale et al. 1996; Martin and Gordon 1988). The introduction of iron could could enhance primary production and alter the carbon cycle by reducing carbon dioxide concentrations in the atmosphere (Boyd et al. 2007; Krishnamurthy et al. 2009), although the indirect effects of this type of fertilization are unclear. Increases in iron concentration also increase nitrogen fixation (Krishnamurthy et al. 2009).

OYASHIO CURRENT. SST of the Oyashio Current varies seasonally from 0°C in early spring to 20°C in the summer (United Nations Environment Programme 2006). Minimum and maximum temperatures occur at depths of approximately 100 m and 300 m.

KUROSHIO CURRENT. SST of the Kuroshio Current ranges from a minimum 16.6° to 25.3°C (United Nations Educational Scientific and Cultural Organization 2009). The surface salinity is less than 32 practical salinity units (psu) in the north to more than 34.5 psu in the south (Tomczak and Godfrey 2003). On interannual timescales, El Niño conditions cause large changes in salinity over the equatorial Pacific as warm, low-salinity waters from the western tropical Pacific are advected east into the central Pacific (Stott et al. 2004). SST has been increasing in the Kuroshio Current since the 1960s (Aquarone and Adams 2009).

The confluence of the warm Kuroshio and cold Oyashio Currents along the eastern coast of Japan creates a dynamic “perturbed zone” of fluctuating ocean fronts and eddies. This creates temperature gradients of up to 8.3°C within a distance of less than 37 km. Moreover, large-scale changes in the Kuroshio and Oyashio current systems can affect the SST of the region through changes in warm/cold water advection (Qiu 2001).

NORTH CENTRAL PACIFIC. The average monthly SST in the North Central Pacific and MRA Study Area is shown for January, April, July, and October, months representative of the seasons winter, spring, summer, and fall, respectively (Figure 4-19 and Figure 4-20). The SSTs in the North Central Pacific range from a maximum of 29.3°C to a minimum 17.8°C (United Nations Educational Scientific and Cultural Organization 2009). Salinity in the North Central Pacific decreases from north to south (Flament et al. 2009), and ranges from 34 to 35 ppt. Annual average SSTs increase from north to south (Flament et al. 2009).

The surface layer of the North Central Pacific typically includes the water column from the surface to a depth of 100 to 200 m (Castro and Huber 2007a), and is characterized by warm, high-salinity water (Norcross et al. 2003). This surface layer is also where photosynthesis occurs. Nutrients required by phytoplankton for photosynthesis include nitrogen and phosphorus (Loh and Bauer 2000). However, the reservoirs of nitrogen and phosphorus are relatively small, and these are therefore biolimiting nutrients (Libes 1992). Surface water concentrations of biolimiting nutrients in the North Central Pacific are uniformly low primarily as a result of biological uptake. Concentrations of bioavailable nitrogen (nitrate and nitrite) are low at the surface (less than 1 µmol/kg), and consequently limit photosynthesis (Flament

et al. 2009). Nutrients can be transported from deeper waters to the surface by cyclonic (counterclockwise) eddies that occur in the subtropical Pacific Ocean (Benitez-Nelson et al. 2007).

The vertical distribution of iron in the western and central Pacific Ocean is similar to nutrient profiles, with low surface concentrations, a mid-depth maximum, and a slight decrease with depth below that mid-depth maximum (Kitayama et al. 2009). However, concentrations of dissolved iron in deep waters are higher in the western Pacific than in the central Pacific, most likely a result of the high atmospheric or lateral inputs to the western Pacific Ocean (Kitayama et al. 2009).

In the North Central Pacific, the thermocline (where temperature changes rapidly with depth) is in the intermediate layer of the the water column, below the surface layer to approximately 1,500 m (Castro and Huber 2007a). Temperature decreases from 25°C at the surface to 5°C at a depth of 700 m (Flament et al. 2009), with the main thermocline typically occurring at depths between 300 and 400 m (Qiu et al. 1997). In contrast to the surface layer, nutrient concentrations in the intermediate layer increase with depth. Nutrients in this layer reach a subsurface maximum as detritus and biogenic materials sink. However, the thermocline prevents mixing of waters above and below. Therefore, nutrients are trapped below the thermocline and begin to decrease slightly with depth.

The deep or bottom layer (below 4,921 ft. [1,500 m]) is uniformly cold, with temperatures less than 4°C (Castro and Huber 2007a; Libes 1992). Nutrient concentrations in deep water are slightly lower than concentrations below the thermocline and are uniformly low. However, deep water masses traveling through ocean basins in thermohaline circulation accumulate nutrients (Libes 1992). When deep water masses are formed at the surface, they are high in oxygen and low in nutrients. As North Atlantic Deep Water and Antarctic Bottom Water travel along the western continental slope toward the Indian and Pacific oceans, the rain of biogenic materials increases the nutrient concentrations of these water masses. These nutrients are brought back to the surface when those water masses upwell in the Indian and Pacific Oceans. Therefore, the Pacific Ocean has higher nutrient concentrations than the Indian and Atlantic Oceans (Libes 1992).

PHILIPPINE SEA. SSTs in the Philippine Sea range from 15° to 29°C (Williams, Jung, and Englebretson 1993). Coldest SST occurs in February near China in the Taiwan Strait. Warmest SST occurs in May near the South China Sea. Surface salinity varies from 34.2 to 34.8 ppt. A salinity maximum (more than 34.8 ppm) occurs at depths of 80 to 200 m. A salinity minimum (less than 34.3 ppt) occurs at a depth of approximately 400 m.

EQUATORIAL PACIFIC. The SST of the Equatorial Pacific ranges from 26 to 30°C (United Nations Educational Scientific and Cultural Organization 2009).

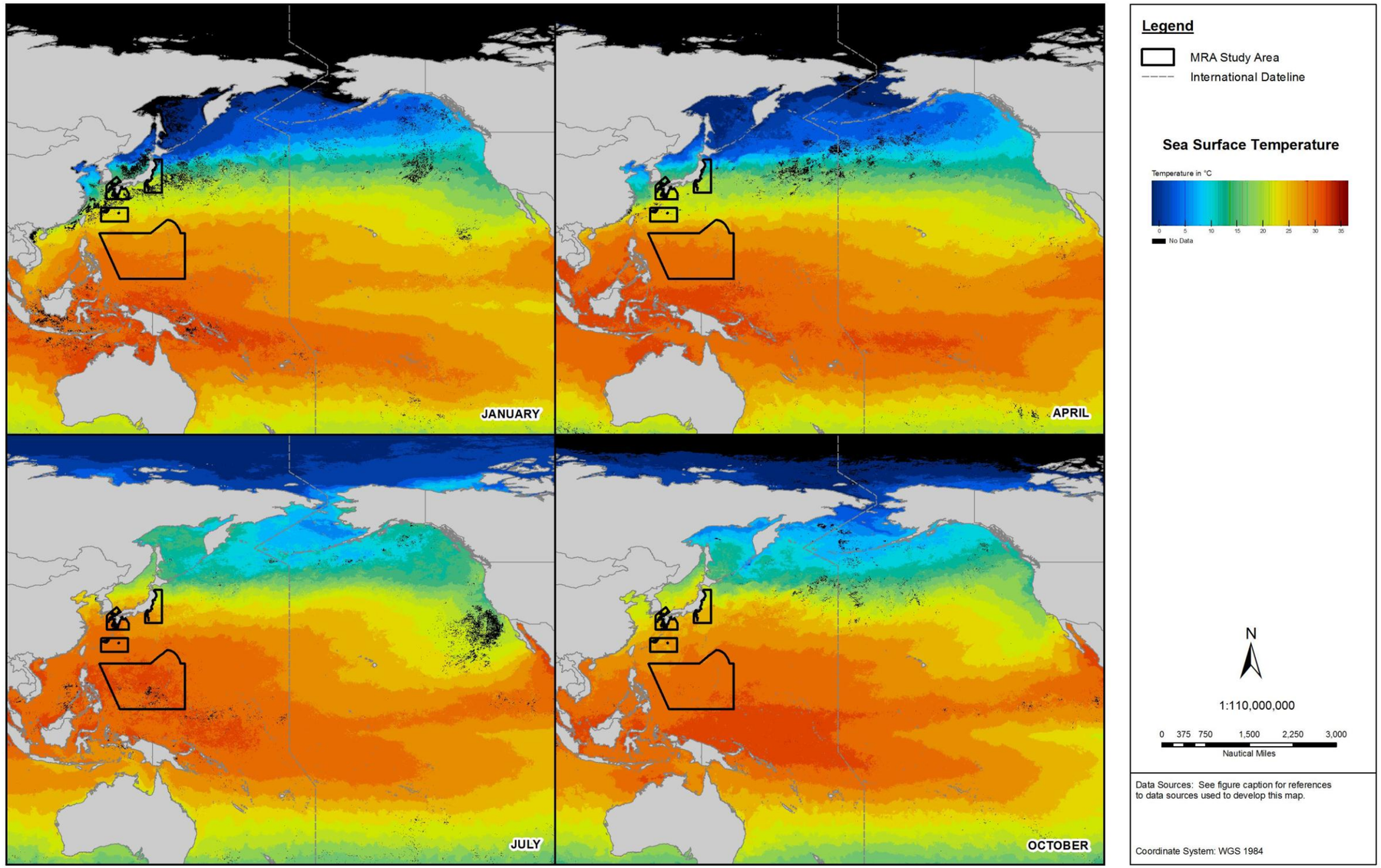

Figure 4-19: Average Monthly Sea Surface Temperature in the North Pacific Ocean
Source: Physical Oceanography Distributed Active Archive Center (2012b, c, d, e).

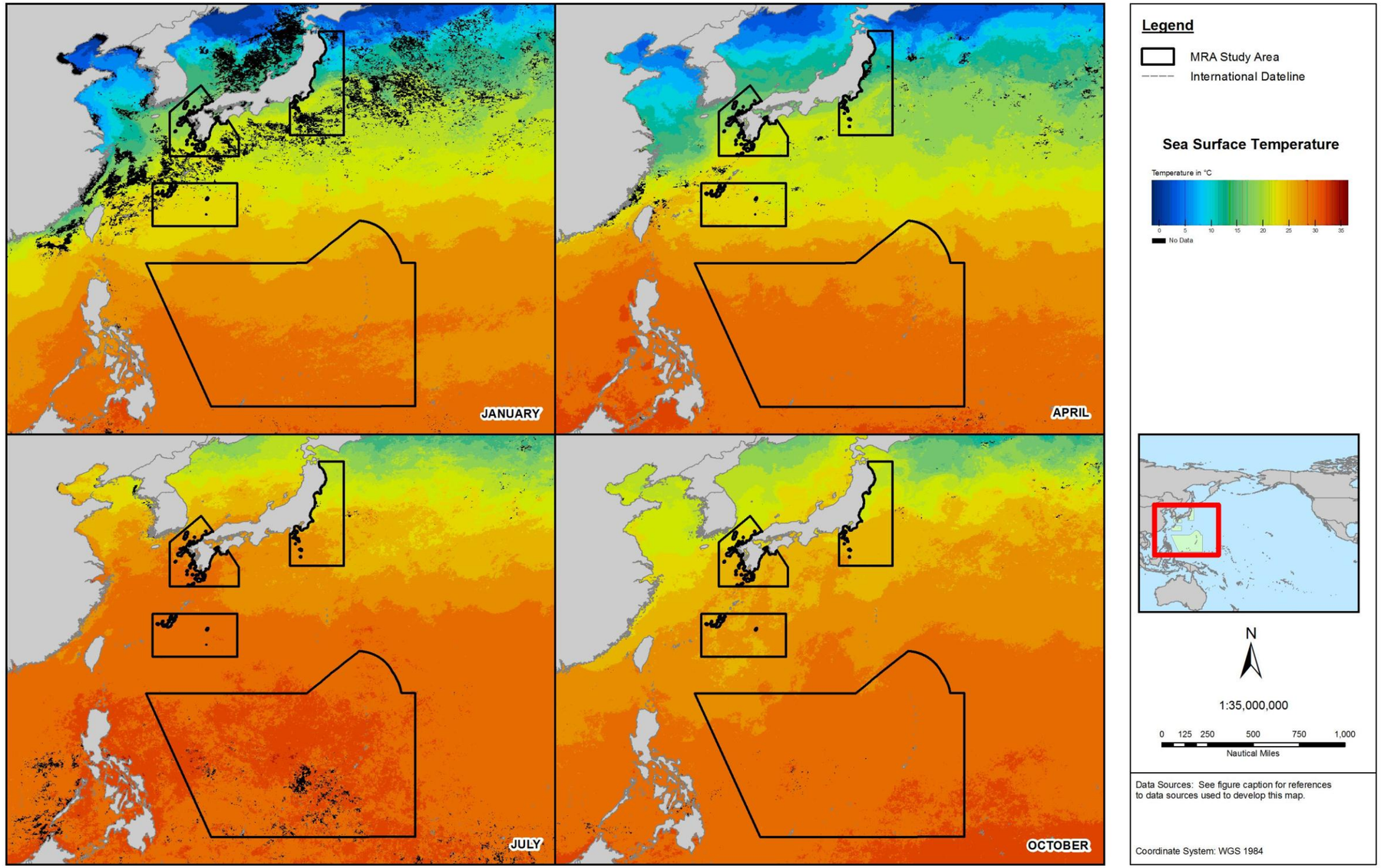

Figure 4-20: Average Monthly Sea Surface Temperature in the MRA Study Area
Source: Physical Oceanography Distributed Active Archive Center (2012b, c, d, e).

4.5.2 Chemical Cycles

The process that returns nutrients to the marine environment is called a biogeochemical cycle. A biogeochemical cycle is a pathway by which a chemical, molecule, or nutrient moves through the biosphere, lithosphere, atmosphere, and hydrosphere. These pathways involve recycling of materials to maintain equilibrium among those reservoirs. Biogeochemical cycles in the ocean include the carbon, nitrogen, silica, sulfur, and iron cycles. The carbon cycle is particularly important because carbon combines with other elements to form organic molecules, which make up cells and subsequently food for organisms (Castro and Huber 2007a). Carbon is readily exchanged between the atmosphere and the ocean. In regions of oceanic upwelling, carbon is released to the atmosphere, while in regions of downwelling, carbon is absorbed from the atmosphere by the ocean. When carbon dioxide enters the ocean, it can be converted to organic or inorganic forms. Through photosynthesis, carbon dioxide is used to produce organic carbon (Castro and Huber 2007a). In photosynthesis, phytoplankton use solar energy and water to turn atmospheric carbon dioxide into carbohydrates. In respiration, the carbohydrates and oxygen produced via photosynthesis are used by organisms, releasing carbon dioxide back into the ocean.

Carbon dioxide also participates in a series of reactions producing inorganic forms that include carbonic acid, bicarbonate, and carbonate (Capone 2008). Oxidations of carbonic acid and bicarbonate result in an increase in hydrogen ions, which decreases pH. While these reactions occur in equilibrium, the ratio of these species depends on factors such as seawater temperature and pressure. However, most dissolved inorganic carbon in the ocean is bicarbonate (Capone 2008); thus, the ocean's waters are well buffered with a pH typically above 8. Bicarbonate combines with calcium in the water to make calcium carbonate (limestone). Calcium carbonate constitutes the shells of marine organisms, including corals. An increase in manmade carbon dioxide results in an increase in the total amount of carbon dioxide in the ocean (Sabine et al. 2004). Increased carbon dioxide in the ocean increases the acidity of seawater, dissolves calcium carbonate, and impairs coral reefs (Feely et al. 2002; Hutchins, Mulholland, and Fu 2009; Kerr 2010; Steinacher et al. 2009). In addition, the carbon cycle is linked to other nutrient cycles, including the nitrogen, silica, and phosphorus cycle (Hutchins, Mulholland, and Fu 2009). Therefore, increased carbon dioxide in the ocean changes the biogeochemical cycles of these nutrients, particularly nitrogen and including iron (Krishnamurthy et al. 2009).

Nitrogen fixation is the most important process in the nitrogen cycle (Capone 2008). The largest reservoir of nitrogen is in the form of inorganic nitrogen gas (Capone 2008). Inorganic nitrogen gas is also produced when bacteria break down organic matter (Hutchins, Mulholland, and Fu 2009). The nitrogen cycle is important because the dissolved inorganic form of this nutrient cannot be used by most organisms (Castro and Huber 2007a). However, some bacteria and blue-green algae can convert dissolved inorganic nitrogen to usable forms of nitrogen such as nitrate, nitrite, and ammonia. Inorganic nitrogen is converted to ammonia through the process of nitrogen fixation, and ammonia is converted into nitrite and subsequently into nitrate through the process of nitrification (Hutchins, Mulholland, and Fu 2009).

The silica cycle is important because silicate forms the exoskeletons (external covering) of a group of phytoplankton called diatoms. Diatoms are the dominant phytoplankton when silica is present, but are replaced by other phytoplankton that do not have silica shells when silica concentrations are limited (Tsunogai 2002). Therefore, the availability of silica controls phytoplankton communities and the distribution of diatoms (Bernard et al. 2010). Diatoms are particularly important because they mediate the export of particulate carbon and therefore play an important role in regulating the carbon cycle and

biochemistry of the ocean (Brzezinski, Villareal, and Lipschultz 1998). In the low-nutrient waters of the North Central Pacific, diatom biomass is typically very low but is periodically enhanced by upwelling as a result of cyclonic eddies (circular movement of water) (Brzezinski, Villareal, and Lipschultz 1998). Meso-scale eddies stimulated diatom blooms in the North Central pacific and may play a critical role in increasing nutrient supply in these oligotrophic open ocean waters (Benitez-Nelson et al. 2007). Sponges also play an important role in silica cycling in diverse marine environments (Maldonado et al. 2005).

The sulfur cycle is of interest because dissolved sulfur compounds are used to generate primary production in the deep sea. Cracks in the seafloor at hydrothermal vents release dissolved materials (including hydrogen sulfide) used as a source of energy by some bacteria, in the absence of light, to produce organic compounds—in a process known as chemosynthesis (Barry, Kochevar, and Baxter 1997). Chemosynthesis also occurs whereby methane is released (Barry, Kochevar, and Baxter 1997) (Barry, Kochevar, and Baxter 1997). Chemosynthetic communities in the Pacific Ocean primarily use hydrogen sulfide, while chemosynthetic communities in the Atlantic Ocean can also use methane as an energy source (Barry, Kochevar, and Baxter 1997).

The iron cycle is important because the availability of iron affects primary production in the marine environment. Iron is highly insoluble in sea water. Only a small fraction of iron is dissolved in seawater and is available for biotic uptake; therefore, iron is biolimiting in the marine environment. The iron hypothesis, formulated by Martin and Gordon (1988), is that lack of iron is the limiting factor for growth of phytoplankton in high-nutrient, low-chlorophyll surface water, including surface waters of the north and equatorial Pacific Ocean. This hypothesis was validated by a series of ocean fertilization experiments near the Galapagos Islands (Coale et al. 1998; Coale et al. 1996), and subsequent research over the past 20 years has established iron as the primary nutrient affecting primary production, particularly in the Southern Ocean and Pacific Ocean (Krishnamurthy et al. 2009). For example, Langmann et al. (2010) showed that a volcanic eruption in 2008 increased iron in the northeast Pacific, led to a phytoplankton bloom, and temporarily increased primary production of surface waters. Increasing the concentration of iron increases primary production and therefore affects the carbon cycle by reducing carbon dioxide concentrations in the atmosphere (Boyd et al. 2007; Krishnamurthy et al. 2009).

4.6 BIOLOGICAL OCEANOGRAPHY

4.6.1 Primary Production

Primary production is the rate at which organic materials are synthesized from inorganic substances by photosynthesis or chemosynthesis (Garrison 1999). It is typically expressed as the grams of carbon fixed by organisms per unit area per of time. Photosynthesis is the major process through which primary production occurs (Castro and Huber 2007b). 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, most photosynthesis is carried out by phytoplankton using a suite of light-harvesting compounds to convert solar energy into chemical energy, the most common being chlorophyll *a* (chl *a*) (Thurman 1997). Intensity and quality of light, availability of nutrients, and seawater temperature all influence primary productivity as generated through photosynthesis (Valiela 1995). Rates of photosynthetic production can vary from less than 0.1 g carbon/square meter (m^2)/day in regions that are oligotrophic (low nutrient and chlorophyll concentrations), such as the western equatorial Pacific, to more than 10 g carbon/m^2/day in highly productive areas (Thurman 1997).

The average monthly net primary production and cholorphy a in the North Central Pacific and MRA Study Area is shown for January, April, July, and October, months representative of the seasons winter, spring, summer, and fall, respectively (Figure 4-21 to Figure 4-24). Net primary production is higher around the Japan Archipelago with colder waters and higher nutrient concentrations compared to the Mariana Archipelago (Figure 4-22). Similarly, the chlorophyll a concentration is higher around the Japan Archipelago with higher phytoplankton concentration are higher compared to the Mariana Archipelago in nutrient limited waters (Figure 4-24).

Another potentially significant source of primary productivity does not occur in the euphotic zone but rather in specific habitats that supply the nutrients necessary for chemosynthesis. Hydrothermal vents, cold seeps, and whale falls can support vast benthic communities of chemosynthetic organisms (Fujikura et al. 1999; Fujiwara et al. 2001; Fujiwara et al. 2000; Hashimoto et al. 1989; Naganuma, Wada, and Fujioka 1996; Tsunogai, Yoshida, and Gamo 2002). Locations of hydrothermal vents, cold seeps, and whale falls reported in the North Pacific Ocean and MRA Study Area are shown in Figure 4-25 and Figure 4-26. Primary production from chemosynthetic communities has been estimated at 0.2 to 1.0 milligram (mg) carbon/m^2/day (Furuya et al. 1998; Shiomoto, Hashimoto, and Murakami 1998). Many organisms live in association with bacteria capable of deriving energy from hydrogen sulfide that is dissolved in the hydrothermal vent or cold seep fluid, or supplied by decaying carcasses of whales (Thurman 1997). Because these bacteria depend on the release of chemical energy, the mechanism responsible for this production is called chemosynthesis. It has been estimated that at any given time, more than 500,000 sulfide-rich whale skeletons lie on the deep-sea floor and may serve as dispersal “stepping stones” for some species (Smith and Baco 2003).

OYASHIO CURRENT. The Oyashio is considered a moderately high productivity (150 to 300 g carbon/m^2/yr) ecosystem (Heileman and Tang 2009). The Kuroshio-Oyashio confluence, mixing warm and cold waters, gives rise to productive waters with a high abundance of phytoplankton and higher trophic levels (Aruga, Yokohama, and Nakanishi 1968; Kasai et al. 1997; Taniguchi 1999). The most prominent feature of phytoplankton dynamics in the Oyashio waters is the large seasonal variation in productivity due to a spring phytoplankton bloom (Kasai et al. 1997; Odate and Furuya 1998; Shiomoto et al. 1994). In the Oyashio waters, near-surface chl *a* values are lowest in winter and reach exceptionally high concentrations during the spring phytoplankton bloom (usually April and May). During the spring bloom, microphytoplankton strains of diatoms are dominant and make up a large portion of phytoplankton biomass in the euphotic zone (Kasai et al. 1997; Shiomoto et al. 1994). Intense spring blooms with near-surface chl *a* concentrations exceeding 5 mg/m^3 were observed from 1972 to 1998. In April, the near-surface chl *a* concentrations range from less than 1 to 37.7 mg/m^3, suggesting that timing, magnitude, and duration of spring blooms vary significantly inter-annually. Initiation and development of the spring bloom in the Oyashio waters result from a combination of increased irradiance and decreased depth of the mixed layer (Limsakul et al. 2002; Limsakul et al. 2001; Yoshimori et al. 1995). The mixed layer occurs from the ocean surface to a depth of between 25 and 200 m where seawater temperature and density are uniform. After the bloom in late spring, chl *a* sharply decreases in the near surface; minimum concentrations occur in August, and a small secondary bloom occurs in October. This secondary bloom can be attributed to a renewal of wind mixing, a corresponding injection of nutrients into a nutrient-depleted upper layer, and sufficient irradiance within the mixed layer. The secondary bloom is short and dissipates rapidly with the declining strength of solar irradiance and deepening of the mixed layer (Limsakul et al. 2002).

Similar to the subtropical waters, cooler waters of the Oyashio also possess a deep chlorophyll maximum (DCM)—a subsurface region of enhanced chlorophyll concentration. However, unlike the

subtropical waters, the DCM of the Oyashio waters is formed at shallower depths (20 to 30 m) during the summer, when the water column has become stratified and nutrients are depleted (Limsakul et al. 2002). Concentrations of chlorophyll in the Oyashio DCM are only 1.2 to 2 times greater than those found at the surface.

Large changes in the winter and spring biomass of phytoplankton and macroplankton over annual, decadal, and inter-decadal time scales could be attributed to climate-related changes in oceanographic processes. Inter-annual changes in the intensity of the winter East Asian Monsoon significantly impact the extent of vertical mixing, nitrate inputs into the euphotic zone, and concentrations of chl *a* in winter and the next spring (Limsakul et al. 2001). A prolonged period of deeper winter mixed layers in the mid-1970s to the mid-1980s resulted in a substantial increase in mixed-layer nitrate concentrations. This change also led to a decrease in winter phytoplankton biomass. In contrast, the spring chl *a* increased steadily during this period. The decline in winter phytoplankton biomass can be attributed to the mixed layer depth; a deeper mixed layer prevents phytoplankton from remaining in the euphotic zone for enough time necessary for growth. Thus, substantial amounts of nutrients are left unused. However, water column stratification in the spring allowed phytoplankton to take advantage of the enhanced ambient concentrations of nutrients (Limsakul et al. 2001).

KUROSHIO CURRENT. The Kuroshio Current is considered a moderately high productivity (150 to 300 g carbon/m^2/yr) ecosystem (Heileman and Tang 2009). Phytoplankton biomass is generally highest in eddies that form on the edge of Kuroshio. In the upper stream of the Kuroshio, onset of El Niño leads to increased primary productivity. This increase, while not completely understood, is likely related to a decrease in the depth of the thermocline during El Niño conditions (Nakata and Hidaka 2003; Sugimoto, Kimura, and Tadokoro 2001). In El Niño years, average chl *a* concentrations are almost twice as high as those measured during La Niña years (Sugimoto, Tadokoro, and Y. Furushima 1995).

EAST CHINA SEA. The East China Sea is considered a highly productive (more than 300 g carbon/m^2/yr) ecosystem (Heileman and Tang 2009). High nutrient levels result in high primary productivity. Two peaks in phytoplankton abundance occur—the highest from July to September, and a lower peak in April.

NORTH CENTRAL PACIFIC. Approximately half of all primary production is supported by oceanic phytoplankton located within subtropical gyres (Falkowski 1994; Karl 1999); however, surface concentrations of chl *a* in the subtropical regions are low (National Aeronautics and Space Administration 1998; Ondrusek et al. 2001). Seasonal variations in phytoplankton abundance are constrained within narrow bounds (monthly means ranging from 0.04 to 0.37 mg chl *a*/m^3) as a result of a semi-permanent stratification and downwelling (typically associated with the subtropical anticyclonic gyres (Limsakul et al. 2002). This stratification, which varies little between seasons, prevents vertical mixing of nutrients that are essential for the production of phytoplankton (Aruga, Yokohama, and Nakanishi 1968; Ayukai and Hattori 1992; Odate and Furuya 1998; Ondrusek et al. 1991; Reid 1962; Sugimoto, Kimura, and Tadokoro 2001); this stratification is typical of plankton dynamics that occur in subtropical waters (Hayward and McGowan 1985; Hayward, Venrick, and McGowan 1983). In these regions of nutrient limitation, nitrogen fixation may be an important source of new nitrogen (Karl 1999; Limsakul et al. 2002).

Seasonal cycles in production relate directly to mixed-layer depth. Nutrient supply is enhanced in the winter with the deepening of mixed layer enabling phytoplankton populations respond rapidly to the higher nutrient flux (Limsakul et al. 2002; Limsakul et al. 2001). Highest chlorophyll concentrations in the southern region occur during the winter months, despite deeper mixing of phytoplankton and decreased

surface irradiance (Limsakul et al. 2002). The stratification of surface waters, especially in the summer, leads to nutrient depletion (Dore et al. 2008). Despite this nutrient depletions, phytoplankton blooms are an annual feature in the NPSG.

The western Pacific can be considered an oligotrophic region. The water column is composed of nutrient-depleted surface area overlying a deeper nutrient rich layer (Rodier and Le Borgne 1997). As such, standing stocks of phytoplankton biomass (Radenac and Rodier 1996) and concentrations of chl *a* are low throughout the Study Area (less than 0.1 mg/m^3) (National Aeronautics and Space Administration 1998). In regions where overall nutrient concentrations are low, the phytoplankton communities are dominated by nanoplankton and picoplankton (Higgins and Mackey 2000; Le Bouteiller, Blanchot, and Rodier 1992). This condition is true for the MRA 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 make up 60% of the total chl *a* measured (Le Bouteiller, Blanchot, and Rodier 1992).

The NPSG is an old ecosystem. The present boundaries of the NPSG have existed since the Pliocene (10^7 years ago) (McGowan and Walker 1985). The NPSG is also considered a “climax” community—an ecosystem that has reached a final and permanent stage of succession, and one that is inexorably linked to the climate. Such a community can be studied to evaluate the effects of climate change on the seascape, community structure, and community dynamics of the ecosystem (Karl 1999). Approximately half of all global primary production is supported by oceanic phytoplankton, yet phytoplankton biomass makes up only about 1 to 2% of the total amount of carbon in plants (Falkowski 1994; Lalli and Parsons 1997). Oceanic subtropical gyres occurring in both hemispheres of the Atlantic and Pacific oceans, as well as in the Indian Ocean, make up more than 40% of the earth’s surface and account for most of the global primary production (Karl 1999).

Although the subtropical waters possess low concentrations of surface chlorophyll, a subsurface region of enhanced chlorophyll concentration exists (the DCM). In the Japan and Okinawa Complexes OPAREA, the DCM is first detected in April and often lasts until October when it is eroded by strong vertical mixing in the region (Limsakul et al. 2002). High mixing levels, decreased irradiance, and reduced water transparency combine to prevent reestablishment of the DCM until April. The depth of the DCM in the subtropical waters off Japan and Okinawa depends on light irradiance and nutrient availability. Mean chlorophyll concentrations in the DCM range from 0.26 to 0.36 mg chlorophyll/m^3, and exceed those found at 10 m by a factor of 2 to 7 (Limsakul et al. 2002). Phytoplankton assemblages in the DCM of the Kuroshio and adjacent subtropical waters are primarily composed of pico- and nanoplankton that have adapted to decreased irradiance levels by enhancing their photosynthetic activity or by altering their carbon to chlorophyll ratios (Furuya 1990; Furuya and Marumo 1983). These phytoplankton are distinct from those occurring in shallower waters and adjacent regions (Furuya and Marumo 1983).

The NPSG is thought to be a semi-enclosed, stable, and relatively homogenous habitat; however, increasing evidence suggests that it exhibits substantial physical, chemical, and biological variability in both time and space (Karl 1999). For example, regions of the NPSG show extensive mesoscale variability demonstrated by the formation of discrete eddies, near-inertial motions, and internal tides (Venrick 1990). In addition, during winter months, tropical cyclones pass through the NPSG, deepening the mixed layer and injecting nutrient-rich water into the typically oligotrophic surface waters, which can fuel ephemeral phytoplankton blooms (Karl 1999). Over longer time scales, the NPSG is affected by the ENSO cycle. During an El Niño event, shifts occur in the circulation patterns creating weaker flow, enhanced

primary production, and intense water column stratification (Karl et al. 1995). These conditions enable community shifts in the phytoplankton toward nitrogen fixing cyanobacteria (such as *Trichodesmium* spp.), altering the ecosystem in the NPSG from a nitrogen-limited to a phosphorus-limited ecosystem (Karl 1999; Karl et al. 1995).

PHILIPPINE SEA. Chlorophyll a concentrations range from a surface low of 0.05 mg chla/m^3 to a maximum of 0.15 mg chl *a*/m^3 at a depth of 120 m Cordero et al. (2012). Gordon, Sprintall, and Ffield (2011) describes the regional oceanography of the Philippine Archipelago; however, no other information is available on primary production.

EQUATORIAL PACIFIC. Upwelling in the equatorial Pacific is estimated to support 50% of annual global new production that portion of phytoplankton production in a given area that is supported by nitrogen from outside the boundaries of the area such as from below the photic. (Eppley and Peterson 1979; Roman et al. 2002). Phytoplankton biomass and chl *a* concentrations are higher throughout the equatorial Pacific than in the NPSG (Mackey et al. 2002). Primary production ranges from over approximately 180 to 453 mg carbon/m^2/yr (United Nations Educational Scientific and Cultural Organization 2009). The phytoplankton community is dominated by high concentrations of picophytoplankton, in particular, two species of prokaryotes, *Prochlorococcus* and *Synechococcus* (Mackey et al. 1997). Large-scale phytoplankton blooms were documented in the Equatorial Pacific at the end of three El Nino events in 1998, 2003, and 2005 (Ryan et al. 2006), resulting from intensified flow of iron-enriched waters of the New Guinea Coastal Undercurrent.

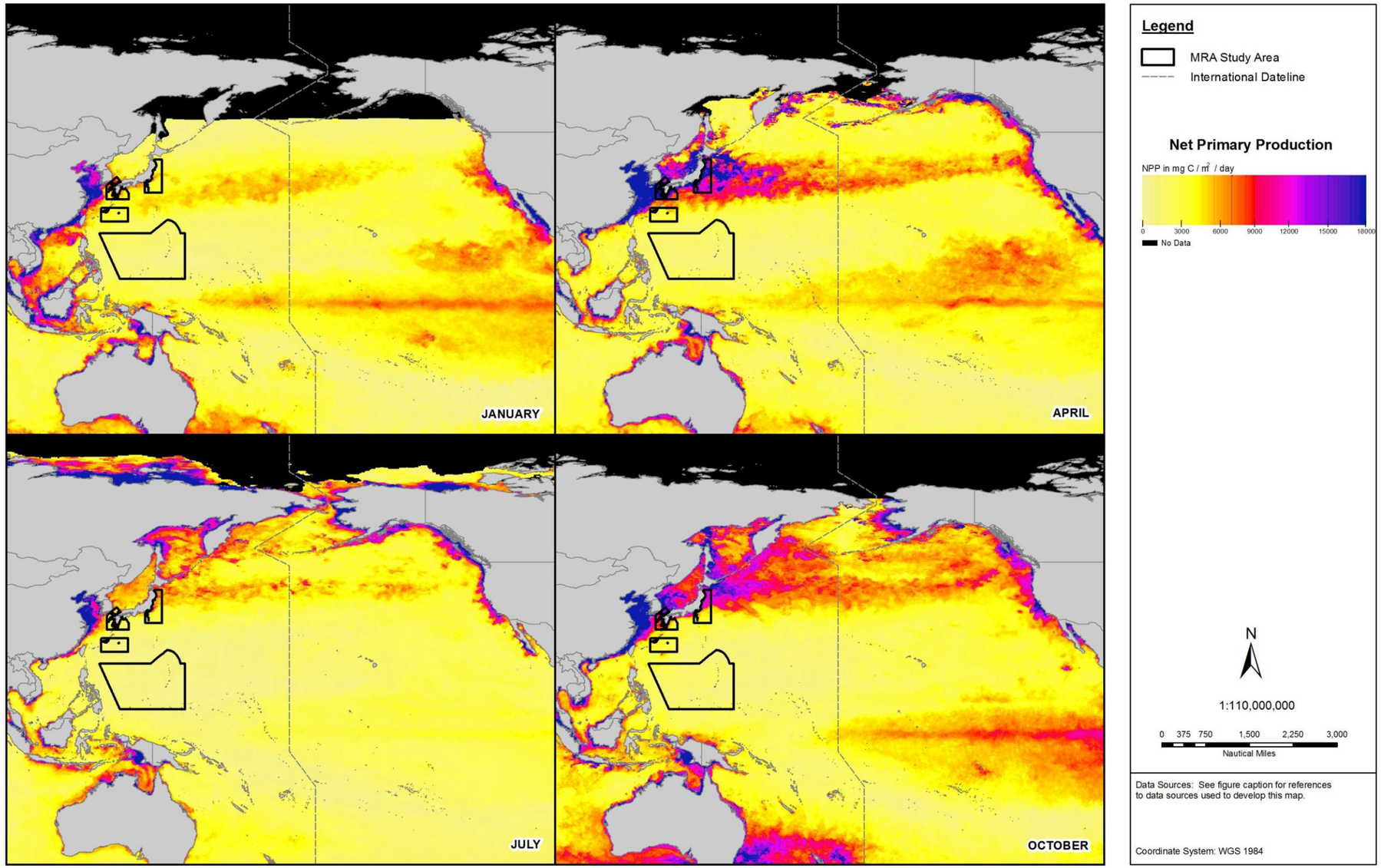

Figure 4-21: Average Monthly Net Primary Production in the North Pacific Ocean
Sources: Behrenfeld and Falkowski (1997) and Oregon State University Ocean Productivity Group (2012a, b, c, d).

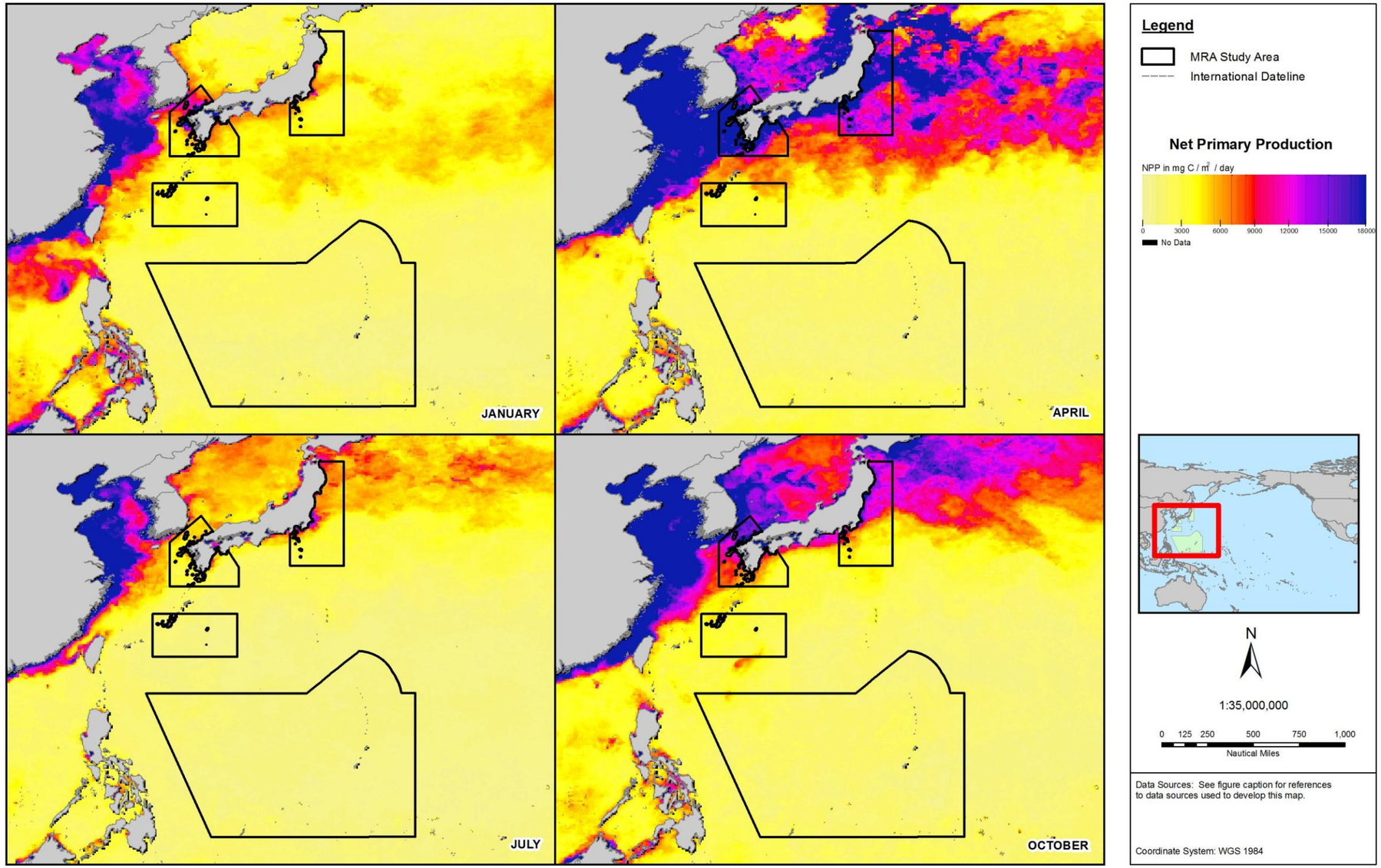

Figure 4-22: Average Monthly Net Primary Production in the MRA Study Area
Sources: Behrenfeld and Falkowski (1997) and Oregon State University Ocean Productivity Group (2012a, b, c, d).

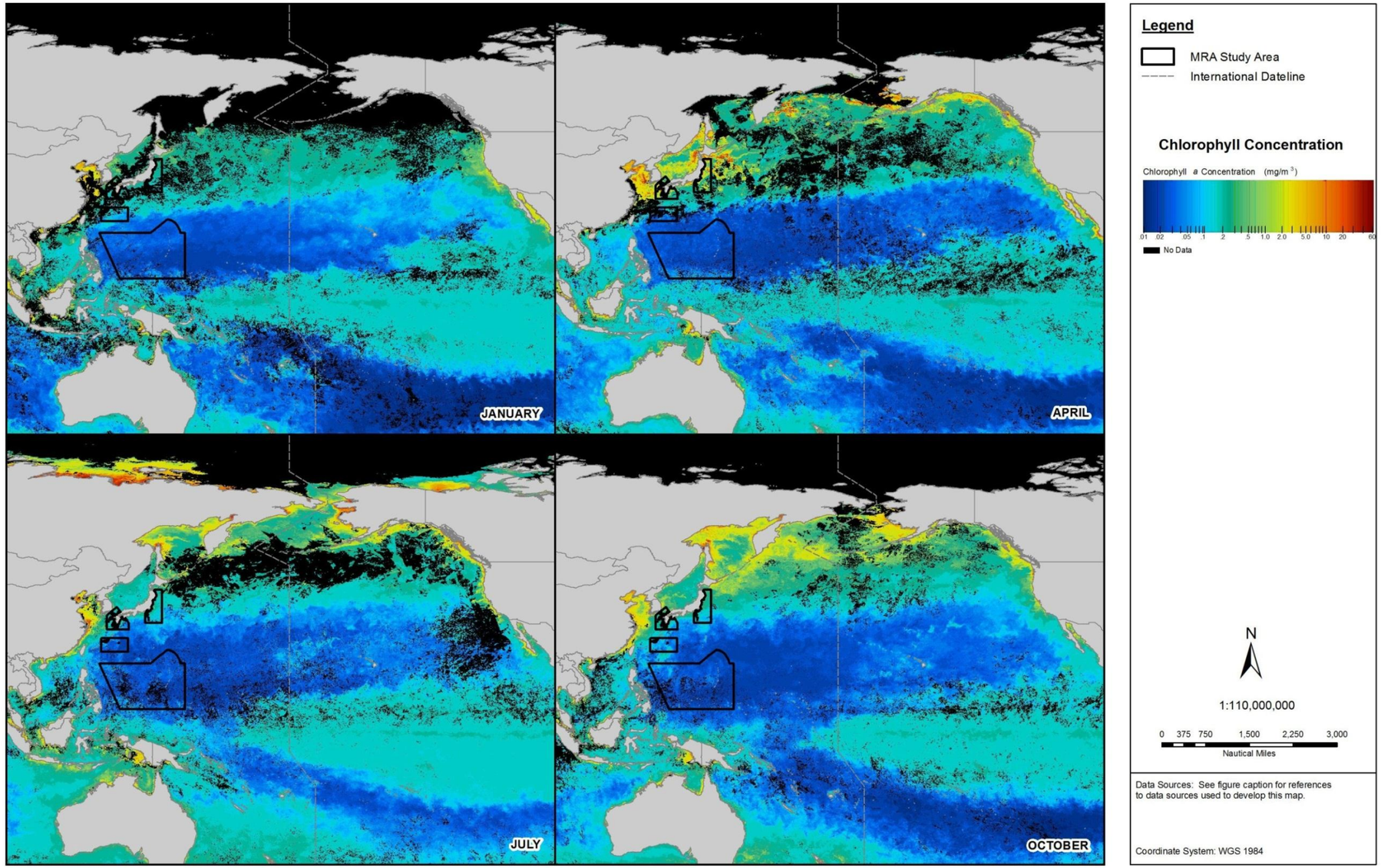

Figure 4-23: Average Monthly Surface Chlorophyll a Concentration in the North Pacific Ocean
Source: National Aeronautics and Space Administration Goddard Space Flight Center OceanColor Group (2012).

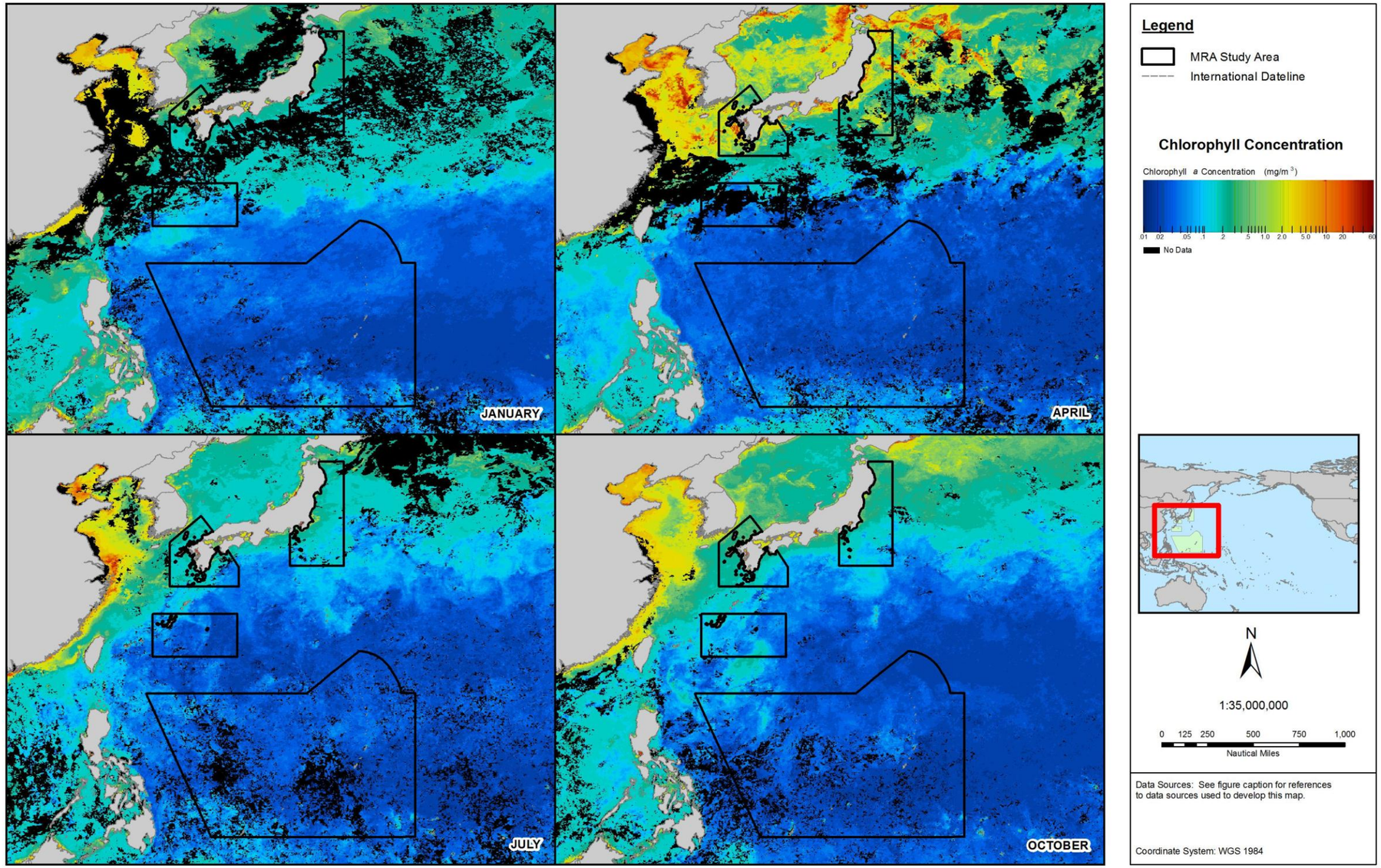

Figure 4-24: Average Monthly Surface Chlorophyll a Concentration in the MRA Study Area
Source: National Aeronautics and Space Administration Goddard Space Flight Center OceanColor Group (2012).

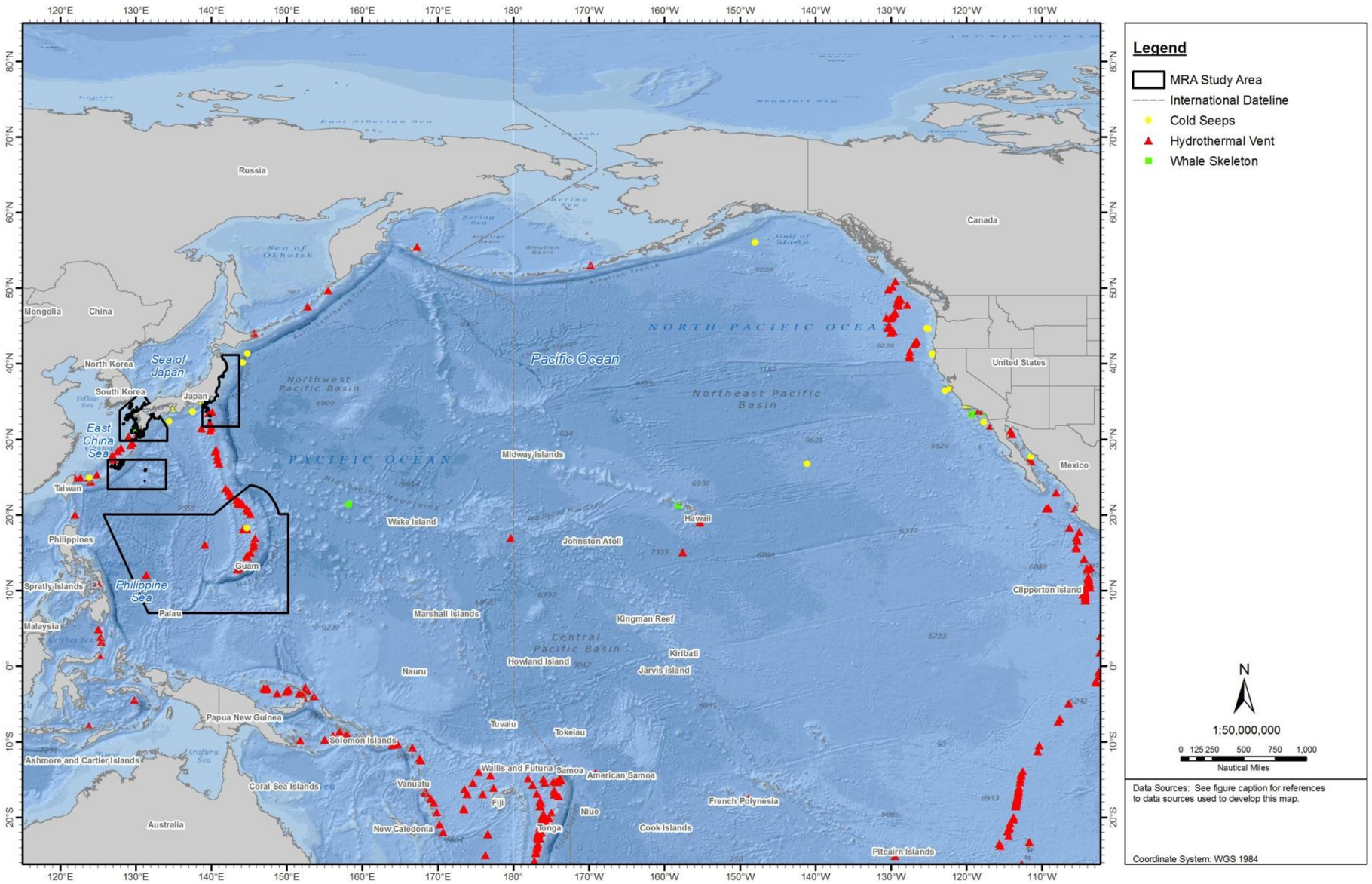

Figure 4-25: Hydrothermal Vents, Cold Seeps, and Whale Skeletons in the North Pacific Ocean
Sources: Baker, Ramirez-Llodra, and Perry (2010) and Beaulieu (2010).

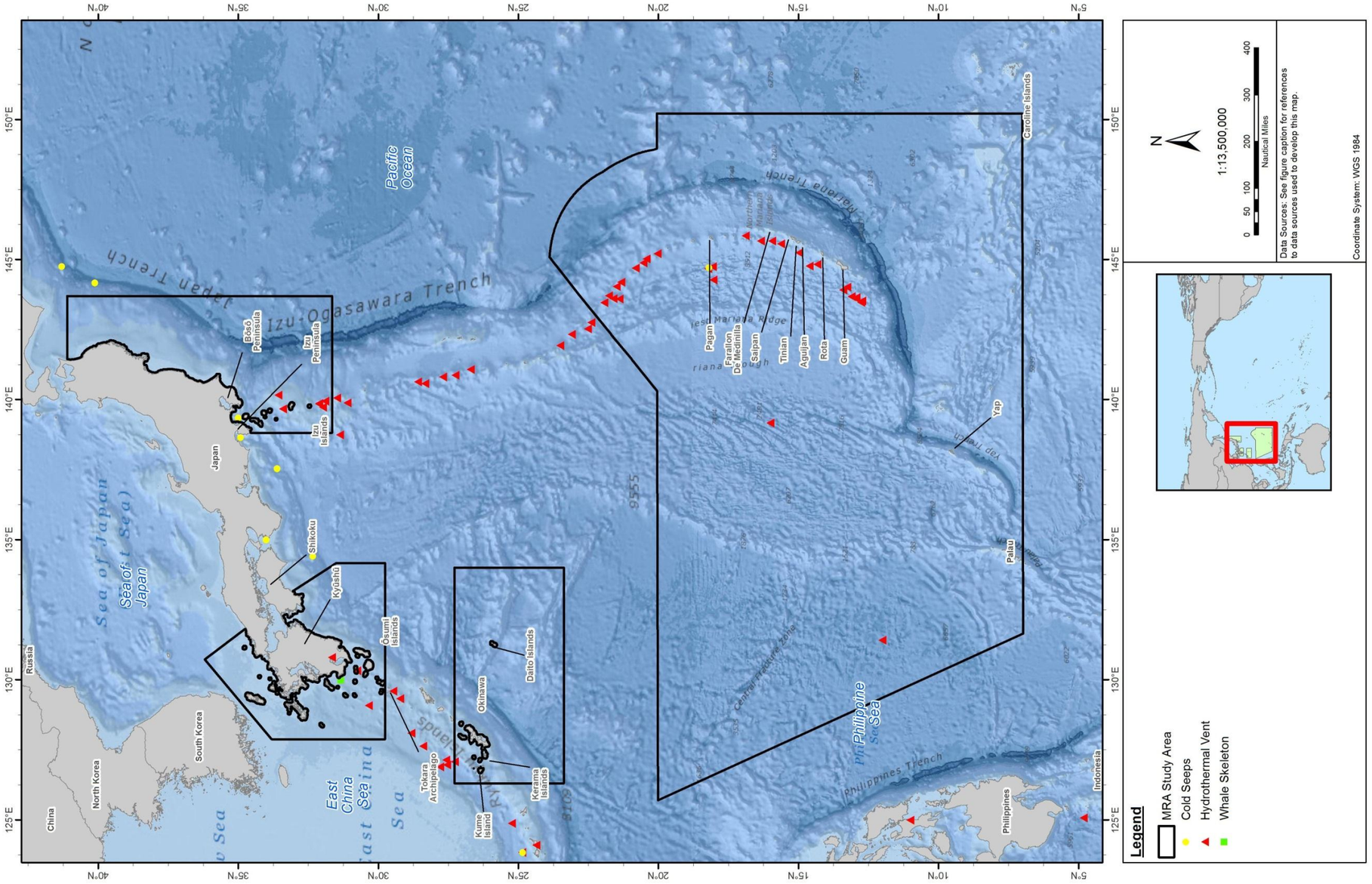

Figure 4-26: Hydrothermal Vents, Cold Seeps, and Whale Skeletons in the MRA Study Area
Sources: Baker, Ramirez-Llodra, and Perry (2010) and Beaulieu (2010).

4.6.2 Secondary Production

Secondary production is production of bacteria and animals through heterotrophic processes, and refers to change in biomass of organisms that consume primary producers (Karl 1999; Scavia 1988; Strayer 1988). This section focuses on secondary production from marine zooplankton (primarily associated with water masses). Other secondary producers, such as marine mammals, sea turtles, corals, and fish, are discussed in later chapters of this Marine Resource Assessment.

Marine zooplankton are aquatic organisms ranging in size from 20 µm to large shrimp and jellyfish (above 2,000 µm) (Parsons, Takahashi, and Hargrave 1984), and can be separated into two distinct categories based on their dependence on 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 found only short distances from the coast (Uchida 1983). Copepods are the dominant zooplankton in most open ocean ecosystems (Toda 1989; Uye, Nagano, and Tamaki 1996). The average length of adult copepods is 1–2 millimeter (mm), but their size may range from small (0.2 mm) to large (>10 mm) (Walter and Boxshall 2012). Zooplankton play a key role in the marine plankton food web by affecting primary productivity via predation and providing food for animals at higher trophic levels (Chang and Fang 2004).

OYASHI CURRENT. In Japanese bays, the nauplii of copepods (cyclopoids and calanoids) are the most abundant food resource for higher trophic levels (Chang and Fang 2004; Hirakawa, Goto, and Hirai 1997). Large copepods (2.2–3.7 mm) are numerically dominant in Oyashi waters (Ayukai and Hattori 1992; Kobari and Ikeda 1999; Mackas and Tsuda 1999; Tsuda, Saito, and Kasai 1999, 2001; Tsuda and Sugisaki 1994). Mesozooplankton in Oyashio waters exhibit considerably more seasonal variation than those in subtropical waters; minimum and maximum monthly means range from 22 to 183 mg/m^3. Maximum values tend to occur in April in coordination with onset of the spring phytoplankton bloom. At this time, young copepodites arrive at the surface to take advantage of the abundant phytoplankton bloom (Limsakul et al. 2002).

KUROSHIO CURRENT. The Kuroshio Current is an important spawning ground for pelagic fish (Aquarone and Adams 2009; Gordon, Sprintall, and Ffield 2011). Small copepods (0.9–1.5 mm) are the most abundant mesozooplankton (Ayukai and Hattori 1992). High biomasses of copepods tend to occur during El Niño events in part because primary production in the upper stream of the Kuroshio increases during an El Niño period (Nakata and Hidaka 2003). While El Niño affects the overall biomass of zooplankton in the region, decadal variability dominates the trends of mesozooplankton biomass (more abundant during the 1970s than the early and mid-1980s (Sugimoto, Kimura, and Tadokoro 2001; Sugimoto, Tadokoro, and Y. Furushima 1995). ENSO events likely influence the position of the NEC bifurcation and subsequent transport success of the larval Japanese eel, *Anguilla japonica,* to the Kuroshio Current (Kim et al. 2007; Zenimoto et al. 2009). Simulations of the NEC bifurcation during El Nino events suggested the transport success of Japanese eel larvae to the Kuroshio would be low (Kim et al. 2007).

EAST CHINA SEA. Zooplankton biomass is highest where the waters of the Kuroshio and Yellow Sea converge (Heileman and Tang 2009). Increasing water temperature and land-based runoff cause spikes in zooplankton biomass in late spring.

NORTH CENTRAL PACIFIC. The North Central Pacific is composed primarily of plankton-poor water. Total zooplankton biomass at the surface examined within the western Pacific and adjacent seas was the lowest within the NEC, reaching concentrations of only 1.35 g wet weight/m^2 (Vinogradov and Parin 1973). Vinogradov and Parin (1973) also surveyed zooplankton biomass in the tropical Pacific, and at their station nearest the Study Area (13°31'N, 139°58'E), zooplankton biomass was very low (11.7 mg/m^3). In subtropical waters, seasonal variations in mesozooplankton are constrained within narrow bounds by the high levels of stratification. Monthly maximum and minimum biomass ranges from 23 to 54 mg/m^3 (Limsakul et al. 2002).

PHILIPPINE SEA. Gordon, Sprintall, and Ffield (2011) describes the regional oceanography of the Philippine Archipelago; however, no information is available on secondary production.

EQUATORIAL PACIFIC. Maximum zooplankton biomass in the equatorial Pacific was highest north of the equator between 1° and 5°N latitude (Roman et al. 2002). Variations in flow of equatorial currents resulted in seasonal variations in zooplankton biomass.

4.6.3 Harmful Algal Blooms

Harmful algal blooms refer to a small percentage of single-celled and macroalgal species that cause harm to humans and the environment by producing toxins or excessive growth (Center for Sponsored Coastal Ocean Research 2010b, 2011). Some harmful algal blooms cause illness or death in humans and marine life resulting from ingestion of toxins (McCormack 2007; Schnetzer et al. 2007; Scholin et al. 2000; Torres de la Riva et al. 2009; Trainer et al. 2000). Other types of harmful algae harm fish and invertebrates by damaging or clogging their gills. Harmful algal blooms can cause substantial economic loss to tourism and fisheries industries (Center for Sponsored Coastal Ocean Research 2010a). Increasing carbon dioxide and nutrient concentrations and temperature in surface waters as a result of climate change may create conditions that result in increased number and duration of harmful algal blooms and marine diseases (Fautin et al. 2010; Harvell et al. 1999; Paerl and Paul 2012).

JAPAN ARCHIPELAGO. Almost all microalgae responsible for various types of fish and shellfish poisoning of humans, including paralytic shellfish poisoning, diarrhetic shellfish poisoning, amnesiac shellfish poisoning, neurotoxic shellfish poisoning, and ciguatera are present in Japanese coastal waters. The most hazardous species are *Chattonella marina*, *C. antiqua*, and *Karenia mikimotoi* (formerly *Gymnodimium mikimotoi*). These species kill finfish and have caused damage to fisheries exceeding 100 million yen ($1 million U.S.). Dinoflagellates (*Cocholodinium polykrikoides* and *Gonyaulax polygramma*) and raphidoflagellates (*Heterosigma akashiwo* and *Fibrocapsa japonica*) are also hazardous species in Japan, killing numerous shellfish and net-penned fish (Fukuyo et al. 2002; Wazniak, Tango, and Butler 2004).

Among the harmful algal bloom species in Japan, those causing paralytic shellfish poisoning and diarrhetic shellfish poisoning have been officially monitored since 1995 at more than 170 sampling stations (Fukuyo et al. 2002). *Alexandrium tamarense* and *A. catenella*, two species known to cause paralytic shellfish poisoning, are widespread and often cause toxin contamination in scallops, mussels, clams, and tunicates. Initially, these organisms affected regions in northern Japan, but they have gradually expanded to affect western Japan as well. *A. tamarense* tends to occur from January to June, with maximum cell densities reaching 103 to 104 cells per liter in April and May (Itakura et al. 2002).

Japan is one of the most highly affected areas for cases of diarrhetic shellfish poisoning (Wazniak, Tango, and Butler 2004); dinoflagellates in Japanese waters responsible for diarrhetic shellfish poisoning

contamination include *Dinophysis fortii* and *D. acuminate*. Affected areas are primarily found in northern Japan. *D. mitra* and *D. tripos* also produce diarrhetic shellfish poisoning toxins (Fukuyo et al. 2002). The dinoflagellate *Heterocapsa circularisquama Horiguchi* has spread along the coast of Japan, causing loss of shellfish production (Matsuyama 2012).

The diatom *Pseudo-nitzchia* sp. is one of the most common phytoplankton species in Japanese waters; approximately 10 different species produce successive blooms throughout the year. Domoic acid (DA) is produced within blooms of *P. multiseries*, *P. delicatissima*, and *P. pseudodelicatissima.* DA acts as a neurotoxin, causing short-term memory loss, brain damage and, in severe cases, death in humans and marine mammals (Bossart 2011; Goldstein et al. 2008; Lefebvre et al. 2002). DA contamination has not yet been detected in wild and aquaculture shellfish in Japan despite intensive surveys. Currently, no monitoring program is in place for neurotoxic shellfish poisoning and ciguatera, although *Karenia breve* (formerly *Gymonodimium brevis*) and *Gambierdiscus toxicus*, causative organisms for these types of poisonings, are found in western Japan (Fukuyo et al. 2002). Toxin contamination of shellfish by these organisms has not been detected; however, *K. brevis* has been associated with fish kills in Japanese waters (Fukuyo et al. 2002; Wazniak, Tango, and Butler 2004).

MARIANA ARCHIPELAGO. Ciguatera fish poisoning caused by several species of harmful dinoflagellates accounts for most public health costs associated with marine harmful algal blooms in U.S. Pacific territorial waters (National Oceanic and Atmospheric Administration 2011). Blooms of the marine cyanobacteria (*Lyngbya majuscula*) overgrow coral reefs in Guam.

CAROLINE ISLANDS. Harmful algal blooms have not been reported in the Caroline Islands.

4.6.4 References

Ando, M. (1975). Source mechanisms and tectonic significance of historical earthquakes along the Nankai trough, Japan. *Tectonophysics, 27*, 119-140.

Aoki, S. and Kohyama, N. (1992). Modern sedimentation in the Japan Trench: Implications of the mineralogy and chemistry of clays sampled from sediment traps. *Marine Geology, 108*, 197-208.

Aquarone, M. C. and Adams, S. (2009). X-23 Kuroshio Current LME. In K. Sherman and G. Hempel (Eds.), *The UNEP Large Marine Ecosystem Report: A Perspective on Changing Conditions in LMEs of the World's Regional Seas*. (UNEP Regional Seas Report and Studies No. 182, pp. 393-401). Nairobi, Kenya: United Nations Environmental Programme.

Aruga, Y., Yokohama, Y. and Nakanishi, M. (1968). Primary productivity studies in February-March in the northwestern Pacific off Japan. *Journal of the Oceanographical Society of Japan, 24*(6), 275-280.

Ashok, K. and Yamagata, T. (2009). Climate change: The El Nino with a difference. *Nature, 461*(7263), 481-484. doi:10.1038/461481a

Associated Press (2005). *Japan: Eruption made 3,300-ft. vapor column*. Retrieved from http://www.msnbc.com/id/8452611/URL, 5 July 2005.

Atlantic Oceanographic and Meteorological Laboratory (2011, Last updated 15 July 2011). Hurricane Research Division. [Web page]. Retrieved from http://www.aoml.noaa.gov/hrd/tcfaq/A1.html, 01 May 2012.

Ayukai, T. and Hattori, H. (1992). Production and downward flux of zooplankton fecal pellets in the anticyclonic gyre off Shikoku, Japan. *Oceanologica Acta, 15*(2), 163-172.

Bailey, J. C. (1993). Geochemical history of sediments in the northwestern Pacific Ocean. *Geochemical Journal, 27*(2), 71-90.

Baker, E., Massoth, G. J., Nakamura, K., Embley, R. W., de Ronde, C. E. J. and Arculus, R. (2005). Hydrothermal activity on near-arc sections of back-arc ridges: Results from the Mariana Trough and Lau Basin. *Geochemistry Geophysics Geosystems, 6*(9), 1-14. doi: 10.1029/2005GC000948

Baker, M. C., Ramirez-Llodra, E. and Perry, D. (2010). *ChEssBase: an online information system on species distribution from deep-sea chemosynthetic ecosystems. Version 3.* World Wide Web electronic publications. Retrieved from www.noc.soton.ac.uk/chess/db_home.php

Baker, N., Fryer, P., Martinez, F. and Yamazaki, T. (1996). Rifting history of the northern Mariana Trough: SeaMARC II and seismic reflection surveys. *Journal of Geophysical Research, 101*(B5), 11427-11455.

Bangs, N. L., Shipley, T. H., Gulick, S. P. S., Moore, G. F. and Nakamura, Y. (2004). Evolution of the Nanka Trough decollement from the trench into the seismogenic zone: Inferences from three-dimensional seismic reflection imaging. *Geology, 32*(4), 273-276.

Barber, R. T. and Chavez, F. P. (1983). Biological consequences of El Niño. *Science, 222*, 1203-1210.

Barry, J. P., Kochevar, R. E. and Baxter, C. H. (1997). The influence of pore-water chemistry and physiology on the distribution of vesicomyid clams at cold seeps in Monterey Bay: Implications for patterns of chemosynthetic community organization. *Limnology and Oceanography, 42*(2), 318-328.

Beaulieu, S. E. (2010). *InterRidge Global Database of Active Submarine Hydrothermal Vent Fields: prepared for InterRidge, Version 2.0.* World Wide Web electronic publication. Retrieved from http://www.interridge.org/IRvents

Behrenfeld, M. J. and Falkowski, P. G. (1997). Photosynthetic rates derived from satellite-based chlorophyll concentration. *Limnology and Oceanography, 42*(1), 1-20.

Belkin, I. M., Cornillon, P. C. and Sherman, C. (2009). Fronts in large marine ecosystems. *Progress In Oceanography, 81*(1-4), 223-236. doi: 10.1016/j.pocean.2009.04.015

Benitez-Nelson, C. R., Bidigare, R. R., Dickey, T. D., Landry, M. R., Leonard, C. L., Brown, S. L., et al. (2007). Mesoscale eddies drive increased silica export in the subtropical Pacific Ocean. *Science, 316*(5827), 1017-1021. doi: 10.1126/science.1136221

Bernard, C. Y., Laruelle, G. G., Slomp, C. P. and Heinze, C. (2010). Impact of changes in river fluxes of silica on the global marine silicon cycle: a model comparison. *Biogeosciences, 7*, 441-453. doi: 10.5194/bg-7-441-2010

Birkeland, C. (1997). Status of coral reefs in the Marianas. In R. W. Grigg and C. Birkeland (Eds.), *Status of Coral Reefs in the Pacific* (pp. 91-100). Honolulu, HI: Sea Grant College Program, School of Ocean and Earth Science and Technology, University of Hawaii.

Bograd, S. J., DiGiacomo, P. M., Durazo, R., Hayward, T. L., Hyrenbach, K. D., Lynn, R. J., et al. (2000). The State of the California Current, 1999-2000: Forward to a new regime? *CalCOFI Report, 41*, 26-52.

Bossart, G. D. (2011). Marine mammals as sentinel species for oceans and human health. *Veterinary Pathology, 48*(3), 676-690. doi:10.1177/0300985810388525

Bost, C. A., Cotte, C., Bailleul, F., Cherel, Y., Charrassin, J. B., Guinet, C., et al. (2009). The importance of oceanographic fronts to marine birds and mammals of the southern oceans. *Journal of Marine Systems, 78*(3), 363-376. doi:10.1016/j.jmarsys.2008.11.022

Boulègue, J., Benedetti, E. L., Dron, D., Mariotti, A. and Letolle, R. (1987). Geochemical and biogeochemical observations on the biological communities associated with fluid venting in Nankai Trough and Japan Trench subduction zones. *Earth and Planetary Science Letters, 83*, 343-355.

Boyd, P. W., Jickells, T., Law, C. S., Blain, S., Boyle, E. A., Buesseler, K. O., et al. (2007). Mesoscale iron enrichment experiments 1993-2005: Synthesis and future directions. *Science, 315*(5812), 612-617. doi: 10.1126/science.1131669

Bruland, K. W., Orians, K. J. and Cowen, J. P. (1994). Reactive trace metals in the stratified central North Pacific. *Geochimica et Cosmochimica Acta, 58*(15), 3171-3182. doi: 10.1016/0016-7037(94)90044-2

Brzezinski, M. A., Villareal, T. A. and Lipschultz, F. (1998). Silica production and the contribution of diatoms to new and primary production in the central North Pacific. *Marine Ecology Progress Series, 167*, 89-104.

Byrne, D. E., Davis, D. M. and Sykes, L. R. (1988). Loci and maximum size of thrust earthquakes and the mechanics of the shallow region of subduction zones. *Tectonics, 7*(4), 833-857.

Capone, D. G. (2008). The Marine Nitrogen Cycle. *Microbe, 3*(4), 186-192.

Castro, C. and Huber, M. E. (2007a). Chemical and physical features of seawater and the world Ocean. In *Marine Biology* (6th ed., pp. 45-68). New York, NY: McGraw-Hill.

Castro, C. and Huber, M. E. (2007b). An introduction to marine ecology. In *Marine Biology* (6th ed., pp. 215-234). New York, NY: McGraw-Hill.

Center for Sponsored Coastal Ocean Research (2010a, Last updated 16 April 2010). *Economic Impacts of Harmful Algal Blooms*. [Fact sheet] Center for Sponsored Coastal Ocean Research. Retrieved from http://www.cop.noaa.gov/stressors/extremeevents/hab/current/econimpact_08.pdf

Center for Sponsored Coastal Ocean Research (2010b, Last updated 22 January 2010). *Harmful Algal Bloom and Hypoxia Research and Control Act*. [Fact sheet] Center for Sponsored Coastal Ocean Research. Retrieved from http://www.cop.noaa.gov/stressors/extremeevents/hab/habhrca/HABHRCA_fact.pdf

Center for Sponsored Coastal Ocean Research (2011, Last updated 16 February 2011). Overview of Harmful Algal Blooms. [Web page]. Retrieved from http://www.cop.noaa.gov/stressors/extremeevents/hab/default.aspx, 21 April 2012.

Chang, W. and Fang, L. (2004). Temporal and spatial variations in the species composition, distribution, and abundance of copepods in Kaohsiung Harbor, Taiwan. *Zoological Studies, 43*(2), 454-463.

Chen, T.-C., Weng, S.-P., Yamazaki, N. and Kiehne, S. (1998). Interannual variation in the tropical cyclone formation over the western North Pacific. *Monthly Weather Review, 126*, 1080-1090.

Chowdhury, M. R., Barnston, A. G., Guard, C., Duncan, S., Schroeder, T. and Chu, P.-S. (2010). Sea-level variability and change in the US-Affiliated Pacific Islands: Understanding the high sea levels during 2006-2008. *Weather, 65*(10), 263-268.

Chowdhury, M. R., Chu, P.-S. and Schroeder, T. (2007). ENSO and seasonal sea-level variability - A diagnostic discussion for the U.S.-affiliated Pacific Islands. *Theoretical and Applied Climatology, 88*, 213-224. doi:10.1007/s00704-006-0245-5

Chowdhury, M. R., Chu, P.-S., Zhao, X., Schroeder, T. and Marra, J. J. (2010). Sea level extremes in the U.S.-Affiliated Pacific Islands - A coastal hazard scenario to aid in decision analyses. *Journal of Coastal Conservation, 14*(1), 53-62. doi:10.1007/s11852-010-0086-3

Coale, K. H., Johnson, K. S., Fitzwater, S. E., Blain, S. P. G., Stanton, T. P. and Coley, T. L. (1998). IronEx-I, an *in situ* iron-enrichment experiment: Experimental design, implementation and results. *Deep-Sea Research II, 45*, 919-945.

Coale, K. H., Johnson, K. S., Fitzwater, S. E., Gordon, R. M., Tanner, S., Chavez, F. P., et al. (1996). A massive phytoplankton bloom induced by an ecosystem-scale iron fertilization experiment in the Equatorial Pacific. *Nature 383*, 495-501.

Conlan, R. and Service, R. (2000). *El Niño and La Niña*. (pp. 8). Washington, DC: National Academy of Science.

Cordero, K., Villanoy, C. L., David, L. T. and Silvano, K. (2012). *Estimating Integrated Phytoplankton Biomass in the Seas around the Philippines*. (pp. 6). Diliman, Quezon City: Marine Science Institute, University of the Philippines. Available from http://sol.oc.ntu.edu.tw/omisar/wksp.mtg/wom11/wom11%20paper/02-1400Cesar.htm

Curtis, G. (1998). Tsunamis. In S. P. Juvik and J. O. Juvik (Eds.), *Atlas of Hawaii* (3rd ed., pp. 76-78). Hilo, HI: University of Hawaii Press.

Davis, D., Suppe, J. and Dahlen, F. A. (1983). Mechanics of fold-and-thrust belts and accretionary wedges. *Journal of Geophysical Research, 88*(B2), 1153-1172.

Department of Defense (1999, Tuesday 15 June). Notice of intent to prepare an Environmental Impact Statement for continued operation of the sound source installed by the Acoustic Thermometry of Ocean Climate (ATOC) project north of Kauai. *Federal Register, 64*(114), 32029.

Dickson, R. R. and Brown, J. (1994). The production of North Atlantic Deep Water: Sources, rates, and pathways. *Journal of Geophysical Research, 99*(C6), 12319-12341. doi: 10.1029/94jc00530

Donguy, J. R., Henin, C., Morliere, A. and Rebert, J. P. (1982). Thermal changes in the western tropical Pacific in relation to the wind field. *Deep-Sea Research, 29*(7A), 869-882.

Dore, J. E., Letelier, R. M., Church, M. J., Lukas, R. and Karl, D. M. (2008). Summer phytoplankton blooms in the oligotrophic North Pacific Subtropical Gyre: Historical perspective and recent observations. [Review]. *Progress in Oceanography, 76*(1), 2-38. doi:10.1016/j.pocean.2007.10.002

Durazo, R., Baumgartner, T. R., Bograd, S. J., Collins, C. A., de la Campa, S., García, J., et al. (2001). The state of the California Current, 2000-2001: A third straight La Niña year. *CalCOFI Report, 42*, 29-60.

Earthquake Engineering Research Institute. (1993). *The Guam Earthquake of August 8, 1993* [EERI Special Earthquake Report]. (pp. 12).

Eldredge, L. G. (1983). *Summary of Environmental and Fishing Information on Guam and the Commonwealth of the Northern Mariana Islands: Historical Background, Description of the Islands, and Review of the Climate, Oceanography, and Submarine Topography*. (NOAA-TM-NMFS-SWFC-40, pp. 181) U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service and Southwest Fisheries Center.

Elsner, J. B. and Liu, K. (2003). Examining the ENSO-typhoon hypothesis. *Climate Research, 25*, 43-54.

Embley, R. W., Baker, E. T., Chadwick, W. W., Jr, Lupton, J. E., Resing, J. A., Massoth, G. J., et al. (2004). Explorations of Mariana Arc volcanoes reveal new hydrothermal systems. *Eos, 85*(4), 37-44.

Eppley, R. W. and Peterson, B. J. (1979). Particulate organic flux and planktonic new production in the deep ocean. *Nature, 282*(5740), 677-680. doi:10.1038/282677a0

Falkowski, P. G. (1994). The role of phytoplankton photosynthesis in global biogeochemical cycles. *Photosynthesis Research, 39*, 235-258.

Fautin, D., Dalton, P., Incze, L. S., Leong, J. A. C., Pautzke, C., Rosenberg, A., et al. (2010). An overview of marine biodiversity in United States waters. *PLoS ONE, 5*(8), e11914. doi:10.1371/journal.pone.0011914

Feely, R. A., Sabine, C. L., Lee, K., Millero, F. J., Lamb, M. F., Greeley, D., et al. (2002). In situ calcium carbonate dissolution in the Pacific Ocean. *Global Biogeochemical Cycles, 16*(4), 91-91 to 91-12. doi:10.1029/2002GB001866

Flament, P., Kennan, S., Lumpkin, R., Sawyer, M. and Stroup, E. D. (2009, Last updated 11 August 2009). *Ocean Atlas of Hawaii.* School of Ocean and Earth Science and Technology, University of Hawai'i. Retrieved from http://www.soest.hawaii.edu/hioos/oceanatlas/marclimat.htm, 02 June 2010.

Fletcher, C. H., III, Grossman, E. E., Richmond, B. M. and Gibbs, A. E. (2002). *Atlas of Natural Hazards in the Hawaiian Coastal Zone*. (Geologic Investigations Series I-2761, pp. 182). Denver, CO: U. S. Department of the Interior and U. S. Geological Survey.

Fletcher, C. H. and Richmond, B. M. (2010). *Climate Change in the Federated States of Micronesia: Food and Water Security, Climate Risk Management, and Adaptive Strategies. Report of Findings 2010*. (pp. 28). Honolulu, HI: University of Hawai'i Sea Grant College Program. Available from http://seagrant.soest.hawaii.edu/climate-change-federated-states-of_micronesia

Folk, R. L. (1954). The distinction between grain size and mineral composition in sedimentary-rock nomenclature. *The Journal of Geology, 62*(4), 344-359. Retrieved from http://www.jstor.org/stable/30065016

Food and Agriculture Organization of the United Nations. (2008). *Climate Change and Food Security in Pacific Island Countries*. (pp. 282). Rome, Italy. Available from http://www.fao.org/climatechange/17003-02529d2a5afee62cce0e70d2d38e1e273.pdf

Fryer, P. (1996). Evolution of the Mariana convergent plate margin system. *Reviews of Geophysics, 34*(1), 89-125.

Fryer, P., Becker, N., Appelgate, B., Martinez, F., Edwards, M. and Fryer, G. (2003). Why is the Challenger Deep so deep? *Earth and Planetary Science Letters, 211*, 259-269. doi:10.1016/S0012-821X(03)00202-4

Fryer, P., Wheat, C. G. and Mottl, M. J. (1999). Mariana blueschist mud volcanism: Implications for conditions within the subduction zone. *Geology, 27*(2), 103-106.

Fujii, T. (1998). Statistical analysis of the characteristics of severe typhoons hitting the Japanese main islands. *Monthly Weather Review, 126*, 1091-1097.

Fujikura, K., Kojima, S., Tamaki, K., Maki, Y., Hunt, J. and Okutani, T. (1999). The deepest chemosynthesis-based community yet discovered from the hadal zone, 7326 m deep, in the Japan Trench. *Marine Ecology Progress Series, 190*, 17-26.

Fujiwara, Y., Kato, C., Masui, N., Fujikura, K. and Kojima, S. (2001). Dual symbiosis in the cold-seep thyasirid clam *Maorithyas hadalis* from the hadal zone in the Japan trench, western Pacific. *Marine Ecology Progress Series, 214*, 151-159.

Fujiwara, Y., Takai, K., Uematsu, K., Tsuchida, S., Hunt, J. C. and Hashimoto, J. (2000). Phylogenetic characterization of endosymbionts in three hydrothermal vent mussels: Influence on host distributions. *Marine Ecology Progress Series, 208*, 147-155.

Fukuyo, Y., Imai, I., Kodama, M. and Tamai, K. (2002). Red tides and other harmful algal blooms in Japan. In *Harmful algal blooms in the PICES region of the North Pacific*. (23, pp. 14) North Pacific Marine Science Organization.

Furuya, K. (1990). Subsurface chlorophyll maximum in the tropical and subtropical western Pacific Ocean: Vertical profiles of phytoplankton biomass and its relationship with chlorophyll *a* and particulate organic carbon. *Marine Biology, 107*, 529-539.

Furuya, K., Hasegawa, O., Yoshikawa, T. and Taguchi, S. (1998). Photosynthesis-irradiance relationship of phytoplankton and primary production in the vicinity of Kuroshio warm core ring in spring. *Journal of Oceanography, 54*, 545-552.

Furuya, K. and Marumo, R. (1983). The structure of the phytoplankton community in the subsurface chlorophyll maxima in the western North Pacific Ocean. *Journal of Plankton Research, 5*(3), 393-406.

Furuya, K., Takahashi, M. and Nemoto, T. (1986). Summer phytoplankton community structure and growth in a regional upwelling area off Hachijo Island, Japan. *Journal of Experimental Marine Biology and Ecology, 96*, 43-55.

Gardner, J. (2010). The West Mariana Ridge, western Pacific Ocean: Geomorphology and processes from new multibeam data. *Geological Society of America Bulletin, 122*, 1378-1388. doi: 10.1130/B30149.1

Garfield, N., Rago, T. A., Schnebele, K. J. and Collins, C. A. (1994). Evidence of a turbidity current in Monterey submarine canyon associated with the 1989 Loma Prieta earthquake. *Continental Shelf Research, 14*(6), 673-686.

Garrison, T. (1999). Seawater chemistry. In *Oceanography: An Invitation to Marine Science* (3rd ed., pp. 138-153). Belmont, CA: Wadsworth Publishing Company.

Gergis, J. L. and Fowler, A. M. (2009). A history of ENSO events since A.D.1525: implications for future climate change. *Climatic Change, 92*(3), 343-387. doi:10.1007/s10584-008-9476-z

Giese, B. S. and Carton, J. A. (1999). Interannual and decadal variability in the tropical and midlatitude Pacific Ocean. *Journal of Climate, 12*, 3402-3418.

Goldstein, T., Mazet, J. A. K., Zabka, T. S., Langlois, G., Colegrove, K. M., Silver, M., et al. (2008). Novel symptomatology and changing epidemiology of domoic acid toxicosis in California sea lions (*Zalophus californianus*): an increasing risk to marine mammal health. *Proceedings of the Royal Society B-Biological Sciences, 275*(1632), 267-276. doi:10.1098/rspb.2007.1221

Gordon, A. L. and Giulivi, C. F. (2004). Pacific decadal oscillation and sea level in the Japan/East Sea. *Deep-Sea Research I, 51*, 653-663.

Gordon, A. L., Sprintall, J. and Ffield, A. (2011). Regional oceanography of the Philippine Archipelago. *Oceanography, 24*(1), 14-27.

Grigg, R. W. (1997). Paleoceanography of coral reefs in the Hawaiian-Emperor Chain – revisited. *Coral Reefs, 16*(Supplement), S33-S38.

Guilyardi, E., Wittenberg, A., Fedorov, A., Collins, M., Wang, C., Capotondi, A., et al. (2009). Understanding El Niño in ocean-atmosphere general circulation models: Progress and challenges. *Bulletin of the American Meteorological Society, 90*, 325-340. doi:10.1175/2008BAMS2387.1

Guo, X., Hukuda, H., Miyazawa, Y. and Yamagata, T. (2003). A triply nested ocean model for simulating the Kuroshio--Roles of horizontal resolution on JEBAR. *Journal of Physical Oceanography, 33*, 146-169.

Handschumacher, D. W., Sager, W. W., Hilde, T. W. C. and Bracey, D. R. (1988). Pre-Cretaceous tectonic evolution of the Pacific plate and extension of the geomagnetic polarity reversal time scale with implications for the origin of the Jurassic "Quiet Zone". *Tectonophysics, 155*, 365-380.

Hare, S. (1998). The Pacific decadal oscillation. *Fisheries Forum, 6*(1), 4,10.

Hare, S. R. and Mantua, N. J. (2000). Empirical evidence for North Pacific regime shifts in 1977 and 1989. *Progress in Oceanography, 47*, 103-145.

Harvell, C. D., Kim, K., Burkholder, J. M., Colwell, R. R., Epstein, P. R., Grimes, D. J., et al. (1999). Emerging marine diseases-climate links and anthropogenic factors. *Science, 285*, 1505-1510.

Hashimoto, J., Ohta, S., Tanaka, T., Hotta, H., Matsuzawa, S. and Sakai, H. (1989). Deep-sea communities dominated by the giant clam, *Calyptogena soyoae*, along the slope foot of Hatsushima Island, Sagami Bay, central Japan. *Palaeogeography, Palaeoclimatology, Palaeoecology, 71*, 179-192.

Hashimoto, M., (Ed). (1991). Submarine topography and geology around the Japanese Islands. In *Geology of Japan* (pp. 163-198). Tokyo, Japan: Terra Scientific Publishing Company.

Hayashi, H. (2004). Faunal analysis of Neogene planktonic foraminifera from forearc sediments of the Japan Trench, ODP site 1151, leg 186. *Island Arc, 13*, 318-331.

Hays, J. (2011, Last updated October 2011). Typhoons in Japan. In *Facts and Details*. [Web page]. Retrieved from http://factsanddetails.com/japan.php?itemid=856&catid=26&subcatid=160#01, 30 May 2012.

Hayward, T. L. (1997). Pacific Ocean climate change: Atmospheric forcing, ocean circulation and ecosystem response. *Trends in Ecology and Evolution, 12*(4), 150-154.

Hayward, T. L. (2000). El Niño 1997-98 in the coastal waters of southern California: A timeline of events. *CalCOFI Report, 41*, 98-116.

Hayward, T. L. and McGowan, J. A. (1985). Spatial patterns of chlorophyll, primary production, macrozooplankton biomass, and physical structure in the central North Pacific Ocean. *Journal of Plankton Research, 7*(2), 147-167.

Hayward, T. L., Venrick, E. L. and McGowan, J. A. (1983). Environmental heterogeneity and plankton community structure in the central North Pacific. *Journal of Marine Research, 41*, 711-729.

Heezen, B. C. and Ewing, M. (1952). Turbidity currents and submarine slumps, and the 1929 Grand Banks earthquake. *American Journal of Science, 250*, 849-873.

Heileman, S. and Tang, Q. (2009). X-22 East China Sea LME. In K. Sherman and G. Hempel (Eds.), *The UNEP Large Marine Ecosystem Report: A Perspective on Changing Conditions in LMEs of the World's Regional Seas*. (UNEP Regional Seas Report and Studies No. 182, pp. 383-392). Nairobi, Kenya: United Nations Environmental Programme.

Heron, S. F., Metzger, E. J. and Skirving, W. J. (2006). Seasonal variations of the ocean surface circulation in the vicinity of Palau. *Journal of Oceanography, 62*(4), 413-426. doi:10.1007/s10872-006-0065-3

Higgins, H. W. and Mackey, D. J. (2000). Algal class abundances, estimated from chlorophyll and carotenoid pigments, in the western Equatorial Pacific under El Niño and non-El Niño conditions. *Deep-Sea Research Part I: Oceanographic Research Papers, 47*, 1461-1483.

Hirakawa, K., Goto, T. and Hirai, M. (1997). Diet composition and prey size of larval anchovy, *Engraulis japonicus*, in Toyama Bay, southern Japan Sea. *Bulletin of the Japan Sea National Fisheries Research Institute, 47*, 67-78.

Hoegh-Guldberg, O., Hoegh-Guldberg, H., Veron, J. E. N., Green, A., Gomez, E. D., Lough, J., et al. (2009). *The Coral Triangle and Climate Change: Ecosystems, People, and Societies at Risk. A Comprehensive Study Involving over 20 Experts and Based on 300 Peer-Reviewed Scientific Articles*. (pp. 276). Sydney, Australia: World Wildlife Fund Australia. Available from www.panda.org/coraltriangle

Howell, E. A., Dutton, P. H., Polovina, J. J., Bailey, H., Parker, D. M. and Balazs, G. H. (2010). Oceanographic influences on the dive behavior of juvenile loggerhead turtles (*Caretta caretta*) in the North Pacific Ocean. *Marine Biology, 157*(5), 1011-1026. doi: 10.1007/s00227-009-1381-0

Hunter, E., Chant, R., Bowers, L., Glenn, S. and Kohut, J. (2007). Spatial and temporal variability of diurnal wind forcing in the coastal ocean. *Geophysical Research Letters, 34*, L03607. doi:10.1029/2006gl028945

Hutchins, D. A., Mulholland, M. R. and Fu, F. (2009). Nutrient cycles and marine microbes in a CO_2-enriched ocean. *Oceanography, 22*(4), 128-145.

Intergovernmental Oceanographic Commission, International Hydrographic Organisation and British Oceanographic Data Centre (2003). *Centenary Edition of the GEBCO Digital Atlas, published on CD-ROM on behalf of the Intergovernmental Oceanographic Commission and the International*

Hydrographic Organization as part of the General Bathymetric Chart of the Oceans, British Oceanographic Data Centre

Intergovernmental Panel on Climate Change (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden and C. E. Hanson (Eds.) (pp. 976). Cambridge, UK: Cambridge University Press.

International Research Institute for Climate and Society (2007, Last updated 16 August 2007). Overview of the ENSO system. [Web page]. Retrieved from http://iri.columbia.edu/climate/ENSO/background/basics.html#enso, 17 April 2012.

International Tsunami Information Center (2012). Japan Tsunami Event 11 March 2011. [Web Page]. Retrieved from http://itic.ioc-unesco.org/index.php?option=com_content&view=article&id=1740&lang=en, 17 April 2012.

Isobe, M. (1998, July 11-12). *Toward integrated coastal zone management in Japan*. Presented at the ESENA Workshop: Energy-related marine issues in the Sea of Japan, Tokyo, Japan.

Isozaki, Y., Maruyama, S. and Furuoka, F. (1990). Accreted oceanic materials in Japan. *Tectonophysics, 181*, 179-205.

Itakura, S., Yamaguchi, M., Yoshida, M. and Fukuyo, Y. (2002). The seasonal occurrence of *Alexandrium tamarense* (Dinophyceae) vegetative cells in Hiroshima Bay, Japan. *Fisheries Science, 68*, 77-86.

Itoh, S. and Yasuda, I. (2010). Characteristics of mesoscale eddies in the Kuroshio-Oyashio extension region detected from the distribution of the sea surface height anomaly. *Journal of Physical Oceanography, 40*(5), 1018-1034. doi:10.1175/2009jpo4265.1

Itou, M., Matsumura, I. and Noriki, S. (2000). A large flux of particulate matter in the deep Japan Trench observed just after the 1994 Snariku-Oki earthquake. *Deep-Sea Research I, 47*, 1987-1998.

Jacobs, G. A., Hurlburt, H. E., Kindle, J. C., Metzger, E. J., Mitchell, J. L., Teague, W. J., et al. (1994). Decade-scale trans-Pacific propagation and warming effects of an El Niño anomaly. *Nature, 370*, 360-363.

Japan Agency for Marine-Earth Science and Technology (2000a). Bathymetry. In *Morphology and Tectonics of the Yap Trench*. [Web Page]. Retrieved from http://www.jamstec.go.jp/jamstec-e/shinkai/yaptrench/bathy.html, 01 May 2012.

Japan Agency for Marine-Earth Science and Technology (2000b). Introduction. In *Morphology and Tectonics of the Yap Trench*. [Web Page]. Retrieved from http://www.jamstec.go.jp/jamstec-e/shinkai/yaptrench/intro.html, 01 May 2012.

Japan Agency for Marine-Earth Science and Technology (2012). Modoki ENSO: A New Phenomenon is Found in the Tropical Pacific. [Web Page]. Retrieved from http://www.jamstec.go.jp/frcgc/research/d1/iod/enmodoki_home_s.html.en, 01 May 2012.

Japan Meteorological Agency, Meterological Research Instititute (2012a). Construction of database of typhoons made landfall in 2004 and their preliminary analysis focused on high wind, heavy rain, and storm surge. In *Research Topics in Typhoon Research Department*. [Web page]. Retrieved from http://www.mri-jma.go.jp/Dep/ty/h16.html, 30 May 2012.

Japan Meteorological Agency, Meterological Research Instititute (2012b). Typhoon Research Department. [Web page]. Retrieved from http://www.mri-jma.go.jp/Dep/ty/ty.html, 30 May 2012.

Jenkins, C. J. (2012). *goSEABED World Seabed Data Browser*. [GIS metadata] Institute for Arctic and Alpine Research, University of Colorado at Boulder. Retrieved from http://instaar.colorado.edu/~jenkinsc/dbseabed/

Jenkins, C. J., Kettner, A. J., Moore, C. and Sharman, G. (2005, Last updated 09/09/2005). *goSEABED World Seabed Data Browser*. Retrieved from http://instaar.colorado.edu/~jenkinsc/dbseabed/goseabed/interactive/, 1 August 2005.

Johnson, G. C. (2008). Quantifying Antarctic bottom water and North Atlantic deep water volumes. *Journal of Geophysical Research, 113*, C05027. doi: 10.1029/2007JC004477

Johnson, R. H. (1973). Acoustic observations of nonexplosive submarine volcanism. *Journal of Geophysical Research, 78*(26), 6093-6096.

JTB USA (2005). *Japanese custom/culture*. Retrieved from http://www.jtbusa.com/enhome/jculture.asp, 17 May 2005.

Julian, B. (1994). Volcanic tremor: Nonlinear excitation by fluid flow. *Journal of Geophysical Research, 99*(B6), 11,859-811,877.

Julian, B. (2002). Seismological detection of slab metamorphism. *Science, 296*, 1625-1626.

Kadena Web Team (2005, Last updated March 16, 2005). *Kadena air base: Okinawa, Japan*, 26 April 2005.

Kanamatsu, T. and Matsuo, K. (2003). Rock magnetic study of sediments from the Japan Trench, ODP leg 186: Implications for deformation of sediments. *Proceedings of the Ocean Drilling Program, Scientific Results, 186*, 1-21.

Kanamori, H. (1972). Tectonic implications of the 1944 Tonankai and the 1946 Nankaido earthquakes. *Physics of the Earth and Planetary Interiors, 5*, 129-139.

Kanamori, H. and Kikuchi, M. (1993). The 1992 Nicaragua earthquake: A slow tsunami earthquake associated with subducted sediments. *Nature, 361*, 714-716.

Kanaori, Y., Kawakami, S. and Yairi, K. (1993). Space-time correlations between inland earthquakes in central Japan and great offshore earthquakes along the Nankai trough: Implication for destructive earthquake prediction. *Engineering Geology, 33*, 289-303.

Karl, D. M. (1999). A sea of change: Biogeochemical variability in the North Pacific Subtropical Gyre. *Ecosystems, 2*(3), 181-214.

Karl, D. M., Letelier, R., Hebel, D., Tupas, L., Dore, J., Christian, J., et al. (1995). Ecosystem changes in the North Pacific subtropical gyre attributed to the 1991-92 El Niño. *Nature, 373*, 230-234.

Karl, T. R., Melillo, J. M. and Peterson, T. C. (Eds). (2009). *Global Climate Change Impacts in the United States: A State of Knowledge Report from the U.S. Global Change Research Program*. (pp. 189). New York, NY: Cambridge University Press. Available from www.globalchange.gov/usimpacts

Kasahara, J., Utada, H., Sato, T. and Kinoshita, H. (1998). Submarine cable OBS using a retired submarine telecommunication cable: GeO-TOC program. *Physics of the Earth and Planetary Interiors, 108*, 113-127.

Kasai, H., Saito, H., Yoshimori, A. and Taguchi, S. (1997). Variability in timing and magnitude of spring bloom in the Oyashio region, the western subarctic Pacific off Hokkaido, Japan. *Fisheries Oceanography, 6*(2), 118-129.

Kawabe, M. (1986). Transition processes between the three typical paths of the Kuroshio. *Journal of the Oceanographical Society of Japan, 42*, 174-191.

Kawabe, M., Fujio, S., Yanagimoto, D. and Tanaka, K. (2009). Water masses and currents of deep circulation southwest of the Shatsky Rise in the western North Pacific. *Deep Sea Research I, 56*, 1675-1687. doi: 10.1016/j.dsr.2009.06.003

Kawabe, M. and Fujito, S. (2010). Pacific Ocean circulation based on observation. *Journal of Oceanography, 66*, 389-403.

Keating, B. H., Mattey, D. P., Helsley, C. E., Naughton, J. J., Epp, D., Lazarewicz, A., et al. (1984). Evidence for a Hot Spot Origin of the Caroline Islands. *Journal of Geophysical Research, 89*(B12), 9937-9948. doi:10.1029/JB089iB12p09937

Kennett, J. P. (1982). *Marine Geology* (pp. 752). Englewood Cliffs, New Jersey: Prentice-Hall, Inc.

Kerr, R. A. (2010). Ocean acidification unprecedented, unsettling. *Science, 328*(5985), 1500-1501. doi: 10.1126/science.328.5985.1500

Kim, H., Kimura, S., Shinoda, A., Kitagawa, T., Sasai, Y. and Sasaki, H. (2007). Effect of El Niño on migration and larval transport of the Japanese eel (*Anguilla japonica*). *ICES Journal of Marine Science: Journal du Conseil, 64*(7), 1387-1395. doi:10.1093/icesjms/fsm091

Kitayama, S., Kuma, K., Manabe, E., Sugie, K., Takata, H., Isoda, Y., et al. (2009). Controls on iron distributions in the deep water column of the North Pacific Ocean: Iron(III) hydroxide solubility and marine humic-type dissolved organic matter. *Journal of Geophysical Research, 114*. doi:10.1029/2008JC004754

Kobari, T. and Ikeda, T. (1999). Vertical distribution, population structure and life cycle of *Neocalanus cristatus* (Crustacea: Copepoda) in the Oyashio region, with notes on its regional variations. *Marine Biology, 134*, 683-696.

Kobayashi, K. (2004). Origin of the Palau and Yap trench-arc systems. *Geophysical Journal International, 157*(3), 1303-1315. doi:10.1111/j.1365-246X.2003.02244.x

Kodaira, S., Takahashi, N., Nakanishi, A., Miura, S. and Kaneda, Y. (2000, July). Subducted seamount imaged in the rupture zone of the 1946 Nankaido earthquake. *Science, 289*, 104-106.

Koenig, R. (2001). Researchers target deadly tsunamis. *Science, 293*, 1251-1253.

Kojima, S., Hayashi, K., Kim, D., Iijima, A. and Furota, T. (2004). Phylogeography of an intertidal direct-developing gastropod *Batillaria cumingi* around the Japanese Islands. *Marine Ecology Progress Series, 276*, 161-172.

Kono, T. (1997). Modification of the Oyashio water in the Hokkaido and Tohoku areas. *Deep-Sea Research I, 44*(4), 669-688.

Kopf, A., Mora, G., Deyhle, A., Frape, S. and Hesse, R. (2003). Fluid geochemistry in the Japan Trench forearc (ODP Leg 186): A synthesis. *Proceedings of the Ocean Drilling Program, Scientific Results, 186*, 1-23.

Kouketsu, S., Kaneko, I., Kawano, T., Uchida, H., Doi, T. and Fukasawa, M. (2007). Changes of North Pacific intermediate water properties in the subtropical gyre. *Geophysical Research Letters, 34*(L02605), 1-5. doi:10.1029/2006GL028499

Krishnamurthy, A., Moore, J. K., Mahowald, N., Luo, C., Doney, S. C., Lindsay, K., et al. (2009). Impacts of increasing anthropogenic soluble iron and nitrogen deposition on ocean biogeochemistry. *Global Biogeochemical Cycles, 23*, 15. doi:10.1029/2008GB003440

Kubota, H. and Wang, B. (2009). How much do tropical cyclones affect seasonal and interannual rainfall variability over the Western North Pacific? *Journal of Climate, 22*(20), 5495-5510. doi:10.1175/2009jcli2646.1

Kubota, I. (1987). The western Pacific and El Niño. *Oceanus, 30*(1), 75-77.

Kubotera, A. and Otsuka, M. (1970). Nature of non-volcanic microtremor observed on the Aso Caldera. *Journal of Physics of the Earth, 18*(1), 115-124.

Lagerloef, G. S. E., Mitchum, G. T., Lukas, R. B. and Niller, P. P. (1999). Tropical Pacific near-surface currents estimated from altimeter, wind, and drifter data. *Journal of Geophysical Research, 104*(C10), 23313-23326.

Lalli, C. M. and Parsons, T. R. (1997). *Biological Oceanography: An Introduction* (2nd ed., pp. 314). Oxford, England: Butterworth Heinemann.

Lander, J. F., Whiteside, L. S. and Hattori, P. (2002). The tsunami history of Guam: 1849-1993. *Science of Tsunami Hazards, 20*(3), 158-174. Retrieved from ftp://ftp.ngdc.noaa.gov/hazards/publications/ref0482_lander.pdf

Lander, J. F., Whiteside, L. S. and Lockridge, P. A. (2003). Two decades of global tsunamis 1982-2002. *Science of Tsunami Hazards, 21*(1), 3-88. Retrieved from ftp://140.172.184.81/hazards/publications/ref1315_lander.pdf

Lander, M. A. (1994). An exploratory analysis of the relationship between tropical storm formation in the western North Pacific and ENSO. *Monthly Weather Review, 122*, 636-651.

Langmann, B., Zaksek, K., Hort, M. and Duggen, S. (2010). Volcanic ash as fertiliser for the surface ocean. *Atmospheric Chemistry and Physics, 10*, 3891-3899. doi:10.5194/acp-10-3891-2010

Lavelle, W. and Mohn, C. (2010). Motion, commmotion, and biophysical connections at deep ocean seamounts. *Oceanography, 23*(1), 90-103.

Le Bouteiller, A., Blanchot, J. and Rodier, M. (1992). Size distribution patterns of phytoplankton in the western Pacific: Towards a generalization for the tropical open ocean. *Deep-Sea Research, 39*(5), 805-823.

Le Pichon, X., Iiyama, T., Boulègue, J., Charvet, J., Faure, M., Kano, K., et al. (1987). Nankai Trough and Zenisu Ridge: A deep-sea submersible survey. *Earth and Planetary Science Letters, 83*, 285-299.

Le Pichon, X., Iiyama, T., Chamley, H., Charvet, J., Faure, M., Fujimoto, H., et al. (1987a). The eastern and western ends of Nankai Trough: Results of Box 5 and Box 7 Kaiko survey. *Earth and Planetary Science Letters, 83*, 199-213.

Le Pichon, X., Iiyama, T., Chamley, H., Charvet, J., Faure, M., Fujimoto, H., et al. (1987b). Nankai Trough and the fossil Shikoku Ridge: Results of Box 6 Kaiko survey. *Earth and Planetary Science Letters, 83*, 186-198.

Lee, D.-K., Niiler, P. P., Lee, S.-R., Kim, K. and Lie, H.-J. (2000). Energetics of the surface circulation of the Japan/East Sea. *Journal of Geophysical Research, 105*(C8), 19561-19573.

Lefebvre, K. A., Bargu, S., Kieckhefer, T. and Silver, M. W. (2002). From sanddabs to blue whales: the pervasiveness of domoic acid. *Toxicon, 40*(7), 971-977. doi:10.1016/s0041-0101(02)00093-4

Lehodey, P., Bertignac, M., Hampton, J., Lewis, A. and Picaut, J. (1997). El Niño Southern Oscillation and tuna in the western Pacific. *Nature, 389*, 715-718.

Levin, L. A. (2003). Oxygen minimum zone benthos: Adaption and community response to hypoxia. *Oceanography and Marine Biology: An Annual Review, 41*, 1-45. Retrieved from http://cmbc.ucsd.edu/Students/Current_Students/SIO277/Levin%202003,%20OMBAR.pdf

Libes, S. M. (1992). *An Introduction to Marine Biogeochemistry* (pp. 734). New York, NY: John Wiley and Sons, Inc.

Limsakul, A., Saino, T., Goes, J. I. and Midorikawa, T. (2002). Seasonal variability in the lower trophic level environments of the western subtropical Pacific and Oyashio waters--A retrospective study. *Deep-Sea Research II, 49*, 5487-5512.

Limsakul, A., Saino, T., Midorikawa, T. and Goes, J. I. (2001). Temporal variations in lower trophic level biological environments in the northwestern North Pacific subtropical gyre from 1950 to 1997. *Progress in Oceanography, 49*, 129-149.

Loh, A. N. and Bauer, J. E. (2000). Distribution, partitioning and fluxes of dissolved and particulate organic C, N and P in the eastern North Pacific and Southern Oceans. *Deep-Sea Research I, 47*(12), 2287-2316. doi: 10.1016/s0967-0637(00)00027-3

Lonely Planet (2003). Japan. In *Lonely Planet World Guide*. Retrieved from http://www.lonelyplanet.com/destinations/north_east_asia/japan/printable.htm, 17 May 2005.

Luo, Y. and Rothstein, L. M. (2011). Response of the Pacific Ocean circulation to climate change. *Atmosphere-Ocean, 49*(3), 235-244. doi:10.1080/07055900.2011.602325

Lynn, R. J., Baumgartner, T., Garcia, J., Collins, C. A., Hayward, T. L., Hyrenbach, K. D., et al. (1998). The state of the California Current, 1997-1998: Transition to El Niño conditions. *CalCOFI Report, 39*, 25-49.

Mackas, D. L. and Tsuda, A. (1999). Mesozooplankton in the eastern and western subarctic Pacific: Community structure, seasonal life histories, and interannual variability. *Progress in Oceanography, 43*, 335-363.

Mackey, D. J., Blanchot, J., Higgins, H. W. and Neveux, J. (2002). Phytoplankton abundances and community structure in the equatorial Pacific. *Deep Sea Research II: Topical Studies in Oceanography, 49*, 2561-2582. doi:10.1016/s0967-0645(02)00048-6

Mackey, D. J., Parslow, J. S., Griffiths, F. B., Higgins, H. W. and Tilbrook, B. (1997). Phytoplankton productivity and the carbon cycle in the western Equatorial Pacific under El Niño and non-El Niño conditions. *Deep-Sea Research Part II: Topical Studies in Oceanography, 44*(9-10), 1951-1978.

Maldonado, M., Carmona, C., Velásquez, Z., Puig, A., Cruzado, A., López, A., et al. (2005). Siliceous sponges as a silicon sink: An overlooked aspect of the benthopelagic coupling in the marine silicon cycle. *Limnology and Oceanography, 50*(3), 799-809. doi:10.4319/lo.2005.50.3.0799

Mantua, N. (2002). Pacific-Decadal Oscillation (PDO) M. C. MacCracken and J. S. Perry (Eds.), *Encyclopedia of Global Environmental Change. Volume 1: The Earth System: Physical and Chemical Dimensions of Global Environmental Change* (pp. 592-594). Chichester, England: John Wiley & Sons, Ltd.

Mantua, N. and Hare, S. R. (2002). The Pacific decadal oscillation. *Journal of Oceanography, 58*, 35-44.

Mantyla, A. W. and Reid, J. L. (1978). Measurements of water characteristics at depths greater than 10 km in the Marianas Trench. *Deep-Sea Research, 25*, 169-173.

Marris, E. (2005). Inadequate warning system left Asia at the mercy of tsunami. *Nature, 433*, 3-5.

Martin, J. H. and Gordon, M. R. (1988). Northeast Pacific iron distributions in relation to phytoplankton productivity. *Deep-Sea Research, 35*(2), 177-196. doi:10.1016/0198-0149(88)90035-0

Matsuyama, Y. (2012). Impacts of the harmful dinoflagellate *Heterocapsa circularisquama* bloom on shellfish aquaculture in Japan and some experimental studies on invertebrates. *Harmful Algae, 14*, 144-155. doi:10.1016/j.hal.2011.10.019

McCormack, G. (2007). Gambierdiscus toxicus - *Ciguatera Dinoflagellate*. In *Cook Island Biodiversity Database*. [Online database] Cook Islands Natural Heritage Trust. Retrieved from http://cookislands.bishopmuseum.org/species.asp?id=8951, 5 September 2010.

McGowan, J. A. and Walker, P. W. (1985). Dominance and diversity maintenance in an oceanic ecosystem. *Ecological Monographs, 55*(1), 103-118.

McGuire, J. D. and Acton, G. D. (2003). Composite depth scales for the Japan Trench, ODP leg 186 sites 1150 and 1151. *Proceedings of the Ocean Drilling Program, Scientific Results,, 186*, 1-23.

Metcalf, W. G. (1968). Shallow currents along the northeastern coast of South America. *Journal of Marine Research, 26*(3), 232-243.

Ministry of Education Culture Sports Science and Technology, Japan Meteorological Agency and Ministry of the Environment. (2009). *Climate Change and Its Impacts in Japan: Synthesis Report on Observations, Projections, and Impact Assessments of Climate Change*. (pp. 74). Available from http://www.env.go.jp/en/earth/cc/report_impacts.pdf

Minobe, S. (1997). A 50-70 year climatic oscillation over the North Pacific and North America. *Geophysical Research Letters, 24*(6), 683-686.

Minobe, S. (1999). Resonance in bidecadal and pentadecadal climate oscillations over the North Pacific: Role in climatic regime shifts. *Geophysical Research Letters, 26*(7), 855-858.

Minobe, S., Sako, A. and Nakamura, M. (2004). Interannual to interdecadal variability in the Japan Sea based on a new gridded upper water temperature dataset. *Journal of Physical Oceanography, 34*, 2382-2397.

Mitchell, N. C., Lyle, M. W., Knappenberger, M. B. and Liberty, L. M. (2003). Lower Miocene to present stratigraphy of the equatorial Pacific sediment bulge and carbonate dissolution anomalies. *Paleoceanography, 18*(2), 1038. doi:10.1029/2002pa000828

Miyazawa, Y., Guo, X. and Yamagata, T. (2004). Roles of mesoscale eddies in the Kuroshio paths. *Journal of Physical Oceanography, 34*, 2203-2222.

Mori, J. and Shimazaki, K. (1984). High stress drops of short-period subevents from the 1968 Tokachi-Oki earthquake as observed on strong-motion records. *Bulletin of the Seismological Society of America, 74*(5), 1529-1544.

Mottl, M. J., Wheat, C. G., Fryer, P., Gharib, J. and Martin, J. B. (2004). Chemistry of springs across the Mariana forearc shows progressive devolatilization of the subducting plate. *Geochimica et Cosmochimica Acta, 68*(23), 4915-4933. doi:10.1016/j.gca.2004.05.037

Mrozowski, C. L. and Hayes, D. E. (1979). The evolution of the Parece Vela Basin, eastern Philippine Sea. *Earth and Planetary Science Letters, 46*(1), 49-67. doi:10.1016/0012-821x(79)90065-7

Naganuma, T., Wada, H. and Fujioka, K. (1996). Biological community and sediment fatty acids associated with the deep-sea whale skeleton at the Torishima seamount. *Journal of Oceanography, 52*, 1-15.

Nakamura, H., Lin, G. and Yamagata, T. (1997). Decadal climate variability in the North Pacific during the recent decades. *Bulletin of the American Meteorological Society, 78*(10), 2215-2225.

Nakata, K. and Hidaka, K. (2003). Decadal-scale variability in the Kuroshio marine ecosystem in winter. *Fisheries Oceanography, 12*(4/5), 234-244.

National Aeronautics and Space Administration (1998, Last updated 23 January 2004). *Goddard Earth Sciences Data and Information Services Center, Distributed Active Archive Center*. Retrieved from ftp://disc1.gsfc.nasa.gov/data/czcs/level_3/monthly_data/subsets/Chlor/

National Aeronautics and Space Administration Goddard Space Flight Center OceanColor Group (2012). *Global Monthly Chlorophyll-a Concentration - January 2012. 4km Level 3 Standard Mapped Image (SMI)*.

National Climatic Data Center (2008, Last updated 20 August 2008). Wind- average wind speed- (MPH). [Web page]. Retrieved from http://www.ncdc.noaa.gov/oa/climate/online/ccd/avgwind.html, 24 August 2012.

National Oceanic and Atmospheric Administration. (2002). Bathymetric Maps [Raster format]. Boulder, CO: National Geophysical Data Center. Available from http://www.ngdc.noaa.gov/mgg/bathymetry/maps/directdownload.html

National Oceanic and Atmospheric Administration (2005a, Last updated 11 January 2005). *What is an El Niño?* Retrieved from http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html, 21 January 2005.

National Oceanic and Atmospheric Administration (2005b, Last updated 11 January 2005). *What is La Niña?* Retrieved from http://www.pmel.noaa.gov/tao/elnino/la-nina-story.html, 23 May 2005.

National Oceanic and Atmospheric Administration (2011, Last updated 16 February 2011). Caribbean and Pacific Island Regions Harmful Algal Blooms. [Web Page]. Retrieved from http://www.cop.noaa.gov/stressors/extremeevents/hab/current/Carib_reg_08.aspx, 21 April 2012.

National Oceanic and Atmospheric Administration, Marine Debris Program (2013). Marine Debris Information: Movement. [Web Page]. Retrieved from http://marinedebris.noaa.gov/marinedebris101/movement.html

National Oceanic and Atmospheric Administration, National Weather Service (2012, Last updated 5 January 2010). Ocean Circulations. [Web Page]. Retrieved from http://www.srh.noaa.gov/jetstream/ocean/circulation.htm

National Research Council of the National Academies (2010). *Ocean acidification: A national strategy to meet the challenges of a changing ocean*. Washington, DC: The National Academies Press. Retrieved from http://www.nap.edu/openbook.php?record_id=12904.

Natural Environment Research Council (2000). The Tsunami Risks Project. [Web Page], 8 August 2005.

Naval Environmental Prediction Research Facility. (1988a). East China Sea. In *Forecasters Handbook for Japan and Adjacent Sea Areas*. (Contractor Report CR 88-11, pp. 4-1 to 4-64). Monterey, CA. Available from http://www.nrlmry.navy.mil/forecaster_handbooks/Japan/Forecasters%20Handbook%20for%20Japan%20and%20Adjacent%20Sea%20Areas.htm

Naval Environmental Prediction Research Facility. (1988b). Large Scale Overview. In *Forecasters Handbook for Japan and Adjacent Sea Areas*. (Contractor Report CR 88-11, pp. 2-1 to 2-96). Monterey, CA. Available from http://www.nrlmry.navy.mil/forecaster_handbooks/Japan/Forecasters%20Handbook%20for%20Japan%20and%20Adjacent%20Sea%20Areas.htm

Naval Environmental Prediction Research Facility. (1988c). Philippine Sea. In *Forecasters Handbook for Japan and Adjacent Sea Areas*. (Contractor Report CR 88-11, pp. 7-1 to 7-56). Monterey, CA. Available from http://www.nrlmry.navy.mil/forecaster_handbooks/Japan/Forecasters%20Handbook%20for%20Japan%20and%20Adjacent%20Sea%20Areas.htm

Nemoto, K. and Kroenke, L. W. (1981). Marine Geology of the Hess Rise 1. Bathymetry, Surface Sediment Distribution, and Environment of Deposition. *Journal of Geophysical Research, 86*(B11), 10734-10752. doi:10.1029/JB086iB11p10734

Niitsuma, N. (2004). Japan trench and tectonics of the Japanese Island arcs. *Island Arc, 13*, 306-317.

Nishimura, Y., Miyaji, N. and Suzuki, M. (1999). Behavior of historic tsunamis of volcanic origin as revealed by onshore tsunami deposits. *Physics and Chemistry of the Earth (A), 24*(11-12), 985-988.

Norcross, B. L., McKinnell, S. M., Frandsen, M., Musgrave, D. L. and Sweet, S. R. (2003). Larval fishes in relation to water masses of the central North Pacific transitional areas, including the shelf break of west-central Alaska. *Journal of Oceanography, 59*(4), 445-460.

North Pacific Marine Science Organization. (2004). *Marine Ecosystems of the North Pacific* [Electronic Version]. (PICES Special Publication 1, pp. 280) North Pacific Marine Science Organization. Available from http://www.pices.int/publications/special_publications/NPESR/2005/npesr_2005.aspx

Oahu Civil Defense Agency. (2003). *Multi-Hazard Pre-Disaster Mitigation for the City and County of Honolulu*. (pp. 783). Prepared by Martin & Chock Inc. Prepared for OCDA, City & County of Honolulu.

Oakley, A. J., Taylor, B., Moore, G. F. and Goodliffe, A. (2009). Sedimentary, volcanic, and tectonic processes of the central Mariana Arc: Mariana Trough back-arc basin formation and the West Mariana Ridge. *Geochemistry Geophysics Geosystems, 10*(8), 1-29. doi:10.1029/2008GC002312

Odate, T. and Furuya, K. (1998). Well-developed subsurface chlorophyll maximum near Komahashi No. 2 seamount in the summer of 1991. *Deep-Sea Research I, 45*, 1595-1607.

Ogawa, Y., Kobayashi, K., Hotta, H. and Fujioka, K. (1997). Tension cracks on the oceanward slopes of the northern Japan and Mariana Trenches. *Marine Geology, 141*, 111-123.

Oguma, S., Suzuki, M. and Nagata, Y. (2002). Seasonal variations in the sea off Sanriku coast, Japan. *Journal of Oceanography, 58*, 825-835.

Okada, H. (1980). Sedimentary environments on and around island arcs: An example of the Japan trench area. *Precambrian Research, 12*, 115-139.

Ondrusek, M. E., Bidigare, R. R., Sweet, S. T., Defreitas, D. A. and Brooks, J. M. (1991). Distribution of phytoplankton pigments in the North Pacific Ocean in relation to physical and optical variability. *Deep-Sea Research, 38*(2), 243-266.

Ondrusek, M. E., Bidigare, R. R., Waters, K. and Karl, D. M. (2001). A predictive model for estimating rates of primary production in the subtropical North Pacific Ocean. *Deep-Sea Research II, 48*, 1837-1863.

Onishi, M. and Ohtani, K. (1997). Volume transport of the Tsushima warm current, west of Tsugaru Strait bifurcation area. *Journal of Oceanography, 53*, 27-34.

Oregon State University Ocean Productivity Group (2012a). *Global Net Primary Production - April 2012*. [GIS data]. Retrieved from http://orca.science.oregonstate.edu/1080.by.2160.monthly.hdf.vgpm.m.chl.m.sst4.php

Oregon State University Ocean Productivity Group (2012b). *Global Net Primary Production - January 2012*. [GIS data]. Retrieved from http://orca.science.oregonstate.edu/1080.by.2160.monthly.hdf.vgpm.m.chl.m.sst4.php

Oregon State University Ocean Productivity Group (2012c). *Global Net Primary Production - July 2012*. [GIS data]. Retrieved from http://orca.science.oregonstate.edu/1080.by.2160.monthly.hdf.vgpm.m.chl.m.sst4.php

Oregon State University Ocean Productivity Group (2012d). *Global Net Primary Production – October 2012*. [GIS data]. Retrieved from http://orca.science.oregonstate.edu/1080.by.2160.monthly.hdf.vgpm.m.chl.m.sst4.php

Otosaka, S., Honda, M. C. and Noriki, S. (2004). La/Yb and Th/Sc in settling particles: Vertical and horizontal transport of lithogenic material in the western North Pacific. *Geochemical Journal, 38*(6), 515-525.

Pacific ENSO Applications Center (1995). *General Information and Imagemap of USAPI*. [Web page] University of Hawaii at Manoa, 13 January 2005.

Pacific RISA (2012a). Commonwealth of the Northern Mariana Islands (CNMI). [Web page]. Retrieved from http://www.pacificrisa.org/cms/index.php?option=com_content&view=article&id=70&Itemid=74, 18 April 2012.

Pacific RISA (2012b). Federated States of Micronesia. [Web page]. Retrieved from http://www.pacificrisa.org/cms/index.php?option=com_content&view=article&id=71&Itemid=72, 18 April 2012.

Pacific RISA (2012c). Pacific Islands Regional Climate Assessment (PIRCA). [Web page]. Retrieved from http://www.pacificrisa.org/cms/index.php?option=com_content&view=article&id=265&Itemid=180 , 17 April 2012.

Pacific RISA (2012d). Republic of Palau. [Web page]. Retrieved from http://www.pacificrisa.org/cms/index.php?option=com_content&view=article&id=74&Itemid=75, 18 April 2012.

Pacific RISA (2012e). Territory of Guam. [Web page]. Retrieved from http://www.pacificrisa.org/cms/index.php?option=com_content&view=article&id=72&Itemid=73, 18 April 2012.

Paerl, H. W. and Paul, V. J. (2012). Climate change: Links to global expansion of harmful cyanobacteria. *Water Research, 46*(5), 1349-1363. doi:10.1016/j.watres.2011.08.002

Park, D. S. R., Ho, C. H., Kim, J. H. and Kim, H. S. (2011). Strong landfall typhoons in Korea and Japan in a recent decade. *Journal of Geophysical Research, 116*, D07105. doi:10.1029/2010jd014801

Park, J.-O., Tokuyama, H., Shinohara, M., Suyehiro, K. and Taira, A. (1998). Seismic record of tectonic evolution and backarc rifting in the southern Ryukyu island arc system. *Tectonophysics, 294*, 21-42.

Parsons, T. R., Takahashi, M. and Hargrave, B. (1984). *Biological Oceanographic Processes* (3nd ed., pp. 330). Oxford, UK: Pergamon Press.

Paulay, G. (2003). Marine biodiversity of Guam and the Marianas: Overview. *Micronesica, 35-36*, 3-25.

Phillips, C. (2011). The 10 most destructive tsunamis in history. In *Australian Geographic*. [Web Page]. Retrieved from http://www.australiangeographic.com.au/journal/the-10-biggest-tsunamis-in-history.htm, 17 April 2012.

Physical Oceanography Distributed Active Archive Center (2012a). *Global Annual Sea Surface Temperature (°C) - 2012. 4 km Moderate Resolution Imaging Spectroradiometer (MODIS) Level 3 SST*. [GIS data]. Retrieved from http://podaac.jpl.nasa.gov/ through use of Duke University Marine Geospatial Ecology Tools at http://mgel.env.duke.edu/mget

Physical Oceanography Distributed Active Archive Center (2012b). *Global Monthly Sea Surface Temperature (°C) - April 2012. 4 km Moderate Resolution Imaging Spectroradiometer (MODIS) Level 3 SST*. [GIS data]. Retrieved from http://podaac.jpl.nasa.gov/ through use of Duke University Marine Geospatial Ecology Tools at http://mgel.env.duke.edu/mget

Physical Oceanography Distributed Active Archive Center (2012c). *Global Monthly Sea Surface Temperature (°C) - January 2012. 4 km Moderate Resolution Imaging Spectroradiometer (MODIS) Level 3 SST*. [GIS data]. Retrieved from http://podaac.jpl.nasa.gov/ through use of Duke University Marine Geospatial Ecology Tools at http://mgel.env.duke.edu/mget

Physical Oceanography Distributed Active Archive Center (2012d). *Global Monthly Sea Surface Temperature (°C) - October 2012. 4 km Moderate Resolution Imaging Spectroradiometer (MODIS) Level 3 SST*. [GIS data]. Retrieved from http://podaac.jpl.nasa.gov/ through use of Duke University Marine Geospatial Ecology Tools at http://mgel.env.duke.edu/mget

Physical Oceanography Distributed Active Archive Center (2012e). *Global Monthly Sea Surface Temperature (°C) – July 2012. 4 km Moderate Resolution Imaging Spectroradiometer (MODIS) Level 3 SST*. [GIS data]. Retrieved from http://podaac.jpl.nasa.gov/ through use of Duke University Marine Geospatial Ecology Tools at http://mgel.env.duke.edu/mget

Piatt, J. F. and Gould, P. J. (1994). Postbreeding dispersal and drift-net mortality of endangered Japanese murrelets. *Auk, 111*(4), 953-961.

Pickard, G. L. and Emery, W. J. (1982). *Descriptive Physical Oceanography: An Introduction* (4th ed., pp. 249). Oxford, United Kingdom: Pergamon Press.

Pickard, G. L. and Emery, W. J. (1990). *Descriptive Physical Oceanography: An Introduction* (5th ed., pp. 320). Oxford, United Kingdom: Pergamon Press.

Polet, J. and Kanamori, H. (2000). Shallow subduction zone earthquakes and their tsunamigenic potential. *Geophysical Journal International, 142*, 684-702.

Polovina, J. J., Howell, E., Kobayashi, D. R. and Seki, M. P. (2001). The transition zone chlorophyll front, a dynamic global feature defining migration and forage habitat for marine resources. *Progress in Oceanography, 49*, 469-483.

Polovina, J. J., Mitchum, G. T., Graham, N. E., Craig, M. P., DeMartini, E. E. and Flint, E. N. (1994). Physical and biological consequences of a climate event in the central North Pacific. *Fisheries Oceanography, 3*(1), 15-21.

Prior, D. B., Bornhold, B. D., Wiseman, W. J., Jr. and Lowe, D. R. (1987). Turbidity current activity in a British Columbia fjord. *Science, 237*, 1330-1333.

Qiu, B. (1995). Variability and energetics of the Kuroshio extension and its recirculation gyre from the first two-year TOPEX data. *Journal of Physical Oceanography, 25*, 1827-1842.

Qiu, B. (2000). Interannual variability of the Kuroshio extension system and its impact on the wintertime SST field. *Journal of Physical Oceanography, 30*, 1486-1502.

Qiu, B. (2001). Kuroshio and Oyashio currents. In J. H. Steele, K. K. Turekian and S. A. Thorpe (Eds.), *Encyclopedia of Ocean Sciences* (pp. 1413-1425). San Diego, CA: Academic Press.

Qiu, B. (2002). The Kuroshio extension system: Its large-scale variability and role in the midlatitude ocean-atmosphere interaction. *Journal of Oceanography, 58*, 57-75.

Qiu, B. (2003). Kuroshio extension variability and forcing of the Pacific decadal oscillations: Responses and potential feedback. *Journal of Physical Oceanography, 33*, 2465-2482.

Qiu, B. and Kelly, K. A. (1993). Upper-ocean heat balance in the Kuroshio extension region. *Journal of Physical Oceanography, 23*, 2027-2041.

Qiu, B., Koh, D. A., Lumpkin, C. and Flament, P. (1997). Existence and Formation Mechanism of the North Hawaiian Ridge Current. *Journal of Physical Oceanography, 27*(3), 431-444. doi: 10.1175/1520-0485(1997)027<0431:EAFMOT>2.0.CO;2

Qiu, B. and Lukas, R. (1996). Seasonal and interannual variability of the North Equatorial Current, the Mindanao Current, and the Kuroshio along the Pacific western boundary. *Journal of Geophysical Research, 101*(C5), 12315-12330.

Qiu, B. and Miao, W. (2000). Kuroshio path variations south of Japan: Bimodality as a self-sustained internal oscillation. *Journal of Physical Oceanography, 30*, 2124-2137.

Qu, T., Mitsudera, H. and Qiu, B. (2001). A climatological view of the Kuroshio/Oyashio system east of Japan. *Journal of Physical Oceanography, 31*, 2575-2589.

Radenac, M. and Rodier, M. (1996). Nitrate and chlorophyll distributions in relation to thermohaline and current structures in the western tropical Pacific during 1985-1989. *Deep-Sea Research II, 43*(4-6), 725-752.

Randall, R. H. (1979). *Geologic Features within the Guam Seashore Study Area*. (Technical Report No. 55, pp. 56). Mangilao, Guam: University of Guam Marine Laboratory. Prepared for U.S. National Park Service.

Randall, R. H. (1985). Habitat geomorphology and community structure of corals in the Mariana Islands. In C. Gabrie and M. Harmelin (Eds.), *Proceedings of the Fifth International Coral Reef Congress, Tahiti, Volume 6* (pp. 261-266).

Randall, R. H. (1995). Biogeography of the reef-building corals in the Mariana and Palau Islands in relation to back-arc rifting and the formation of the Eastern Philippine Sea. *Natural History Research, 3*(2), 193-210.

Randall, R. H. (2003). An annotated checklist of hydrozoan and scleractinian corals collected from Guam and other Mariana Islands. *Micronesica, 35-36*, 121-137.

Randall, R. H. and Eldredge, L. G. (1977). Effects of typhoon Pamela on the coral reefs of Guam. In D. L. Taylor (Ed.), *Proceedings of the Third International Coral Reef Symposium, Volume 2* (pp. 525-531). Miami, Florida: University of Miami, Rosenstiel School of Marine and Atmospheric Science.

Reid, J. L., Jr. (1962). On circulation, phosphate-phosphorus content, and zooplankton volumes in the upper part of the Pacific Ocean. *Limnology and Oceanography, 7*, 287-306.

Rodier, M. and Le Borgne, R. (1997). Export flux of particles at the equator in the western and central Pacific ocean. *Deep-Sea Research II, 44*(9-10), 2085-2113.

Roman, M. R., Dam, H. G., Le Borgne, R. and Zhang, X. (2002). Latitudinal comparisons of equatorial Pacific zooplankton. *Deep Sea Research II: Topical Studies in Oceanography, 49*(13-14), 2695-2711. doi:10.1016/s0967-0645(02)00054-1

Ryan, J. P., Ueki, I., Chao, Y., Zhang, H. C., Polito, P. S. and Chavez, F. P. (2006). Western Pacific modulation of large phytoplankton blooms in the central and eastern equatorial Pacific. *Journal of Geophysical Research, 111*(G2), G02013. doi:10.1029/2005jg000084

Rydelek, P. A. and Sacks, I. S. (1990). Asthenospheric viscosity and stress diffusion: A mechanism to explain correlated earthquakes and surface deformations in NE Japan. *Geophysical Journal International, 100*, 39-58.

Sabine, C. L., Feely, R. A., Gruber, N., Key, R. M., Lee, K., Bullister, J. L., et al. (2004). The oceanic sink for anthropogenic CO_2. *Science, 305*(5682), 367-371. Retrieved from http://www.jstor.org/stable/3837507

Sakurai, Y. (2007). An overview of the Oyashio ecosystem. *Deep Sea Research II: Topical Studies in Oceanography, 54*(23–26), 2526-2542. doi:10.1016/j.dsr2.2007.02.007

Saunders, M. A., Chandler, R. E., Merchant, C. J. and Roberts, F. P. (2000). Atlantic hurricanes and NW Pacific typhoons: ENSO spatial impacts on occurrence and landfall. *Geophysical Research Letters, 27*(8), 1147-1150.

Scavia, D. (1988). On the role of bacteria in secondary production. *Limnology and Oceanography, 33*(5), 1220-1224.

Schlappa, K. (2004). Appendix A: Air quality and climate report. In *Inventory and Monitoring Program Pacific Island Network Monitoring Plan*. (pp. 57) National Park Service.

Schnetzer, A., Miller, P. E., Schaffner, R. A., Stauffer, B. A., Jones, B. H., Weisberg, S. B., et al. (2007). Blooms of *Pseudo-nitzschia* and domoic acid in the San Pedro Channel and Los Angeles harbor areas of the Southern California Bight, 2003-2004. *Harmful Algae, 6*, 372-387. doi:10.1016/j.hal.2006.11.004

Scholin, C. A., Gulland, F., Doucette, G. J., Benson, S., Busman, M., Chavez, F. P., et al. (2000). Mortality of sea lions along the central California coast linked to a toxic diatom bloom. *Nature, 403*(6765), 80-84. doi:10.1038/47481

Schwing, F. B., Bograd, S. J., Collins, C. A., Gaxiola-Castro, G., García, J., Goericke, R., et al. (2002). The state of the California Current, 2001-2002: Will the California Current System keep its cool, or is El Niño looming? *CalCOFI Reports, 43*, 31-68.

Schwing, F. B., Moore, C. S., Ralston, S. and Sakuma, K. M. (2000). Record coastal upwelling in the California Current in 1999. *CalCOFI Reports, 41*, 148-160.

Scripps Institution of Oceanography, Experimental Climate Prediction Center (2011, Last updated October 13, 2011). El Niños of the past. [Web page]. Retrieved from http://meteora.ucsd.edu/~pierce/elnino/history.html, 30 May 2012.

Seno, T. (1999). Syntheses of the regional stress fields of the Japanese islands. *Island Arc, 8*, 66-79.

Seno, T. (2002). Tsunami earthquakes as transient phenomena. *Geophysical Research Letters, 29*(10), 1-4. doi:10.1029/2002GL014868

Seno, T., Stein, S. and Gripp, A. E. (1993). A model for the motion of the Philippine Sea plate consistent with NUVEL-1 and geological data. *Journal of Geophysical Research, 98*(B10), 17941-17948.

Shimozuru, D., Kamo, K. and Kinoshita, W. T. (1966). Volcanic tremor of Kilauea Volcano, Hawaii, during July-December, 1963. *Bulletin of the Earthquake Research Institute, 44*, 1093-1133.

Shiomoto, A., Hashimoto, S. and Murakami, H. (1998). Primary productivity and solar radiation off Sanriku in May 1997. *Journal of Oceanography, 54*, 539-544.

Shiomoto, A., Sasaki, K., Shimoda, T. and Matsumura, S. (1994). Primary productivity in the offshore Oyashio in the spring and summer 1990. *Journal of Oceanography, 50*, 209-222.

Small, R. J., deSzoeke, S. P., Xie, S. P., O'Neill, L., Seo, H., Song, Q., et al. (2008). Air-sea interaction over ocean fronts and eddies. [Article; Proceedings Paper]. *Dynamics of Atmospheres and Oceans, 45*(3-4), 274-319. doi:10.1016/j.dynatmoce.2008.01.001

Smith, C. R. and Baco, A. R. (2003). Ecology of whale falls at the deep-sea floor. *Oceanography and Marine Biology: An Annual Review, 41*, 311-354.

Smithsonian National Museum of Natural History (1995). Volcanic activity report: Ruby. In *Bulletin of the Global Volcanism Network*. [Web page]. Retrieved from http://www.geo.mtu.edu/volcanoes/central_pacific/marianas/gvn/marianas.v20n10.html, 6 January 2005.

Smithsonian National Museum of Natural History (2012a). Volcanic activity report: Agrigan. In *Bulletin of the Global Volcanism Network*. [Web Page]. Retrieved from http://www.volcano.si.edu/world/volcano.cfm?vnum=0804-16=, 23 April 2012.

Smithsonian National Museum of Natural History (2012b). Volcanic activity report: Alamagan. In *Bulletin of the Global Volcanism Network*. [Web Page]. Retrieved from http://www.volcano.si.edu/world/volcano.cfm?vnum=0804-18=, 23 April 2012.

Smithsonian National Museum of Natural History (2012c). Volcanic activity report: Anatahan. In *Bulletin of the Global Volcanism Network*. [Web Page]. Retrieved from http://www.volcano.si.edu/world/volcano.cfm?vnum=0804-20=, 23 April 2012.

Smithsonian National Museum of Natural History (2012d). Volcanic activity report: Asuncion. In *Bulletin of the Global Volcanism Network*. [Web Page]. Retrieved from http://www.volcano.si.edu/world/volcano.cfm?vnum=0804-15=, 23 April 2012.

Smithsonian National Museum of Natural History (2012e). Volcanic activity report: Esmeralda Bank. In *Bulletin of the Global Volcanism Network*. [Web Page]. Retrieved from http://www.volcano.si.edu/world/volcano.cfm?vnum=0804-21=, 23 April 2012.

Smithsonian National Museum of Natural History (2012f). Volcanic activity report: Farallon de Pajaros. In *Bulletin of the Global Volcanism Network*. [Web Page]. Retrieved from http://www.volcano.si.edu/world/volcano.cfm?vnum=0804-14=, 23 April 2012.

Smithsonian National Museum of Natural History (2012g). Volcanic activity report: Guguan. In *Bulletin of the Global Volcanism Network*. [Web Page]. Retrieved from http://www.volcano.si.edu/world/volcano.cfm?vnum=0804-19=, 23 April 2012.

Smithsonian National Museum of Natural History (2012h). Volcanic activity report: Pagan. In *Bulletin of the Global Volcanism Network*. [Web Page]. Retrieved from http://www.volcano.si.edu/world/volcano.cfm?vnum=0804-17=, 23 April 2012.

Smithsonian National Museum of Natural History (2012i). Volcanic activity report: Ruby. In *Bulletin of the Global Volcanism Network*. [Web Page]. Retrieved from http://www.volcano.si.edu/world/volcano.cfm?vnum=0804-202, 23 April 2012.

Starmer, J., Asher, J., Castor, F., Gochfeld, D., Gove, J., Hall, A., et al. (2008). The state of coral reef ecosystems of the Commonwealth of the Northern Mariana Islands. In J. E. Waddell and A. M. Clarke (Eds.), *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2008*. (NOAA Technical Memorandum NOS NCCOS 73, pp. 437-463). Silver Spring, MD: NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team.

Stefansson, A. and Gislason, S. R. (2001). Chemical weathering of basalts, southwest Iceland: Effect of rock crystallinity and secondary minerals on chemical fluxes to the ocean. *American Journal of Science, 301*, 513-556.

Steinacher, M., Joos, F., Frolicher, T. L., Plattner, G.-K. and Doney, S. C. (2009). Imminent ocean acidification in the Arctic projected with the NCAR global coupled carbon cycle-climate model. *Biogeosciences, 6*, 515-533. doi:10.5194/bg-6-515-2009

Stott, L., Cannariato, K., Thunell, R., Haug, G. H., Koutavas, A. and Lund, S. (2004). Decline of surface temperature and salinity in the western tropical Pacific Ocean in the Holocene epoch. *Nature, 431*, 56-59.

Strayer, D. (1988). On the limits of secondary production. *Limnology and Oceanography, 33*(5), 1217-1220.

Sugimoto, T., Kimura, S. and Tadokoro, K. (2001). Impact of El Niño events and climate regime shift on living resources in the western North Pacific. *Progress in Oceanography, 49*, 113-127.

Sugimoto, T., Tadokoro, K. and Y. Furushima, Y. (1995). Climate and weather effects on the chlorophyll concentration in the northwestern North Pacific. In H. Sakai and Y. Nozaki (Eds.), *Biogeochemical Processes and Ocean Flux in the Western Pacific* (pp. Pages 575-592). Tokyo, Japan: Terra Scientific Publishing Company (TERRAPUB).

Takahashi, M., Koike, I., Ishimaru, T., Saino, T., Furuya, K., Fujita, Y., et al. (1980). Upwelling plumes in Sagami Bay and adjacent water around the Izu Islands, Japan. *Journal of the Oceanographical Society of Japan, 36*, 209-216.

Talley, L. D. (1993). Distribution and formation of North Pacific intermediate water. *Journal of Physical Oceanography, 23*(3), 517-537. doi:10.1175/1520-0485(1993)023<0517:DAFONP>2.0.CO;2

Taniguchi, A. (1999). Differences in the structure of the lower trophic levels of pelagic ecosystems in the eastern and western subarctic Pacific. *Progress in Oceanography, 43*, 289-315.

Tatsumi, Y., Kani, T., Ishizuka, H., Maruyama, S. and Nishimura, Y. (2000). Activitation of Pacific mantle plumes during the Carboniferous: Evidence from accretionary complexes in southwest Japan. *Geology, 28*(7), 580-582.

Taylor, B. and Martinez, F. (2003). Back-arc basin basalt systematics. *Earth and Planetary Science Letters, 210*, 481-497. doi:10.1016/S0012-821X(03)00167-5

Teague, W. J., Jacobs, G. A., Perkins, H. T., Book, J. W., Chang, K.-I. and Suk, M.-S. (2002). Low-frequency current observations in the Korea/Tsushima Strait. *Journal of Physical Oceanography, 32*(6), 1621-1641. doi:10.1175/1520-0485(2002)032<1621:LFCOIT>2.0.CO;2

Tetra Tech, Inc. (2010). WorldBathInt [GIS data]. *GEBCO Digital Atlas*. (Centenary ed., Derived from data sent by Pauline Weatherall, British Oceanographic Data Center [19 January 2010] to Joel Peters and

Kitty Courtney, Tetra Tech, Inc.). Norfolk, VA: Department of the Navy, Naval Facilities Engineering Command, Atlantic. Available from http://www.bodc.ac.uk/projects/international/gebco/

The Environmental Company. (2004). *Year 2003 Assessment of Marine and Fisheries Resources, Farallon de Medinilla, Commonwealth of the Northern Mariana Islands* [Final report]. (pp. 46). Honolulu, HI. Prepared for Pacific Division Naval Facilities Engineering Command.

Thunell, R., Tappa, E., Varela, R., Llano, M., Astor, Y., Muller-Karger, F., et al. (1999). Increased marine sediment suspension and fluxes following an earthquake. *Nature, 398*, 233-236.

Thurman, H. V. (1997). *Introductory Oceanography* (8th ed., pp. 544). Upper Saddle River, NJ: Prentice Hall.

Toba, Y. and Murakami, H. (1998). Unusual behavior of the Kuroshio Current System from winter 1996 to summer 1997 revealed by ADEOS-OCTS and other data--Suggestion of topographically forced alternating-jet instability. *Journal of Oceanography, 54*, 465-478.

Toda, H. (1989). Surface distributions of copepods in relation to regional upwellings around the Izu Islands in summer of 1988. *Journal of the Oceanographical Society of Japan, 45*, 251-257.

Tomczak, M. and Godfrey, J. S. (2003). The Pacific Ocean. In *Regional Oceanography: An Introduction.* (2nd ed., pp. 105-174). Daya Publishing House. Retrieved from http://www.es.flinders.edu.au/~mattom/regoc/pdfversion.html.

Toole, J. M., Millard, R. C., Wang, B. and Pu, S. (1990). Observations of the Pacific North Equatorial Current bifurcation at the Philippine coast. *Journal of Physical Oceanography, 20*, 307-318.

Torres de la Riva, G., Johnson, C. K., Gulland, F. M. D., Langlois, G. W., Heyning, J. E., Rowles, T., et al. (2009). Association of an unusual marine mammal mortality event with *Pseudo-nitzschia* spp. blooms along the southern California coastline. *Journal of Wildlife Diseases, 45*(1), 109-121.

Toyoda, K. and Masuda, A. (1990). Sedimentary environments and chemical composition of Pacific pelagic sediments. *Chemical Geology, 88*(1-2), 127-141. doi:10.1016/0009-2541(90)90107-i

Trainer, V. L., Adams, N. G., Bill, B. D., Stehr, C. M., Wekell, J. C., Moeller, P., et al. (2000). Domoic acid production near California coastal upwelling zones, June 1998. *Limnology and Oceanography, 45*(8), 1818-1833.

Trenberth, K. E. (1997). The definition of El Niño. *Bulletin of the American Meteorological Society, 78*(12), 2771-2777.

Tsuda, A., Saito, H. and Kasai, H. (1999). Life histories of *Neocalanus flemingeri* and *Neocalanus plumchrus* (Calanoida: Copipoda) in the western subarctic Pacific. *Marine Biology, 135*, 533-544.

Tsuda, A., Saito, H. and Kasai, H. (2001). Geographical variation of body size of *Neocalanua cristatus*, *N. plumchrus* and *N. flemingeri* in the subarctic Pacific and its marginal seas: Implications for the origin of large form of *N. flemingeri* in the Oyashio area. *Journal of Oceanography, 57*, 341-352.

Tsuda, A. and Sugisaki, H. (1994). In situ grazing rate of the copepod population in the western subarctic North Pacific during spring. *Marine Biology, 120*, 203-210.

Tsunogai, S. (2002). The western north pacific playing a key role in global biogeochemical fluxes. *Journal of Oceanography, 58*, 245-257.

Tsunogai, U., Yoshida, H. and Gamo, T. (2002). Carbon isotopic evidence of methane oxidation through sulfate reduction in sediment beneath cold seep vents on the seafloor at Nandai Trough. *Marine Geology, 187*, 145-160.

U.S. Department of the Navy. (1994). *Oceanographic Forecaster's Handbook*. Misawa, Japan: U.S. Naval Oceanography Command Detachment.

U.S. Department of the Navy. (1997a). *Natural Resources Management Plan, Naval Air Facility, Atsugi*. (pp. 111). Pearl Harbor, HI. Prepared by Belt Collins Hawaii. Prepared for Pacific Division, Naval Facilities Engineering Command.

U.S. Department of the Navy. (1997b). *Natural Resources Management Plan, Yokosuka Naval Complex*. (pp. 170). Pearl Harbor, HI. Prepared by Belt Collins Hawaii. Prepared for Pacific Division, Naval Facilities Engineering Command.

U.S. Department of the Navy. (1998). *Natural Resources Management Plan, COMFLEACT Sasebo, Japan*. (pp. 114). Pearl Harbor, HI. Prepared by Belt Collins Hawaii. Prepared for Pacific Division, Naval Facilities Engineering Command.

U.S. Department of the Navy. (2003a). *Final Environmental Assessment, Inner Apra Harbor Maintenance Dredging Guam*. Pearl Harbor, HI: Pacific Division, Naval Facilities Engineering Command.

U.S. Department of the Navy. (2003b). *Integrated Natural Resources Management Plan--Farallon de Medinilla and Tinian Military Lease Areas--Commonwealth of the Northern Mariana Islands: Plan Duration: FY 03-12*. Prepared by P. Helber Hastert & Fee. Prepared for Commander, U.S. Naval Forces Marianas.

U.S. Department of the Navy. (2004). Integrated Natural Resources Management Plan: Commander Fleet Activities, Okinawa, Japan [CD-ROM]. Prepared by Naval Facilities Engineering Command, Pacific, Pearl Harbor, Hawai'i.

U.S. Department of the Navy. (2005a). *Marine Resources Assessment for the Japan and Okinawa Complexes Operating Area* [Final report]. (Contract # N62470-02-D-9997, CTO 0028, pp. 394). Pearl Harbor, HI: Pacific Division, Naval Facilities Engineering Command. Prepared by Geo-Marine, Inc., Plano, Texas.

U.S. Department of the Navy. (2005b). *Marine Resources Assessment for the Marianas Operating Area* [Final report]. (Contract # N62470-02-D-9997, CTO 0028, pp. 416). Pearl Harbor, HI: Pacific Division, Naval Facilities Engineering Command. Prepared by Geo-Marine, Inc., Plano, Texas.

U.S. Geological Survey (2004a). *Tsunami statistics*. [Data]. Retrieved from http://earthquake.usgs.gov/eqinthenews/2004/usslav/tsustats.pdf 8 June 2005.

U.S. Geological Survey (2005a, Last updated 28 January 2005). *Major volcanoes of the Mariana Islands*. Retrieved from http://vulcan.wr.usgs.gov/Volcanoes/MarianaIslands/Maps/map_mariana_islands_volcanoes.html, 28 January 2005.

U.S. Geological Survey (2012). Poster of the Great Tohoku Earthquake (northeast Honshu, Japan) of March 11, 2011 - Magnitude 9.0. [Web page]. Retrieved from http://earthquake.usgs.gov/earthquakes/eqarchives/poster/2011/20110311.php, 05 June 2012.

U.S. Geological Survey, Earthquake Hazards Program (2004b). *Historical seismicity, Rota Region Northern Mariana Islands, seismicity 1990 to present, seismicity in 2004, and magnitude 7 and greater earthquakes since 1900*. Retrieved from http://neic.usgs.gov/neis/ bulletin/neic_scbz_h.html, 19 January 2005.

U.S. Geological Survey, Earthquake Hazards Program (2005b, Last updated 28 January 2005). *Earthquake history of Guam*. Retrieved from http://neic.usgs.gov/neis/states/guam/guam_history.html, 28 January 2005.

Uchida, R. N. (1983). *Summary of Environmental and Fishing Information on Guam and the Commonwealth of the Northern Mariana Islands: A Review of the Plankton Communities and Fishery Resources*. (NOAA Technical Memorandum NMFS-SWFC-33, pp. 159). Honolulu, HI: US Department of Commerce, NOAA, NMFS, Southwest Fisheries Center Honolulu Laboratory.

Uda, M. (1970). Fishery oceanographic studies of frontal eddies and transport associated with the Kuroshio System including the "Subtropical Countercurrent". In J. C. Marr (Ed.), *The Kuroshio* (pp. 593-604). Honolulu, Hawaii: East-West Center Press.

Uematsu, M., Duce, R. A. and Prospero, J. M. (1985). Deposition of atmospheric mineral particles in the North Pacific Ocean. *Journal of Atmospheric Chemistry, 3*, 123-138.

United Nations Educational Scientific and Cultural Organization. (2009). *Global Open Oceans and Deep Seabed (GOODS) - Biogeographic Classification*. (IOC Technical Series, 84, pp. 95). Paris, France: UNESCO-IOC.

United Nations Environment Programme. (2006). Regional definition. In A. V. Alekseev, F. F. Khrapchenkov, P. J. Baklanov, Y. G. Blinov, A. N. Kachur, I. A. Medvedeva, I. A. Minakir and G. D. Titova (Eds.), *Oyashio Current*. (GIWA Regional assessment 31, pp. 13-21). Kalmar, Sweden: University of Kalmar. Available from http://www.unep.org/dewa/giwa/areas/reports/r31/regional_definition_giwa_r31.pdf

Uye, S.-I., Nagano, N. and Tamaki, H. (1996). Geographical and seasonal variations in abundance, biomass and estimated production rates of microzooplankton in the inland Sea of Japan. *Journal of Oceanography, 52*, 689-703.

Valiela, I. (1995). *Marine Ecological Processes* (2nd ed.). New York, NY: Springer-Verlag.

Venrick, E. L. (1990). Phytoplankton in an oligotrophic ocean: Species structure and interannual variability. *Ecology, 71*(4), 1547-1563.

Vinogradov, M. Y. and Parin, N. V. (1973). On the vertical distribution of macroplankton in the tropical Pacific. *Oceanology, 13*, 104-113.

von Huene, R., Langseth, M., Nasu, N. and Okada, H. (1982). A summary of Cenozoic tectonic history along the IPOD Japan Trench transect. *Geological Society of America Bulletin, 93*, 829-846.

Walter, T. C. and Boxshall, G. A. (2012). World of Copepods database. [Web page]. Retrieved from http://www.marinespecies.org/copepoda/, 06 June 2012.

Wazniak, C., Tango, P. and Butler, W. (2004). Abundance and frequency of occurrence of brown tide, *Aereococcus anophagefferens*, in the Maryland Coastal Bays. In *Maryland's Coastal Bays: Ecosystem Health Assessment*. (DNR-12-1202-0009, pp. 7-2 to 7-10). Annapolis, MD: Maryland Department of Natural Resources.

WeatherSpark (2012a). Average weather for Aomori, Japan. [Web page]. Retrieved from http://weatherspark.com/averages/33235/Aomori-Aomori-Prefecture-Japan, 24 August 2012.

WeatherSpark (2012b). Average weather for Fukuoka, Japan. [Web page]. Retrieved from http://weatherspark.com/averages/33194/Fukuoka-Fukuoka-Prefecture-Japan, 24 August 2012.

WeatherSpark (2012c). Average weather for Miyazaki, Japan. [Web page]. Retrieved from http://weatherspark.com/averages/33197/Miyazaki-Miyazaki-Prefecture-Japan, 24 August 2012.

WeatherSpark (2012d). Average weather for Okinawa, Japan. [Web page]. Retrieved from http://weatherspark.com/averages/33303/Okinawa-Okinawa-Prefecture-Japan, 24 August 2012.

Web Japan (2012). Japan Fact Sheet: Geography and Climate. [Fact sheet]. Retrieved from http://web-japan.org/factsheet/en/pdf/e01_geography.pdf, 1 May 2012.

Weng, H. Y., Ashok, K., Behera, S. K., Rao, S. A. and Yamagata, T. (2007). Impacts of recent El Nino Modoki on dry/wet conditions in the Pacific rim during boreal summer. *Climate Dynamics, 29*(2-3), 113-129. doi:10.1007/s00382-007-0234-0

White, W. B. and He, Y. (1986). Interannual variability in the heat content of the Kuroshio extension associated with the 1982 ENSO event. *Journal of Physical Oceanography, 16*, 309-321.

Williams, F. R., Jung, G. H. and Englebretson, R. E. (1993). 4. Geological structure & physical oceanography. In *Forecasters Handbook for the Philippine Islands and Surrounding Waters*. (NRL/PU/7541--92-0001, pp. 4-1 to 4-88). Monterey, CA: Naval Research Laboratory. Prepared for Forecast Support Branch, Marine Meteorology Division. Available from http://www.nrlmry.navy.mil/forecaster_handbooks/Philippines2/Forecasters%20Handbook%20for%20the%20Philippine%20Islands%20and%20Surrounding%20Waters%20Geological%20Structure%20and%20Physical%20Oceanography.pdf

Wolanski, E., Richmond, R. H., Davis, G., Deleersnijder, E. and Leben, R. R. (2003). Eddies around Guam, an island in the Mariana Islands group. *Continental Shelf Research, 23*(10), 991-1003. doi:10.1016/s0278-4343(03)00087-6

Wu, M. C., Chang, W. L. and Leung, W. M. (2004). Impacts of El Niño--Southern oscillation events on tropical cyclone landfalling activity in the western North Pacific. *Journal of Climate, 17*, 1419-1428.

Wyrtki, K., Magaard, L. and Hager, J. (1976). Eddy energy in the oceans. *Journal of Geophysical Research, 81*(15), 2641-2646.

Yamagata, T., Shibao, Y. and Umatani, S. (1985). Interannual variability of the Kuroshio extension and its relation to the Southern Oscillation/El Niño. *Journal of the Oceanographical Society of Japan, 41*, 274-281.

Yamazaki, T., Murakami, F. and Saito, E. (1993). Mode of seafloor spreading in the northern Mariana Trough. *Tectonophysics, 221*, 207-222.

Yoshimori, A., Ishizaka, J., Kono, T., Kasai, H., Saito, H., Kishi, M. J., et al. (1995). Modeling of spring bloom in the western subarctic Pacific (off Japan) with observed vertical density structure. *Journal of Oceanography, 51*, 471-488.

Zenimoto, K., Kitagawa, T., Miyazaki, S., Sasai, Y., Sasaki, H. and Kimura, S. (2009). The effects of seasonal and interannual variability of oceanic structure in the western Pacific North Equatorial Current on larval transport of the Japanese eel *Anguilla japonica*. *Journal of Fish Biology, 74*(9), 1878-1890. doi:10.1111/j.1095-8649.2009.02295.x

Zhang, J. and Lay, T. (1992). The April 5, 1990 Mariana Islands earthquake and subduction zone stresses. *Physics of the Earth and Planetary Interiors, 72*, 99-121.

5.0 MARINE MAMMALS

5.1 INTRODUCTION

Marine mammals are a diverse group of approximately 130 species (Jefferson, Webber, and Pitman 2008). Most of these species occur and live predominantly in the marine habitat, though some species spend portions of time in terrestrial habitats (e.g., seals) or in some cases, freshwater environments (e.g., certain freshwater dolphins) (Jefferson, Webber, and Pitman 2008; Rice 1998). The exact number of formally recognized marine mammal species changes periodically with new scientific understanding or findings (Rice 1998). Even the higher-level classification of marine mammals is controversial, as understanding of their origins and relationships continues to evolve. A current species list, *Marine Mammal Species and Subspecies* is maintained by the Society for Marine Mammology (Perrin et al. 2009). Marine mammals in the Marine Resource Assessment (MRA) Study Area occur from coastal waters to the open ocean. This chapter provides profiles of marine mammals in the MRA Study Area for the Japan and Mariana Archipelago (the MRA Study Area)[1]. Organization of text within each section of this chapter will cover, in order as which it appears: global, regional, and MRA Study Area specific information (when available). The MRA Study Area specific information will be covered from north to south, or the Japan Archipelago and Mariana Archipelago, respectively.

5.1.1 Global Distribution and Preferred Habitat

Cetaceans (whales, dolphins, and porpoises) inhabit virtually every marine environment. Pinnipeds (seals, sea lions, and walruses) are semiaquatic marine mammals widely distributed in coastal habitats. Marine Mammals are most concentrated in temperate waters, near topographical features (Caro et al. 2011; Kaschner et al. 2011). However, their distribution is influenced by a number of factors. Primary among these are patterns of major ocean currents, which, in turn, affect prey productivity. Marine mammal distribution is affected by demographic, evolutionary, ecological, habitat-related, and anthropogenic factors (Bjorge 2002; Bowen et al. 2002; Forcada 2008; Stevick, McConnell, and Hammond 2002). Continuous movement of water from the ocean bottom to the surface creates a nutrient-rich, highly productive environment for marine mammal prey (Jefferson, Webber, and Pitman 2008). For most cetaceans during feeding, prey distribution, abundance, and foraging quality largely determine where they occur at any specific time (Heithaus and Dill 2008). In addition to prey distribution, availability, and bathymetry, salinity additionally affects marine mammal distribution. None of these factors is truly independent from the others, and relative strengths of these influences likely change with alterations in oceanic conditions (Caro et al. 2011). Sexual segregation in marine mammals, through same-sex grouping or individual isolation, can occur seasonally, physically (habitat), or socially. Researchers hypothesize that this phenomenon results from predation risk, energy budgets, foraging dynamics, thermal niche-fecundity, or other social and ecological factors—these are described fully in (Wearmouth and Sims 2008).

Most of the large cetaceans are migratory, but many small cetaceans do not migrate in the strictest sense. Instead, they undergo seasonal dispersal or shifts in density. Pinnipeds occur mostly in coastal

[1] Portions of this chapter were written by Dr. T. A. Jefferson, under contract to Tetra Tech. Some of the material in the species accounts contained in this chapter was summarized from the book "Marine Mammals of the World: A Comprehensive Guide to Their Identification" (Jefferson, Webber, and Pitman 2008) for which the authors have full copyright permissions.

habitats or within those regions over the continental shelf. They require land or shallow coastal waters as habitat for reproducing, resting, and (in some cases) feeding, so none of these species has its primary range in open ocean waters. Some global concentration areas for marine mammal species richness (number of different species) have been located in temperate waters in both hemispheres, and include areas around New Zealand, Japan, Baja California, the Galapagos Islands, the Southeast Pacific, and the Southern Ocean. More specifically, in the northern hemisphere, the concentration areas include the waters surrounding Japan and North Korea, Northwest Africa, the Southern United States, parts of the mid-Atlantic ridge, Baja California, the Galapagos Islands, and Hawai‘i (Caro et al. 2011). For summaries of the general biology and ecology of marine mammals beyond the scope of this section, see Reynolds and Rommel (1999), Twiss and Reeves (1999), Hoelzel (2002), Berta et al. (2006), Jefferson et al. (2008), Perrin et al. (2008), and (Kaschner et al. 2011).

The Japan Archipelago portion of the MRA Study Area lies within an oceanic region of transition. The vast majority of the marine mammal species with confirmed or possible occurrence in the Japan MRA Study Area are cetaceans, although pinnipeds do occur as well (Table 5-1). Okinawa has the northernmost population of the endangered dugong. Marine mammals with both cool and warm water preferences occur in this area (Table 5-1). The southern portions of the Study Area generally has very low levels of primary productivity, as the Kuroshio and Tsushima currents carry warm, tropical, and nutrient-depleted waters along the Pacific coast and into the Sea of Japan. Any local concentration areas in productivity may attract all components of the food chain. However, the more northern areas of the Study Area are heavily influenced by the cold, nutrient-rich Oyashio Current, resulting in a high abundance of phytoplankton and higher trophic levels; Oyashio waters are among the most productive waters in the world (Aruga, Yokohama, and Nakanishi 1968; Kasai et al. 1997; Taniguchi 1999).

Japan has a long history of hunting marine mammals, in particular, cetaceans. In addition to pelagic whaling for great whales (the larger baleen and the sperm whale) using factory ships, Japan conducted “small-type” coastal whaling operations (Miyazaki 1983; Nishiwaki 1973). This hunting method was used mostly for the smaller species of whales, like the minke, Baird’s beaked, short-finned pilot, and killer whales. In addition, numerous local fisheries in Japan targeted various species of dolphins and porpoises (Dall’s porpoise and striped dolphin are the most common targets) using hand-held harpoons, drives, and various types of nets (Kishiro and Kasuya 1993; Ohsumi 1972). These latter fisheries take place mostly within Japan’s national waters. Locations in the Japan MRA Study Area and vicinity where community-based coastal whaling takes place are Hakodate, Ayukawa, Wada, and Taiji; Baird’s beaked whales, short-finned pilot whales, and Risso’s dolphins are the primary targets (Japan Small-Type Whaling Association 2002). Management details within Japanese waters, including specifics regarding catches of marine mammals under a special scientific permit, are beyond the scope of this document.

Most of what is known about the biology of cetaceans in Japan comes from or is associated with the whaling and dolphin-hunting industries. The Japanese Whale Research Programme under Special Permit program in the North Pacific (JARPN [1994-1999] and JARPN II [2000-present]) involves annual catches of minke, Bryde’s, sperm, and sei whales with stated objectives that include an examination of the feeding ecology and stock structure determination of these species (Clapham et al. 2003; Government of Japan 2002). For this reason, much is known about distribution, population biology, and life history of some Japanese cetacean stocks. However, little ecological work has been conducted until very recently. In a review of Japan's scientific whaling, (Robertson 2010) suggests the program is a front for commercial whaling, which still involves buying and selling in improperly regulated markets. In addition to whales killed under scientific whaling, documented evidence indicates that Japan historically falsified catch data on sperm and Bryde’s whales in its coastal fishery up to at least 1987 (Ivashchenko, Clapman,

and Brownell 2011). There is no avenue for legal hunting as agreed upon by the International Whaling Commission.

The Mariana Archipelago portion of the MRA Study Area lies within an oceanic province of generally very low levels of primary productivity. Any local concentration areas in productivity may attract all components of the local food chain. Strong interactions between the local oceanography and topography exist in this portion of the MRA Study Area. The MRA Study Area is composed of a series of seamounts. Seamount topography has been previously correlated with enhanced productivity due to the formation of vortices capable of mixing nutrients to the surface and entraining phytoplankton in the overlying waters (Rogers 1994). In addition, passage of the North Equatorial Current (NEC) through the Mariana Archipelago can create regions of enhanced turbulence. Passage of the current of the NEC can initiate formation of eddies on the lee side of the islands (Wolanski et al. 2003); these are capable of entraining phytoplankton and creating localized regions of enhanced primary production visible as increased concentrations of chlorophyll *a* (chl *a*) in the surface waters.

Gannier (2002) reviewed cetacean occurrence in various locations of the tropical Pacific and provided a general assessment. Areas without a significant continental shelf domain do not shelter large densities of bottlenose dolphins. A stable component of four oceanic or semi-oceanic species is present in all areas: spinner and pantropical spotted dolphins, Risso's dolphin, and pilot whale. Spinner and pantropical spotted dolphins are among the two most prevalent species in all areas. As recorded in (Endo, Yong-Un, et al. 2007) a small boat survey conducted off the coasts of the U.S. Territory of Guam (Guam) and Saipan in 2010 encountered spinner dolphins, sperm whales, and a group of pantropical spotted dolphins at a rate of 0.96 sightings/100 kilometers (km). A similar survey of the island of Guam, (HDR 2011) encountered them at a rate of 0.900/100 km. In a 16-day, 1,285 nautical miles (nm) trackline survey from Hawai'i to Guam, (Oleson and Hill 2010) encountered 25 cetacean groups and detected over 100 vocalizations. From Guam to Hawai'i, a 17-day, 1,285 nm survey observed 21 cetacean groups and recorded over 150 hours of acoustical data (Oleson and Hill 2010). Occurrence of all marine mammals in the Mariana Archipelago portion of the MRA Study Area and vicinity are shown on Figure 5-1, the survey effort is depicted in Figure 5-2. Species specific distributions and sightings are discussed within each species profile. The locations of open ocean areas covered in each species profile are shown in Chapter 1, Figure 1-1.

Predictions assessing the role of climate change on global marine mammal populations and distributions portend changes from existing patterns and current data. Climate change is predicted to affect species range. Many cetacean species are limited in their range by water temperature. (Lambert et al. 2011) in a paper which modeled species in the northern Atlantic showed forthcoming shifts in distributions with future temperature shifts. Climate change models also predict (i.e., under the Intergovernmental Panel on Climate Change [IPCC]-A1B intermediate scenario for 2040 to 2049) that the Northern Hemisphere will undergo a decrease in the number of native species, including in the waters surrounding Japan. The loss is predicted to occur near coastlines or across the continental shelf. Some species populations will decrease, whereas others will increase. Within the next 40 years, overall marine mammal species' richness is expected to decrease in lower latitudes and increase in higher latitudes. Over half (54 percent [%]) of species are predicted to undergo increases in their ranges, and 45% will undergo reduction in range. The total change in range, for most taxa, is expected to be less than 10% (Caro et al. 2011). Although these changes in marine mammal range and species richness seem small, predicting actual effects of climate change on marine mammals globally is difficult.

5.1.2 Biology, Life History, and Behavior

Four main types of marine mammals are generally recognized: cetaceans, pinnipeds, sirenians (manatees, dugongs, and sea cows), and several species of marine carnivores (marine otters and polar bears) (Jefferson, Webber, and Pitman 2008; Rice 1998). The Order Cetacea is divided into two suborders. The toothed whales, dolphins, and porpoises (Suborder Odontoceti) range in size from slightly longer than 1 meter (m) to more than 18 m and have teeth, which they use to capture and consume individual prey. In a study conducted by (Noren et al. 2012), breath-hold capacity among odontocetes (Pacific white-sided dolphin, common bottlenose dolphin, and the killer whale) increased with body size. The baleen whales (Suborder Mysticeti) are universally large (more than 5 m as adults), and they are batch feeders that use baleen instead of teeth to engulf, suck, or skim large numbers of small prey from the water or ocean floor sediments (Heithaus and Dill 2008). Detailed reviews of the different groups of cetaceans can be found in Perrin et al. (2009). Most pinnipeds are also divided into two groups: phocids (true seals) and the otariids (fur seals and sea lions). The single species of walrus is in many ways an intermediate between the true seals and sea lions (Berta, Sumich, and Kovacs 2006). The order Sirenia (sirenians) includes the three species of manatee and the dugong, as well as the extinct Stellar's sea cow, all of which are slow moving plant eaters—the only true herbivores among marine mammals. Finally, three other species of marine carnivores are usually classified as marine mammals: the polar bear and two otter species (the sea otter and marine otter).

Although the sensory systems of pinnipeds, sirenians, and the marine carnivores have developed substantial modifications from their terrestrial relatives through evolution, overall the cetacean sensory systems have undergone even greater evolutionary adaptations (changes). All species of toothed whales, dolphins, and porpoises are considered capable of echolocation, although its presence has been proven in only a few species. Echolocation is a process for locating prey or other objects by emitting sound waves that reflect back to the animal (Wartzok and Ketten 1999). This sensory ability has resulted in extensive changes to the anatomy, physiology, ecology, and behavior of these animals. Generally, cetaceans, particularly toothed whales, dolphins, and porpoises, are acoustically oriented animals. Acoustics are a key sensory mechanism to cetaceans (i.e., natural sounds, calls from other whales or dolphin, or human-caused acoustic events) that influence many aspects of their lives. While most marine mammal groups may have at least some basic ability to use echo ranging (using sound to locate prey or objects), none is considered to have the advanced acoustic sonar capabilities of the toothed whales, dolphins, and porpoises. General reviews of cetacean sound production and hearing may be found in (Richardson et al. 1995), (Edds-Walton 1997), (Wartzok and Ketten 1999), and (Au et al. 2000). For a discussion of acoustic concepts, terminology, and measurement procedures, as well as underwater sound propagation, (Urick 1983) and (Richardson et al. 1995) are recommended. For a recent review of marine mammal sensory systems, see Thewissen (2008).

Coloration patterns across cetaceans may help predict prey species, intra-species interactions, and behavior. Smoothly countershaded (darker coloration on dorsal half of body and lighter coloration on ventral side) species were likely to prey on fish and squid. Sharply countershaded cetaceans likely occur in large groups (four or more individuals) and prey on fish and squid. Species with striking markings seem to affect intraspecific communication and prey on fish or squid. Species with white flanks show demonstrative behaviors and prey on fish, whereas a white head indicates species feeding on fish or krill (Endo et al. 2006). This information may be helpful in predicting behavior of cetaceans without specific species identification.

5.1.3 Global Threats and Management

Marine mammal populations can be influenced by a number natural factors and human activities. These factors impact marine mammal populations directly by injuring or hunting individuals outright, or indirectly, for example, through reduced survival or via lowered reproductive success (see Twiss and Reeves 1999 for a general discussion of marine mammal conservation).

Marine mammals are influenced by natural phenomena such as storms and other extreme weather patterns. Generally, not much is known about how large storms and other weather patterns affect marine mammals, other than that mass strandings (when marine mammals run aground) sometimes coincide with hurricanes, typhoons, and other tropical storms (Marsh 1989; Rosel and Watts 2008). The changing global climate is significantly impacting some populations of marine mammals (Salvadeo et al. 2010; Simmonds and Eliott 2009). Climate change can affect marine mammal species directly through habitat loss (especially those species that depend on ice or sandy islands) and indirectly via impacts on prey, changing prey distributions and locations, and changing water temperature. Changes in prey can impact marine mammal foraging success, which in turn affects reproduction success and survival. Climate change also may influence marine mammals through effects on human behavior, such as increased shipping and oil and gas extraction resulting from sea ice loss (Alter, Simmonds, and Brandon 2010).

Mass die offs of some marine mammal species have been linked to consumption of poisoned plankton or other organisms, such as die offs of California sea lions and northern fur seals from poisoning caused by the diatom species *Pseudo-nitzschia* (Doucette et al. 2006; Fire et al. 2008; Lefebrve et al. 2010; Thomas et al. 2010; Torres de la Riva et al. 2009). All marine mammals have parasites that, under normal circumstances, probably do little overall harm, but under certain conditions can cause serious health problems or even death (Bull et al. 2006; Fauquier et al. 2009). Disease affects some individuals (especially the older animals), and occasionally disease epidemics can injure or kill a large percentage of the population (Keck et al. 2010; Ohishi, Fujise, and Maruyama 2008; Paniz-Mondolfi and Sander-Hoffmann 2009).

Human impacts on marine mammals that have received much attention in recent decades include hunting (both commercial and native practices), fisheries interactions (such as gear entanglement or shootings by fishers), bycatch (accidental or indirect catch), ship strikes, noise pollution, chemical pollution, and general habitat deterioration or destruction. Direct hunting, as in whaling and sealing operations, provided the original impetus for marine mammal management efforts and has driven much of the early research on cetaceans and pinnipeds (Twiss and Reeves 1999). However, indirect captures of animals in fishing nets and gear (bycatch) is likely an even bigger current problem and may account for the deaths of more marine mammals than any other cause (Hamer, Childerhouse, and Gales 2010; Northridge 2008; Read 2008). A review of 55 techniques to reduce bycatch of marine mammals (identification and analysis) appeared in (Werner et al. 2006). Ship strikes are a growing issue for most marine mammals, such as North Atlantic right whales. Ship strikes may significantly affect the population of a species, particularly in small populations, and possibly on larger scales (Laist et al. 2001; Van Waerebeek et al. 2007; Vanderlaan et al. 2009) however, the true global impact of ship strikes (especially form propeller wounds) is difficult to quantify (Byard et al. 2012).

Noise, in particular human-caused seismic exploration sounds and sonar, or other types of pulses produced by various sources including geologic exploration and government, commercial, or private sources are of particular concern to marine mammals because noise can cause marine mammal

behavioral disturbance, injury, and in some cases death (Tyack 2009; Würsig and Richardson 2008). For an in-depth review of potential effects of vessel noise pollution on baleen wales, see Tyack (2008). In addition to the noise from seismic exploration or sonar sources cited above, noise from whale watching vessels that spend time in the vicinity of marine mammals have received a great deal of attention recently (Wartzok 2009). Species-specific effects from anthropogenic sound should be considered, and may affect frequencies among species' calls and other parameters related to hearing and vocalization. (Clark et al. 2009) showed that in New England waters, calls of right whales were masked to a much greater degree than those of humpbacks or fin whales under the same conditions, and may be more sensitive to increased noise in the ocean.

Chemical pollution is also of great concern, although for the most part, an understanding of its effects on marine mammals is just beginning (Reijnders, Aguilar, and Borrell 2008). Recently, the 5.5-year expedition of the *Odyssey* collected 955 biopsy samples from sperm whales around the world to provide a consistent baseline database of ocean contamination for interpreting future measures of effects (Ocean Alliance 2010). Chemical pollutants found in pesticides flow into the marine environment from human use on land and are absorbed into the bodies of marine mammals, accumulating in their blubber, or are transferred to the young via mother's milk (Fair et al. 2010). Important factors that determine levels of pesticides and industrial pollutants accumulating in marine mammals are habitat and diet. Living closer to the source of pollutants and feeding on higher-level organisms increase potential to accumulate toxins (Moon, Kannan, Choi, Yu, et al. 2010). Buildup of human-made, long-lasting compounds in marine mammals not only increases their likelihood of contracting diseases or developing tumors but also compromises functioning of their reproductive systems (Fair et al. 2010). The risk of adverse health effects is particularly high when contaminants are transferred to a calf through its mother's milk (Fair et al. 2010). Oil and other chemical spills are types of ocean contamination that can have damaging effects on some marine mammal species (see Matkin et al. 2008).

Finally, general habitat deterioration and loss is a major factor for almost all coastal and inshore species of marine mammals, especially those that live in rivers or estuaries, and may lead to depletion of a habitat's prey base and complete loss of habitat (Kemp 1996; Smith et al. 2009).

5.2 SPECIES LIST AND STATUS

All marine mammals in the United States are protected under the Marine Mammal Protection Act (MMPA), and some species receive additional protection under the Endangered Species Act (ESA). Within the framework of the MMPA, a marine mammal "stock" is defined as "a group of marine mammals of the same species or smaller taxon [species] in a common spatial arrangement that interbreed when mature." For management under the MMPA, a stock is considered an isolated population, or group of individuals, within a whole species, that is found in the same geographical area. However, in practice, recognized stocks may fall short of this ideal because of a lack of information or other reasons, and in some cases may even include multiple species, such as with certain beaked whales (Carretta et al. 2010). Forty-one marine mammal species are known to exist in the MRA Study Area. Table 5-1 provides a summary of the status and occurance of marine mammals in the Japan and/or Mariana Archipelago MRA Study Area.

Table 5-1: Marine Mammals with Possible or Confirmed Presence in the MRA Study Area

Species Name and Regulatory Status					Ecological Presence						
Common Name	Scientific Name	ESA Listing	MMPA Status	IUCN	Open Ocean				Coastal Waters		
					NCP	KU	ECS	PS	JA	MA	CI
Order Cetacea											
Suborder Mysticeti (baleen whales)											
Family Balaenidae (right and bowhead whales)											
North Pacific Right Whale	*Eubalaena japonica*	Endangered	Protected, Depleted	Endangered	-	P	P	-	P	-	-
Family Balaenopteridae (rorquals)											
Omura's Whale	*Balaenoptera omurai*	--	--	Data Deficient	P	P	P	P	P	-	-
Humpback Whale	*Megaptera novaeangliae*	Endangered	Protected, Depleted	Least Concern	P	S	S	S	P	P	P
Minke Whale	*Balaenoptera acutorostrata*	Not Listed	Protected	Least Concern	P	P	P	P	P	P	-
Bryde's Whale	*Balaenoptera brydei/edeni*	Not Listed	Protected	Data Deficient	P	P	E	P	P	P	S
Sei Whale	*Balaenoptera borealis*	Endangered	Protected, Depleted	Endangered	P	P	S	S	P	S	-
Fin Whale	*Balaenoptera physalus*	Endangered	Protected, Depleted	Endangered	P	P	P	S	P	S	S
Blue Whale	*Balaenoptera musculus*	Endangered	Protected, Depleted	Endangered	P	P	S	P	P	P	P
Family Eschrichtiidae (gray whale)											
Gray Whale	*Eschrichtius robustus*	Endangered (Western North Pacific population)	Protected, Depleted (Western North Pacific population)	Least concern	-	S	-	-	S	-	-
Suborder Odontoceti (toothed whales)											
Family Physeteridae (sperm whale)											
Sperm Whale	*Physeter macrocephalus*	Endangered	Protected, Depleted	Vulnerable	P	P	S	P	P	P	P
Family Kogiidae (pygmy and dwarf sperm whales)											
Pygmy Sperm Whale	*Kogia breviceps*	Not Listed	Protected	Data deficient	P	P	S	P	P	P	P
Dwarf Sperm Whale	*Kogia sima*	Not Listed	Protected	Data deficient	P	P	S	P	S	P	P
Family Ziphiidae (beaked whales)											
Cuvier's Beaked Whale	*Ziphius cavirostris*	Not Listed	Protected	Least concern	P	P	S	P	S	P	P
Blainville's Beaked Whale	*Mesoplodon densirostris*	Not Listed	Protected	Data deficient	P	P	S	P	S	P	P
Baird's Beaked Whale	*Berardius bairdii*	Not Listed	Protected	Data deficient	P	P	-	-	S	-	-
Longman's Beaked Whale	*Indopacetus pacificus*	Not Listed	Protected	Data deficient	P	P	S	P	P	P	P
Hubbs' Beaked Whale	*Mesoplodon carlhubbsi*	NA	NA	Data deficient	P	P			S		
Ginkgo-Toothed Beaked Whale	*Mesoplodon ginkgodens*	NA	NA	Data deficient	P	P	S	P	P	P	P
Stejneger's Beaked Whale	*Mesoplodon stejnegeri*	Not Listed	Protected	Data deficient	P	P	-	-	P	-	-
Family Delphinidae (dolphins)											
Rough-Toothed Dolphin	*Steno bredanensis*	Not Listed	Protected	Least concern	P	P	P	P	P	S	S
Common Bottlenose Dolphin	*Tursiops truncatus*	Not Listed	Protected	Least concern	S	P	P	P	P	S	S
Long-Beaked Common Dolphin	*Delphinus capensis*	Not Listed	Protected	Data deficient	-	P	P	-	P	-	-
Short-Beaked Common Dolphin	*Delphinus delphis*	Not Listed	Protected	Least concern	P	P	P	-	P	-	-
Pantropical Spotted Dolphin	*Stenella attenuata*	Not Listed	Protected, Depleted (Pacific Northeastern Offshore stock)	Least concern	P	P	P	P	P	P	P
Spinner Dolphin	*Stenella longirostris*	Not Listed	Protected, Depleted (Eastern stock in eastern tropical Pacific)	Data deficient	S	S	S	S	S	S	S
Striped Dolphin	*Stenella coeruleoalba*	Not Listed	Protected	Least concern	P	P	P	P	P	P	p
Fraser's Dolphin	*Lagenodelphis hosei*	Not Listed	Protected	Least concern	P	P	S	P	S	P	P
Risso's Dolphin	*Grampus griseus*	Not Listed	Protected	Least concern	P	P	P	P	P	-	-
Pacific White-Sided Dolphin	*Lagenorhynchus obliquidens*	Not Listed	Protected	Least concern	-	P	P	-	P	-	-
Northern Right Whale Dolphin	*Lissodelphis borealis*	Not Listed	Protected	Least concern	-	P	-	-	P	-	-
Melon-Headed Whale	*Peponocephala electra*	Not Listed	Protected	Least concern	P	P	S	P	S	P	P

Table 5-1: Marine Mammals with Possible or Confirmed Presence in the MRA Study Area

Species Name and Regulatory Status					Ecological Presence						
Common Name	Scientific Name	ESA Listing	MMPA Status	IUCN	Open Ocean				Coastal Waters		
					NCP	KU	ECS	PS	JA	MA	CI
Pygmy Killer Whale	*Feresa attenuata*	Not Listed	Protected	Data deficient	P	P	S	P	S	P	P
False Killer Whale	*Pseudorca crassidens*	Proposed – Endangered (Insular Hawaiian stock)	Protected	Data deficient	S	P	P	P	P	S	S
Killer Whale	*Orcinus orca*	Endangered (Southern Resident population)	Protected, Depleted (AT1 Transient population; Southern Resident population)	Data deficient	P	P	P	S	P	S	S
Short-Finned Pilot Whale	*Globicephala macrorhynchus*	Not Listed	Protected	Data deficient	P	P	P	P	P	P	P
Indo-Pacific Bottlenose Dolphin	*Tursiops aduncus*	NA	NA	Data deficient	-	P	P	P	P	-	-
Family Phocoenidae (porpoises)											
Finless Porpoise	*Neophocaena phocaenoides*	NA	NA	Vulnerable	-	-	S	-	S	-	-
Dall's Porpoise	*Phocoenoides dalli*	Not Listed	Protected	Least concern	P	P	-	-	P	-	-
Order Carnivora											
Suborder Pinnipedia											
Family Otariidae (fur seals and sea lions)											
Northern Fur Seal	*Callorhinus ursinus*	Not Listed	Protected, Depleted (Pribilof Island/Eastern Pacific stock)	Vulnerable	-	P	-	-	P	-	-
Family Phocidae (true seals)											
Spotted Seal	*Phoca largha*	Threatened (Southern stock)	Protected, Depleted	Data deficient	-	S	P	-	P	-	-
Order Sirenia											
Suborder											
Family Dugongidae (dugongs)											
Dugong	*Dugong dugon*	NA	NA	Vulnerable	-	P	-	-	P	-	P

Source: (National Marine Fisheries Service 2011b), Accessed January 5, 2012.
Notes:
Not included is the Japanese sea lion (*Zalophus japonicus*), which was once present in the southern Sea of Japan and the coastal waters of Japan but is now presumed extinct (Nishiwaki 1973; Nishiwaki and Nagasaki 1960; Rice 1998).The last credible report was of 50 to 60 individuals on Takeshima Island (southern Sea of Japan) in 1951 (Rice 1998). Individual sightings were reported in 1974 and 1975, but these individuals likely were captive (escaped or freed) California sea lions (*Zalophus californianus*) (Rice 1998)
[1] Endangered Species Act (ESA) listing status. (National Marine Fisheries Service 2011b).
[2] All marine mammals are protected under the Marine Mammal Protection Act (MMPA). Populations or stocks that have fallen below the optimum sustainable population level are depleted.
[3] International Union for Conservation of Nature (IUCN) and Natural Resources listing (International Union for Conservation of Nature and Natural Resources 2012b).
[4] Ecoregional presence relates to open ocean and coastal waters of the MRA Study Area. Ecoregional presence in open ocean waters include: the North Central Pacific Gyre (NCP), the Kuroshio (KU), the East China Sea (ECS), and the Philippine Sea (PS). Ecoregional presence in coastal waters include: near shore waters of the Japan Archipelago (JA), the Mariana Archipelago (MA), and the Caroline Islands (CI). Each species may have a primary range (P), secondary range (S), or may be an extralimital (Ex) species in these areas.
[E]Extralimital Species - A species that does not normally occur in the area, but for which there are one or more records that are considered beyond the normal range of the species.
NA = Not applicable

Extralimital species are not covered with full species profiles in theis chapter. In the Japan portion of the MRA Study Area, the Japanese sea lion (*Zalophus japonicus*) was once present in the southern Sea of Japan and the coastal waters of Japan but is now presumed to be extinct (Nishiwaki 1973; Nishiwaki and Nagasaki 1960; Rice 1998). The last credible report was of 50 to 60 individuals on Takeshima Island (southern Sea of Japan) in 1951(Rice 1998). Individual sightings were reported in 1974 and 1975, but it is likely that these individuals were escaped California sea lions (*Zalophus californianus*) (Rice 1998). Other extralimital species in this portion of the MRA Study Area include the harbor seal (*Phoca vitulina*), the ringed seal (*Phoca hispid*), the ribbon seal (*Phoca fasciat*), the northern elephant seal (*Mirounga angustirostris*), the bearded seal (*Erignathus barbatus*), and the bowhead whale (*Balaena mysticetes*).

In the Mariana portion of the MRA Study area there are very rare sightings of the dugong here and no confirmed records for the North Pacific right whale or Hawaiian monk seal. The dugong very rarely strays into this area, and no pinniped species is known to be a regular inhabitant of the Micronesia region (Reeves et al. 1999). There are rare reports of seals at these islands; however, species identification could not be verified. (Eldredge 1991) called attention to the possibility that Hawaiian monk seals and northern elephant seals wander far enough from their normal ranges to appear at the Marshall or Gilbert Islands in the Micronesia region.

This Page Intentionally Left Blank

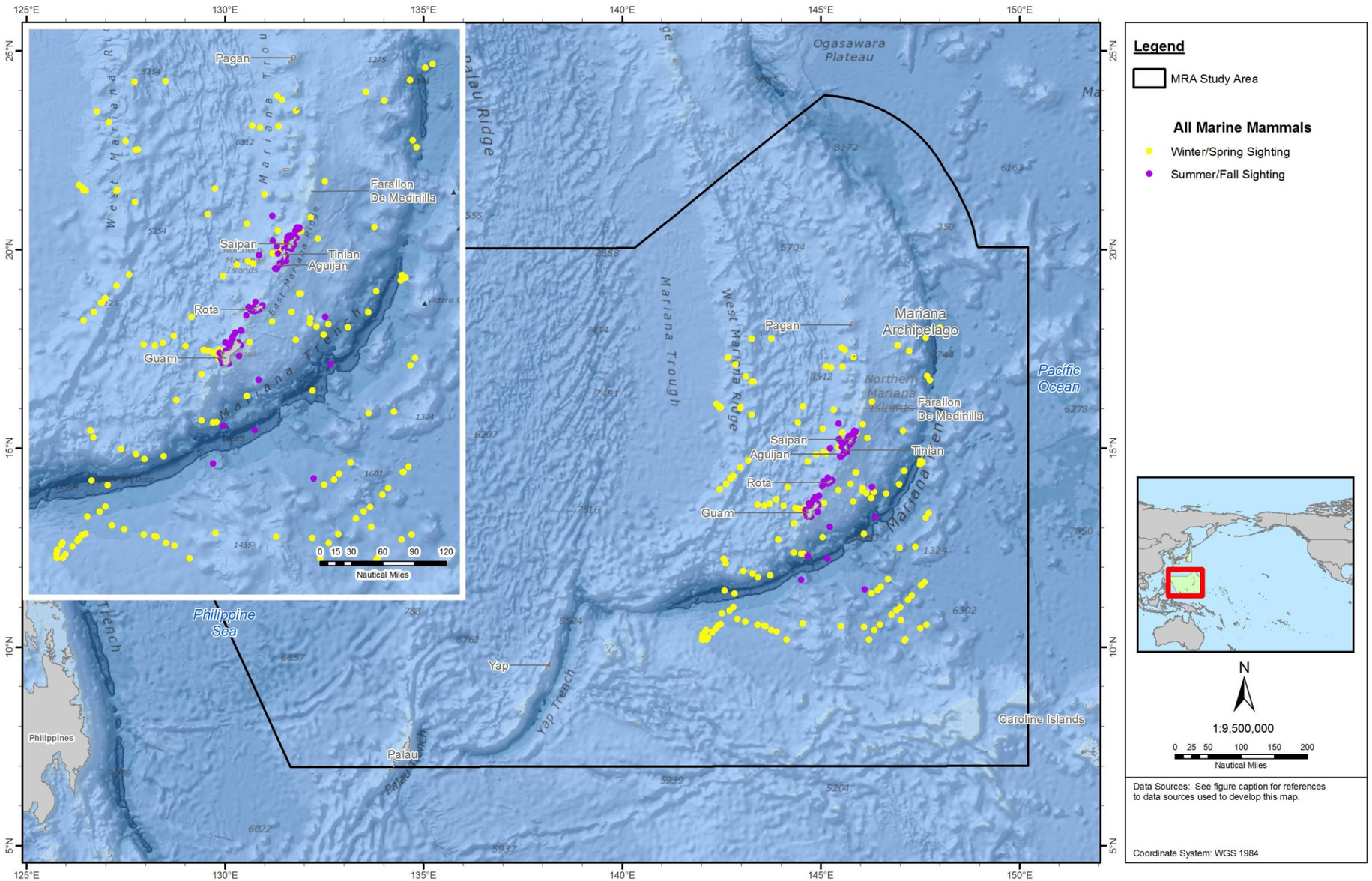

Figure 5-1: Sightings of All Marine Mammals in the Mariana Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented.
Sources: Fulling, Thorson, and Rivers (2011); HDR (2011, 2012); Hill et al. (2013); Hill et al. (2011); Mobley (2007); U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific (2007).

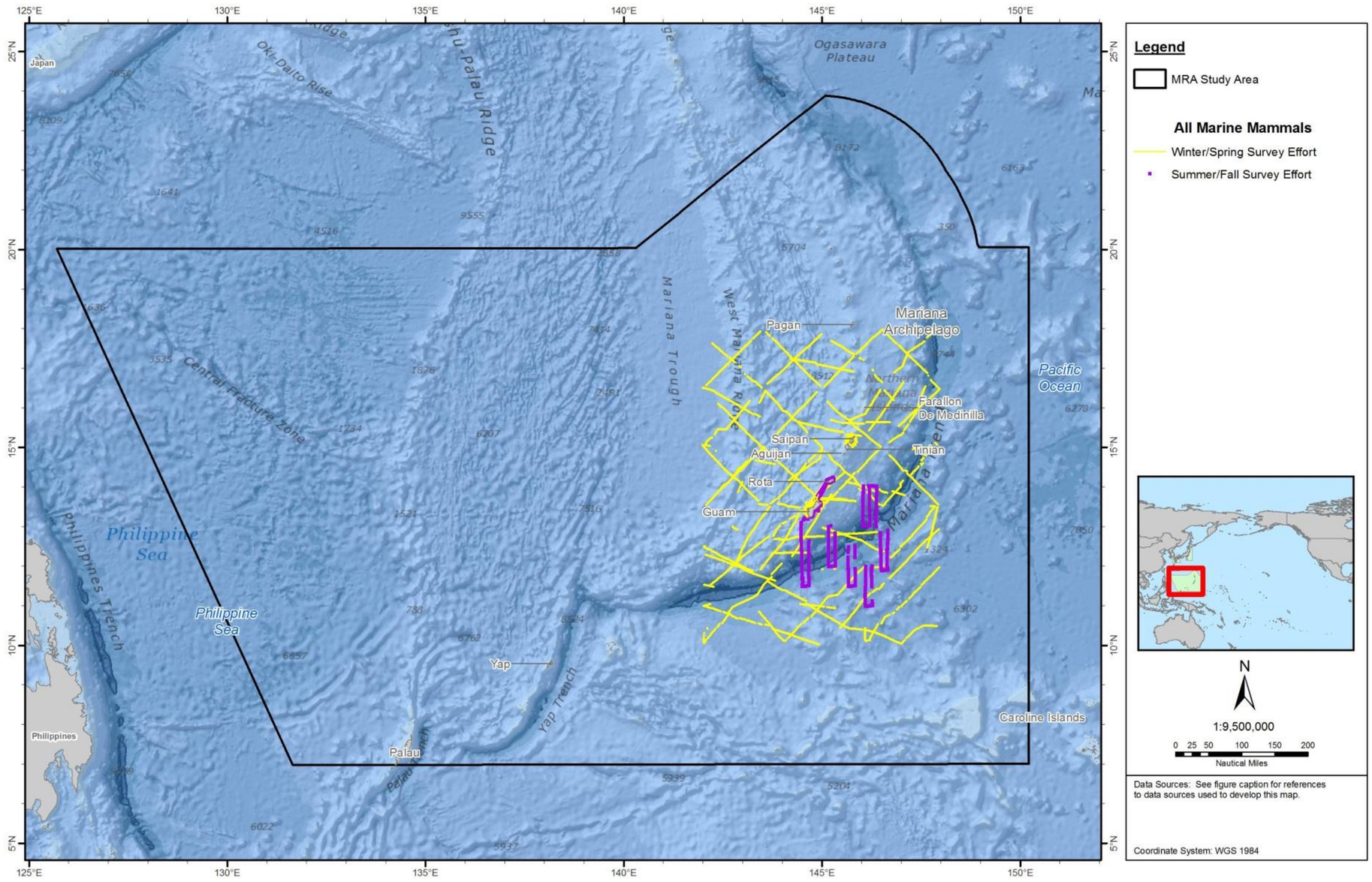

Figure 5-2: Survey Effort for All Marine Mammal Sightings in the Mariana Portion of the MRA Study Area

Sources: Fulling, Thorson, and Rivers (2011); HDR (2011, 2012); Hill et al. (2013); Hill et al. (2011); Mobley (2007); U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific (2007).

5.3 NORTH PACIFIC RIGHT WHALE (*EUBALAENA JAPONICA*)

The North Pacific right whale is not expected to occur within the MRA Study Area, yet has been historically documented in Japanese waters. For this reason, updated range maps will not be provided for this species within this MRA.

5.3.1 Description

Right whales in the North Atlantic and North Pacific were once classified together as a single species, the northern right whale. However, genetic data have now determined them to represent two separate species: the North Atlantic right whale (*Eubalaena glacialis*) and the North Pacific right whale *(Eubalaena japonica*) (Rosenbaum et al. 2000).

Right whales have a robust body shape; overall body color is black, although many individuals also have irregular white patches on their undersides (Reeves and Kenney 2003). There is no dorsal fin on the broad back. North Pacific right whales are larger than their North Atlantic counterparts (Reeves and Kenney 2003). The largest recorded North Pacific right whales are an 18.3-m female and a 16.4-m male (Straley, Quinn, and Gabriele 2009); these can weigh up to 54,000 kilograms (kg). The head is nearly one-third of the total body length. The jawline is arched and the upper jaw is very narrow in dorsal view. The head is covered with irregular whitish patches called “callosities” that have whale lice attached.

5.3.2 Status and Management

The North Pacific right whale is one of the world’s most endangered large whale species (IWC 2001; Perry, DeMaster, and Silber 1999). North Pacific right whales are endangered under the ESA and are depleted (below their optimal sustainable population level) under the MMPA. This species is also listed as endangered by the International Union for Conservation of Nature (IUCN) and falls under Appendix I Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) regulations. In 1931, the Convention for the Regulation of Whaling were the first, international protection guidelines for this species, yet Japan and the Soviet Union did not agree or sign the document (National Marine Fisheries Service). Critical habitat for the North Pacific right whale has been designated in the Gulf of Alaska. The designated area includes waters in the western Gulf of Alaska and in the southeastern Bering Sea.

5.3.3 Population and Abundance

The estimated historical population was over 11,000 animals, but research indicates their numbers are now much lower. At this time, the National Oceanic and Atmospheric Administration (NOAA) Eastern North Pacific Stock reports no reliable numbers exist for the minimum abundance of this species (Allen and Angliss 2010a) although there are estimates. Two populations are evident: the eastern Pacific and the western Pacific. The population in the eastern North Pacific is generally considered very small and one of the most endangered baleen whale populations in the world. Previous estimates had perhaps fewer than a hundred animals (Clapham et al. 2004). Aerial surveys conducted in 1998, 1999, and 2000 photographed 13 individual animals from this population (LeDuc et al. 2001). Among these, the only resighting in all 3 years was of a single individual. Thus a total of 11 individuals were identified (LeDuc et al. 2001). This photographic recapture rate is consistent with a very small population size, the lowest estimate being 17 whales (National Oceanic and Atmospheric Administration 2009). In the western North Pacific, the population may number in the low hundreds (Brownell et al. 2001; Clapham et al. 2004). Research by Wade et al. (2010) indicates more recently that numbers are several hundred or

more. The rare sighting of multiple females and calves within one Bearing Sea group, (Wade et al. 2006) suggests northern Pacific populations may still be able to recover from critical endangerment.

5.3.4 Biology, Ecology, and Behavior

Right whales, like humpback whales, have been documented breaching (leaping from the water) and lobtailing (slapping the tail on the surface of the water) (Kenney 2008). Sightings of right whales have been rare in Hawaiian waters; on one of these occasions, they were seen in a group association with humpback whales (Government of Japan 2002; Salden and Mickelsen 1999).

Group Size. In the North Pacific, few individuals are observed, and they are usually alone (Brownell et al. 2001). LeDuc (2001) spotted single animals, a pair, and a group of five animals during aerial surveys. The only exception is an area of the southeastern Bering Sea where small groups of right whales (at least five and possibly seven individuals, but no calves) have been sighted in several successive years (Tynan, DeMaster, and Peterson 2001).

Predator/Prey Interactions. North Pacific right whales feed primarily on calanoid copepods (*Calanus marshallae*), a type of zooplankton. Calanoid copepods are a vital part of marine food webs, providing an energy-rich food source for predators such as large fish and some whales. North Pacific right whales have also been observed feeding on an extensive bloom of a single-celled marine plant (*Emiliania huxleyi*) (Tynan, DeMaster, and Peterson 2001). When feeding, right whales skim prey from the water (Pivorunas 1979; Woodward, Winn, and Fish 2006). They feed both at the surface and throughout the water column, moving through patches of zooplankton with open mouths for long periods (4 to 6 minutes [min]) at slow speeds (Gregr and Coyle 2009). Right whales are also known to feed close to the sea floor, because they have been observed at the surface at the end of an extended dive with mud on the head (Kenney 2008).

Killer whales and large sharks prey on the North Pacific right whale. Calves and juveniles are known to be the primary target of killer whales, and scars on some individuals suggest that attacks by false killer whales occur as well (Kenney 2008).

Life History. Little is known regarding the life history of the North Pacific right whale, and much of what is known comes from whaling records. Right whales in the North Pacific probably reach sexual maturity at a body length of 14.5 to 15.5 m for males and 15 to 16 m for females, which corresponds to an age of approximately 10 years (Straley, Quinn, and Gabriele 2009). One premise of their life history involves "sperm competition." This describes a reproductive strategy that involves physical competition between the sperm of two or more different male right whales; only one of which can fertilize the egg of a female (MacLeod 2010). No coastal calving grounds have been identified for right whales in the western North Pacific, which suggests offshore breeding occurs (Scarff 1986). Calves are born during December through March after 12 to 13 months of gestation (Best 1994). Weaning occurs at 8 to 17 months (Hamilton, Marx, and Kraus 1995). A 3-year calving interval is typical in the North Atlantic (Friedlaender et al. 2011). Right whales are known to live over 70 years (Jefferson, Webber, and Pitman 2008).

Migration. Little is known about the seasonal migration patterns of the right whales; however, a general movement northward in the spring and summer and southward in the fall is typical. Historical whaling records provide virtually the only information on North Pacific right whale distribution. During the summer, whales were found in the Gulf of Alaska, along both coasts of the Kamchatka Peninsula, the southeastern Bering Sea, and in the Okhotsk Sea (Clapham et al. 2004; Shelden et al. 2005). Vocal recordings indicated heightened habitat use in the southeastern Bering Sea in mid-summer to early fall

(Munger et al. 2008). The whales were most widely dispersed in fall and spring, with whales occurring in mid-ocean waters and extending from the Sea of Japan to the eastern Bering Sea. In winter, right whales were found in the Ryukyu Islands (south of Kyūshū, Japan), the Ogasawara Islands, the Yellow Sea, and the Sea of Japan (Reilly, Bannister, Best, Brown, Brownell, Butterworth, Clapham, Cooke, Donovan, Urban, et al. 2008). Historical concentrations of sightings in the Bering Sea and recent sightings indicate that this region remains an important summer habitat for eastern North Pacific right whales (Shelden et al. 2005; Tynan, DeMaster, and Peterson 2001). (Scarff 1986) hypothesized that those right whales summering in the eastern North Pacific mate, calve, and overwinter in the mid-Pacific or in the western North Pacific.

Hearing/Vocalization. Morphometric analyses of the inner ear of right whales resulted in an estimated hearing frequency range of approximately 10 hertz (Hz) to 22 kilohertz (kHz), based on established marine mammal models (Parks et al. 2004).

North Pacific right whale calls are classified into five categories: (1) up, (2) down-up, (3) down, (4) constant, and (5) unclassified. Frequencies of these vocalizations are between 50 and 500 Hz (Gibbs, Harcourt, and Kemper 2011; Li, Nachtigall, and Breese 2011); typical sounds are in the 300 to 600 Hz range with up- and down-sweeping modulations (Aketa 2002). (Aketa 2002) found that lower (<200 Hz) and higher (>900 Hz) frequency sounds are relatively rare. (Lopez 2011). The 'up' call is the predominant type (Lopez 2011; Morell 2011). Typically, the "up" call is a signal sweeping from about 90 to 150 Hz in 0.7 seconds (s.) (Amesbury et al. 2001; Lopez 2011; Parks and Tyack 2005). Source levels for pulsive calls of North Atlantic right whales are 172 to 187 decibels with a reference pressure of one micropascal at one meter (dB re 1 µPa-m) (Parks and Tyack 2005; Thomson and Richardson 1995). Other sound types produced by North Atlantic right whales have a source level ranging from 137 to 162 dB re 1 µPa-m for tonal calls and 174 to 192 dB re 1 µPa-m for broadband gunshot sounds (Parks and Tyack 2005). Right whales commonly produce calls in a series of 10 to 15 calls lasting 5 to 10 min, followed by silence lasting an hour or more; some individuals do not call for periods of at least 4 hours (Lopez 2011). This calling pattern is similar to the "moan cluster" reported for North Atlantic right whales by (Li, Nachtigall, and Breese 2011). Vocalization rates of North Atlantic right whales are also highly variable, whereby calls peak between August and October (earliest in June and the latest in December), diel patterns are observed, and individuals have been known to remain silent for hours (Mellinger et al. 2007). Sound production is common in surface active groups of the North Atlantic right whale (Parks and Tyack 2005), and has recently been determined to be produced by only males (Williams, Krkosek, et al. 2011).

Diving. Because knowledge of this species and direct data on it are limited, North Pacific right whale dive behavior is assumed similar to the diving behavior of the North Atlantic right whale. Typical dive times range from 10 to 20 min (Kenney 2008). Baumgartner and Mate (2003) found that the average depth of a North Atlantic right whale dive was based on both the average depth of peak copepod abundance and the average depth of the bottom mixed layer's upper surface. When feeding, North Atlantic right whales dive rapidly from the surface to between 260 and 575 feet (ft.) (80 and 175 m) deep. Here they remain for 5 to 14 min and then rapidly ascend to the surface. Longer surface intervals have been observed for reproductively-active females and their calves (Baumgartner and Mate 2003).

5.3.5 Habitat and Distribution

The North Pacific right whale has historic range within the Japan portion of the Japan portion of the MRA Study Areas, yet have no recent confirmed citings within either portions of the MRA Study Area.

Because this species is not expected to occrur in the MRA Study Area, this species profile will not include updated range maps.

Right whales occur in subpolar to temperate waters. The geographic range of the North Pacific right whale is shown on Figure 5-3. Sightings in the Bering Sea are clustered in relatively shallow water (waters with a bottom depth of 50 to 80 m) (Tynan, DeMaster, and Peterson 2001). Whaling records reveal a shift in habitat preferences from the 1960s to the 1980s from waters of the southeastern Bering Sea slope and shelf, eastern Aleutian Islands and the Gulf of Alaska slope and abyssal plain to southeastern Bering Sea middle shelf. Since 1979, North Pacific right whale sightings have occurred in waters less than 200 m deep, whereas up to the late 1960s, they were seen in waters exceeding 2,000 m in depth (Shelden et al. 2005). Analysis of whaling records, lead to the conclusion that right whales prefer cold water with low variability annually but high variability within seasons (Gregr 2011). This is characteristic of areas with predicable high frontal activity. Habitat changes depending on the season: open ocean feeding in spring, and foraging along the shelf-edge and on-shelf later in the season (Gregr 2011).

Feeding habitat for right whales is where prey, especially zooplankton, is plentiful (Reeves and Kenney 2003) because of oceanic conditions, such as sea surface temperatures, stratification, bottom topography, and currents. Concentration is further enhanced by behavior of the prey organisms (Tynan, DeMaster, and Peterson 2001). In the North Pacific, the feeding range is thought to include the Gulf of Alaska, the Aleutian Islands, the Bering Sea, and the Sea of Okhotsk. The location of calving grounds is unknown (Brownell et al. 2001; Shelden and Clapham 2006).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. The North Pacific right whale historically occurred across the Pacific Ocean north of 35°N, with concentrations in the Gulf of Alaska, eastern Aleutian Islands, south-central Bering Sea, Sea of Okhotsk, and the Sea of Japan (Clapham et al. 2004; Scarff 1986; Scarff 1991; Straley, Quinn, and Gabriele 2009) (Figure 5-3 and Figure 5-4).

KUROSHIO CURRENT. During the summer-fall period, the area of expected occurrence is north of 35°N off the Pacific coast of Japan based on both the presumed northward migration and available occurrence records. The likelihood of species presence in this area is low. Numbers or occurrences are unknown seaward of 400 nm in this area (Clapham et al. 2004). The predicted occurrence for the MRA Study Area reflects the possibility of encounters with right whales close to shore, as well as in much deeper waters.

EAST CHINA SEA. Waters adjacent to the East China Sea are included in the known primary range of this species (Figure 5-3 and Figure 5-4).

PHILIPPINE SEA. The Philippine Sea is not included in the known primary range of this species; however, encounters with this whale here is a remote possibility (Figure 5-3 and Figure 5-4).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. During the winter-spring period, right whales are expected to occur from the coast (not including bays) to about 400 nm (740 km) offshore. This is based on most available records citing them within a few hundred miles of the coast (Clapham et al. 2004). The predicted occurrence

within the Japan MRA Study Area reflects the possibility that right whales might be encountered close to shore, as well as in much deeper waters.

MARIANA ARCHIPELAGO. There are no confirmed records of the North Pacific right whale in the Micronesia region; however, (Reeves et al. 1999) noted the remote possibility of encountering this species here. Sightings have been made both in waters on and seaward of the shelf off the Hawaiian Islands in April of 1996 (Government of Japan 2002; Salden and Mickelsen 1999; Witteveen, Worthy, and Roth 2009).

CAROLINE ISLANDS. The Caroline Islands are not included in the known primary range of this species (Figure 5-3).

5.3.6 Species-specific Threats

The North Pacific right whale has been hunted in Japanese fisheries beginning in the 1500s, and by Europeans and Americans starting in 1835. They have been heavily exploited by Soviet hunting as well. This species, as are others, is susceptible to entanglements in fishing gear and ship strikes (Jefferson, Webber, and Pitman 2008). Research by (Nowacek, Johnson, and Tyack 2004) on North Atlantic right whales suggests that received sound levels of only 133 to 148 dB re 1 µPa-m for the duration of the sound exposure are likely to disrupt feeding behavior; the authors did note, however, that a return to normal behavior would be expected within minutes of when the source is turned off. All of these threats may be exacerbated by effects of climate change on their primary habitats (Jefferson, Webber, and Pitman 2008).

This Page Intentionally Left Blank

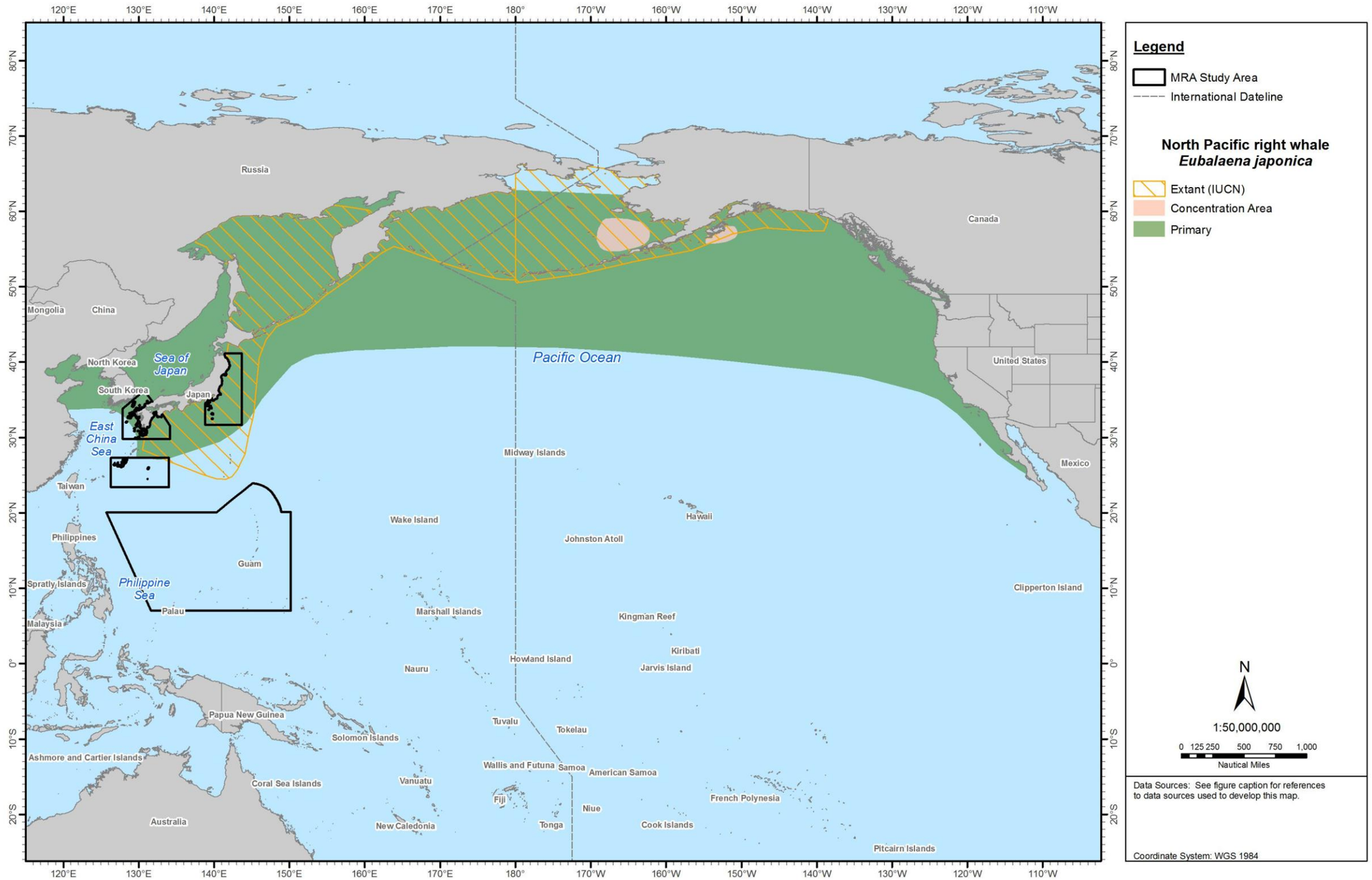

Figure 5-3: Geographic Range of the North Pacific Right Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

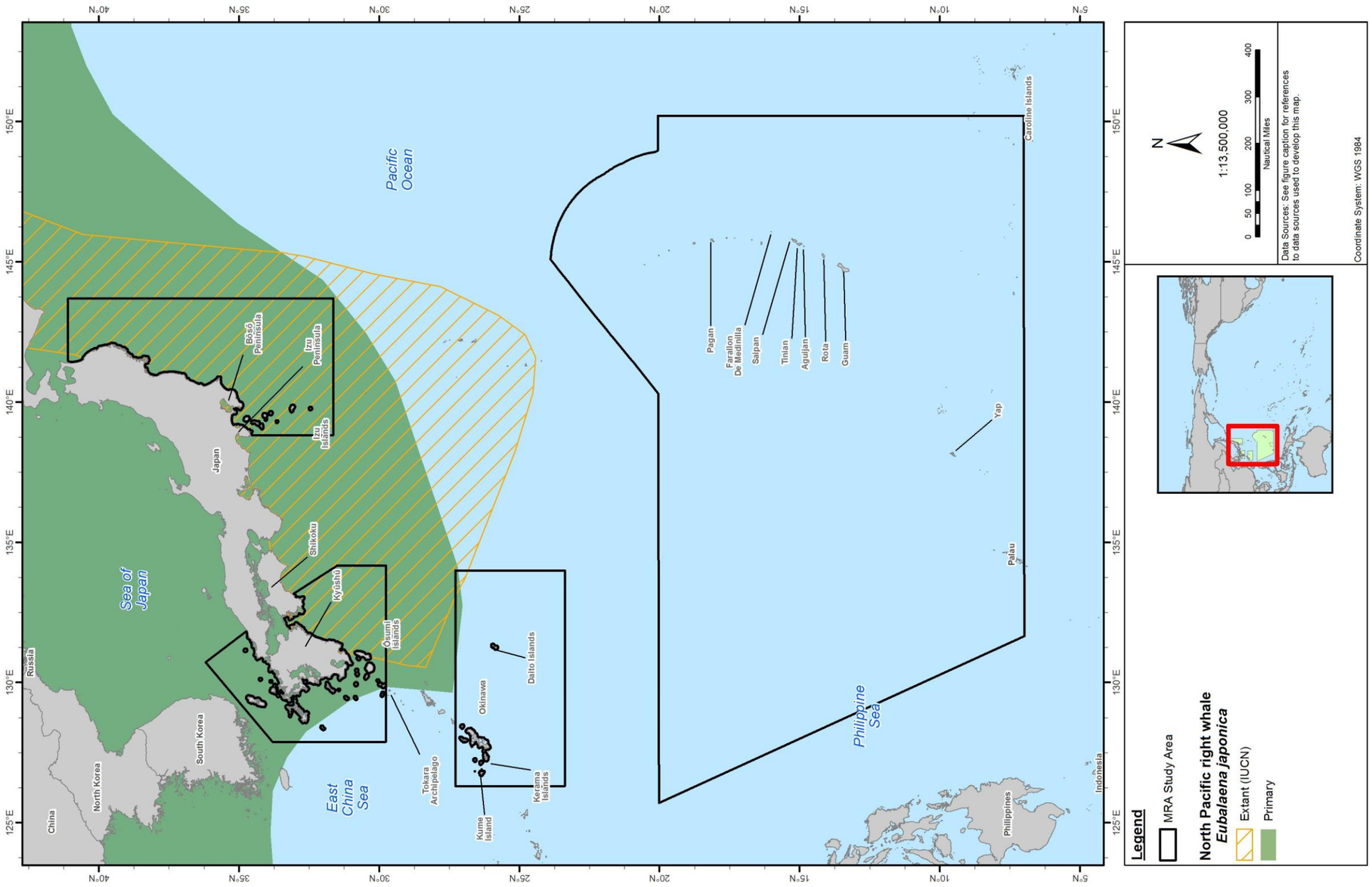

Figure 5-4: Geographic Range of the North Pacific Right Whale in the MRA Study Area

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.4 OMURA'S WHALE (*BALAENOPTERA OMURAI*)

5.4.1 Description

Medium-sized baleen whales were historically considered either one of two species: *Balaenoptera edeni* (Bryde's whale) or *Balaenoptera borealis* (sei whale). Three genetically distinct types of morphologically similar whales are now known to the species level, including the Bryde's whale (*Balaenoptera brydei/edeni*), the pygmy or dwarf Bryde's whales (*Balaenoptera brydei*) (Kato and Perrin 2008; Rice 1998; Sasaki et al. 2006), and Omura's whale (species was first described in 2003). Once the pygmy or dwarf Bryde's whale was keyed, it became apparent that the term "pygmy Bryde's whale" had also been mistakenly used for some specimens of *Balaenoptera omurai* (Reeves et al. 2004). The Omura's whale is now phylogenetically recognized as a separate species (Sasaki et al. 2006).

The Omura's whale is physically distinct from those species it had been mistaken for in the past; the coloration of this whale is more consistent with that found in the fin whale (Wada, Oishi, and Yamada 2003). The throat of Omura's whale is similar to the fin whale in that its coloration varies widely, whereas the remaining ventral area is white. Other characteristics similar to the fin whale include the white inner surface of the flippers white, a white left gape, and a white bottom of the fluke (tail) with a black margin. One main difference from a Bryde's whale's predominant characteristics is that the Omura's whale lacks lateral ridges on its head (Wada, Oishi, and Yamada 2003).

Omura's whales are documented to be unique in their cranial morphology, with a relatively broad, flat skull. The rostrum tapers from the base with a dorsally convex lateral margin. Omura's whale has the most unique baleen whale characteristics. Its baleen plates are broad and short, having straight, rigid fringes with a grey-white coloration. The number of baleen plates (200 on one side) is much smaller than those seen in other, similar whales (Wada, Oishi, and Yamada 2003). For the type specimen, body length was measured under 12 m. Omura's whale is much smaller than the physically similar fin whale (Wada, Oishi, and Yamada 2003). Specific characteristics and population trends are difficult to substantiate due to the small number of confirmed specimens. Weight of this animal is unknown.

5.4.2 Status and Management

Omura's whale is listed as "data deficient" by the IUCN and falls under Appendix I CITES regulations. It is protected under the MMPA mostly due to the historical relastionship with the Bryde's whale. Omura's whale is not currently recognized by the International Whaling Commission (IWC) (Reilly, Bannister, Best, Brown, Brownell, Butterworth, Clapham, Cooke, Donovan, Urbán, et al.).

5.4.3 Population and Abundance

There are no worldwide estimates for Omura's whale. Through use of sighting data, (Ohsumi 1980) estimated a population of 1,800 individuals for the Solomon Islands as part of the "Bryde's whale" stock. Based on this species' previously incorrect identifications, this estimate might instead represent Omura's whale abundance. No abundance estimates specific to the MRA Study Area are available.

5.4.4 Biology, Ecology, and Behavior

Group size. Omura's whale generally occurs alone or in pairs (Jefferson, Webber, and Pitman 2008).

Predator/Prey Interactions. Not much is known of the prey interactions of this species. Like other rorquals (any of several baleen whales of the family Balaenopteridae having longitudinal grooves on the throat and a small, falcate, pointed dorsal fin), Omura's whales are lunge feeders, and are believed to feed on a diversity of krill and fish (Hoelzel, Dorsey, and Stern 1989; Jefferson, Webber, and Pitman 2008).

Similar to other baleen whales, Omura's whales probably are subject to chance attacks by killer whales.

Life History. Little is known about Omura's whale. Life history characteristics may be similar to other related species.

Migration. Little is known about Omura's whale. Migration characteristics may be similar to other related species.

Hearing/Vocalization. Little is known about Omura's whale. Hearing/vocalization characteristics may be similar to other related species.

Diving. Little is known about Omura's whale. Diving characteristics may be similar to other related species.

5.4.5 Habitat and Distribution

Not much is known of the geographic range of Omura's whale, as limited sightings of this whale have been confirmed. This species has been documented above the continental shelf in nearshore waters (Jefferson, Webber, and Pitman 2008), but they are known to occupy both deep-water and nearshore areas (Reilly, Bannister, Best, Brown, Brownell, Butterworth, Clapham, Cooke, Donovan, Urbán, et al. 2008).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. Omura's whale is occurs in tropical and subtropical waters of the western Pacific and eastern Indian Oceans (Jefferson, Webber, and Pitman 2008).

KUROSHIO CURRENT. Omura's whale is known to occur in the tropical and subtropical waters of the western Pacific (Figure 5-5 and Figure 5-6) (Jefferson, Webber, and Pitman 2008). In 2003, the Omura's whale was described from accounts in the Philippines, eastern Indian Ocean, Indonesia, Sea of Japan, and the Solomon Islands (Wada, Oishi, and Yamada 2003). From the type specimen, discovered through a stranding in the Sea of Japan, a morphological baseline is available for this species (Reilly, Bannister, Best, Brown, Brownell, Butterworth, Clapham, Cooke, Donovan, Urbán, et al. 2008).

EAST CHINA SEA. The East China Sea is included in the known range of this species (Figure 5-5 and Figure 5-6). In the Solomon Islands, these whales were found dissimilar to Bryde's whales in the offshore waters of the western north Pacific and the East China Sea (Yoshida and Kato 1999).

PHILIPPINE SEA. The Philippine Sea is included in the known range of this species (Figure 5-5 and Figure 5-6).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Omura's whale has been sighted a few time in nearshore waters and is possibly within the MRA Study Area (Jefferson, Webber, and Pitman 2008).

Kyūshū Island, Ōsumi Island, Tokara Archipelago. The stranding from which most of the known physical characteristics of this species were observed occurred on the coast of Tsunoshima Island (Wada, Oishi, and Yamada 2003).

MARIANA ARCHIPELAGO. Omura's whale has been sighted a few times in nearshore waters and is possibly within the MRA Study Area (Jefferson, Webber, and Pitman 2008).

CAROLINE ISLANDS. Omura's whale has been sighted a few times in nearshore waters and is possibly within the MRA Study Area (Jefferson, Webber, and Pitman 2008).

5.4.6 Species-specific Threats

Omura's whale may be subject to direct catch through fisheries targeting similar species. This species may also be threatened through instances of by-catch. Some evidence indicates inclusion of Omura's whale in artisanal fishing practices in the Philippines (Reilly, Bannister, Best, Brown, Brownell, Butterworth, Clapham, Cooke, Donovan, Urbán, et al. 2008). This species is susceptible to both ship strikes and entanglement in fishing gear . (Reilly, Bannister, Best, Brown, Brownell, Butterworth, Clapham, Cooke, Donovan, Urbán, et al. 2008)

This Page Intentionally Left Blank

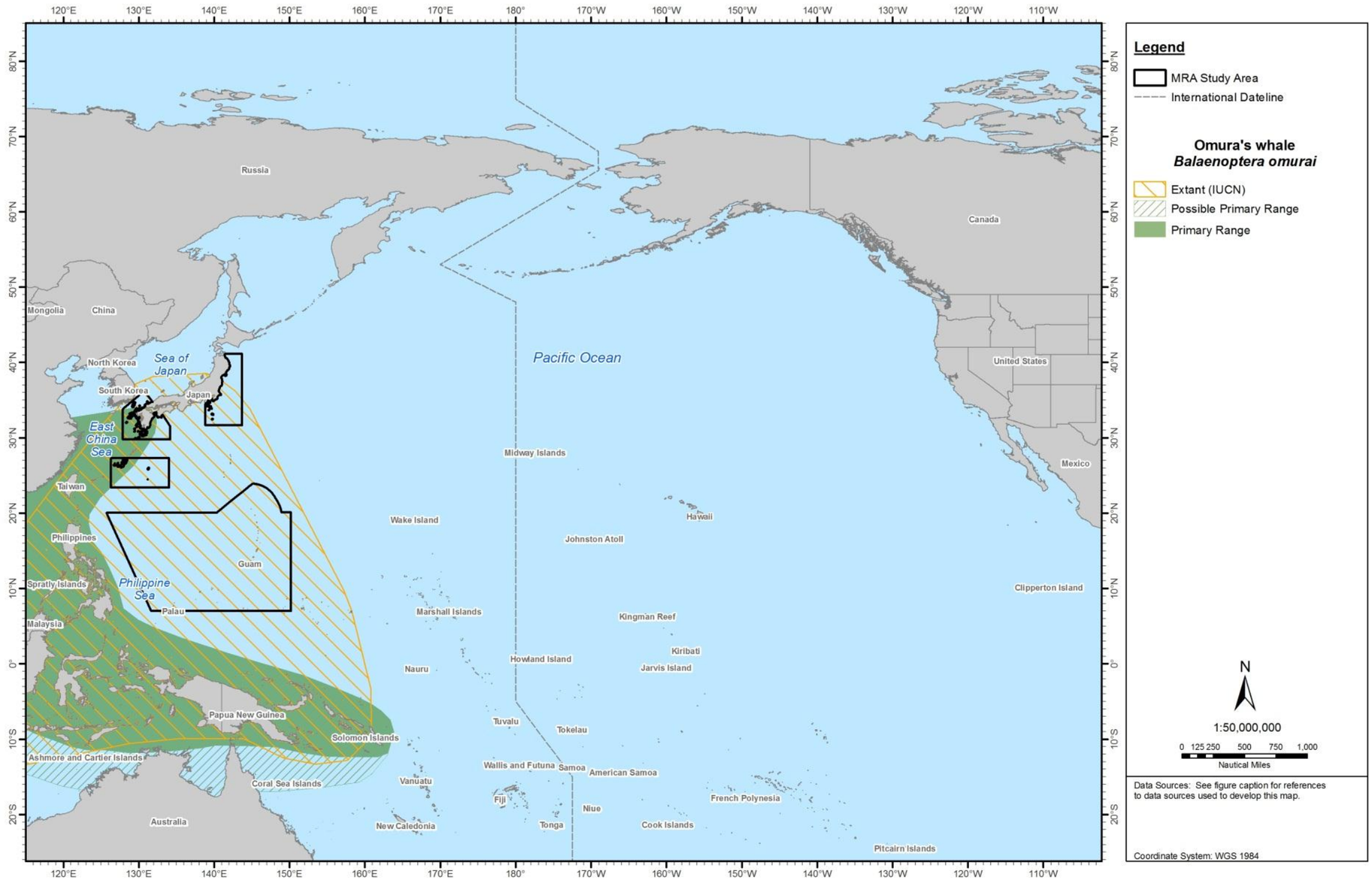

Figure 5-5: Geographic Range of the Omura's Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

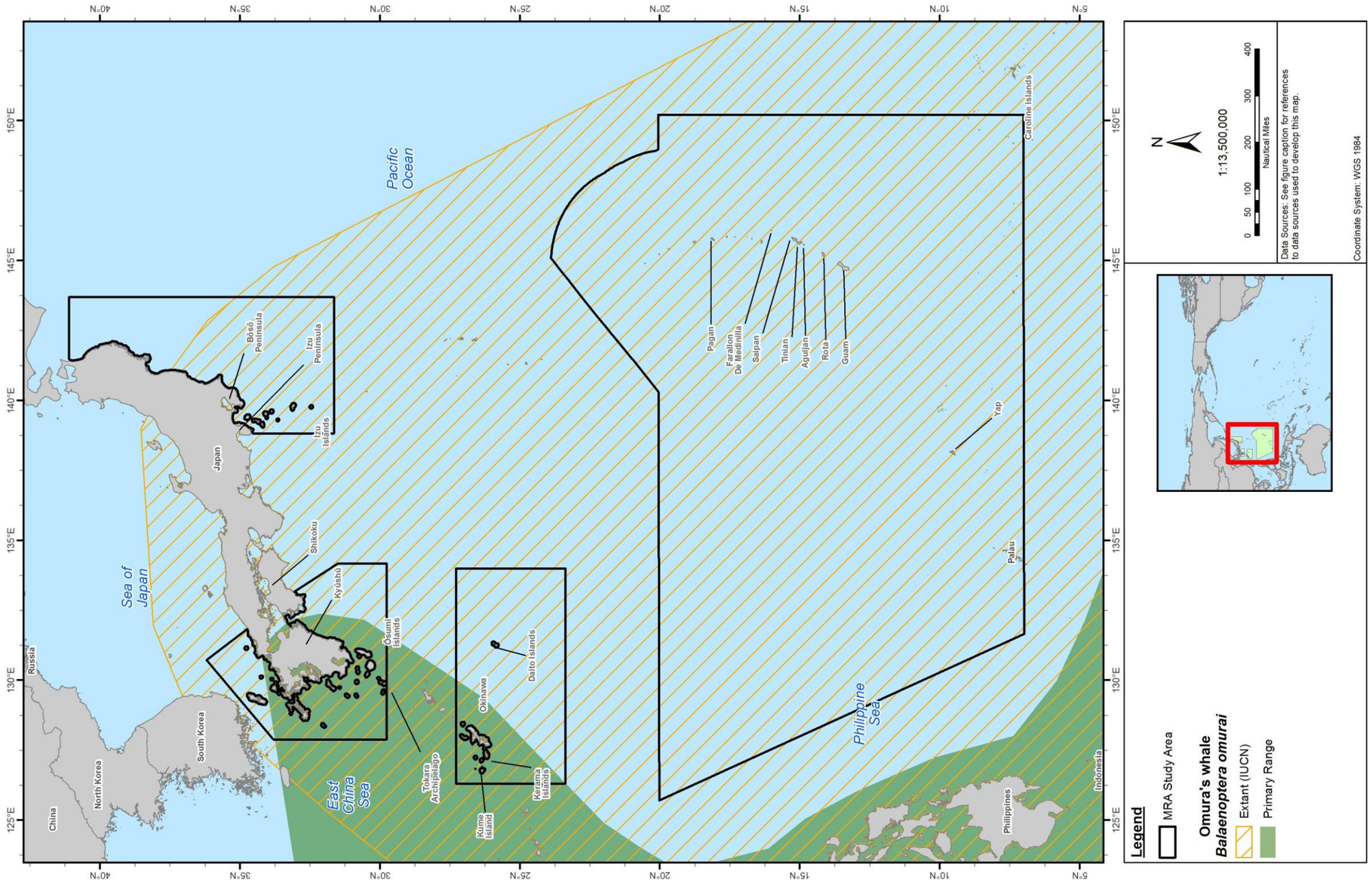

Figure 5-6: Geographic Range of the Omura's Whale in the MRA Study Area

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.5 HUMPBACK WHALE (*MEGAPTERA NOVAEANGLIAE*)

5.5.1 Description

The humpback whale may be the best-known and most-recognizable of all the great whale species. It is a major target of many whale-watching operations worldwide.

Humpback whales are more robust than other rorqual whales. The flippers are unique; they are very long (about one-third of the body length) and have a distinctive scalloped leading edge. The head is larger than in other rorquals with a wide, flat upper jaw covered with a series of knobs. The flukes have a concave, serrated trailing edge, and the unique patterns of scalloping and color markings can be used to identify individuals. The ventral pleats extend to the navel or beyond (Clapham and Mead 1999; Jefferson, Webber, and Pitman 2008).

Body color is mostly black on the upper surface; the flippers are mostly white. The ventral side is variably patterned in black and white (Clapham and Mead 1999; Jefferson, Webber, and Pitman 2008). Southern Hemisphere humpbacks generally have much more extensive white coloration, and much of the sides may be white. Individual humpback whales may be identified via these patterns (Katona et al. 1979), and more recently through use of specific matching software (Kniest, Burns, and Harrison 2010).

Adult humpback whales are 11 to 16 m long and weigh at least 40,000 kg. Newborns are about 4.3 m long and weigh about 680 kg. There are 270 to 400 black to olive-green baleen plates on each side of the mouth (Jefferson, Webber, and Pitman 2008). In the field, estimates of body size can be based on fluke width measurements and species-specific mathematical formulas (Sousa-Lima and Groch 2010).

5.5.2 Status and Management

Humpback whales are depleted under the MMPA and endangered under the ESA. This species is also listed as a species of least concern by the IUCN and falls under Appendix I CITES regulations. Based on evidence of population recovery in many areas, National Marine Fisheries Service (NMFS) is considering the species for removal or downlisting from the U.S. Endangered Species List (National Marine Fisheries Service 2009a).

In the U.S. North Pacific, the stock structure of humpback whales is defined based on feeding areas because of the species' fidelity to feeding grounds (Carretta et al. 2010). NMFS has designated three stocks: (1) the Central North Pacific stock, consisting of winter and spring populations of the Hawaiian Islands that migrate to northern British Columbia and Alaska, the Gulf of Alaska, the Bering Sea, and Aleutian Islands; (2) the Western North Pacific stock, consisting of winter and spring populations off Asia that migrate to Russia and the Bering Sea and Aleutian Islands; and (3) the California, Oregon, Washington, and Mexico stock, consisting of winter and spring populations in coastal Central America and coastal Mexico that migrate to coastal California and to British Columbia in summer and fall (Allen and Angliss 2010a). There are an estimated ≥ 3.2 annual deaths or serious injuries caused by fisheries in the California/Oregon/Washington stock (Carretta et al. 2012). The Western North Pacific stock is the stock considered to occur in the MRA Study Area (Calambokidis et al. 1997).

5.5.3 Population and Abundance

An estimated 35,000 to 40,000 humpback whales occur globally. The current best population estimates for the entire North Pacific, based on data pooled across all winter and summer regions, are 19,594 (Calambokidis et al. 2008) and 21,063 using fluke identifications from 2004 to 2006 (U.S. Fish and

Wildlife Service 2003). From this population, approximately 900 migrate to the western Pacific and may be hunted illegally (Allen and Angliss 2010d; Dalton 2008). Geographically, the nearest stock assessment for United States waters was conducted for the California/Oregon/Washington stock, estimated at greater than 2,000 whales. A new stock, the American Samoa stock, was included in this assessment, yet no abundance estimate is available for this stock at this time. Point estimates for Asian waters is between 938 and 1,107 with no calculated coefficient of variation (CV) (Allen and Angliss 2010d). The population in Asian waters is estimated between 900 and 1100, and the Russian population is estimated between 100 and 700. The size of this population is small as a result of the large number of whales killed illegally by the U.S.S.R. from 1947 to 1973. These two populations may not be isolated from one another. Certain stocks are apparently still depleted from whaling but most are showing strong evidence of recovery (Calambokidis and Barlow 2004; Jefferson, Webber, and Pitman 2008; Stevick et al. 2003) (United Nations Environment Programme n.d.-a). Via abundance surveys, the North Pacific population of humpback whales is estimated to have increased by 6.6% (Zerbini et al. 2006). Estimates from Ogaswara and Okinawa waters indicate the population for this stock is increasing as well (Allen and Angliss 2010d).

5.5.4 Biology, Ecology, and Behavior

Humpback whales show many behaviors at the surface, including breaching, tail slapping, and other visible displays. A few cases of interspecific activity, theorized to constitute play, have been documented between humpback whales and bottlenose dolphins in the Hawaiian islands (i.e., in one case, the whale was photographed using its head to lift the dolphin out of the water) (Deakos et al. 2010). They are sometimes seen releasing bubble clouds, which may indicate aggression or may be playful depending on the context. Sometimes small numbers of bubbles are released from their mouths. Although the exact anatomical and physiological dynamic of this practice remain unclear, the behavior is also believed to help prevent intrusion of water into the respiratory system (Reidenberg and Laitman 2007).

Group Size. The size of a group of humpback whales can range from single individuals to large groups of up to 20 or more (Clapham and Mead 1999). Within feeding grounds, relatively large numbers of humpbacks may be observed within a limited area. Groups of males may occur on the breeding grounds as well, ranging in size from a few animals to over 15, competing for access to females (Baker and Herman 1984; Clapham 1996; Pack et al. 1998; Tyack and Whitehead 1983). In eastern Australia, pairs are most frequently seen, followed by mothers with calves, then threesomes (mother, calf, and escort [an accompanying adult believed to be a male]), lone females, and groups of four and more (Uchida 1982). In winter breeding grounds, as has been demonstrated in the Pacific (Hawai‘i) and other areas worldwide, a population bias exists toward males (Vanderlaan, Hay, and Taggart 2003).

Predator/Prey Interactions. Humpback whales feed on a wide variety of invertebrates and small schooling fishes. It has been shown that humpback whales are generalist predators, eating small fish and krill in proportions correlated to the relative abundance of prey species, which varies at different feeding grounds (Trianni and Kessler 2002). The most common invertebrate prey are krill; the most common fish prey are herring, mackerel, sand lance, sardines, anchovies, and capelin (Clapham and Mead 1999). Humpback whales have been observed in South Africa feeding on crustaceans during mid-spring (Barendse et al. 2010). Feeding occurs both at the surface and in deeper waters, wherever prey is abundant (Friedlaender, Lawson, and Halpin 2009). In Antarctica, this species was associated with small (<35 millimeters [mm]) juvenile prey (Santora et al. 2010). Humpback whales are the only species of baleen whale that show strong evidence of cooperation when they feed in large groups (D'Vincent, Nilson, and Hanna 1985). The primary feeding range of the Western North Pacific stock is not known.

This species is attacked by both killer whales and false killer whales, as evidenced by tooth rake scars on their bodies and fins (Jefferson, Webber, and Pitman 2008). In a stranding survey from 1877 to 2005 in New Caledonia, the Loyalty Islands, and Vanuatu, one humpback whale showed signs of predation by killer whales (Borsa 2006). Humpback whales observed in the feeding grounds off Washington and California had the highest rate of rake marks (bite mark scars on their flukes) of any of the feeding grounds observed (Steiger et al. 2008). During predation by killer whales, humpbacks are known to employ the "fight" strategy, characterized by physical defense, possibly enhanced through use of calluses or barnacles, a behavior common in whales having robust, maneuverable bodies that calve in coastal areas (Ford and Reeves 2008).

Life History. Female humpbacks become sexually mature at 4 to 9 years old (Clapham 1996). In the Gulf of Maine, females are sighted with their first calf at a much younger age than their Pacific Ocean counterpart, 5.91 years and 11.8 years, respectively (Gabriele, Straley, and Neilson 2007). Pregnancy lasts approximately a year. Calves are weaned before 1 year. The time between pregnancies is usually 2 to 3 years, although occasionally females give birth to calves in successive years (Clapham 1996). From 1976 to 2010, 39 females surveyed in Hawaiian calving grounds were calculated to have 2 to 8 calves over the 20- to 26-year span (Vanderlaan, Hay, and Taggart 2003). In Hawaiian calving grounds, mother-calf pairs in association with a single male (escort) did not demonstrate changes in behavior. Conversely, when associating with more than one male, mother-calf pairs spent more time traveling (35% increase) and less time at rest (29% decrease). Calves within the pair exhibited less surface time (10% decrease) and increased breaths between dives (16 to 22% increase) when associating with more than one male. These behavioral changes may contribute to a decrease in calf fitness as a result of increased energy expenditures (Cartwright and Sullivan 2009). Within this breeding area, it was documented longer/larger mothers produce larger claves, preferred by male escorts (Pack et al. 2009). Males and females live approximately 20.7 and 19.8 years, respectively (Vanderlaan, Hay, and Taggart 2003), yet some tagged individuals have been sighted for over 30 years in Alaskan waters (Mizroch et al. 2011).

Migration. Humpback migrations are complex and span long distances (Calambokidis 2009). Each year, most humpback whales migrate from high-latitude summer feeding grounds to low latitude winter breeding grounds, one of the longest migrations known for any mammal; individuals can travel nearly 4,970 miles (8,000 km) from feeding to breeding areas (Clapham and Mead 1999).

Migration routes are typically over 250 miles (400 km) offshore. The exact migration routes taken by humpback whales in the North Pacific and western Pacific are not completely known, although recordings of humpback whales singing in oceanic waters about 1,243 miles (2,000 km) north-northeast of Hawaiʻi, and 745 to 870 miles (1,200 to 1,400 km) west of the mainland coast of California provide some clues (Norris, Jacobsen, and Cerchio 2000; Norris, McDonald, and Barlow 1999). Studies show whales tend to move north from Hawaiʻi on a track very close (within 1°) to magnetic north (Mate, Gisiner, and Mobley 1998). Humpbacks average a migration speed of 2.5 miles (4 kilometers per hour [km/hr]) (Lagerquist et al. 2008). Results from a tagging study estimated animals took 39 days to travel the entire 4,200-km migration route to the upper Gulf of Alaska (Mate, Gisiner, and Mobley 1998). Singing whales migrating from the Hawaiian breeding ground swam at 1.6 km/hr (Noad and Cato 2007). The specific migration route between the Japanese breeding ground and the apparent Aleutian Island/Bering Sea/Gulf of Alaska feeding ground is not clear. The wintering/breeding grounds are thought to be located in the western North Pacific, the Bonin Islands, Ryukyu Islands and south to the Philippines where the oceanic portions of the MRA Study Area overlap the range for this species. Breeding grounds are also found in the waters of the Great Barrier Reef from June to September, where whales travel north from Antarctica using a strict route based on water temperature and depth (Smith

et al. 2012). Within this migration, singing whales swim at a mean speed of 2.5 km/hr, versus mean swim speed of non-singing whales of 4.0 km/hr—possibly a trade-off of migration time and female attraction (Noad and Cato 2007). Feeding grounds are not found in the MRA Study Area. Antarctica feeding grounds also provide habitat for whales migrating to and from the Cook islands and American Samoa (Hauser et al. 2010). Humpback whales have been seen deviating from predicted routes in South Africa due to changes in food availability (Barendse et al. 2010). Recently, Stevick et al. (2010) reported an exceptionally long-distance migration of over 6,000 miles (9,800 km) by a female humpback in the southern hemisphere, a new migration distance record for humpbacks. Although individuals from the northern hemisphere have been known to migrate tot eh southern hemisphere (Stone, Florez-Gonzalez, and Katona 1990) ene flow has been evidenced between southern and northern hemisphere populations in low latitude breeding grounds (Rizzo and Schulte 2009).

Hearing/Vocalization. From a humpback audiogram, using a mathematical model and the predicted audiogram, a sensitivity to frequencies from 700 Hz to 10 kHz was shown, with maximum relative sensitivity between 2 and 6 kHz (Houser, Helweg, and Moore 2001). Humpback whales were affected by long-distance (200 km) anthropogenic sound created during an Ocean Acoustic Waveguide Remote Sensing experiment. Here the effect on the whales was complete lack of calls over the duration of the sound. Humpback whales exhibit a variety of behavioral changes in response to many different sounds, including those produced by other whales (Risch et al. 2012).

Humpback whales are known to produce three classes of vocalizations: (1) “songs” in the late fall, winter, and spring by solitary males; (2) social sounds within groups while within the wintering (calving) grounds; and (3) sounds while within the feeding grounds (Thomson and Richardson 1995). This species produces sounds much in the same way as humans do, by changing the tension of vibrating membranes, pneumatically (Mercado et al. 2010).

Social calls are from 50 Hz to more than 10 kHz (Silber 1986). While the one published paper on female vocalizations has reported that sounds appear to be simple (Simao and Moreira 2005), this study upon further review may have mistakenly assumed biological origin to these sounds. The male song, however, is complex and changes between seasons. Components of the song range from under 20 Hz to 4 kHz and occasionally 8 kHz, with source levels of 144 to 174 dB re 1 µPa-m, with a mean of 155 dB re 1 µPa-m. (Au, Darling, and Andrews 2001) recorded high-frequency harmonics (to 13.5 kHz) and source level between 171 and 189 dB re 1 µPa-m of humpback whale songs. Songs have also been recorded within feeding grounds (Clark and Clapham 2004; Mattila, Guinee, and Mayo 1987). The main energy lies between 0.2 and 3.0 kHz, with frequency peaks at 4.7 kHz. “Feeding” calls, unlike song and social sounds, are highly stereotyped series of narrow-band trumpeting calls. These are 20 Hz to 2 kHz, less than 1 s. in duration (Wada et al. 1991), and have source levels of 175 to 192 dB re 1 µPa-m. The fundamental frequency of feeding calls is approximately 500 Hz (D'Vincent, Nilson, and Hanna 1985). Calf calls were recorded in Hawaiian waters where a male calf emitted pulsed (71%), frequency modulated (FM) (19%), and amplitude modulated (AM) (10%) signals. These simple, low frequency (220 Hz) sounds were short (170 milliseconds [ms]) with a narrow bandwidth (2 kHz) (Zoidis et al. 2008).

The best-known types of sounds produced by humpback whales are songs, which are thought to be breeding displays used only by adult males (Helweg et al. 1992). Singing is most common within breeding grounds during the winter and spring months, but occasionally is heard outside breeding areas and out of season (Clark and Clapham 2004; Mattila, Guinee, and Mayo 1987). Singing males were likely to associate with mother-calf pairs, starting to sing only if a male escort was not already present, and associating with that mother-calf pair for a greater amount of time than other groups (Smith et al.

2008). Humpback song is an incredibly elaborate, hierarchical series of patterned vocalizations (Payne and McVay 1971). Humpback whale songs vary geographically, with different populations singing different songs, and all members of a population using the same basic song. However, the song evolves over the course of a breeding season, but remains nearly unchanged from the end of one season to the start of the next (Payne, Tyack, and Payne 1983). Recorded songs in Australian waters were shorter than those within Hawaiian breeding grounds (Miksis-Olds et al. 2008). When the songs change, they can be passed to unrelated individuals of the same generation within a population. These cross-group song variations are known as cultural changes (Uchida 1985) and are easily learned based on the simple organization of sounds into rhythmic groups that can be repeated to form whole songs (Handel, Todd, and Zoidis 2009). In Atlantic feeding grounds, over a 2-year study, calls occurred most often in November, and longest sessions were recorded in April, concurrent with feeding routines and migration preparation (Vu et al. 2012).

Although baleen whales were previously thought to not produce vocalizations during feeding or foraging practices, more recent recordings documented clicks associated with lunging behavior (Stimpert et al. 2007). A total of 34,000 megaclicks were recorded at night produced by two whales in the northwest Atlantic, between 143 and 154 dB re 1 µPa pp below 2 kHz.

Male and female humpback whales also produce surface-generated sounds known as “social sounds” via activities like “breaching” and pectoral “slapping” that they use to communicate. These types of communication are produced during migration. Social calls such as underwater “grunts,” “groans,” and “barks” almost exclusively occur when different groups socially integrate (Dunlop, Cato, and Noad 2008). During increased wind speeds and background noise, humpbacks switch from vocal signals to surface-generated signals (Dunlop, Cato, and Noad 2010). This shift may ensure messages are not lost in the louder environment.

Diving. Humpback whale diving behavior depends on the time of year (Clapham and Mead 1999). In summer, most dives last less than 5 min. In winter (December through March), dives average 10 to 15 min (Clapham and Mead 1999). On wintering grounds they dive fairly deep; Baird and Whitehead (2000) recorded dives deeper than 100 m. In Hawaiʻi, the competitive behavior of displacing/maintaining primary escorts has been shown to be associated with not only surface time, but also time spent during dives to the seafloor where whales inflated their pleats and chased one another (Herman et al. 2007). When calves are present, their proximities to their mothers decrease when they surface, and because calves do not dive as deep or as often as their mothers, mothers may significantly shorten the durations of their dives. As the season progresses and calves age, mothers are less responsive to calves, and calves increase dive coordination with their mothers (Szabo and Duffus 2008). Within wintering grounds near the west Antarctic Peninsula, during some feeding dives, the whales were found to engulf up to 70% of their body size. During some of these dives, lunges included extreme accelerations up to 2.5 meters per second (m/s.) (Ware, Friedlaender, and Nowacek 2011).

Humpbacks spend most of their time in the upper 120 m of the water column within the feeding grounds (Dietz et al. 2002; Dolphin 1987a; Witteveen et al. 2008). Humpbacks typically lift their flukes before a dive (Jefferson, Webber, and Pitman 2008; Katona et al. 1979). A study of tagged humpback whales off Maui found the maximum dive depth to be 176 m (Baird, Ligon, and Hooker 2000). Studies from feeding grounds in southeast Alaska found that foraging dives tended to be short, less than 2.8 min and less than 60 m deep (Dolphin 1987b). Overall, this species was found to dive deeper and longer in the presence of prey or when foraging (Hazen et al. 2009). Humpback foraging dives are limited to very short durations despite their large body size (Goldbogen et al. 2008). Additional information on

humpback whale diving behavior can be found in studies by Darling et al. (2006) and Darling and Berube (2001).

5.5.5 Habitat and Distribution

Although humpback whales typically travel over deep, oceanic waters during migration, their feeding and breeding habitats are mostly in shallow, coastal waters over continental shelves (Clapham and Mead 1999). Humpback feeding habitats are typically shallow banks or ledges with high seafloor relief (Hamazaki 2002; Payne, Heinemann, and Selzer 1990). Within breeding grounds, females with calves occur in significantly shallower waters than other groups of whales, and breeding adults use deeper, more offshore waters (Ersts and Rosenbaum 2003; Smultea 1994). The habitat requirements of wintering humpbacks appear to be controlled by the conditions necessary for calving, such as warm water (24 to 28°C [degrees Celsius]) and relatively shallow, low-relief ocean bottom in protected areas, created by islands or reefs (Clapham 2000; Craig and Herman 2000; Smultea 1994). During migration from Antarctica to Australian waters, humpback whales follow strict ranges that depend on water depth (30 to 58 m) and surface water temperature (21 to 32°C) (Smith et al. 2012). Some trans-oceanic interchange between the North Pacific and South Pacific breeding populations also occurs (Medrano-González et al. 2001). It has been hypothesized the most likely route for interbreeding of northern and southern humpback whales is in the equatorial waters of the eastern Pacific Ocean (Medrano-González et al. 2001). The historical winter range in the western North Pacific included the waters around Taiwan, Hainan Island, and the Mariana and Marshall Islands (Darling and Mori 1993).

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

North Pacific humpback whales are distributed primarily in four distinct wintering areas: the Ryukyu and Ogasawara (Bonin) Islands (south of Japan), Hawai‘i, the Revillagigedo Islands off Mexico, and along the coast of mainland Mexico (Calambokidis et al. 2001). During the summer, North Pacific humpback whales feed in a nearly continuous band from Southern California to the Aleutian Islands, Kamchatka Peninsula, and the Bering and Chukchi seas (Calambokidis et al. 2001) . Humpback whales summer throughout the central and western portions of the Gulf of Alaska, including in Prince William Sound, around Kodiak Island (including Shelikof Strait and the Barren Islands), and along the southern coastline of the Alaska Peninsula. The northern Bering Sea, Bering Strait, and the southern Chukchi Sea along the Chukchi Peninsula appear to form the northern extreme of the humpback whale range (Allen and Angliss 2010a). Historical accounts of whaling by indigenous (1981 to 1986), British (1820 to 1840), and American (1825 to 1880) commercial vessels in Philippine waters may account for a reduction in range and abundance of humpback whales in this area (Acebes 2009).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. The secondary range of the humpback whale is known to include waters of the North Central Pacific Gyre. Some interchange of whales among different wintering grounds. Matches between Hawai‘i and Japan, and Hawai‘i and Mexico have been found (Calambokidis et al. 2001; Salden and Mickelsen 1999). However, the overlap appears relatively small between the

Western North Pacific humpback whale population and Central and Eastern North Pacific populations (Calambokidis et al. 2001).

KUROSHIO CURRENT. The waters of the Ogasawara (Bonin) Islands off Japan are considered one of the main wintering grounds for humpback whales of the western North Pacific population (December through May with peak abundance in February) (Mori 1999) The seas around the Ogasawara and Ryukyu Islands (Okinawa and Amami Islands) are the two major breeding and calving areas in Japan (Yamada et al. 1998). (Mori 1999) suggested that calving might actually take place in waters with slightly higher temperatures than the waters of the Ogasawara Islands, for example, in the lower latitudes along the Ogasawara Islands rim, possibly extending from the Kazan Retto to the Northern Mariana Islands. Catches off the Amami Islands during the whaling season of December to April were documented in (Miyazaki and Nakayama 1989). There may be a low occurrence of humpback whales seaward of the shelf break, north of 35°N, around the Ogasawara and Ryukyu Islands and throughout the rest of the Japan MRA Study Area. Most of the population is expected to occur within feeding grounds north of the MRA Study Area during this time of year.

EAST CHINA SEA. The East China Sea is included in the known secondary range of the humpback whale (Figure 5-7 and Figure 5-8).

PHILIPPINE SEA. Parts of the Philippine Sea are included in the known primary and secondary ranges of this species (Figure 5-7 and Figure 5-8). Humpbacks have been documented in recent years off Taiwan and the Philippines (Yamaguchi, Acebes, and Miyamura 2002), although whether whales are breeding within these latter areas or just using them as stop-over points is unknown.

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. During the winter-spring period, an area of expected occurrence extends south of 30°N. The waters between the Ogasawara and Ryukyu Islands connects animals moving between these breeding areas and other breeding grounds in the Mariana Islands, Philippines, and Taiwan. An area of concentrated occurrence extends from the shoreline out to around 185 km offshore of the Ogasawara and Ryukyu Islands.

MARIANA ARCHIPELAGO. Although (Townsend 1935) indicated that many humpbacks had been caught off the Mariana Islands in earlier years, additional surveys of Taiwan and Saipan suggested that humpback whales are no longer common there and have not generally reinhabited this part of the range (Darling and Mori 1993; Fulling, Thorson, and Rivers 2011).

Farallon de Medinilla. During a wildlife survey one humpback whale was seen in January of 2006 about 400 m north of Farallon de Medinilla (FDM). Another three humpbacks were identified in March of 2006 400 m east of the island (Vogt 2008).

Saipan. February 18th, 2007 two humpback whales were identified 29 km north of Saipan (Vogt 2008). A 2007 cruise acoustically recorded and sighted humpbacks off the coast of Saipan (Fulling, Thorson, and Rivers 2011). During the Saipan sightings, tail-slapping, breaching, and chin-slapping were observed—behaviors documented and known from breeding grounds on previous surveys (Pack et al. 1998). (Darling and Mori 1993) suggested preliminary humpback whale sightings off Saipan might indicate the range of the population is expanding, or alternatively, these could have been just a few transient individuals. The winter range of the Western North Pacific stock may include Saipan (Jefferson, Webber, and Pitman 2008), as previous recordings of humpback whales at Guam, Rota, and Saipan (Eldredge

1991, 2003) have been obtained. Another sighting of a humpback whale was reported off the north coast of Saipan (2011).

Rota. Some evidence suggests that the winter range of the Western North Pacific stock may include the Mariana Islands (Jefferson, Webber, and Pitman 2008), as recent recordings of humpback whales at Guam, Rota, and Saipan (Eldredge 1991, 2003) have been obtained.

Guam. Similarly to Rota, evidence suggests that the winter range of the Western North Pacific stock occasionally may include the Mariana Islands (Jefferson, Webber, and Pitman 2008), as recent recordings of humpback whales at Guam, Rota, and Saipan (Eldredge 1991, 2003; Fulling, Thorson, and Rivers 2011) have been obtained.

CAROLINE ISLANDS. Waters around the Caroline Islands are included in the known secondary range of the humpback whale (Figure 5-7 and Figure 5-8).

5.5.6 Species-specific Threats

Humpback whales have been hunted by commercial whalers in all major oceans, and many stocks were seriously depleted by whaling that took place mostly in the 1900s. They were taken both by coastal and oceanic whaling operations, and some have continued to be taken by artisanal whalers in the Caribbean and the South Pacific over the past few decades. A minimum of 200,000 were killed in the Southern Hemisphere in the twentieth century (National Marine Fisheries Service 2012g). The species has been fully protected by the IWC since 1965, but the Soviets and other nations illegally (and secretively) killed more than 72,000 humpbacks following World War II and up until 1973 (Clapham et al. 2003). There is interest in resuming the direct harvest of this species. This includes a proposal of up to 50 takes per year from Japanese waters for this nation's scientific research program (National Marine Fisheries Service). In the Republic of (South) Korea, "whale meat" markets still can buy and sell meat from stranded or bycaught marine mammals. A deoxyribonucleic acid (DNA) surveillance study from 2003 to 2005 verified presence and ready availability of humpback whale meat in food markets, although labels identified the product as minke whale meat (a legally hunted species), not as humpback whale meat (Baker et al. 2006).

Additional threats to humpback populations include entanglement in fishing gear, vessel collisions, and disturbance by human-caused noise. Entanglements can cause severe injury and even death, especially when multiple body parts are entangled and the whale cannot surface. Foraging is also typically hindered, and this may occur over multiple months during longer entanglements or indefinitely until the animal starves to death. Open rope wounds can result in infections, and hemorrhaging from tissue damage can cause mortality (Cassoff et al. 2011). In southeast Alaska, a survey of caudal scarring estimated that the majority of whales within the area have, at one time in their lives, been subject to entanglements, although not lethally (Neilson et al. 2009). Off the Pacific coast of Mexico, most entanglements are associated with pot and gill net gear, where buoy and/or groundlines are responsible in the majority of the instances. In this area, humpbacks become entangled on the fluke (53%) and mouth (43%) (Johnson et al. 2005). Whale-ship encounters (ship strikes) with humpback whales are known to result in injury or mortality. When vessel speed drops below 6.2 m/s., ships noted whales remained at greater distances, the animals were more successful at keeping a safe distance from the ship. It is believed this avoidance at a greater distance will reduce strike occurrences (Gende et al. 2011). Even research-oriented, vessel-based activities, including tagging whales, can cause behavioral changes in humpback whales, such as increased respiratory frequencies, increases in swimming speeds (Alves,

Moreira, et al. 2010), shorter dives, and reduced surfacing to long-dive ratio (Boye, Simon, and Madsen 2010). These changes possibly indicate stress responses, which are additionally influenced by group size and behavioral state (i.e., whether feeding or breeding) (Cantor et al. 2010). During a whale watching excursion, (Stamation et al. 2010) saw avoidance behavior such as increased dive time and increased time submerged, but also reported that some whales initiated interactions (i.e., approached the vessels). It was also noted the type of group determined the degree of response (e.g., groups with calves were more sensitive to the vessel's presence). The reaction to the vessel was less noticeable when vessels operated within regulatory parameters (Stamation et al. 2010). Climate change in areas such as the southern ocean, where many baleen whales occur including the humpback whale, has been documented to change the abundance and distribution of krill. This alteration in prey could lower foraging success of this whale in the future (Vogt 2004).

In an analysis by (Carvalho et al. 2010) of strandings off the coast of Brazil, humpback whales were shown susceptible to parasites. For more detailed information on specific host-parasite species identified through this study, refer to Carvalho et al. (2010). The barnacle *Xenobalanus* has been found on this animal in the eastern tropical Pacific (ETP), indicating attachment to a fast-swimming host is possible (Kane et al. 2008). Surface activity such as breaching and slapping may be a barnacle removal mechanism (Felix, Bearson, and Falconi 2006). Humpback whales are also susceptible to respiratory bacteria, and these may negatively affect the overall health of the animal (Acevedo-Whitehouse, Rocha-Gosselin, and Gendron 2010). Pollutants such as polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDE), and chlordanes have been detected in Pacific Ocean humpbacks, yet at smaller concentrations than those found in the blubber of whales in the Atlantic Ocean (Elfes et al. 2010).

This Page Intentionally Left Blank

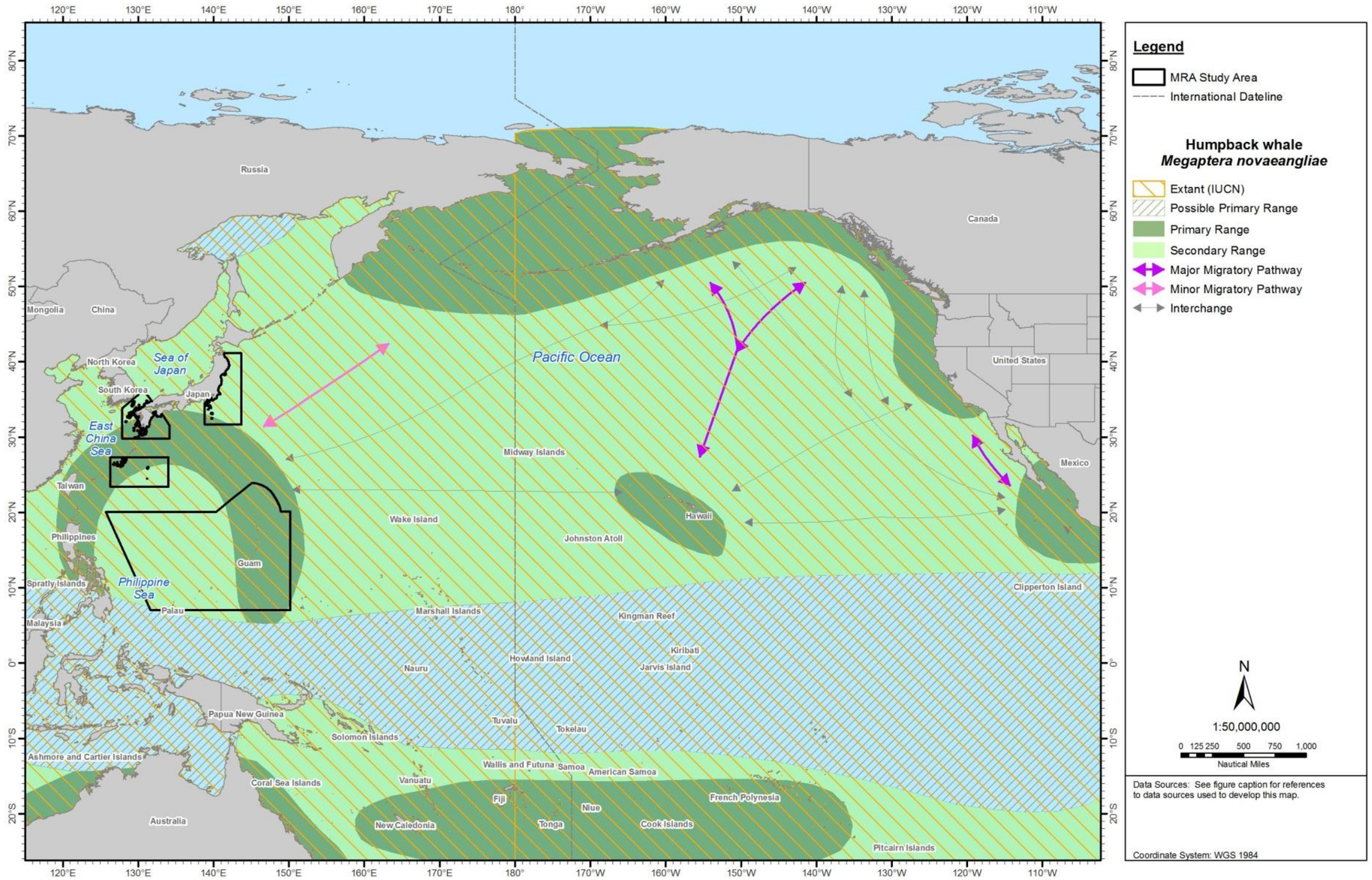

Figure 5-7: Geographic Range of the Humpback Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

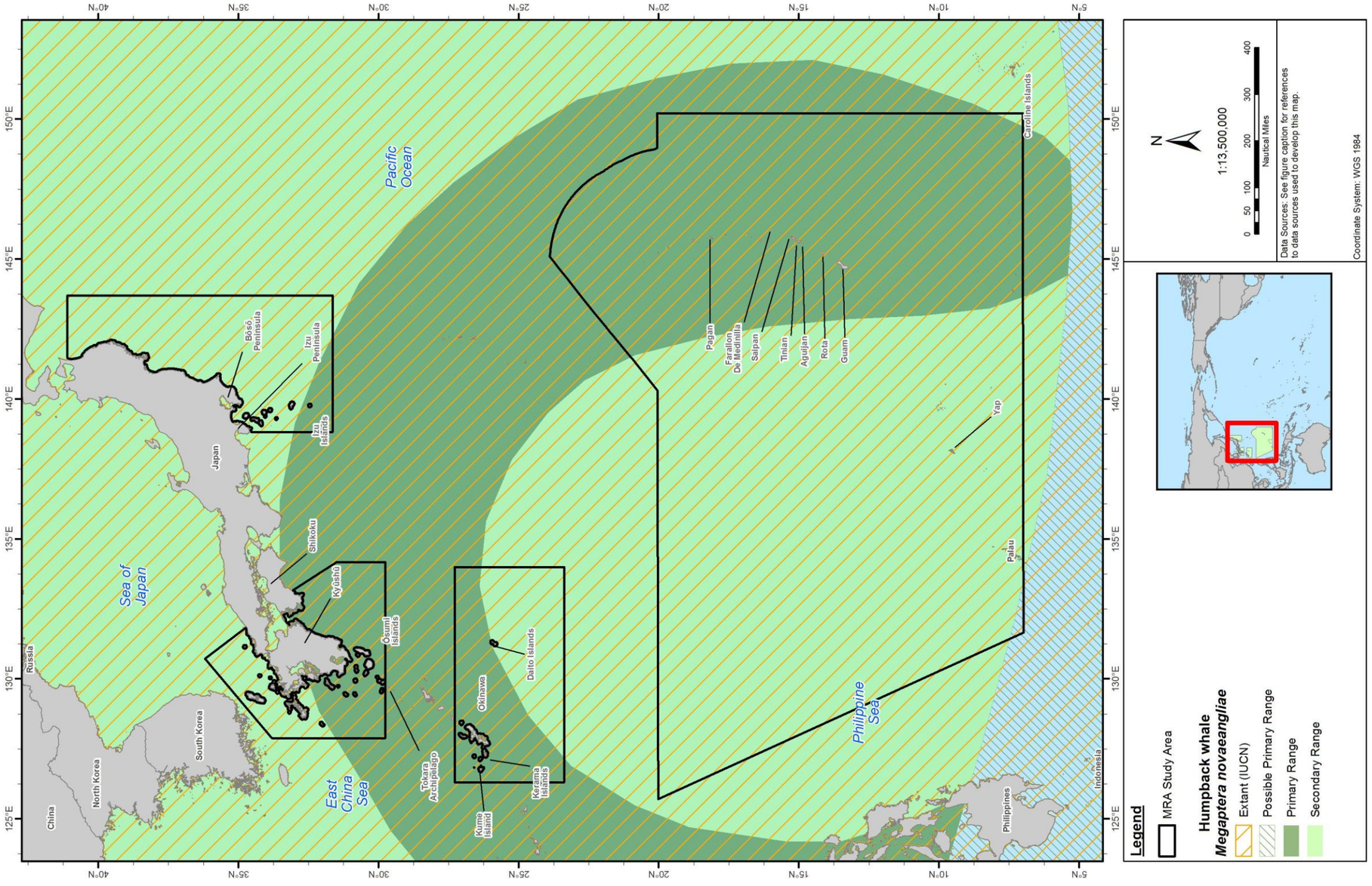

Figure 5-8: Geographic Range of the Humpback Whale in the MRA Study Area
Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.6 COMMON MINKE WHALE (*BALAENOPTERA ACUTOROSTRATA*)

5.6.1 Description

Until recently, all minke whales were classified as the same species. Three subspecies of the common minke whale are now recognized: *Balaenoptera acutorostrata davidsoni* in the North Atlantic, *Balaenoptera acutorostrata scammoni* in the North Pacific, and a third (formally unnamed but generally called the dwarf minke whale) that mainly occurs in the Southern Hemisphere (Jefferson, Webber, and Pitman 2008).

The common minke whale's head is extremely pointed, v-shaped, and the median head ridge is prominent on top of the rostrum. The dorsal fin is tall, falcate, and is located about two-thirds of the way back from the snout tip (Jefferson, Webber, and Pitman 2008). This species has 50 to 70 moderately short throat grooves and 231 to 285 baleen plates, which are cream or white in color (Jefferson, Webber, and Pitman 2008).

The body coloration is distinct: dark gray dorsally, white on the ventral side, and streaks of intermediate shades on the sides. Some of the streaks extend to the head and create a chevron. The most distinctive marking of common minke whales is a brilliant white patch on each flipper. This band is generally visible through the water when animals are swimming near the surface (Stewart and Leatherwood 1985).

A smaller species of the rorquals, minke whale adults reach lengths averaging 6.5 to 8.8 m and can attain a maximum length of 10.7 m. Maximum body weight is about 9,200 kg. Length at birth is 2.0 to 2.8 m (Jefferson, Webber, and Pitman 2008).

5.6.2 Status and Management

The common minke whale is protected under the MMPA and is not listed under the ESA. This species is also listed as least concern by the IUCN and falls under Appendix I CITES regulations. Minke whales in coastal waters of California, Oregon, and Washington (including Puget Sound) are considered a separate stock from the Alaskan stock (Carretta et al. 2010). The IWC recognizes three stocks of minke whales in the North Pacific: one in the Sea of Japan/East China Sea (J-Stock), one in the rest of the western Pacific west of 180°N (O-Stock), and one in the remainder of the Pacific (Donovan 1991). It has been suggested that only three breeding groups occur in the western North Pacific, and that at least one of these (group W) breeds in the vicinity of the Bonin-Japan Trench during winter (Smith 2003). However, it has also been suggested multiple stocks occur within what is now considered the J-stock, and that current levels of bycatch could lead to depletion or even extinction of those stocks (Lavery et al. 2003). This would presumably correlate to minke whales observed around the Mariana Islands, but is still speculative and based primarily on modeling results.

Japanese scientific whaling permits continue to allow the capture and killing of common minke whales. From 1985 to 2011 special permits takes from pelagic and coastal Japanese waters have totaled 10,793 and 1,463 whales, respectively. From June 2010 to February 2011 185 common minke whales were harvested from Japan's pelagic waters and another 105 whales were harvested from Japanese coastal waters from April 2010 to October 2010 (International Whaling Comission 2012).

5.6.3 Population and Abundance

An estimated 25,000 minke whales are present in the northwest Pacific and Okhotsk Sea (Hurd 2012). The geographically nearest stock assessment for United States waters was conducted for the Hawaiian stock, for which no abundance estimate is reported, but which seems to vary seasonally. No trend data are available regarding the Hawaiian stock (Carretta et al. 2011l). In a stock assessment completed by (Allen, Bejder, and Krutzen 2011), the J-Stock status was categorized as strategic, designated for populations in which the anthropogenic mortality exceeds the potential biological removal level. This stock could be added to the ESA listing in the future. The assessment also estimated this stock as composed of 6,260 individuals, with a minimum abundance estimate at 5,247 whales. The O-Stock is believed to be more abundant, and is still hunted with special permits. In 2006 the minke whale catch form the O-stock was 195 out of a permitted 220 whales (Josephson 2006).

5.6.4 Biology, Ecology, and Behavior

Group Size. Common minke whales are typically sighted alone or in small groups of two to three. This species sometimes congregates in feeding areas within inshore and coastal waters. Groups are often segregated by age, sex, and reproductive class such as by mothers and calves, breeding females, juvenile males or females, etc. (Jefferson, Webber, and Pitman 2008; Murphy 1995).

Predator/Prey Interactions. This species preys on small invertebrates and schooling fish, such as sand eel, Pollock, herring, and cod. Similar to other rorquals, common minke whales are lunge feeders, often plunging through patches of shoaling fish or krill (Hoelzel, Dorsey, and Stern 1989; Jefferson, Webber, and Pitman 2008). In the North Pacific, major foods include small invertebrates, krill, capelin, herring, Pollock, haddock, and other small shoaling fish (Jefferson, Webber, and Pitman 2008; Kuker, Thomson, and Tscherter 2005; Lindstrom and Haug 2001). Minke whales display prey selection for Japanese anchovy in the western North Pacific (Murase et al. 2007). In Antarctica, this species was associated with intermediate (35 to 44 mm) krill prey (Santora et al. 2010). Minke whales have been documented feeding in locations of strong tidal currents in inshore waters. Higher concentration of Minke whales was correlated with high abundance of phytoplankton, primarily in warm plume events (more so than a cold-current dominated area) (Dorsey et al. 1990). Some site fidelity has been documented for this species in Québec waters, where minke whales have been seen gathering prey into dense congregations before surface feeding strikes (Kuker, Thomson, and Tscherter 2005).

Minke whales are prey for killer whales (Dahlheim and White 2010; Ford et al. 2005); a common minke was observed under attack by killer whales near British Columbia (Weller 2008). During predation by killer whales, minke whales are known to employ the "flight" strategy, characterized by directional, sustained swimming of speeds over 15 km/hr, common for whales with streamlined bodies that prefer pelagic habitats and calving grounds (Ford and Reeves 2008). Minke blubber has been found in the digestive tract of Greenland sharks off the coast of Norway, yet DNA analysis led researchers to conclude that the sharks had scavenged blubber discarded by whaling vessels and had not hunted minke whales as live prey (Akiyama and Ohta 2007). The lamprey, *Petromyzon marinus* (in its marine stage), has been photographically documented to feed on minke whales, through visual presence of the whole animal or identifiable scars (Science Daily 2007).

Life History. Annual and biennial breeding are typical for this species, and calving occurs after a 10- to 11-month pregnancy (Jefferson, Webber, and Pitman 2008; Sigurjonsson 1995). Mating may occur in winter or early spring but has never been observed (Stewart and Leatherwood 1985).

Migration. These whales generally participate in annual migrations between low-latitude breeding grounds in the winter and high-latitude feeding grounds in the summer (Kuker, Thomson, and Tscherter 2005). Minke whales generally occupy waters over the continental shelf, including inshore bays, and even occasionally enter estuaries. However, records from whaling catches and research surveys worldwide indicate an open ocean component to the minke whale's habitat. The migration paths of the common minke whale include travel between breeding and feeding grounds, and have been shown to follow patterns of prey availability (Jefferson, Webber, and Pitman 2008).

No obvious migration from low-latitude, winter breeding grounds to high-latitude, summer feeding locations is apparent in the western North Pacific, as in the North Atlantic (Horwood 1990); however, some monthly changes in densities have been found at both high and low latitudes (Okamura et al. 2001). In the northern part of their range, minke whales are believed to be migratory, whereas they appear to establish home ranges in the inland waters of Washington and along central California (Dorsey 1983), and exhibit site fidelity to these areas between years (Borggaard, Lien, and Stevick 1999).

Hearing/Vocalization. While no data on hearing abilities of this species are available, (Ketten 1997) hypothesized that mysticetes have acute infrasonic hearing based on apical ratios and the absence of a bony latera support within the ear's anatomy.

Recordings in the presence of minke whales have included both high- and low-frequency sounds (Beamish and Mitchell 1973; Mellinger, Carson, and Clark 2000; Winn and Perkins 1976). Two basic forms of pulse trains that were attributed to minke whales have been decribed: a "speed up" pulse train with energy in the 200 to 400 Hz band, with individual pulses lasting 40 to 60 ms, and a less-common "slow-down" pulse train characterized by a de-accelerating series of pulses with energy in the 250 to 350 Hz band (Mellinger, Carson, and Clark 2000). A third "boing" vocalization has been attributed to minke whales in the North Pacific (Rankin and Barlow 2005). Acoustic detections of the boing were confirmed as a minke call in 2007 in the first coastal documentation of a minke in Hawaiian waters (Rankin et al. 2007). Recorded vocalizations from minke whales have dominant frequencies of 60 to greater than 12,000 Hz, depending on vocalization type (Richardson 1995). Recorded source levels, depending on vocalization type, range from 151 to 175 dB re 1 µPa-m (Ketten 1998). (Gedamke, Costa, and Dunstan 2001) recorded a complex and stereotyped sound sequence ("star-wars vocalization") in the Southern Hemisphere that spanned a frequency range of 50 Hz to 9.4 kHz. Broadband source levels between 150 and 165 dB re 1 µPa-m were calculated. "Boings" recorded in the North Pacific have many striking similarities to the star-wars vocalization, in both structure and acoustic behavior. "Boings," recently confirmed to be produced by minke whales (Rankin et al. 2007), have been suggested as possibly a breeding call, consisting of a brief pulse at 1.3 kHz followed by an AM call with greatest energy at 1.4 kHz, with slight frequency modulation over a duration of 2.5 s. (Rankin and Barlow 2005).

Diving. Minke whales are known to feed over underwater slopes at depths ranging between 65 and 330 ft. (20 and 100 m) (Hoelzel, Dorsey, and Stern 1989; Perrin and Brownell 2008). A study of the surfacing interval of minke whales off Monterey Bay, California, found the average foraging dive duration to be 4.43 (± 2.27) min, typically with one longer dive followed by a series of shorter dives (Dorsey et al. 1990; Stern 1992). Most dives are relatively short, with short surface intervals. Minke whales have been observed preparing for longer dives by performing several short shallow dives. The mean dive time for minke whales has been observed to be 108 (± 95) s., with a range of 7 to 380 s. (Lyndersen and Øritsland 1990). The most common surfacing pattern of minke whales involves about four surfacings, interspersed by short duration dives averaging 38 s.. Mean surfacing interval is around 60 to 80 s. and has been found to vary, depending on the time of day and behavior (Stockin et al. 2001).

5.6.5 Habitat and Distribution

Minke whales generally occupy waters over the continental shelf, including inshore bays and even occasionally estuaries. However, based on whaling catches and surveys worldwide, a deep-ocean component to the minke whale's distribution also exists. Much depends on their migration and prey availability (Jefferson, Webber, and Pitman 2008; Watanabe et al. 2012).

Common minke whales are distributed in polar, temperate, and tropical waters (Jefferson, Webber, and Pitman 2008); they are less common in the tropics than in cooler waters (Figure 5-9 and Figure 5-10). The specific distribution, especially in the Southern Hemisphere, is not well known because all minke whales had been lumped into one species in the past. The northern boundary of their range is within subarctic and arctic waters (Kuker, Thomson, and Tscherter 2005).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. The common minke whale range is known to include the North Central Pacific Gyre (Figure 5-9) (Miyashita and Fujise 1997; Okamura et al. 2001; Yamada 1997).

KUROSHIO CURRENT. Minke whales are found in both coastal and offshore waters all around Japan (Miyashita and Hatanaka 1997). The area of expected occurrence for the minke whale is from the shelf break out to 150 nm (278 km) from shore. This expected close-to-shore, year-round pattern is based upon whaling and survey data (Horwood 1990; Okamura et al. 2001). Whaling catches off the Korean coastline are also reported (Dalebout et al. 2003). Some evidence suggests residency of populations in the warmer waters of southern Japan (Wada 1983). The likelihood of species presence within the Japan MRA Study Area is presumed low, but this may be because of less data from offshore waters (primarily because coastal whaling vessels did not travel far offshore). Occurrence patterns in both seasons are believed similar within the MRA Study Area, although seasonal shifts in minke whale high density areas have been noted for waters off Japan (Okamura et al. 2001).

No migration as in the North Atlantic is obvious for the western Pacific (Horwood 1990). The overall impression is movement of minke whales from south of Japan to the north and back, or movement in and out of the marginal seas (Horwood 1990; Miyashita and Hatanaka 1997). It has been further suggested a northward seasonal migration of minke whales off Japan (Okamura et al. 2001). Females migrate into the coastal regions earlier than do the males (Horwood 1990).

EAST CHINA SEA. An increasing abundance of the J-Stock population living in the East China Sea has been recognized (Allen, Bejder, and Krutzen 2011).

PHILIPPINE SEA. Minke whales are believed to occasionally occur in the waters of the Philippine Sea (Figure 5-9 and Figure 5-10).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Minke whales are found in both coastal and offshore waters all around Japan, although the density generally appears to be higher in coastal waters (Miyashita and Hatanaka 1997). Therefore, the area of expected occurrence for the minke whale is from the shelf break out to 150 nm (278 km) from shore. Numbers or occurrences are unknown from the shore to the shelf break. The large amount of fishing in Japan waters, coupled with the high rate of near-shore (10 nm from land, 10 to 220 m depth) entanglements seen from the East Sea of Korea (Sea of Japan) may be an issue for the Japan

Archipelago minke population as well (Song et al. 2010). Although the J-stock is considered depleted (protected since 1986), the O-stock can be hunted under special permits (scientific whaling). A DNA analysis of whale meat sold at Japanese markets between 1997 and 2004 found that 46.1% of the meat came from the protected J-stock (Lukoschek et al. 2009).

MARIANA ARCHIPELAGO. The minke whale may occur near the coastline (although not expectedly in harbors and lagoons) based on sightings in shallow waters at other locales around the world. It also may occur seaward of the coastline based on oceanic occurrences of this species. Passive acoustic and hydrophone array data obtained during two surveys of the Mariana Islands, identified a minke whale near the Mariana Trench (Fulling, Thorson, and Rivers 2011) and an estimatedf 33 to 540 whales present in the Mariana Islands (Norris et al. 2011).

Saipan. One whale (either a Bryde's or a Minke whale) was seen 50 km north of Saipan on July 28th, 2007 (Vogt 2008).

CAROLINE ISLANDS. The range of the minke whale does include the waters near the Caroline Islands (Figure 5-9 and Figure 5-10).

5.6.6 Species-specific Threats

Until the latter half of the 1900s, minke whales were often considered too small to hunt and were generally disregarded as a species worth hunting. However, with the depletion of the larger rorquals, common minke whales have been heavily hunted in recent years (more than 100,000 were taken in the North Atlantic alone). This species is now one of the most commonly taken whale species by commercial and "scientific" whalers (at least in the Northern Hemisphere). This species is still hunted by Norway in the North Atlantic and by Japan and Korea in the North Pacific (National Marine Fisheries Service). In the Republic of (South) Korea, "whale meat" markets still can buy and sell meat from stranded or bycaught marine mammals. A surveillance study of DNA in whale meat at food markets from 2003 to 2005 found that minke whale meat was sold in these food markets (Baker et al. 2006). Analysis of the minke whale meat sold in Japanese markets show the mercury concentrations were higher within this species than in other species analyzed (Bryde's, sei, Arctic minke, and fin whales) yet, there was no significant difference between J- and O-Stocks (Endo et al. 2012).

Some minke whales are caught in fishing gear and others suffer from vessel strikes and habitat disturbance. Other sources of anthropogenic mortality include bycatch from pots, gill nets, and set nets (Allen, Bejder, and Krutzen 2011). Mortality rate from bycatch is estimated to be 0.076/year (natural mortality rates are 0.024/year) (Zhang, Song, and Na 2010). Entanglements can cause severe injury and even death when multiple body parts are entangled and the whale cannot surface. Foraging is also typically hindered by entanglements, and this may occur over multiple months or indefinitely until the animal starves to death. Mortality and injury occurs from entanglements as a result of scarring, from infection of open wounds, and by hemorrhaging resulting from tissue damage (Cassoff et al. 2011; Kot, Ramp, and Sears 2009). Minke whales have been shown to vocally and behaviorally react to experimental ropes/nets. Recommendations for the use of rope with high contrasting colors (black and white) to ensure avoidance behavior by minke whales has proven successful (Kot et al. 2012).

Minke whale fatalities in California waters have been attributed to naturally occurring toxins such as the neurotoxin domoic acid (DA) produced during harmful algal blooms (Fire et al. 2010). Other health issues such as cataracts, possibly caused by prolonged hyperglycemia, have been reported in these whales (Harms, Lovewell, and Rotstein 2008). Minke whales, including individuals found in Korean waters, are known to bioaccumulate toxins such at butylins, which have been used in antifouling paint

on fishing hulls, fishing nets, and marine platforms. These chemicals may also cause immunosuppression (Choi et al. 2011). In this same area, pollutants such PCBs, organochlorine pesticides (OCP), PBDEs (Moon, Kannan, Yun, et al. 2010) and perfluorinated compounds (PFC) (Moon et al. 2012) have been detected in the blubber and liver tissue of minke whales.

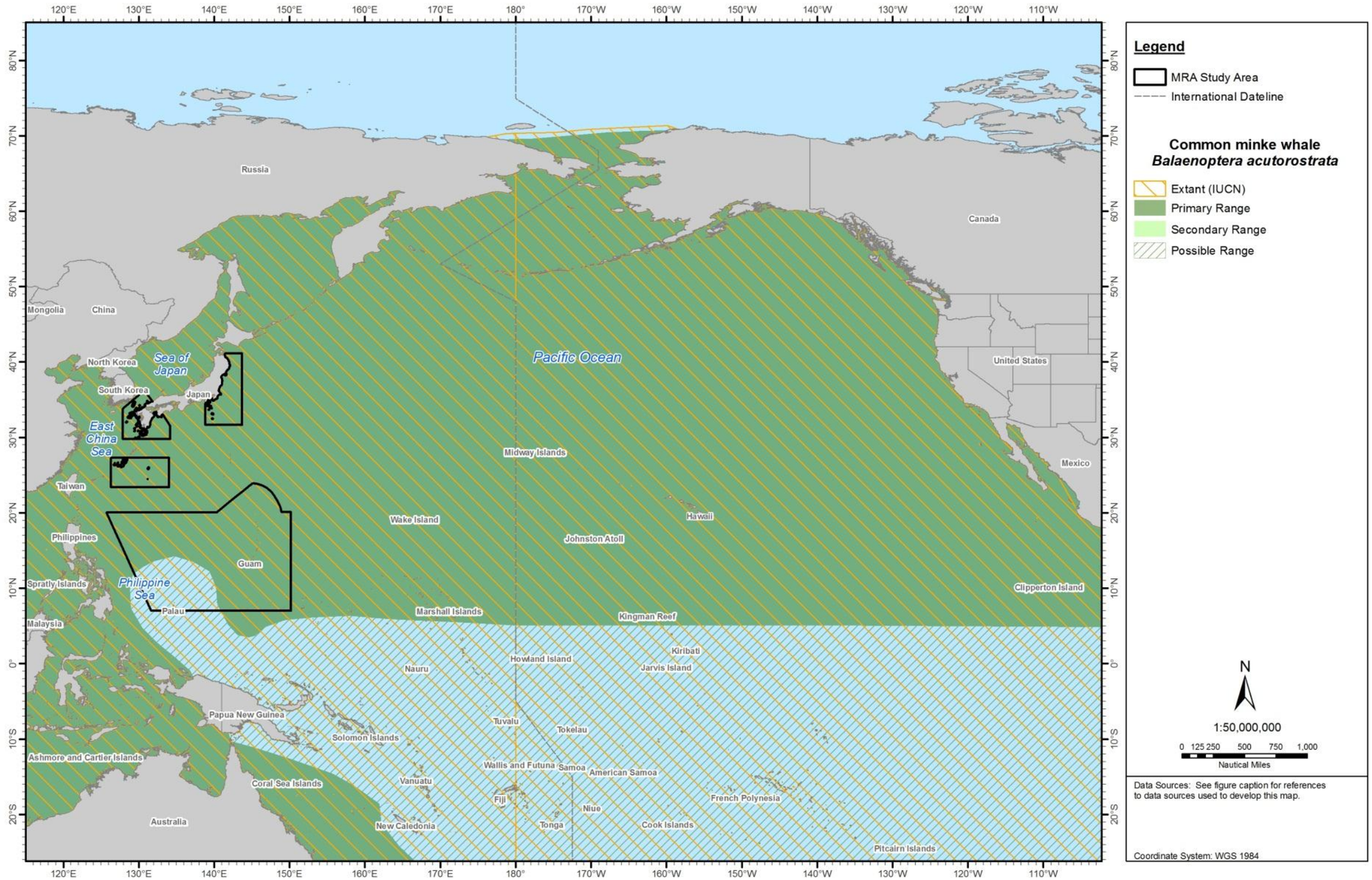

Figure 5-9: Geographic Range of the Common Minke Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

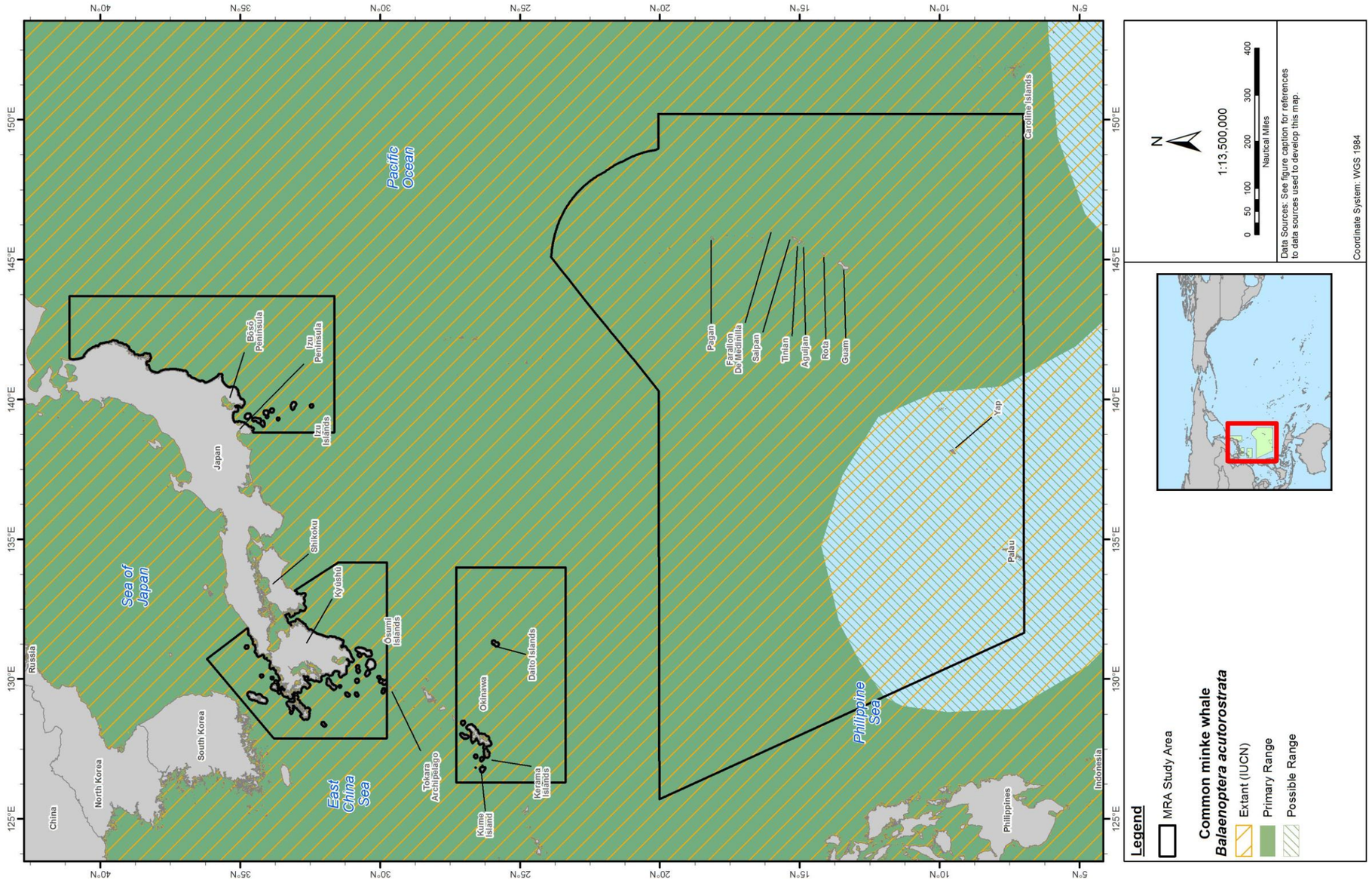

Figure 5-10: Geographic Range of the Common Minke Whale in the MRA Study Area

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.7 BRYDE'S WHALE (*BALAENOPTERA BRYDEI/EDENI*)

5.7.1 Description

Bryde's whales (*Balaenoptera brydei/edeni*) are among the least known of the large baleen whales. Their classification and true number remain uncertain (Alves, Dinis, et al. 2010). Until recently, all medium-sized baleen whales were considered members of one of two species, *Balaenoptera edeni* (Bryde's whale) or *Balaenoptera borealis* (sei whale). However, at least three genetically distinct types of these whales are now known, including the pygmy or dwarf Bryde's whales (Kato and Perrin 2008; Rice 1998). The IWC continues to use the name *Balaenoptera edeni* for all Bryde's-like whales, although at least two species are recognized. In 2003, a new species (Omura's whale, *Balaenoptera omurai*) was described, and it became evident that the term pygmy Bryde's whale had been mistakenly used for specimens of *Balaenoptera omurai* (Reeves et al. 2004).

Bryde's whales have a streamlined, sleek body shape. They usually have three prominent ridges on the rostrum (other rorquals generally have one). The head makes up one-fourth of the body length. The dorsal fin is tall and falcate, and rises from the back at a relatively steep angle. The dorsal fin is often notched on the trailing edge. Flukes are broad, with a straight trailing edge (Jefferson, Webber, and Pitman 2008).

Bryde's whales have a counter-shaded color pattern and are dark gray dorsally and lighter ventrally. There is often a pinkish tinge on the lower white areas, and the body may be covered in circular round scars made by lampreys or cookie-cutter sharks. The upper jaw has uniformly dark lips (Jefferson, Webber, and Pitman 2008).

Adult Bryde's whales can be up to 15.5 m long and weigh up to about 40,000 kg; however, a smaller species rarely attains more than 10 m in length (Jefferson, Webber, and Pitman 2008). Bryde's whales have 285 to 350 dark gray baleen plates on each side of the mouth (Kato and Perrin 2008).

5.7.2 Status and Management

This species is protected under the MMPA and is not listed under the ESA. This species is also listed as data deficient by the IUCN and falls under Appendix I CITES regulations. The IWC recognizes three management stocks of Bryde's whales in the North Pacific: western North Pacific, eastern North Pacific, and East China Sea (Donovan 1991), although the biological basis for defining separate stocks of Bryde's whales in the central North Pacific is not clear (Carretta et al. 2010). Current genetic research confirms that gene flow among Bryde's whale populations is low and suggests that management actions treat each as a distinct entity to ensure proper conservation of biological diversity (Kanda et al. 2007). The western North Paciffic stock and East China Sea stock may be seen in the MRA Study Area.

Japanese scientific whaling permits continue to allow the capture and killing of Bryde's whales. From 1985 to 2011 special permits takes from pelagic and coastal Japanese waters have totaled 452 and 94 whales, respectively. From June 2010 to August 2010 50 Bryde's whales were harvested from Japan's pelagic waters (International Whaling Comission 2012).

5.7.3 Population and Abundance

Historical accounts of whaling by indigenous (1981 to 1986), British (1820 to 1840), and American (1825 to 1880) commercial vessels in Philippine waters may account for a reduction in range and abundance of

Bryde's whales in this area (Acebes 2009). There are no estimates of global abundance, but regional estimates indicate a possible 20,000 to 30,000 Bryde's whales in the North Pacific Ocean, 40,000 to 80,000 in the tropics and sub-tropics, and log-normal 20th percentile of a 2002 survey estimates there are 327 whales in the Hawaiian Exclusive Economic Zone (EEZ). There no annual deaths or serious injuries caused by fisheries in the Hawaiian stock (Carretta et al. 2012). (Carretta et al. 2011b; United Nations Environment Programme n.d.-b). The best estimate of the ETP population is 13,000 (CV=0.202) individuals (Carretta et al. 2010). A 2007 cetacean survey (Fulling, Thorson, and Rivers 2011) estimated the number of this species in Guam and the Commonwealth of the Northern Mariana Islands (CNMI) as 233. No trend estimates are available for the MRA Study Area. Little is known of population status and trends for most Bryde's whale populations.

5.7.4 Biology, Ecology, and Behavior

Group Size. This species is generally seen alone or in pairs (Tershy 1992), although they have been recorded in groups of 10 to 20 individuals, most often within feeding grounds (Jefferson, Webber, and Pitman 2008; Miyazaki and Wada 1978b).

Predator/Prey Interactions. Bryde's whales primarily feed on schooling fish and are lunge feeders. Prey includes anchovy, sardine, mackerel, herring, krill, and other invertebrates, such as pelagic red crab (Baker and Madon 2007; Jefferson, Webber, and Pitman 2008; Nemoto and Kawamura 1977). Bryde's whales have been observed using "bubble nets" to herd prey (Jefferson, Webber, and Pitman 2008; Kato and Perrin 2008). Bubble nets are used in a feeding strategy whereby the whales dive and release bubbles of air that float up in a column and trap prey inside; the whales then lunge through the column to feed. They have been seen to form multi-year, stable pair, associations during their lives where synchronized diving and foraging occur (Alves, Dinis, et al. 2010).

Bryde's whale is known to be prey for killer whales, as evidenced by an aerial observation of 15 killer whales attacking a Bryde's whale in the Gulf of California (Weller 2008). During predation by killer whales, Bryde's whales are known to employ the "flight" strategy, characterized by directional, sustained swimming of speeds over 15 km/hr, common for whales with streamlined bodies that prefer pelagic habitats and calving grounds (Ford and Reeves 2008).

Life History. The Bryde's whale does not have a well-defined breeding season in most areas, with at least some breeding occurring throughout the year. A 2-year reproductive cycle consists of an 11- to 12-month pregnancy, 6 months of lactation, and 6 months of resting (Kato and Perrin 2008).

Migration. Long longitudinal migrations are not typical of Bryde's whales, although limited shifts in distribution toward and away from the equator, in winter and summer, have been observed (Best 1996; Cummings 1985). The Bryde's whales' large wintering grounds may extend from the western North Pacific to the central North Pacific, with 20°N perhaps being the northernmost boundary (Ohizumi, Matsuishi, and Kishino 2002). During the winter, Bryde's whales are distributed in the western North Pacific around the Mariana, Ogasawara, Kazan, and Philippine Islands, as well as near New Guinea (Ohizumi, Matsuishi, and Kishino 2002). Tagging data suggest that Bryde's whales undertake considerable east-west migrations, and that the stock in the western and central North Pacific does the same (Kishiro 1996). In summer, the distribution of Bryde's whales in the western North Pacific extends as far north as 40°N, but many individuals remain in lower latitudes, as far south as about 5°N. Data also suggest that winter and summer grounds partially overlap in the central North Pacific (Kishiro 1996; Ohizumi, Matsuishi, and Kishino 2002). Bryde's whales are also distributed in the central North Pacific in

summer; the southernmost summer distribution of Bryde's whales inhabiting the central North Pacific is about 20°N (Kishiro 1996). By November, Bryde's whales are usually absent from their central North Pacific summering area (Miyashita et al. 1996); in the western North Pacific, they migrate as far south as the equator in winter (Kishiro 1996; Miyashita et al. 1996). In March, Bryde's whales are found at high densities in several areas of the central Pacific, from approximately 175°E to 150°W and 15°N to 5°S (Miyashita et al. 1996). Some whales remain at higher latitudes (around 25°N) in both winter and summer (Kishiro 1996). They have been recorded swimming at speeds of 25 km/hr (Jefferson, Webber, and Pitman 2008; Kato and Perrin 2008).

Hearing/Vocalization. While no data on hearing ability for this species are available, (Ketten 1997) hypothesized that mysticetes have acute infrasonic hearing based on apical ratios and the absence of a bony latera support within the ear's anatomy**.**

Bryde's whales produce low frequency tonal and swept calls similar to those of other rorquals (Oleson et al. 2003). Calls vary regionally, yet all but one of the call types has a fundamental frequency below 60 Hz. They last from 0.25 s. to several seconds, and are produced in extended sequences (Oleson et al. 2003).

Diving. Bryde's whales spend most of their time at or near the surface (Alves, Dinis, et al. 2010). Bryde's whales might dive for as long as 20 min and to depths of 300 m (Cummings 1985; Kato and Perrin 2008). Studies have shown that Bryde's whales spend 84.5% of their time diving near the surface and in shallow dives of less than 40 m and 15.5% of their time in deep dives. The maximum dive durations ranged between 6.5 and 9.4 min, and the maximum dive depths ranged between 885 and 950 ft. (270 and 2,900 m) (Alves, Dinis, et al. 2010). Generally, Bryde's whales arch their backs before a dive but rarely raise their flukes.

5.7.5 Habitat and Distribution

Little is known of Bryde's whale habitat preferences. Historical accounts of whaling by indigenous (1981 to 1986), British (1820 to 1840), and American (1825 to 1880) commercial vessels in Philippine waters may account for a reduction in range and abundance of Bryde's whales in this area (Acebes 2009). They make only short-distance movements within tropical and subtropical oceanic waters, and are often associated with high-density patches of pelagic schooling fishes (Kato and Perrin 2008). Their summer distribution is highly associated with the distribution of prey species (Watanabe et al. 2012). Whaling catches also have shown that the Bryde's whale is not always a coastal species (Ohsumi 1977). The Bryde's whale appears to have a preference for water temperatures between approximately 15 and 20°C (Yoshida and Kato 1999). Bryde's whales were recently documented for the first time near the main Hawaiian Islands (Smultea, Jefferson, and Zoidis 2010).

Unlike other baleen whale species, Bryde's whale is restricted to tropical and subtropical waters, and does not generally occur beyond 40° in either hemisphere (Jefferson, Webber, and Pitman 2008) (Figure 5-11 and Figure 5-12). They are found in the Atlantic, Pacific, and Indian oceans.

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. Bryde's whales occur primarily in offshore oceanic waters of the North Pacific. Data suggest that winter and summer grounds partially overlap in the central North Pacific (Kishiro 1996; Ohizumi, Matsuishi, and Kishino 2002). Bryde's whales are distributed in the central North Pacific in summer; the southernmost summer distribution of Bryde's whales inhabiting the central North

Pacific is about 20° N (Kishiro 1996). The Bryde's whale is expected to occur from the 50 m isobath to seaward of the Mariana Islands MRA Study Area and vicinity (Figure 5-11).

KUROSHIO CURRENT. Whale watching operations have noted the movement of a Bryde's whale from the Ogasawara Islands to Sanriku (Omura 1977). Whale watches were documented off the Amami Islands during the whaling season (December to April) (Miyazaki and Nakayama 1989).

EAST CHINA SEA. The East China Sea is included in the primary and secondary ranges of this species (Figure 5-11).

PHILIPPINE SEA. The Philippine Sea is included in the primary and secondary ranges of this species (Figure 5-11 and Figure 5-12).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. (Kato et al. 1996) noted possible inshore-offshore movements off Kochi. There are four major whaling grounds off Japan for this species: waters off the Ogasawara Islands, Sanriku, Wakayama, and west Kyūshū (Omura 1977).

Kyūshū Island, Ōsumi Islands, and Tokara Archipelago. A concentrated occurrence is at the southwest end of Kyūshū; occurrence is predictable, and whale watching targets this species (Kato and Miyashita 2004).

MARIANA ARCHIPELAGO. Occurrence pattern is believed to be the same throughout the year. A total of 18 Bryde's whales were seen during a 2007 survey of the Mariana Islands (U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007). Bryde's whale sightings have been recorded throughout the archipelago, usually at depths of 2,500 to 5,000 m (Fulling, Thorson, and Rivers 2011). For details regarding the (Fulling, Thorson, and Rivers 2011), sightings, including behavior and sexes, see (U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007) (Figure 5-13).

Farallon de Medinilla. One sighting in July 1999 occurred approximately 9.3 to 18.5 km west of FDM (Vogt 2008).

Saipan. One whale (either a Bryde's or a Minke whale) was seen 50 km north of Saipan on July 28th, 2007 (Vogt 2008).

Guam. A sighting 195 km southeast of Guam during December 1996 was reported to the NOAA Fisheries for its Platforms of Opportunity Program (Figure 5-13). One reported stranding in this area occurred in August 1978 (Eldredge 1991, 2003). During a 2007 survey, a possible Bryde's whale was reported west of Guam (Fulling, Thorson, and Rivers 2011). Another was seen 200 nm off the southern coast of the island (Fulling, Thorson, and Rivers 2011).

CAROLINE ISLANDS. Although the summer distribution is believed to remain north of 20°N (Kishiro 1996), waters around the Caroline Islands may be included in the Bryde's whale secondary range (Figure 5-12).

5.7.6 Species-specific Threats

Although whaling records before 1962 often confused sei and Bryde's whales, Bryde's whales were never hunted as heavily as blue, fin, and sei whales. Fewer than 8,000 were taken in the Southern Hemisphere in the 1900s. As a result, most populations of the Bryde's whale have not been seriously depleted. In recent years, some Bryde's whales have been taken by the Japanese in the North Pacific, and low numbers of small whales that may be of this species have been taken by artisanal whalers from villages in Indonesia (although some of these may in fact be Omura's whales) (National Marine Fisheries Service). In the Republic of (South) Korea "whale meat" markets still can buy and sell meat from stranded or bycaught marine mammals. A DNA surveillance study from 2003 to 2005 found Bryde's whale meat present in food markets (Baker et al. 2006). They may also be highly threatened by a reduction in food supply (United Nations Environment Programme).

Bryde's whale habitat in the Hauraki Gulf coincides with shipping lanes, and a number of these whales have been struck and killed by large vessels in recent years (Baker and Madon 2007). Entanglements can cause severe injury and even death when multiple body parts are entangled and the whale cannot surface. Foraging is typically hindered by entanglements, and this may occur over multiple months or indefinitely until the animal starves to death. Mortality and injury occur from entanglements as a result of scarring, infection from open wounds, and hemorrhaging from tissue damage (Cassoff et al. 2011). Habitat modification and noise disturbance may be additional human-caused threats; however, the species is not considered endangered or threatened, and the western North Pacific stock is thought to be increasing (Jefferson, Webber, and Pitman 2008).

The barnacle *Xenobalanus* has been found on this animal in the ETP, indicating possibility of attachments to a fast-swimming host (Kane et al. 2008). Concentrations of butylin and phenyltin were found in the organs and tissue of Bryde's whales off the coast of Thailand (Harino et al. 2007a).

This Page Intentionally Left Blank

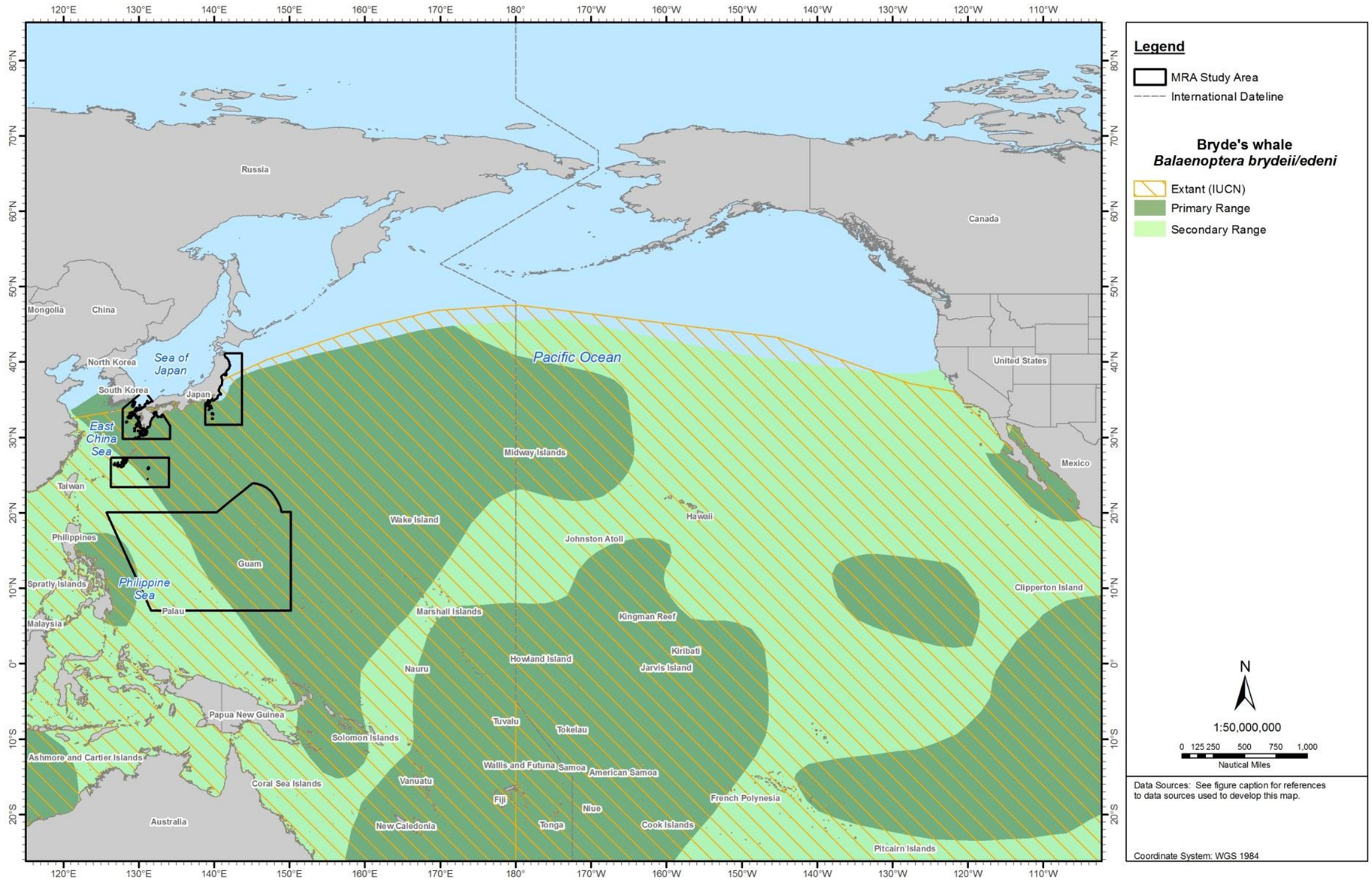

Figure 5-11: Geographic Range of Bryde's Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

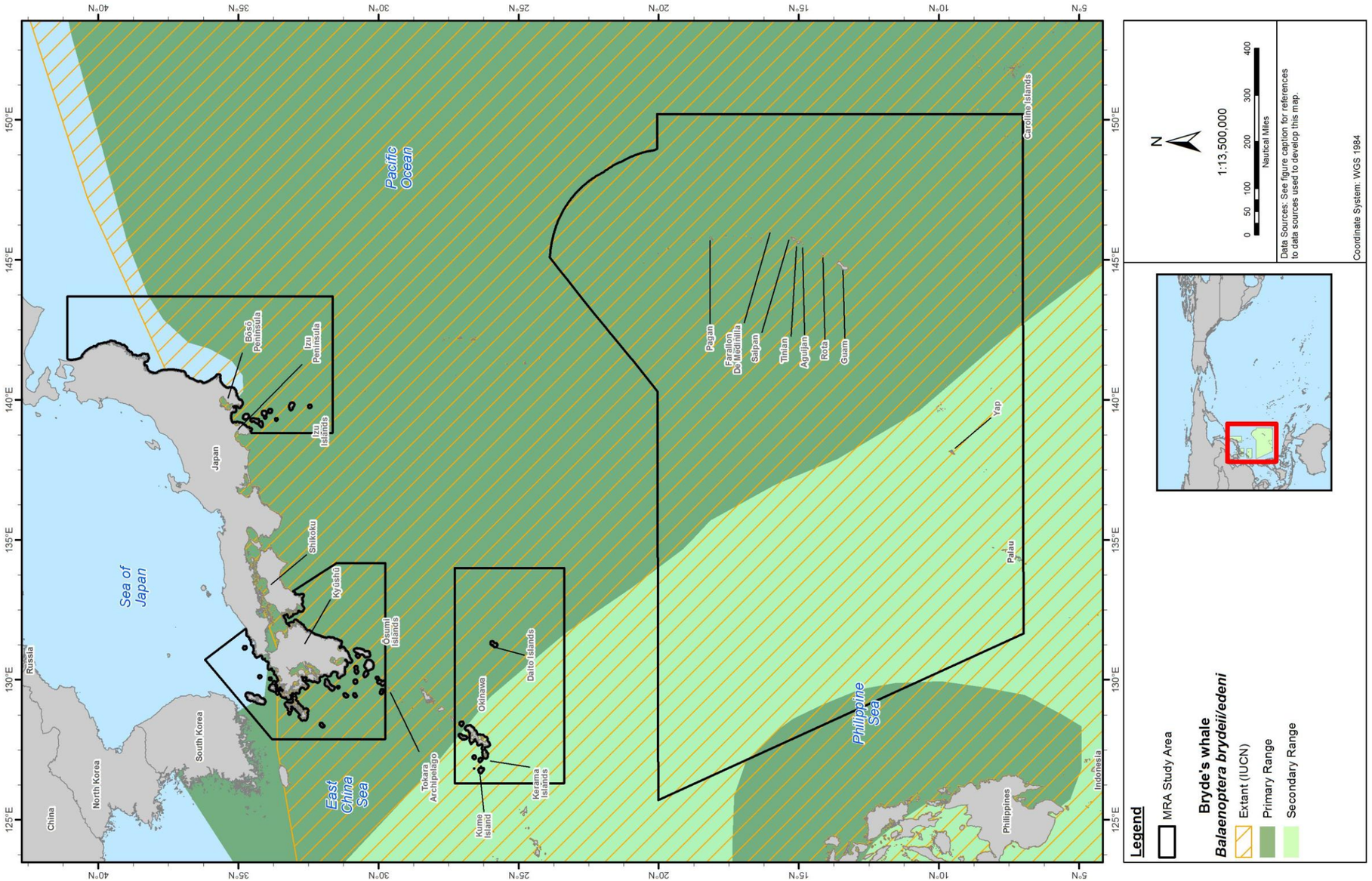

Figure 5-12: Geographic Range of Bryde's Whale in the MRA Study Area
Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

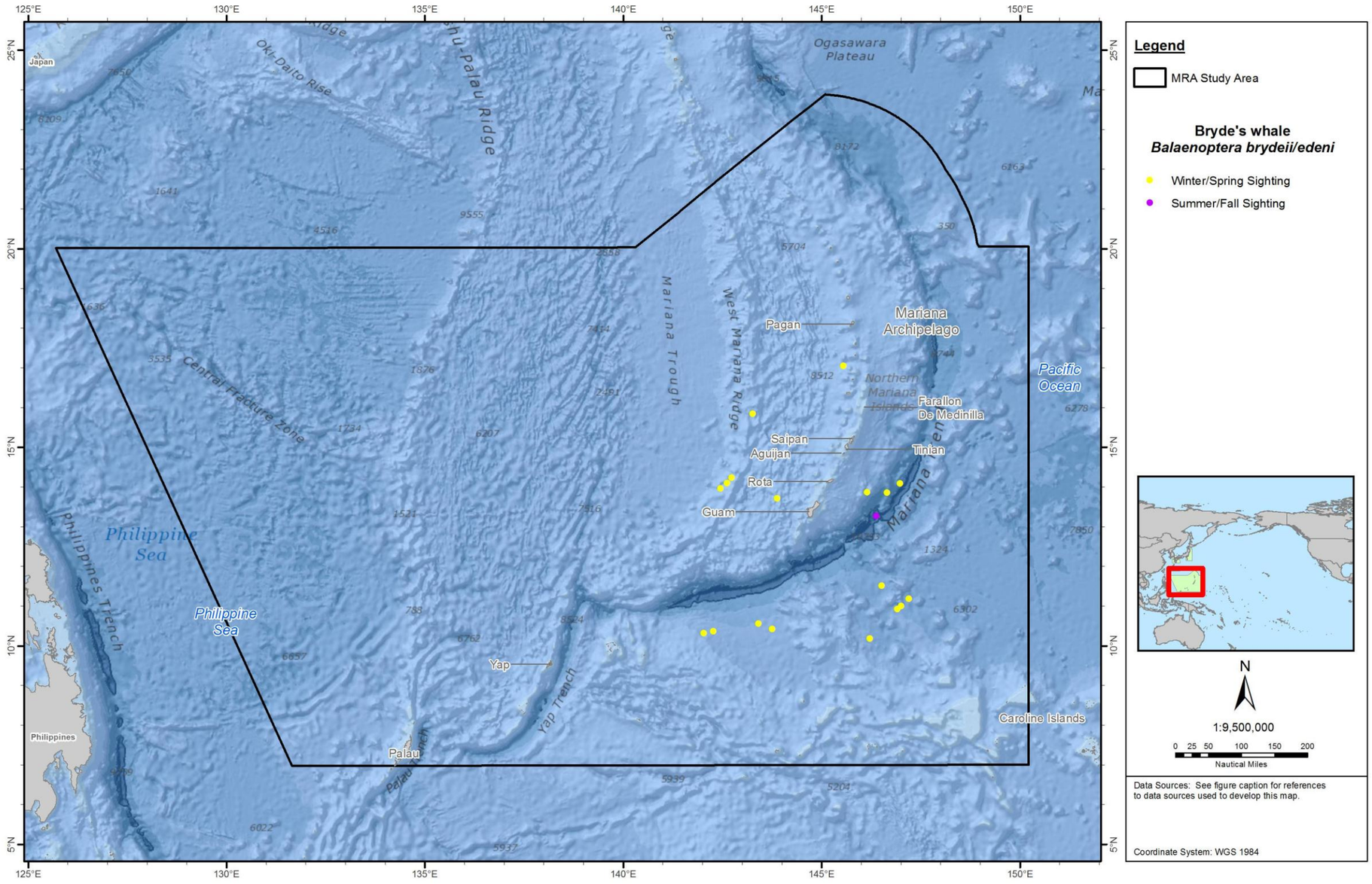

Figure 5-13: Sightings of the Bryde's Whale in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented.
Sources: Fulling, Thorson, and Rivers (2011); Mobley (2007); U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific (2007).

This Page Intentionally Left Blank

5.8 SEI WHALE (*BALAENOPTERA BOREALIS*)

5.8.1 Description

The sei whale is one of at least three genetically distinct species of medium-sized rorquals, including the Bryde's whales (Kato and Perrin 2008; Rice 1998) and Omura's whale (*Balaenoptera omurai*) (Wada, Oishi, and Yamada 2003).

Because of similar appearance, the sei whale and Bryde's whales are often difficult to differentiate (Mead 1977). The sei whale can also be confused with blue, fin, or minke whales. Adult blue and fin whales, though similarly shaped, are much larger than sei whales, while minke whales are smaller (Mizroch and Breiwick 1984). Sei whales are the third-largest whale species (after blue and fin whales) (Calambokidis et al. 2007). The sei whale's dorsal fin is strongly falcate (similar in shape to the minke whale) but is slightly taller than that of the blue and fin whales, and tends to be jointed (i.e., having a sharp bend in the axis). The sei whale has a single prominent ridge along the length of the rostrum, whereas the Bryde's whale has three (Horwood 2009; Jefferson, Webber, and Pitman 2008). Sei whales are dark gray dorsally, becoming lighter gray ventrally. Sei whales are sometimes seen with a slight chevron on the back (Horwood 2009; Jefferson, Webber, and Pitman 2008). They have a dark lower lip, unlike the whitened lower lip seen in fin whales. Baleen is dark gray with a yellowish hue. Baleen plates number around 350 on each side and are less than 80 centimeters (cm) in length (Horwood 2009).

Adult sei whales average 15 m (maximum of 18 m) long (females may be larger than males) and weigh approximately 20 metric tons (up to 100,000 pounds [lbs.]) (Calambokidis et al. 2007). Sei whales are slender rorquals.

5.8.2 Status and Management

The sei whale is listed as endangered under the ESA and as depleted under the MMPA. This species is also listed as endangered by the IUCN and falls under Appendix I CITES regulations. Sei whales found in United States' waters are separated into four stocks: the Hawaiian Stock, eastern North Pacific Stock, Nova Scotia Stock, and the Western North Atlantic Stock (Chen, Watson, and Chou 2011). The Eastern North Pacific population has been protected since 1976, but is likely still impacted by the effects of continued unauthorized takes (Carretta et al. 2010). There are no annual deaths or serious injuries caused by fisheries in the Hawiian stock (Carretta et al. 2012). The recovery plan for the sei whale proposes actions to reduce anthropogenic impacts detrimental to population recovery. A few of these actions include coordination of agencies, accurate mapping of population trends and stock structure, improved knowledge of life history, and reduced human-caused injury and mortality. The comprehensive list of detailed proposed tasks is in (Estep et al. 2005).

Japanese scientific whaling permits continue to allow the capture and killing of sei whales. From 1985 to 2011 special permits takes from pelagic and coastal Japanese waters have totaled 792 and one sei whale, respectively. From June 2010 to August 2010 100 sei whales were harvested from Japan's pelagic waters (International Whaling Comission 2012).

5.8.3 Population and Abundance

Current global abundance is estimated to be a minimum of 80,000 individuals (Horwood 2009; Jefferson, Webber, and Pitman 2008). The geographically nearest stock assessments were conducted for the Eastern North Pacific stock (an estimated 126 whales, and the Hawai'i stock (77 whales [CV=1.06])

(Carretta et al. 2011p). A different estimate for the Hawaiian Stock is 40 to 80 individuals, and for the Eastern North Pacific Stock between 35 and 50 individuals (National Marine Fisheries Service 2011b). The population of sei whales living around Guam and the CNMI is believed to be 166 (Cassoff et al. 2011).

Although commercial whaling all but exhausted the known population of this species, the Northern Atlantic and North Pacific populations are believed to be relatively abundant, yet the populations within the Southern Ocean are still largely depleted (Chen, Watson, and Chou 2011). Although no data on current population trends are available, the Pacific population is generally believed to be on the rise partially as a result of its protected status since 1976 (Carretta et al. 2011p).

5.8.4 Biology, Ecology, and Behavior

Group Size. Group sizes are generally low, but are believed to vary by location (Horwood 2009). In warmer waters, sei whales have been found in groups of two to five individuals (Horwood 2009; Leatherwood et al. 1988). They are often solitary in temperate waters. Within feeding grounds, they can be solitary or can form large, loose aggregations of up to 100 whales (Horwood 2009).

Predator/Prey Interactions. Feeding occurs primarily around dawn (Horwood 2009) or at night (Baumgartner and Fratantoni 2008), appearing to correlate with vertical migrations of prey species. Unlike some rorquals, the sei whale skims to obtain its food, yet like others, it does sometimes lunge and gulp for food (Horwood 2009). In the North Pacific, sei whales feed on a diversity of prey, including copepods, krill (tiny crustaceans), fish (specifically sardines and anchovies), and cephalopods (squids, cuttlefish, octopuses) (Horwood 2009; Nemoto and Kawamura 1977). There is evidence from the Indian Ocean, that fish aggregating devices also attract this species, which may cause the targeted fish species to initially move away from the area (Brehmer, Josse, and Nottestad 2012).

During predation by killer whales, sei whales are known to employ the "flight" strategy, characterized by directional, sustained swimming of speeds over 15 km/hr, common for whales with streamlined bodies preferring pelagic habitats and calving grounds (Ford and Reeves 2008). Scars are common on the skin of sei whales, possibly from bites by lampreys or cookie-cutter sharks (Jefferson, Webber, and Pitman 2008).

Life History. Males and females reach sexual maturity at around 10 years of age (Horwood 2009). Sei whales typically follow a reproductive cycle of 2 years: a 10 to 12 month pregnancy and a lactation period of 6 to 9 months (Gambell 1985; Sigurjonsson 1995). Conception peaks in June in the Southern Hemisphere and in December in the Northern Hemisphere (Horwood 2009). Calving happens in mid-winter (Jefferson, Webber, and Pitman 2008), and calves are weaned at 7 months of age. Sei whales hybridize with fin whales occasionally (Jefferson, Webber, and Pitman 2008).This species may live to nearly 60 years of age (Best and Lockyer 2002). In November 2007, two sei whale groups including three subadults were documented during a survey in the main Hawaiian Islands. These were the first sightings near Oahu and the first documentation of subadults. This suggests that Hawai‘i may be a reproductive area for the sei whale, whose breeding and calving ground locations remain unknown in the Pacific (Smultea, Jefferson, and Zoidis 2010).

Migration. Sei whales spend the summer feeding in high latitude subpolar regions and return to lower latitudes to calve in winter. Exact migration pattern remains largely unknown. Whaling data provide some evidence of a differential migration pattern by reproductive class, with females arriving at and departing from feeding areas earlier than males (Horwood 1987; Perry, DeMaster, and Silber 1999), and

migration structured by sex and age class (Calambokidis et al. 2007). Sei whales are known to swim at speeds greater than 15 miles (25 km/hr) and may be the second fastest cetacean, after the fin whale (Horwood 2009; Jefferson, Webber, and Pitman 2008).

Hearing/Vocalization. While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing based on apical ratios and the absence of a bony latera support within the ear's anatomy.

Sei whale vocalizations have been recorded only on a few occasions. These consist of paired sequences (0.5 to 0.8 s., separated by 0.4 to 1.0 s.) of seven to 20 short (4 ms), FM sweeps between 1.5 and 3.5 kHz; source level is not known (Thomson and Richardson 1995). Low frequency calls were recorded in the Atlantic ocean, off the coast of Maine, consisting of a sweeping call from 82 to 34 Hz for 1.4 s. (Baumgartner et al. 2008). (Cantor et al. 2010) noted a diel periodicity (moving from depth to surface and back again at different times of day) to vocalization, relative to depth of prey during vertical migration off the coast of Maine. Off the Antarctic Peninsula, small groups of sei whales were recorded making low-frequency vocalizations described by (McDonald et al. 2005) as growls or moans. These calls durations were, on average, 0.45 ± 0.3 s., with an average frequency of 433 ± 192 Hz. This same type of low-frequency call was recorded off the Hawaiian coast in winter months, where calls swept from 100 to 44 Hz over 1.0 s.. A second sweep was recorded starting at 39 Hz and decreasing to 21 Hz over 1.3 s.. Vocalization may increase when prey is at depth, and feeding activity shifts to daytime socializing, indicating sei whales do not feed on deeper populations of copepods (Baumgartner and Fratantoni 2008).

Diving. Limited dive data are available for this species. Similar to some other rorquals, sei whales dive more by sinking than through an arched dive. They rarely raise their flukes (Jefferson, Webber, and Pitman 2008; Smultea, Jefferson, and Zoidis 2010). Feeding sei whales are known to dive and surface in a predictable series, remaining directly below the surface between breaths (Jefferson, Webber, and Pitman 2008; Smultea, Jefferson, and Zoidis 2010).

5.8.5 Habitat and Distribution

Sei whales have a worldwide distribution and are found primarily in cold, temperate to subpolar latitudes (Figure 5-14 and Figure 5-15). During the winter, sei whales are found from 20°N to 23°N and during the summer from 35° N to 50° N (Horwood 2009; Masaki 1976, 1977; Smultea, Jefferson, and Zoidis 2010). There have been groups of sei whales sighted south of 20°N near the CNMI (Fulling, Thorson, and Rivers 2011). They are considered absent, or at very low densities, in most equatorial areas. They appear to prefer regions of steep bathymetric relief, such as the continental shelf break, canyons, or basins between banks and ledges (Best and Lockyer 2002; Gregr and Trites 2001; Kenney and Winn 1987; Schilling et al. 1992). Prey availability greatly influences the distribution of the sei whale (Watanabe et al. 2012). Within feeding grounds, the distribution is largely associated with oceanic frontal systems (Horwood 1987). Characteristics of preferred breeding grounds are unknown because these generally have not been identified.

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. Sei whales are likely present in the North Central Pacific Gyre and are seen at least as far south as 20°N (Horwood 1987, 2009). In the east, they range as far south as Baja California, Mexico, and as far north as the Aleutian Islands; in the west, they range to Japan and Korea (Reeves et al. 1999).

KUROSHIO CURRENT. This species is more likely to occur offshore seaward of the shelf break on the Pacific coast of Japan (Figure 5-14 and Figure 5-15) north of the China prefecture on Honshū. This is based on lower numbers of whaling catches of this species in this area (Horwood 1987; Springer et al. 1999), as well as the fact that few individuals make their way into the Sea of Japan (Reeves et al. 1998).

EAST CHINA SEA. The East China Sea is believed to be a part of the sei whale's secondary range (Figure 5-14).

PHILIPPINE SEA. The Philippine Sea is believed to be a part of the sei whale's primary and secondary ranges (Figure 5-14 and Figure 5-15).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. During the winter-spring, the area of expected occurrence of sei whales extends south to about 32°N on the Pacific coast of Japan where cooler water temperatures prevail. This takes into consideration the general migration pattern of this species into lower latitude breeding grounds and the distribution of occurrence records (Horwood 1987; Springer et al. 1999).

MARIANA ARCHIPELAGO. Two unconfirmed sei whales were tagged in the general vicinity of the Northern Mariana Islands (1,515 km northwest of Ritidian Point, Guam) in January 1972 (Ohsumi and Masaki 1975). These two individuals were later killed a few hundred km south of the western Aleutian Islands in June 1972 (Horwood 1987; Ohsumi and Masaki 1975). Sixteen sei whales were seen during a 2007 survey of the Mariana Islands (Fulling, Thorson, and Rivers 2011; U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007); acoustical recordings of the species in that area may have indicated presence of more individuals (Norris et al. 2011). Cow-calf pairs and individual sei whales were documented around Guam and the CNMI during this surveying cruise (Cassoff et al. 2011; Fulling, Thorson, and Rivers 2011).

Saipan. Cow-calf pairs and individual sei whales were documented around Guam and the CNMI in areas where ocean depth exceeded 3000 m, during a surveying cruise in 2007 (Figure 5-16). Sei whales, during this survey, were seen approximately 50 km southwest of the coast of Saipan (Cassoff et al. 2011; Fulling, Thorson, and Rivers 2011).

Guam. Cow-calf pairs and individual sei whales were documented around Guam and the CNMI in areas where ocean depth exceeded 3000 m, during a surveying cruise in 2007 (Figure 5-16). Sei whales, during this survey, were seen approximately 100 km southwest of Guam (Cassoff et al. 2011; Fulling, Thorson, and Rivers 2011).

CAROLINE ISLANDS. The Caroline Islands are not believed to be included in sei whale primary or secondary distribution (Figure 5-14 and Figure 5-15).

5.8.6 Species-specific Threats

Before protection from the IWC in 1978, the sei whale was heavily targeted by the whaling industry. Sei whales appear to be the preferred species among many cultures consuming whale meat. The heaviest period of exploitation occurred between the 1950s and 1970s. Whaling took place in the North Pacific (at least 74,000 taken) and North Atlantic (14,000 taken) Oceans, but most hunting was in the Southern Hemisphere (200,000 taken) (Jefferson, Webber, and Pitman 2008). Still, in 2009, mitochondrial DNA

(mtDNA) analysis of meat sold in California and South Korea, originating in Japan, was identified as belonging to a few whale species, including the sei whale (Baker et al. 2010).

Additional threats to the sei whale may include predation by killer whales, and parasites of the genitalia, stomach, and intestines (Jefferson, Webber, and Pitman 2008). Vessel strikes and entanglement in fishing gear may also increase sei whale mortality (Chen, Watson, and Chou 2011). Whale-ship collisions may become of greater concern based on continued increase in merchant shipping traffic (Calambokidis et al. 2007).

This Page Intentionally Left Blank

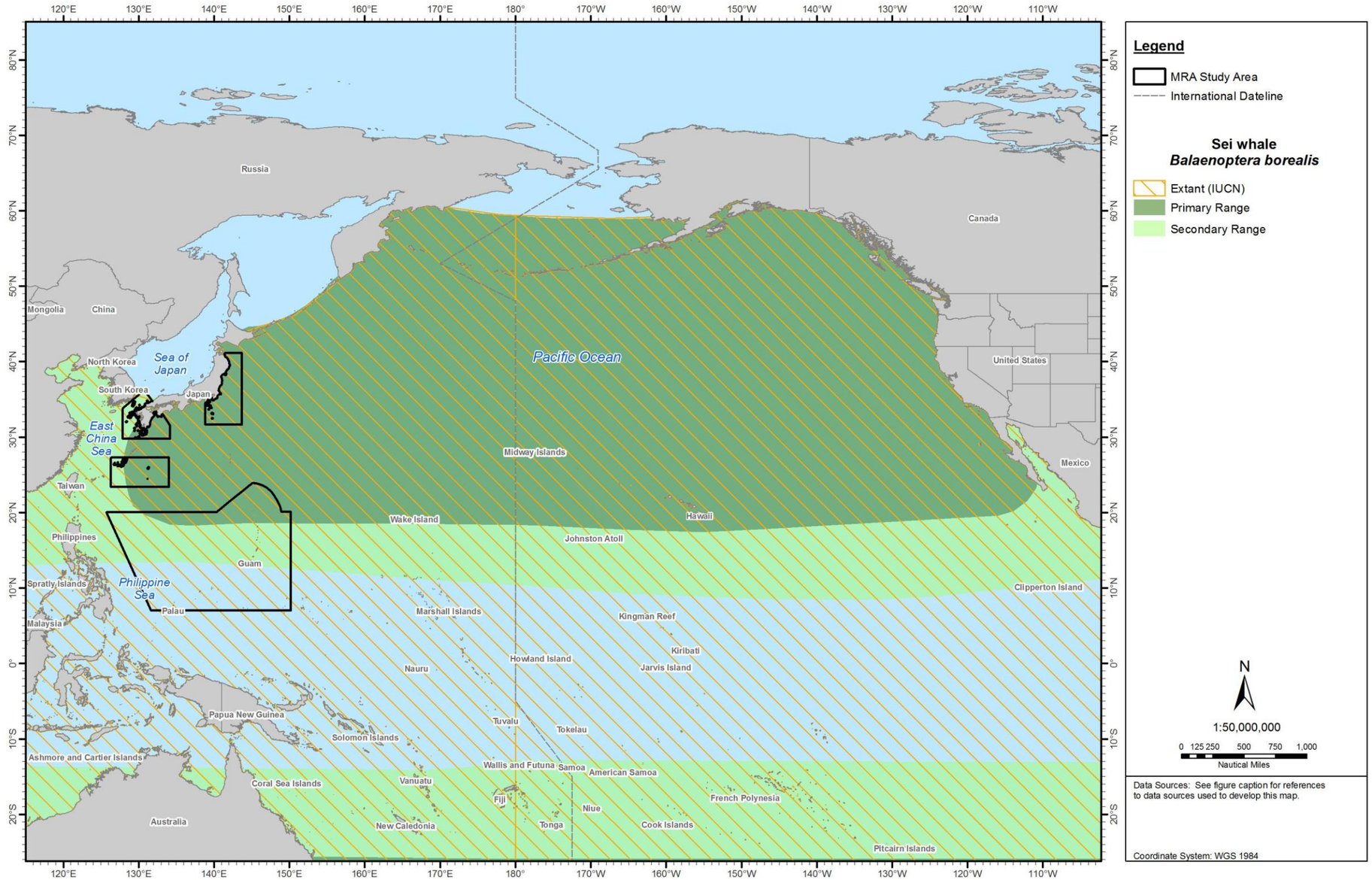

Figure 5-14: Geographic Range of the Sei Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

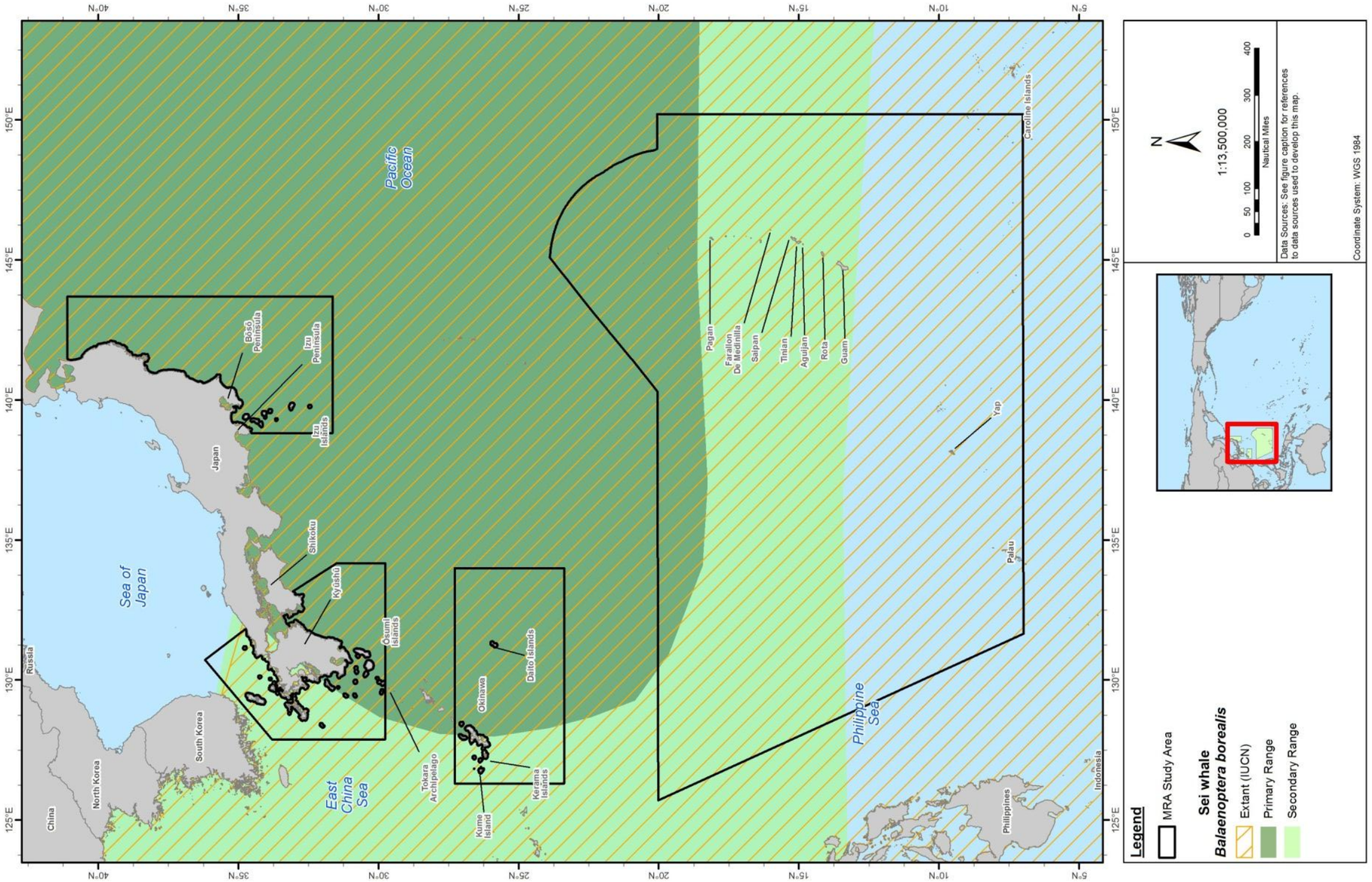

Figure 5-15: Geographic Range of the Sei Whale in the MRA Study Area
Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

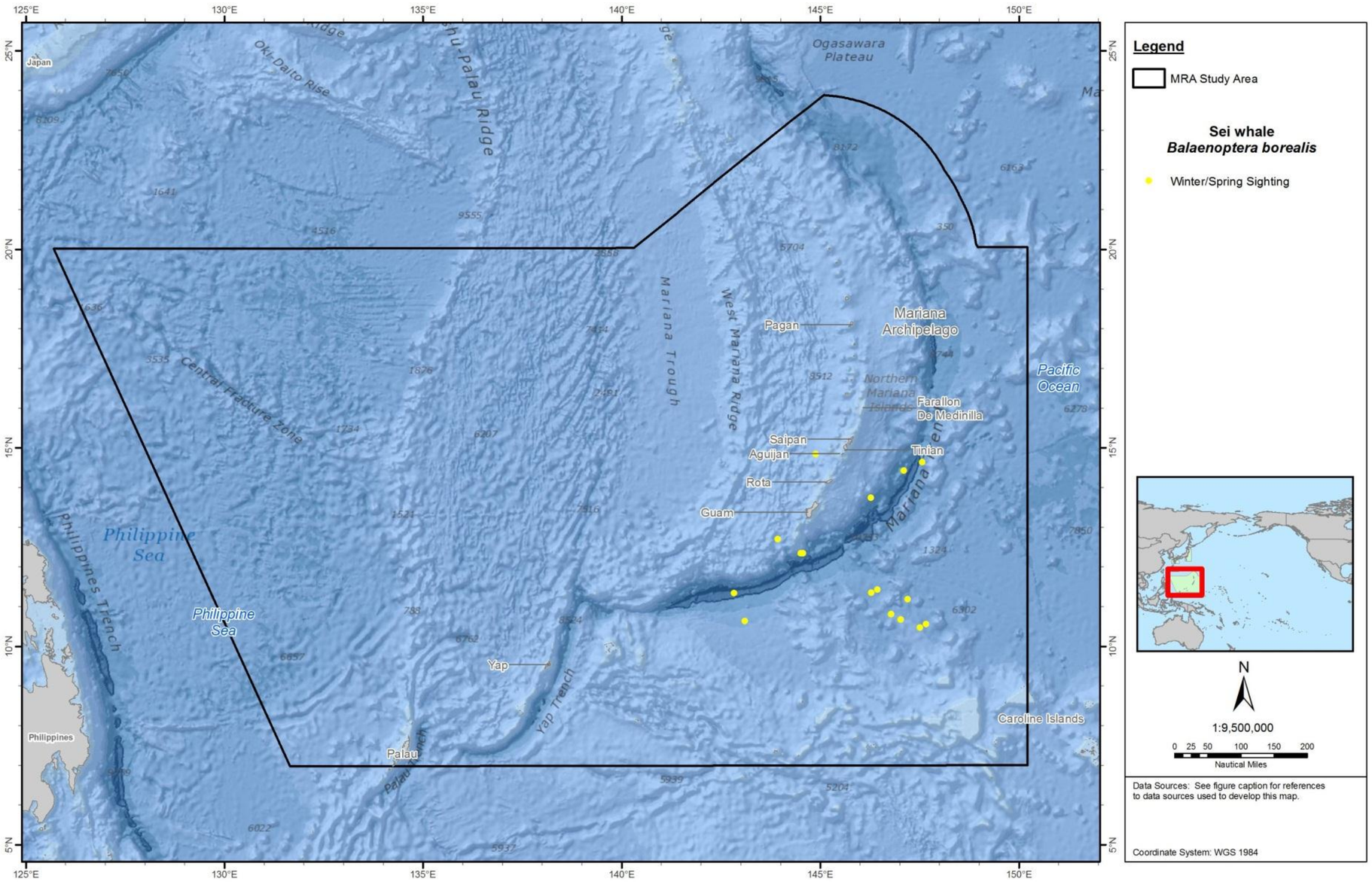

Figure 5-16: Sightings of the Sei Whale in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented.
Sources: Fulling, Thorson, and Rivers (2011); U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific (2007).

This Page Intentionally Left Blank

5.9 FIN WHALE (*BALAENOPTERA PHYSALUS*)

5.9.1 Description

Fin whales are very large, long, and sleek whales. Their dorsal fin is variably shaped, but is usually pointed and small, located toward the posterior end of the whale. The upper edge of the caudal peduncle has a distinct, sharp ridge. The head (when viewed from above) has a more tapered appearance than that of the blue whale (Jefferson, Webber, and Pitman 2008).

The bodies of fin whales are dark gray on their dorsal surface, and white or cream colored on their ventral surface. They have distinct asymmetrical coloration on their lower jaw. The right side of their lower jaw is white, while the left side of their lower jaw is black. It is possible to identify individuals using their "blaze" pattern on the right side of their head and the V-shaped chevron across the dorsal surface, behind the head (Jefferson, Webber, and Pitman 2008).

Fin whale baleen plates number at about 260 to 480 plates on each side of their mouth (Reeves, Smith, et al. 2002). Fin whales have an average length of 21.2 m and an average mass of 52,584 kg (Acevedo-Gutiérrez, Croll, and Tershy 2002), with females growing somewhat larger than males (Jefferson, Leatherwood, and Webber 1993a). At birth, they are about 6.0 to 6.5 m long (Jefferson, Webber, and Pitman 2008).

5.9.2 Status and Management

The fin whale is listed as endangered under the ESA and as depleted under the MMPA. This species is also listed as endangered by the IUCN and falls under Appendix I CITES regulations. Pacific fin whale population structure is not well known. There is no designated critical habitat for this species in the North Pacific. The IWC recognizes two management stocks in the North Pacific: a single widespread stock in the North Pacific and a smaller stock in the East China Sea (Donovan 1991). Both stock may have range in the MRA Study Area. The 2010 recovery plan for fin whales includes those living in the Atlantic, Pacific, and Southern Oceans. The recovery Plan's main goal is to lay out the steps necessary to downlist the fin whale from endangered to threatened status, including interagency coordination in determining current population characteristics, monitoring long-term trends accurately, conducting risk analyses, identifying and protecting habitat, and minimizing anthropogenic threats (e.g., from acoustic sources and entanglements) (National Marine Fisheries Service 2010).

Japanese scientific whaling permits continue to allow the capture and killing of fin whales. From 1985 to 2011 special permits takes from pelagic Japanese waters have totaled 17 fin whales. From December 2010 to February 2011 two fin whales were harvested from these pelagic waters (International Whaling Comission 2012).

5.9.3 Population and Abundance

An estimated 140,000 fin whales occur globally, and they are relatively abundant in the Pacific (Jefferson, Webber, and Pitman 2008; Mizroch et al. 2009). The northern hemisphere is thought to harbor approximately 40,000 fin whales (United Nations Environment Programme). The stock assessment completed for this species closest to the MRA Study Area was for the Hawaiian stock—an estimated 174 whales (0.027 calling whales/1000 km^2 [CV=0.72]) live in that EEZ (Carretta et al. 2011g). There are no annual deaths or serious injuries caused by fisheries in the Hawaiian stock (Carretta et al. 2012). Some very old and outdated estimates of abundance are available for fin whales in the area:

15,000 to 20,000 for the North Pacific populations, and less than 200 for the East China Sea population (Nishiwaki and Norris 1966). Abundance surveys have indicated an estimated 4.8% increase in the North Pacific population of fin whales (Zerbini et al. 2006).

5.9.4 Biology, Ecology, and Behavior

Group Size. The typical group size of fin whales ranges from 1 to 20, with an average group size of 2 (Branch and Butterworth 2001; Canese et al. 2006; Coakes et al. 2005). However, they are considered a social species and are often seen feeding in large groups and sometimes in mixed species groups with humpback and minke whales (Jefferson, Webber, and Pitman 2008; Johnston, Thorne, and Read 2005).

Predator/Prey Interactions. This species preys on small invertebrates such as copepods, as well as squid and schooling fishes such capelin, herring, and mackerel (Goldbogen et al. 2006; Jefferson, Webber, and Pitman 2008). Off the coast of California, fin whales forage in shallow waters (10 to 100 m), targeting swarms of krill (de Guevara, Lavaniegos, and Heckel 2008). Fin whales tend to congregate around krill concentration areas. In Antarctica, this species was associated with large (>45 mm), offshore krill (Santora et al. 2010). Fin whales are lunge feeders, engulfing prey with high volumes of water. During these dives, a whale can engulf between 60 and 82 square meters of water and prey (Goldbogen, Pyenson, and Shadwick 2007). The larger the whale, the larger its calculated engulfing capacity, and thus its foraging capacity (Goldbogen, Potvin, and Shadwick 2010).

The fin whale is not known to have a significant number of predators. However, in regions where killer whales are abundant, some fin whales exhibit attack scars on their flippers, flukes, and flanks—suggesting possible predation by killer whales (Aguilar 2008). During predation by killer whales, fin whales are thought to employ the "flight" strategy, characterized by directional, sustained swimming of speeds over 15 km/hr, common for whales with streamlined bodies that prefer pelagic habitats and calving grounds (Ford and Reeves 2008).

Life History. Sexual maturity for the fin whale is around 6 to 10 years for males and 7 to 12 years for females. Peak breeding activity of the Northern Hemisphere fin whale may occur between December and January. Low-frequency vocalizations occur during courtship rituals (Reeves, Smith, et al. 2002). Pregnancies last around 11 to 12 months. A year after mating, calving occurs again during winter, after which calves stay with their mothers for approximately 6 to 8 months. Females give birth every 2 to 3 years to a single calf. According to a Mediterranean study by (Sleptsov 1961), predicted life span differs among each of the three distinct life stages: high rate of mortality of fin whales in the calf phase results in a predicted average life span between 6 and 10.1 years; mortality drops in the immature and mature life stages, increasing predicted lifespans to 8.2 to 14.3 years and 15.6 to 37.8 years, respectively (Sleptsov 1961).

Migration. Locations of breeding and calving grounds of the fin whale are unknown; but the whales typically migrate seasonally to higher latitudes every year to feed, and migrate to lower latitudes to breed (Kjeld et al. 2006; MacLeod, Simmonds, and Murray 2006). Recoveries of marked whales demonstrate long migrations from low-latitude winter grounds to high-latitude summer grounds, and extensive longitudinal movements both in-season and between years, within and between the main summer concentration areas (Mizroch et al. 2005). The fin whale's ability to adapt to areas of high productivity controls this species' migratory pattern (Canese et al. 2006; Reeves, Smith, et al. 2002). Fin whales are one of the fastest cetaceans, capable of attaining speeds of 37 km/hr (Jefferson, Webber, and Pitman 2008; Marini et al. 1996).

Hearing/Vocalization. While no data on hearing ability for this species are available, Ketten (1997) hypothesized that all mysticetes have acute infrasonic hearing based on apical ratios and the absence of a bony latera support within the ear's anatomy. (Croll, Acevedo-Gutierrez, et al. 2001) found no significant change in foraging behavior during source signals of 140 dB re 1 µPa, indicating this level of sound does not affect some behaviors of the fin whale as other noise levels do for other species.

Infrasonic, pattern sounds have been documented for fin whales (Watkins, Tyack, and Moore 1987). Fin whales produce a variety of sounds with a frequency range up to 750 Hz. The long, patterned 15 to 30 Hz vocal sequence is most typically recorded; only males are known to produce these (Croll et al. 2002). The most typical fin whale sound is a 20 Hz infrasonic pulse (actually an FM sweep from about 23 to 18 Hz), with durations of about 1 s. and which can reach source levels of 184 to 186 dB re 1 µPa-m (maximum up to 200) (Charif et al. 2002; Thomson and Richardson 1995). It has been suggested that these long, patterned vocalizations might function as male breeding displays, much like those of the male humpback whale's song (Croll et al. 2002).

Diving. Fin whales are lunge feeders and are known to feed both at the surface and at depth. They have been found to spend much of their time at depths greater than 330 ft. (100 m), where large shoals of krill congregate. The maximum dive depth for foraging fin whales is 335 ± 160 ft. (100 ± 50 m) (Acevedo-Gutiérrez, Croll, and Tershy 2002). Foraging fin whales lunge an average of 1.7 times per dive and a maximum of eight times. Fin whales are known to have a theoretical dive limit of 28.6 min, which they rarely reach unless they dive under some sort of stress. Dive times are variable—fin whales in one study dove for an average of only 6.3 min, with the longest being 14.7 min (Acevedo-Gutiérrez, Croll, and Tershy 2002; Croll, Acevedo-Gutierrez, et al. 2001). Typically, they do not raise their flukes before they dive (Jefferson, Webber, and Pitman 2008). Fin whale dives are typically 5 to 15 min, separated by sequences of 4 to 5 blows at 10- to 20-s. intervals (Cetacean and Turtle Assessment Program 1982; Lafortuna et al. 2003; Stone et al. 1992). Significant differences in blow intervals, dive times, and blows per hour between surface-feeding and non-surface-feeding fin whales have been found (Kopelman and Sadove 1995). Fin whales dive to 97.9 (±standard deviation [S.D.] 32.59) m, with a duration of 6.3 (±S.D. 1.53) min when foraging; and to 59.3 (±S.D. 29.67) m, with a duration of 4.2 (±S.D. 1.67) min when not foraging (Croll, Acevedo-Gutierrez, et al. 2001). Fin whale dives exceeding 150 m and coinciding with the diel migration of krill were reported by (Panigada et al. 1999).

5.9.5 Habitat and Distribution

Fin whales typically congregate in areas of high productivity. They spend most of their time in coastal and shelf waters, but can often be found in waters approximately 6,560 ft. (2,000 m) deep (Aissi et al. 2008; Reeves, Smith, et al. 2002). Attracted to certain areas for feeding, fin whales are often seen closer to shore after periodic patterns of upwelling and the resultant increased krill density (Azzellino et al. 2008). This species of whale is not known to have a specific habitat and is highly adaptable, following prey typically off the continental shelf (Azzellino et al. 2008; Panigada et al. 2008). In the Bay of Fundy, Canada, the fin whale population has been found to use three different types of (water) current for feeding. These currents include non-wake habitat, eddy habitat, and free stream habitat (close to shore). Prey concentrations are thought to be high in the slow current velocities of these habitats (Johnston, Thorne, and Read 2005).

The fin whale occurs in all the world's oceans (Jefferson, Webber, and Pitman 2008). Fin whales prefer temperate and polar waters and are scarcely seen in warm, tropical waters (Reeves, Smith, et al. 2002). The distribution of fin whales in the Pacific during the summer is thought to range from the Chukchi Sea

south to 35°N on the Sanriku coast of Honshū, to the Subarctic Boundary in the western and central Pacific, and to 32°N off the coast of California. During the winter, this species has been documented from 60°N to 23°N, and they have frequently been recorded in offshore waters west of southern California and northern Baja California, Mexico (Mizroch et al. 2009). Fin whales are thought to be relatively abundant in North Pacific offshore waters (Berzin and Vladimirov 1981; Carretta et al. 2010). Acoustic signals thought to be attributed to the fin whale have also been detected in the central Pacific (Northrop, Cummings, and Thompson 1968). Fin whales have been recorded in the ETP (Ferguson 2005) and are frequently sighted there during offshore ship surveys.

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. Fin whales are expected to occur in oceanic waters within the MRA Study Area (Figure 5-17). Fin whales in the Pacific are found during the summer in the northern portion of the North Central Pacific Gyre to 32° N off the coast of California (Barlow 1995; Forney, Barlow, and Carretta 1995). Fin whales are relatively abundant in North Pacific offshore waters (Berzin and Vladimirov 1981; Mizroch et al. 2009).

KUROSHIO CURRENT. During winter-spring, the expected occurrence of the fin whale is from the middle of Honshū (beyond the shelf break) south. This area is a presumed breeding area, a theory supported by (Mizroch et al. 2005). The area of expected occurrence of the fin whale extends into the Sea of Japan, as evidence indicates a resident stock there (Mizroch et al. 2005). During summer-fall, expected occurrence is north of 35°N (beyond the shelf) because most of the population occurs at this time of year within the northern feeding grounds (Mizroch et al. 2005). Occurrence is also expected in the Sea of Japan, based on evidence of a resident stock there.

EAST CHINA SEA. A concentrated occurrence is in the East China Sea, south of 30°N, based on evidence of a major whaling ground there (Mizroch et al. 2005). Likelihood of species presence in the southern area of the East China Sea (off the shelf) is low. The occurrence may be related to presence of other possible non-migrators and potential residents. Numbers or occurrences are unknown within this area.

PHILIPPINE SEA. Although the Philippine Sea is within the fin whale's secondary range, they typically avoid warm waters. Yet, they may be present in this part of the MRA Study Area (Figure 5-17 and Figure 5-18).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. The Japan Archipelago is within the primary range of this species, and they frequent coastal waters within this area (Figure 5-18).

Bōsō Peninsula, Izu Peninsula, and Izu Islands. Fin whales may occur in these areas because a possible resident stock occurs off the northeast coast of Honshū (Mizroch et al. 2005).

MARIANA ARCHIPELAGO. No occurrence records exist for the fin whale in the Mariana Islands MRA Study Area and vicinity, but this area is within the known distribution range of this species. Fin whales can occur over the continental shelf and in oceanic waters. Occurrence pattern is expected to be the same throughout the year.

CAROLINE ISLANDS. Although the Caroline Islands are within the fin whale's secondary range, fin whales typically avoid warm waters (Figure 5-17 and Figure 5-18); nonetheless, they may be present in this part of the MRA Study Area.

5.9.6 Species-specific Threats

Whaling for fin whales was heavy from the late 1800s to early 1900s, and many populations were badly depleted. In 2009, mtDNA analysis of meat sold in California and South Korea from Japan indicated the meat had derived from a few species, including the fin whale, thus identifying whaling as a persistent problem for the species (Baker et al. 2010). Because the diet of the fin whale consists of euphasiids (almost exclusively), any change in prey distribution or abundance could threaten their populations (Acevedo-Gutiérrez, Croll, and Tershy 2002; Azzellino et al. 2008). Some euphasiid species off the North Atlantic coast of Britain have declined precipitously; over time, this could cause a decline in fin whale abundance in the area (MacLeod, Simmonds, and Murray 2006; Panigada et al. 2005).

Because of their surface feeding techniques, fin whales are susceptible to ship collisions. In the Mediterranean, their estimated average mortality was 1.7 whales per year between the years of 1972 and 2001 (Aissi et al. 2008; Gannier and West 2005). In one survey on stranded whales in Washington waters, fin whales had the highest occurrence of ship-strike mortality, a threat of increasing concern for this species based on their behavior (which may place them in proximity to vessels) and on their abundance in the area (Douglas et al. 2008). In addition to ship strikes, anthropogenic noise, as for other marine mammals, can negatively affect the fin whales. Fin whales have been shown to alter their vocalizations and behavior in the presence of airgun noise (Castellote, Clark, and Lammers 2012).

Fin whales are vulnerable to reparatory bacteria, and these may negatively impact overall animal health (Acevedo-Whitehouse, Rocha-Gosselin, and Gendron 2010). Fin whales are also susceptible to chemical contaminants such as OCPs, PCBs, and dichlorodiphenyltrichloroethane (DDT), which are found at higher concentrations in males (Fossi et al. 2010; Nino-Torres et al. 2010; Panigada et al. 2005).

This Page Intentionally Left Blank

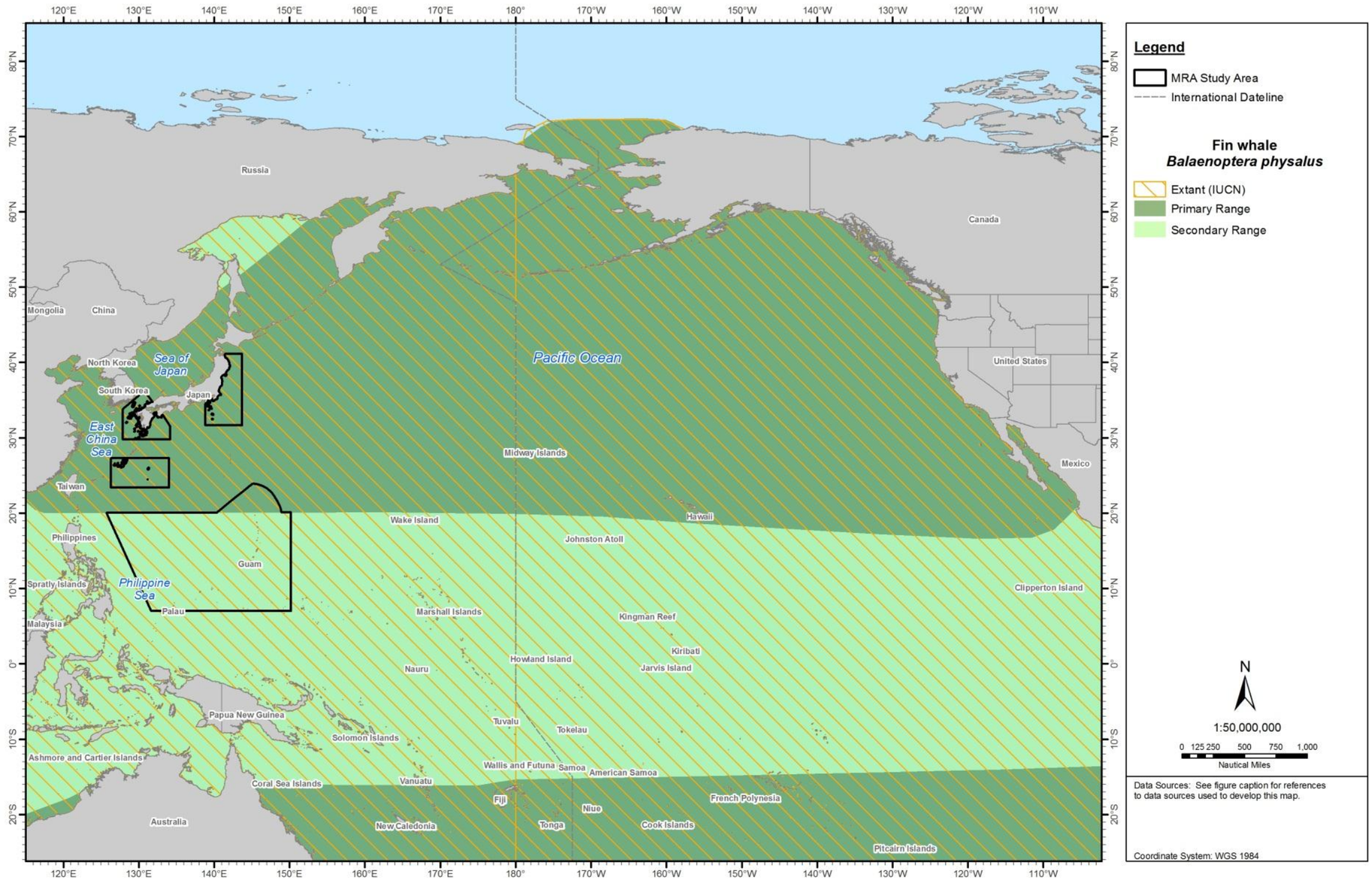

Figure 5-17: Geographic Range of the Fin Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

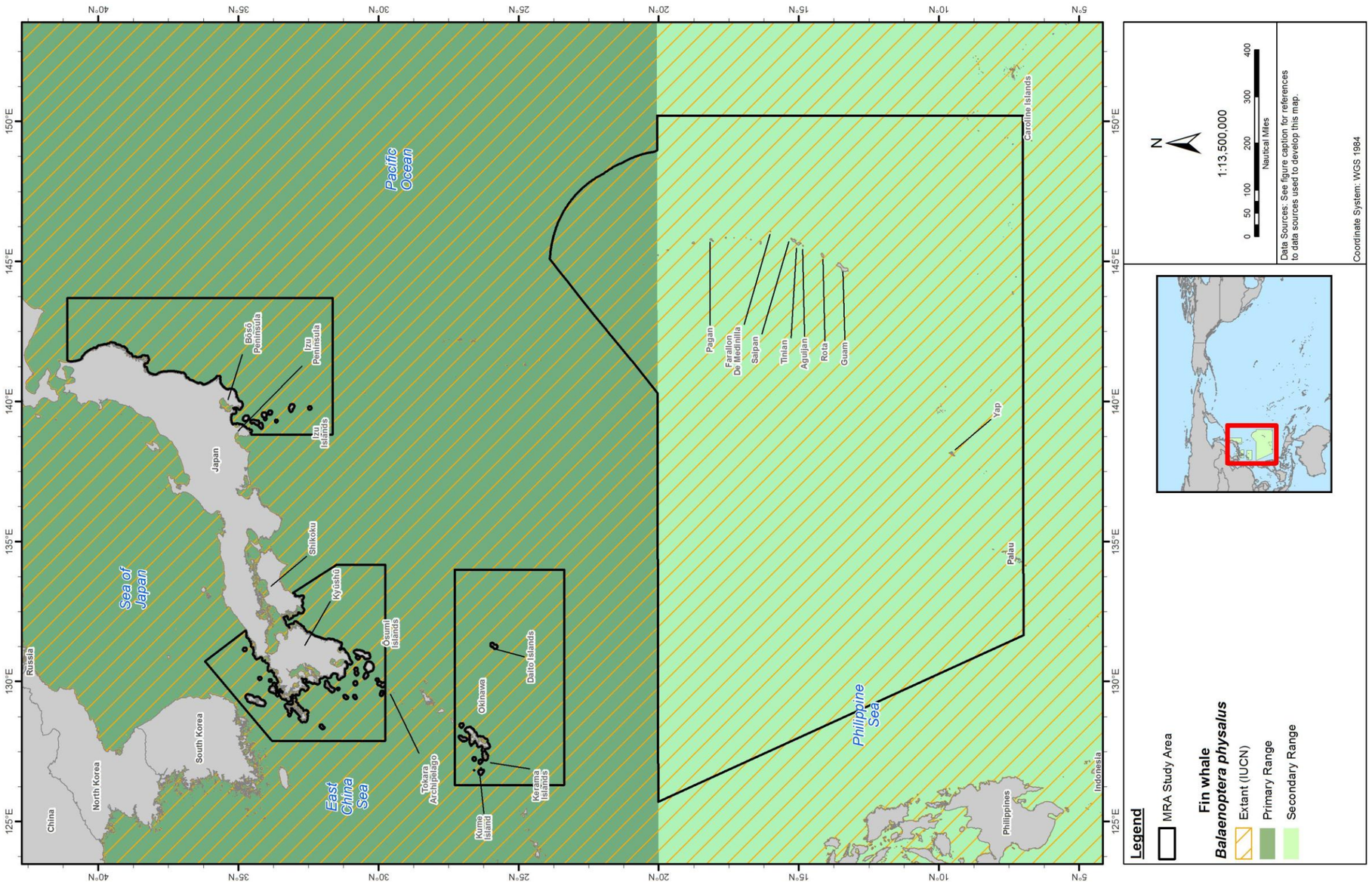

Figure 5-18: Geographic Range of the Fin Whale in the MRA Study Area

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.10 BLUE WHALE (*BALAENOPTERA MUSCULUS*)

5.10.1 Description

The world's population of blue whales can be separated into three subspecies, based on geographic location and some morphological differences. The true blue whales have been divided into two subspecies found in the Northern Hemisphere (*Balaenoptera musculus musculus*) and the Southern Hemisphere (*Balaenoptera musculus intermedia*). The third subspecies, the pygmy blue whale (*Balaenoptera musculus brevicauda*), is known to have overlapping ranges with both subspecies of true blue whales (Best et al. 2003; Reeves, Stewart, et al. 2002).

The blue whale is the largest mammal to have ever lived. They are slender overall, and their head has a very flat profile with two dorsal blowholes. When viewed from above, it is wide and has the shape of a gothic arch. Blue whales have a very small dorsal fin located near the posterior end of the animal, about 3/4 of the way back (Jefferson, Webber, and Pitman 2008).

Adult Antarctic or "true" blue whales are approximately 30 m long (average 24.7 m long), whereas pygmy blue whales are approximately 24.1 m long (Branch, Mikhalev, and Kato 2009; Reeves, Stewart, et al. 2002). Adult blue whales have an average mass of 92,671 kg (Acevedo-Gutiérrez, Croll, and Tershy 2002). The blue whale has approximately 260 to 400 baleen plates on each side of its mouth; these are black in color (pygmy blue whales have somewhat broader baleen). Females grow longer and heavier than males (Reeves, Stewart, et al. 2002). Blue whales have mottled blue-gray bodies. This mottling pattern can be highly variable, and can be used to identify individuals. As a result of their consumption of diatoms, their ventral surface can have a visible yellow sheen.

5.10.2 Status and Management

The blue whale is listed as endangered under the ESA and as depleted under the MMPA. This species is also listed as endangered by the IUCN and falls under Appendix I CITES regulations. For the MMPA stock assessment reports, the eastern North Pacific Stock of blue whales includes animals found in the eastern North Pacific from the northern Gulf of Alaska to the ETP (Carretta et al. 2010). The most current recovery plan for the blue whale was completed in 1998. It details goals for delisting or downlisting this species by determining accurate stock characteristics in order to monitor abundance trends, protecting critical habitat, reducing anthropogenic threats (e.g., vessel collisions, noise pollution, entanglements), through interagency cooperation and outreach (Reeves et al. 1998).

5.10.3 Population and Abundance

Little is known about the current global population size of blue whales. In the North Pacific, up to five distinct populations of blue whales are believed to occur (Reeves et al. 1998). One population estimate for the Pacific Ocean gives 1,400 blue whales in the ETP (Carretta et al. 2005a). The geographically nearest stock assessment population estimate for the Eastern North Pacific stock gives an estimate of 2,497 blue whales. The Central North Pacific stocks have no abundance estimates reported (Carretta et al. 2005a). Possibly, population information can also be obtained via acoustic studies (Stafford et al. 2004; Stafford, Nieukirk, and Fox 2001), whereby distinct call types are associated with specific populations (Stafford, Nieukirk, and Fox 2001). These types of acoustic surveys have found more blue whale vocalizations in the western Pacific than in the east, suggesting populations may be larger than sighting surveys indicate (Rankin, Barlow, and Stafford 2006). Line-transect surveys are also used to estimate population abundance. A survey off the coast of Chile in 1998 using this model-based method

concluded the resident population was 9.5% of pre-exploitation levels, higher than the population estimate (<1% pre-exploitation size) of the Antarctic blue whales (Williams, Hedley, et al. 2011). Widespread whaling over the last century is believed to have decreased the population to approximately 1% of its pre-whaling population size (Branch et al. 2007; Sirovic et al. 2004). Increase in overall blue whale abundance was documented between 1979 and 1994, but no evidence suggests an increase in the population since then (Barlow 1994; Barlow and Taylor 2001; Carretta et al. 2010).

5.10.4 Biology, Ecology, and Behavior

Group Size. Blue whales are found alone or in pairs, though larger groups of 10 or more animals are known to occur within feeding grounds (Jefferson, Webber, and Pitman 2008; Schoenherr 1991).

Predator/Prey Interactions. This species preys almost exclusively on various types of zooplankton, especially krill. They lunge feed and consume approximately 6 tons of krill per day (Jefferson, Webber, and Pitman 2008; Pitman et al. 2007). They sometimes feed at depths greater than 330 ft. (100 m), where their prey maintains dense groupings (Acevedo-Gutiérrez, Croll, and Tershy 2002). Off the coast of California, feeding commonly occurs between 250 and 300 m deep (Calambokidis et al. 2007). The lunge feeding techniques used by blue whales are so effective, despite the high energy demands of diving, that a single foraging dive can provide 90 to 240 times the amount of energy from prey consumption than the dive requires (Smith 2003).

Blue whales have been documented as prey of killer whales (Jefferson, Webber, and Pitman 2008; Pitman et al. 2007). During predation by killer whales, blue whales are known to employ the "flight" strategy, characterized by directional, sustained swimming of speeds over 15 km/hr, common for whales with streamlined bodies that prefer pelagic habitats and calving grounds (Ford and Reeves 2008). Little evidence has accumulated to confirm that killer whales attack this species in the North Atlantic or Southern Hemisphere (Sears and Perrin 2008).

Life History. From data gained through Soviet Union illegal catch data, the length at which 50% of female blue whales become sexually mature is 23.4 m (Branch and Mikhalev 2008). After a gestation period of 11 months, females give birth to a single calf every 2 to 3 years during the winter. Calving is considered to occur in tropical and subtropical waters (Jefferson, Webber, and Pitman 2008).

Migration. Most baleen whales spend their summers feeding in productive waters near the higher latitudes and winter in the warmer waters at lower latitudes (Sirovic et al. 2004). Blue whales in the North Pacific are known to migrate between higher latitude feeding grounds of the Gulf of Alaska and the Aleutian Islands to lower latitude breeding grounds of California and Baja California, Mexico (Calambokidis et al. 2009; Carretta et al. 2005a). These animals have shown site fidelity, returning to their mother's feeding grounds on their first migration (Calambokidis and Barlow 2004). Blue whales belonging to the western Pacific stock may feed in summer, south of the Aleutians and in the Gulf of Alaska, and migrate to wintering grounds at lower latitudes in the western Pacific and central Pacific (Stafford et al. 2004; Watkins et al. 2000). Increasing evidence indicates the presence of a residential group of blue whales in southern California waters (Etnoyer et al. 2006)

Hearing/Vocalization. While no data on hearing ability of this species are available, Ketten (1997) hypothesized mysticetes have acute infrasonic hearing based on apical ratios and the absence of a bony latera support within the ear's anatomy. Changes in vocalization have been documented during seismic exploration events whereby calls increased on the day exploration occurred and while the speaker was operating. This may be behavior compensating for increased background noise (Di Iorio and Clark 2010),

contrasting with the lack of behavioral changes (calls and/or location) during airgun activity in the ETP (Dunn and Hernandez 2009). Also, no consistent changes in foraging activity in blue whales where received sound levels were 140 dB re 1 µPa were reported. Occasional changes in vocalization were recorded during these sound transmissions (Croll, Acevedo-Gutierrez, et al. 2001).

Blue whale vocalizations are long, patterned, low-frequency sounds with durations up to 36 s. (Thomson and Richardson 1995), repeated every 1 to 2 min (Mellinger and Clark 2003). Their frequency range is 12 to 420 Hz, with dominant energy in the infrasonic range at 12 to 25 Hz (Buchan, Rendell, and Hucke-Gaete 2010; Ketten 1998; Mellinger and Clark 2003). Source levels are up to 188 dB re 1 µPa-m (Ketten 1998; McDonald et al. 2001). During the Magellan II Sea Test (at-sea exercises designed to test systems for antisubmarine warfare), off the coast of California in 1994, blue whale vocalization source levels at 17 Hz were estimated in the range of 195 dB re 1 µPa-m (Aburto 1997). In the northeast Pacific, blue whales produce a two-part call: call A is characterized by an AM vocalization with a duration of 17 s., and call B is characterized by an FM call about 19 s. in duration. In the ETP, calls were most abundant from February to June, and with B type calls showing a high diel pattern (calls reduced in daylight hours) (Stafford and Moore 2005). B type calls are produced more frequently by male whales (Oleson, Wiggins, and Hildebrand 2007). In recordings analyzed by Hoffman et al. (2010), synchronization of frequency patterns with minute frequency shifts was detected, possibly indicating fine-scale evolutionary advantage for communication within populations. Vocalizations of blue whales appear to vary among geographic areas (Rivers 1997), with clear differences in call structure suggestive of separate populations for the western and eastern regions of the North Pacific (Stafford, Nieukirk, and Fox 2001); yet, mimicry may occur among certain populations where ranges overlap (Stafford and Moore 2005).

Diving. Blue whales, like other rorqual species, such as the fin whale, lunge on average 2.4 times per dive with a maximum of six times before coming to the surface to breathe (Acevedo-Gutiérrez, Croll, and Tershy 2002; Croll, Clark, et al. 2001). Foraging blue whales off Baja California, Mexico, were found to forage at depths greater than 100 m, with the maximum average depth of 130 ± 50 m during two-lunge dives, 160 ± 35 m during three-lunge dives, and 150 ± 50 m during four-lunge dives (Acevedo-Gutiérrez, Croll, and Tershy 2002). Blue whales, along with fin whales, are known to perform the shortest dives relative to body size of the cetaceans. The theoretical dive limit for blue whales is 31.2 min; however, their foraging dives typically average approximately 7.8 min (Acevedo-Gutiérrez, Croll, and Tershy 2002), with maximum dive durations of 14.7 min (Croll, Clark, et al. 2001). The longest recorded dive was 36 min, but dives over 30 min are considered rare (Sears and Perrin 2008). It has been suggested that blue whales dive with reduced duration to maintain their capabilities to conserve energy, aiming to expend the least amount of energy for the most amount of krill (Smith 2003). Blue whales typically surface before deeper dives and take multiple blows/breaths timed close together. The initial blow may be related to body size and behavioral state of the whale (Best et al. 2003). Blue whales often raise their fluke before a dive, although not in every case (Jefferson, Webber, and Pitman 2008; Whitehead 1985). Although diving requires large amounts of energy, lunge feeding targets high-density krill aggregations, thus yielding an extremely large amount of food energy for the whale (Smith 2003).

5.10.5 Habitat and Distribution

The blue whale inhabits all oceans and spends most of its time near the coast, over the continental shelf, and is sometimes found in oceanic waters. Blue whales typically avoid areas covered by sea ice; however, they do spend much of their time near the ice edge in the Antarctic (Branch 2007; Kasamatsu, Matsuoka, and Hakamada 2000; Sirovic et al. 2004). Changes in sea-surface temperatures that in turn control fronts moving through the water can affect krill movement. Studies show that in colder years

where ice was present, the number of blue whale calls was greater, while in warmer years where ice was absent, whale calls were reduced (Arranz et al. 2011)—likely representing changes in blue whale abundance based on prey availability. Because blue whales feed exclusively on krill, they follow the temporal migration of their krill prey, and therefore spend much of their time along these fronts, sometimes following the melting and freezing of ice edges (Arranz et al. 2011; Doniol-Valcroze et al. 2007). It had been concluded blue whale call locations in the western North Pacific were associated with relatively cold, productive waters and fronts (Moore et al. 2002). Antarctic blue whale-type calls have been detected in the ETP in July (Sirovic et al. 2004).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. Blue whales have a global distribution, in all major oceans and many enclosed seas (Figure 5-19). The range of the blue whale is known to encompass much of the North Pacific Ocean, from Kamchatka (Russia) to southern Japan in the west, and from the Gulf of Alaska south to at least Costa Rica in the east (Reeves et al. 1998).

KUROSHIO CURRENT. Very little information is available for this species within this area. During winter-spring, occurrence of the blue whale is expected in the southern part of this area, beyond the shelf break, based on the assumption that animals would mostly be within the breeding grounds. Any occurrence may be attributable to presence of possible non-migrators or potential resident animals in the more southern portions of the range (as is known from the eastern North Pacific).

EAST CHINA SEA. This species may occur especially during the summer-fall in the Sea of Japan, East China Sea, and the northeast part of the MRA Study Area, although the likelihood is not high and the East China Sea is included in the secondary range of this species (Figure 5-19). Feeding areas are unknown but are presumably north of this area.

PHILIPPINE SEA. The Philippine Sea is included in the known primary range of the blue whale (Figure 5-19 and Figure 5-20).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Waters off the coast of the Japan Archipelago are included in the known primary and secondary ranges of this species (Figure 5-19 and Figure 5-20) but blue whales are expected only seaward of the shelf break. Yet the lack of blue whales off the coast of southern Japan could signify persistence in range shifts resulting from historic whaling (National Marine Fisheries Service). In 1913, a stranded blue whale was reported in the Amami Islands (Miyazaki and Nakayama 1989).

MARIANA ARCHIPELAGO. No occurrence records exist for the blue whale in the Mariana Islands MRA Study Area and vicinity (Figure 5-19 and Figure 5-20), but this area is within the known distribution range for this species. There is a low likelihood of this species occurring seaward of the 50 m isobath—based upon the low likelihood of encountering this species in either coastal or oceanic waters in this area.

CAROLINE ISLANDS. The Caroline Islands are included in the known primary range of the blue whale (Figure 5-19 and Figure 5-20). Whether the blue whale occurs seaward of the 50 m isobath is unknown.

5.10.6 Species-specific Threats

Blue whales were heavily exploited by commercial whalers throughout the earlier part of the twentieth century, and were hunted to "commercial extinction." Because the population of blue whales throughout its range was thought to be decimated to approximately 1% of its pre-exploitation numbers, the overall population is considered unrecovered and populations still must increase before the numbers are back to a stable population size.

In a study of whale vocalization in Saguenay-St. Lawrence Marine Park, blue whales were found to be particularly susceptible to severe masking of their vocalizations from anthropogenic sound sources as a result of their relatively weak calls (30 decibel [dB]) (Simard, Roy, and Gervaise 2008). In the California Blight, blue whale calls were less likely to produce calls in the presence of mid-frequency active sonar. This vocalization response increased as the sonar became closer and louder. Although no diel pattern was observed in their responses, the long-term implications of the call disruption is unknown (Melcon et al. 2012). In California, ship strikes appear to be responsible for the death of some stranded individuals (Berman-Kowalewski et al. 2010).

Because they feed almost exclusively on krill, blue whales are affected by any change in krill populations or distribution. Global warming has induced changes in trends of both distribution and abundance of krill. A change in their prey species that may affect foraging success would hinder the reproductive success of this species, thereby slowing any rise in population numbers of the blue whale (Acevedo-Gutiérrez, Croll, and Tershy 2002; Arrigoni et al. 2011).

This Page Intentionally Left Blank

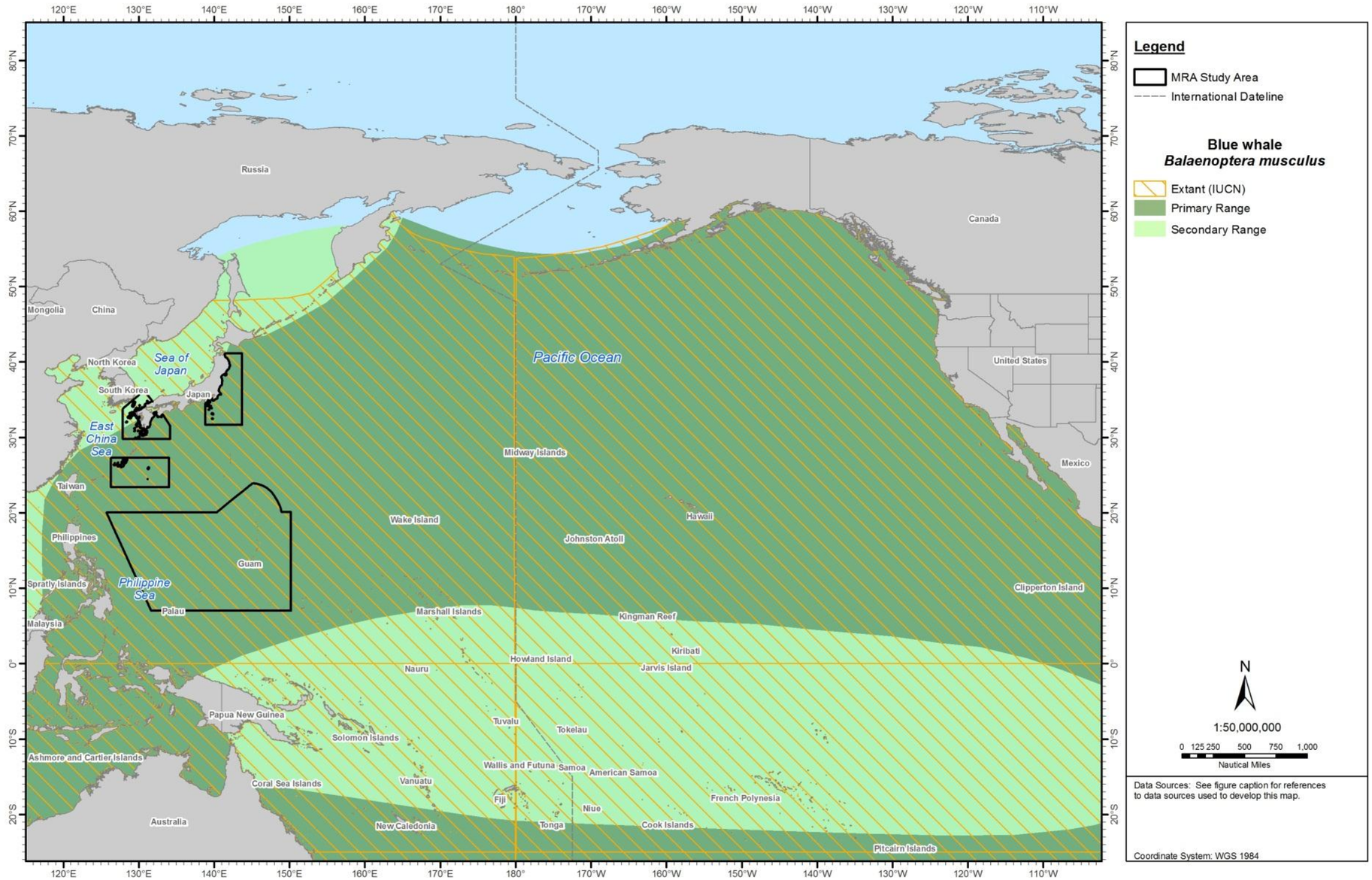

Figure 5-19: Geographic Range of the Blue Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

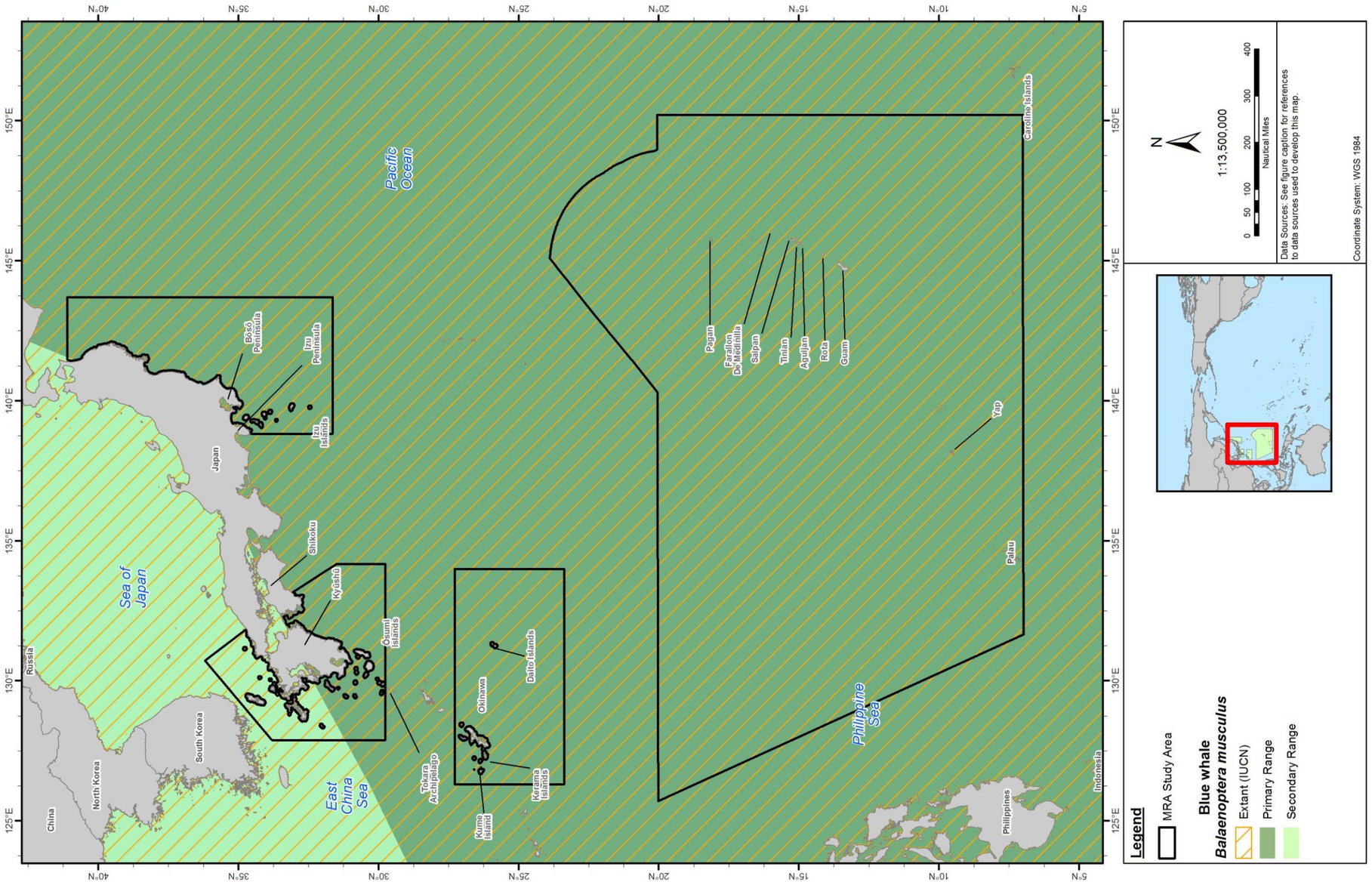

Figure 5-20: Geographic Range of the Blue Whale in the MRA Study Area

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.11 GRAY WHALE (*ESCHRICHTIUS ROBUSTUS*)

The gray whale is not ecpected to occur within the MRA Study Area, yet has been historically documented in Japanese waters. For this reason, updated range maps will not be provided for this species within this MRA.

5.11.1 Description

Gray whales are easily identified by their mottled grayish-brown color and the white to orange patches of whale lice and barnacles attached to their bodies, particularly to their heads and tails (Jefferson, Webber, and Pitman 2008). Instead of a dorsal fin, a dorsal hump is present, followed by a series of 8 to 14 smaller "knuckles" or bumps along the dorsal ridge of the tail stock. The flippers are paddle-shaped with pointed tips. The upper jaw is moderately arched, and the head appears triangular when viewed from the top. Adults are 11 to 15 m long and weigh up to 45,000 kg (Jefferson, Webber, and Pitman 2008); females are slightly larger than males (Leatherwood et al. 1988).

5.11.2 Status and Management

All populations of the gray whale are protected under the MMPA; the Western Pacific population is endangered (foreign) under the ESA and is depleted under the MMPA. The species as a whole is also listed as least concern by the IUCN (Western population is critically endangered) and falls under Appendix I CITES regulations. There are two North Pacific populations of gray whales: the Western population (also known as the western North Pacific or the Korean-Okhotsk population) is critically endangered under the IUCN and shows no apparent signs of recovery, while the Eastern Pacific population (also known as the eastern North Pacific or the California-Chukchi population) appears to have recovered from exploitation and was removed from listing under the ESA in 1994 (Swartz, Taylor, and Rugh 2006). The Western Pacific population has possible range within the MRA Study Area. Gray whales began to receive protection from commercial whaling in the 1930s. However, hunting of the western population continued for many more years. The IWC sets a quota allowing catch of 169 gray whales annually from the eastern population for aboriginal subsistence (United Nations Environment Programme).

5.11.3 Population and Abundance

Two genetically and geographically distinct populations of the gray whale occur in the Pacific—the western and eastern populations—together estimated around 22,000 in abundance (United Nations Environment Programme). The western population is found in the Japan portion of the MRA Study Area. The closest stock assessment completed for this species, surveying the Eastern North Pacific Stock, resulted in an estimate of 19,126 (CV=7.1%) individuals in 2006/07 where an increase in population had been seen recently (Allen and Angliss 2010c). The western population abundance estimate from 1997 to 2003 was between 55 and 109, and was increasing at a rate of approximately 3% annually (Bradford et al. 2008), which would result in an estimated population of 123 in 2010 (Bradford et al. 2008; Jefferson, Webber, and Pitman 2008). Nevertheless, as reported by the (Marine Mammal Commission 2003), the western Pacific populations have shown no true signs of recovery although the IUCN reports a positive population trend (Reilly et al. 2000). The extremely small population size, coupled with the slow rate of population growth, are important factors in the critically endangered status of the Western Pacific population of gray whales.

5.11.4 Biology, Ecology, and Behavior

Group Size. Within the feeding grounds, gray whales are often solitary, but may be near each other at food-rich areas (Leatherwood et al. 1988). During migration, gray whales are predominantly solitary or in small groups; groups of more than six are rare (Jones and Swartz 2009; Rice et al. 1981). In the breeding lagoons, female-calf pairs and groups of consorting adults and juveniles are most common. Female-calf pairs are concentrated in the inner lagoons (Jones and Swartz 2009).

Predator/Prey Interactions. Gray whales are primarily bottom feeders. Their prey includes a wide range of invertebrates living on or near the seafloor; these occur during the summer in dense colonies on the continental shelf seafloor of Arctic regions (Swartz, Taylor, and Rugh 2006). The whales filter amphipods and other crustaceans with their baleen plates. Gray whales occasionally engulf fishes, herring eggs, cephalopods, and crab larvae (Jefferson, Webber, and Pitman 2008; Jones and Swartz 2009; Newell and Cowles 2006). Off the coast of British Columbia, gray whales were noted opportunistically feeding on crab larvae (instead of their primary prey of mysids), and in turn allowing dense aggregation of mysids to reestablish, ensuring the sustainability of this food source (Nelson et al. 2008). Although gray whales generally fast during the migration and calving season, opportunistic feeding may occur in or near the calving lagoons or in the shallow coastal waters along the migration path (Jones and Swartz 2009). During the feeding season, an adult gray whale is known to consume approximately 2,645 lbs. of food (1,200 kg) daily (Jones and Swartz 2009). The whales carry most of the sediment with them when they surface to breathe, creating mud plumes in their wake (Jefferson, Webber, and Pitman 2008; Jones and Swartz 2009). When foraging at the ocean floor, gray whales spend most of their time rolled to the right side of their bodies at an angle greater than 45° (Woodward and Winn 2006).

The gray whale is preyed upon by killer whales, in groups that typically range from 3 to 4 killer whales (Barrett-Lennard et al. 2011). When a retreating grey whale reaches bottom depths of less 3 m, the attack is usually abandoned by the killer whale group (Barrett-Lennard et al. 2011). Killer whales often target gray whale calves. Many individuals exhibit attack scars indicating not all attacks are fatal; however, fatalities are known. Killer whales feeding on carcasses will occur in waters from 15 to 75 m deep, where the carcasses will be periodically abandoned and revisited for several days (Barrett-Lennard et al. 2011). During predation by killer whales, gray whales are known to take evasive action (Baldridge 1972). Killer whales target calves during the spring migration into colder northern waters (Jones and Swartz 2009).

Life History. Both male and female gray whales reach sexual maturity from 6 to 12 years of age (average 8 years of age) (Jones and Swartz 2009). Mating has been observed throughout all months of the year; however, calving season ranges from November to early March. Breaching, spyhopping (raising the head out of the water), and lobtailing are common within the breeding grounds (Jones and Swartz 2009). Pregnancies may last between 11 and 13 months, and females typically give birth to one calf every 2 years. Prior to reaching the Mexican calving grounds, some individuals are born off California (Jefferson, Webber, and Pitman 2008; Jones and Swartz 2009). Survival rates of non-calf and calf western Pacific gray whales is estimated at 0.951 and 0.701, respectively (Bradford et al. 2008). Although females typically return to the same lagoon to calve over the course of their lifetimes, it is not known if individuals generally return to their own birthplaces to calve. While many details of western gray whale life history are unknown, general life history patterns are assumed similar for the two populations (Swartz, Taylor, and Rugh 2006).

Migration. This species makes the longest annual migration of any mammal, 9,320 to 12,425 miles (15,000 to 20,000 km) roundtrip (Jefferson, Webber, and Pitman 2008; Jones and Swartz 2009). The migration connects Arctic feeding grounds with southern mating and calving regions; calving occurs in temperate and in subtropical coastal waters in winter. The western North Pacific population is distributed off the coast of Russia, Japan, North Korea, South Korea, and China (Weller et al. 2002). This population spends the summer and fall feeding in the Okhotsk Sea, particularly along the northeastern coast of Sakhalin Island where gray whales have exhibited seasonal and annual site fidelity (Weller et al. 2002; Weller et al. 1999). The winter calving grounds are unknown but are suspected to be near the coast of the South China Sea and off the east coast of the Korean Peninsula based on sighting and whaling records (Jones and Swartz 2009; Kato and Kasuya 2002). During these north-south migrations, western gray whales remain in shallow, nearshore waters, except when passing through the La Perouse and Tatarskiy Straits off the southern tip of Sakhalin Island or migrating through the Sea of Japan, the Yellow Sea, and the East China Sea (Weller et al. 2002). Possible overwintering has been documented near Barrow, Alaska, and may be correlated with an increase in population size and/or a decrease in sea ice from climate change (Stafford et al. 2007). The northward migration to the feeding grounds occurs in two phases. The first phase in late January through March consists of newly-pregnant females, who go first to maximize feeding time, followed by adult females and males, then juveniles. The second phase, in April through May, consists primarily of mothers and calves who have remained in the breeding area longer, allowing calves to strengthen and rapidly increase in size before the northward migration (Jones and Swartz 2009).

Prior to the turn of the 20th century, two groups of gray whales may have migrated to Japanese waters (Weller et al. 2002). One group possibly migrated along the east coast of Japan from the Kuril Islands and Hokkaidō to Shikoku and entered the Seto Inland Sea, a suggested calving site for this group (Nishiwaki and Kasuya 1970; Omura 1974). The other group, probably part of the Korean stock, occurred off the north coast of Yamaguchi prefecture, in the Sea of Japan, and off the west coast of Kyūshū, in the East China Sea, and migrated along the east coast of Korea and then to southwest Honshū and northwest Kyūshū (Omura 1974). Both east and west coast groups probably migrated to and from the Okhotsk Sea feeding grounds and possibly intermingled in the Seto Inland Sea (Nishiwaki and Kasuya 1970). It has been suggested that the east coast group likely joined the Korean stock (or even the California stock) after being driven from the Seto Inland Sea calving grounds by the increase in industrial development and boat traffic in this area (Omura 1974). Despite (Omura 1974)claim, researchers have since argued that the Seto Inland Sea likely had never been a calving or mating area for western North Pacific gray whales (Weller et al. 2002).

Gray whales are generally slow-moving animals (Jefferson, Webber, and Pitman 2008). Migrating gray whales sometimes exhibit a unique “snorkeling” behavior, whereby they surface cautiously, exposing only the area around the blowhole, exhale quietly without a visible blow, and sink silently beneath the surface (Jones and Swartz 2009).

Hearing/Vocalization. The structure of the gray whale ear has evolved for low-frequency hearing (Ketten 1992b). The ability of gray whales to hear frequencies below 2 kHz has been demonstrated in playback studies (Cummings, Thompson, and Cook 1968; Dahlheim and Ljungblad 1990; Moore and Clarke 2002) and in their responsiveness to underwater noise associated with oil and gas activities (Malme et al. 1986; Moore and Clarke 2002). Gray whale responses to noise include changes in swimming speed and direction to move away from the sound source; abrupt behavioral changes from feeding to avoidance, with a resumption of feeding after exposure; changes in calling rates and call structure; and changes in surface behavior, usually from traveling to milling (Moore and Clarke 2002).

The characteristics of gray whale vocalizations ave been extensively documented Au, Popper, and Fay (2000). Gray whales produce broadband signals ranging from 100 Hz to 4 kHz (and up to 12 kHz) (Dahlheim, Fisher, and Schempp 1984; Jones and Swartz 2009). The most common sounds within the breeding and feeding grounds are knocks (Jones and Swartz 2009), which are broadband pulses from about 100 Hz to 2 kHz, with most energy at 327 to 825 Hz (Thomson and Richardson 1995). The source level for knocks is approximately 142 dB re 1 uPa-m (Cummings, Thompson, and Cook 1968). During migration, individuals most often produce low-frequency moans (Crane and Lashkari 1996).

Diving. When foraging, gray whales typically dive to between 50 and 60 m for 5 to 8 min. In the breeding lagoons, dives usually take less than 6 min (Jones and Swartz 2009), although dives as long as 26 min have been recorded. When migrating, gray whales may remain submerged near the surface for 7 to 10 min and travel 500 m or more before resurfacing to breathe. The maximum known dive depth is 170 m (Jones and Swartz 2009).

5.11.5 Habitat and Distribution

The gray whale has historic range within the Japan portion of the Japan portion of the MRA Study Areas, yet have no recent confirmed citings within either portions of the MRA Study Area. Because this species is not expected to occrur in the MRA Study Area, this species profile does not include updated range maps.

Gray whales primarily occur in shallow waters over the continental shelf and are considered one of the most coastal of the great whales (Jefferson, Webber, and Pitman 2008; Jones and Swartz 2009). Feeding grounds are generally less than 225 ft. (68 m) deep (Jones and Swartz 2009). The breeding grounds consist of subtropical lagoons, which are protected from the open ocean by narrow entrances marked by lines of whitewater over barrier sand bars (Jones and Swartz 2009). These warm water protected lagoons are more conducive to rearing calves and mating, and offer protection from predation by killer whales (Jones and Swartz 2009). Females may also use the shallow lagoons to escape from harassment by courting males, which concentrate at the lagoon entrances and outer coastal areas (Jones and Swartz 2009). In Russian feeding grounds, gray whales have been associated with waters shallower than 30.5 m, and that range from hundreds of m to 5 km offshore (Meier et al. 2007).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. The North Central Pacific Gyre could be a secondary range of this species (Jones and Swartz 2009; Rugh et al. 2008).

KUROSHIO CURRENT. The western North Pacific population ranges from at least the Straits of Korea and Seto Inland Sea of Japan in the south, to the Okhotsk Sea and Kamchatka Peninsula in the north (Jones and Swartz 2009). Several records of gray whales off Hokkaidō suggest few gray whales migrate through this area (Brownell and Kasuya 1999). Occurrence pattern is based largely on whaling and sighting records (Kato and Kasuya 2002; Omura 1974). Based on the lack of specific information on the migration pattern for this very small population and the probability that the monthly spreads of both seasons span both northward and southward migrations, occurrence is assumed similar year-round. They may occur in low numbers in bays and inland seas if individuals stray into inshore waters, although occurrence at 50 nm (93 km) offshore is more likely.

EAST CHINA SEA. Gray whales also extend into the East China Sea and Sea of Japan (Tsushima Strait) based on possible movement pattern toward winter breeding grounds off the coast of Korea in the South China Sea (Figure 5-21).

PHILIPPINE SEA. The Philippine Sea is not a part of the known primary or secondary range of this species (Figure 5-21 and Figure 5-22).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Recent sightings and strandings of gray whales south of the Okhotsk Sea are rare (Brownell and Kasuya 1999). A dead gray whale was recorded off the Sea of Japan coast of Hokkaidō in May 1996 (Brownell and Kasuya 1999). Gray whale records off the Pacific coast of Japan have been extremely scarce (Nishiwaki and Kasuya 1970). One gray whale was sighted in the Ise Bay region on the Pacific coast of central Japan in March to May 1982 (Furuta 1984).

MARIANA ARCHIPELAGO. The coastal waters around the Mariana Islands are not a part of the known primary or secondary range of this species (Figure 5-21 and Figure 5-22).

CAROLINE ISLANDS. The Caroline Islands are not a part of the known primary or secondary range of this species (Figure 5-21 and Figure 5-22).

5.11.6 Species-specific Threats

Gray whales have been known to suffer from entanglements and ship strikes. During a visual survey of anthropogenic scars on whales in Russian waters, (Bradford et al. 2009) calculated 20% of the western population had detectable scarring: 18.7% of scars were attributed to entanglement in fishing gear and 2.0% to ship strikes. Gray whales' behavioral changes during seismic surveys decreased significantly when mitigation measures included a 4 km buffer zone with a reduction of number and total volume of air guns used (Johnson et al. 2007). Gray whales may also be susceptible to the negative effects of climate change, which is anticipated to decrease primary production within current feeding grounds (Coyle et al. 2007).

During a mass stranding in California in 2002, gray whales were found intoxicated with domoic acid, associated with harmful algal blooms and correlated with both inshore and offshore foraging (de la Riva et al. 2009). Gray whales are also susceptible to reparatory bacteria that may negatively impact overall animal health (Acevedo-Whitehouse, Rocha-Gosselin, and Gendron 2010).

This Page Intentionally Left Blank

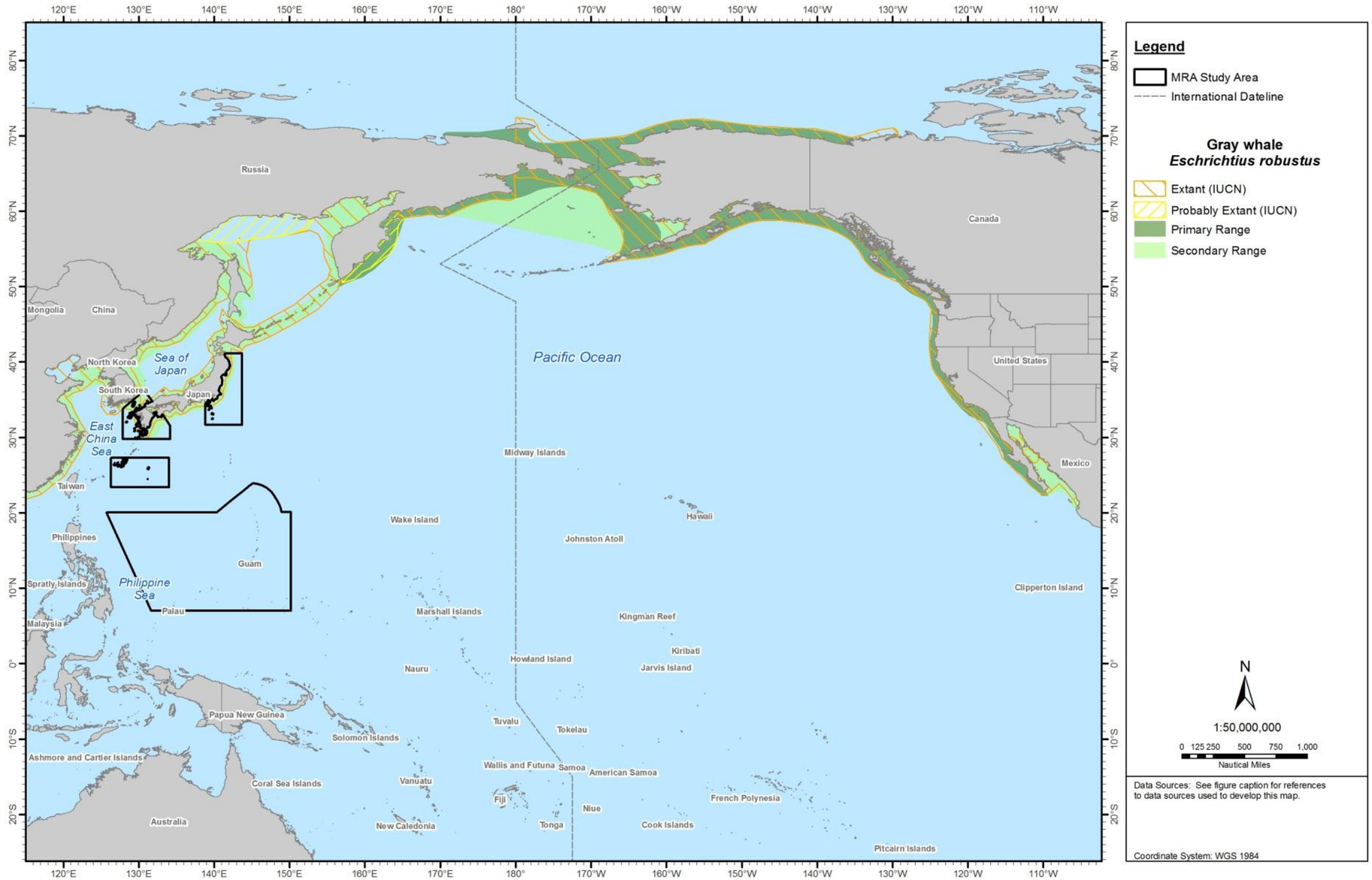

Figure 5-21: Geographic Range of the Gray Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

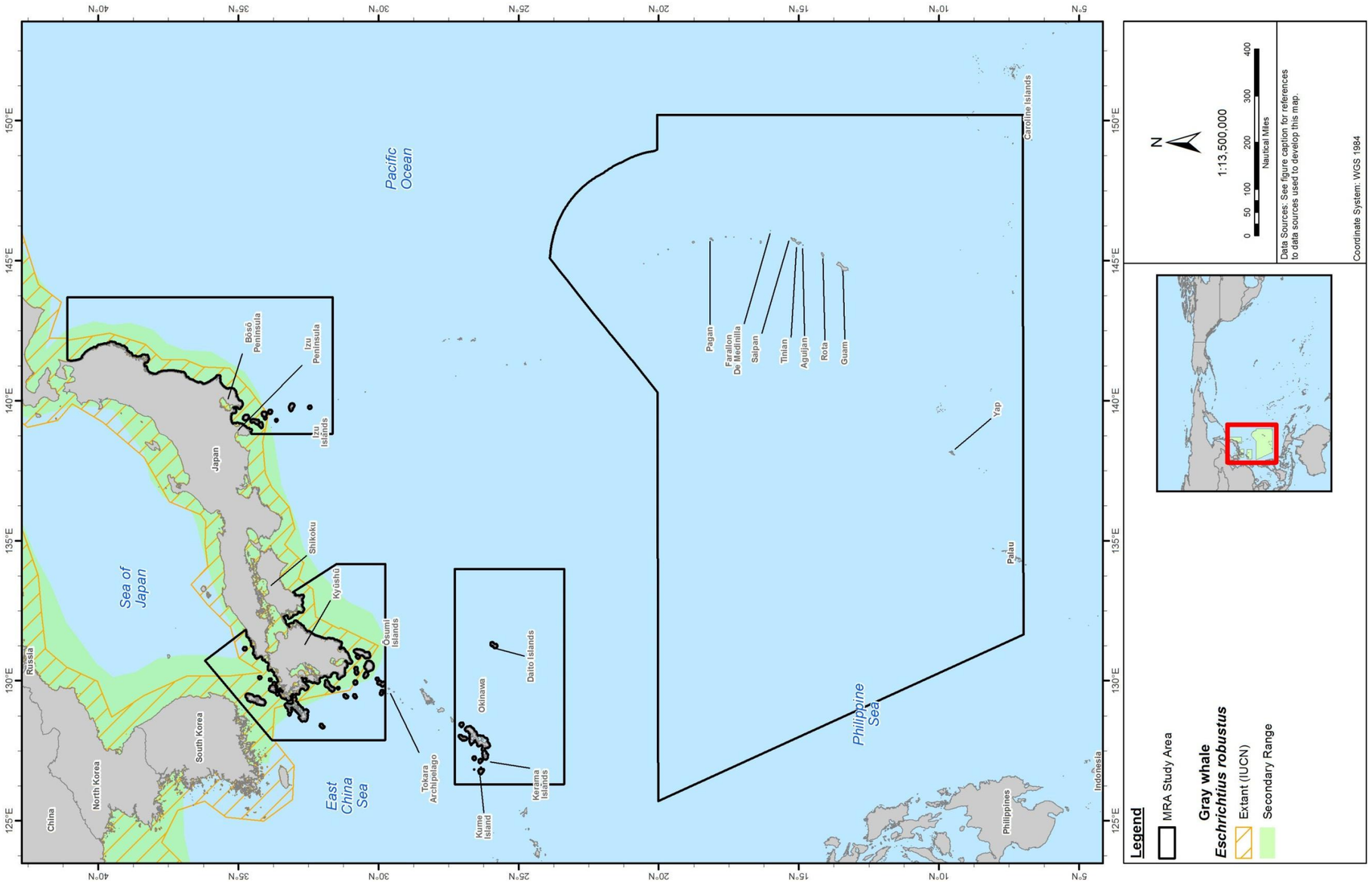

Figure 5-22: Geographic Range of the Gray Whale in the MRA Study Area

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.12 SPERM WHALE (*PHYSETER MACROCEPHALUS*)

5.12.1 Description

Disagreement was longstanding as to whether the sperm whale is more closely related to toothed whales or baleen whales; however, the sperm whale is now firmly considered a toothed whale (odontocete) (Jefferson, Webber, and Pitman 2008). Moreover, some controversy regarding the correct scientific name has evidently been resolved, with the current specification of *Physeter macrocephalus* (Rice 1989).

The sperm whale is the largest species of odontocete, or toothed whale. The head is disproportionately large, comprising one-quarter to one-third of the total body length and is relatively square in shape (Rice 1989). The narrow, rod-shaped lower jaw is underslung, and barely visible when closed due to the size of the massive rostrum. The single blowhole is located at the front of the head and is offset slightly to the left. The flippers are relatively short, wide, and paddle-shaped. There is a low rounded dorsal hump and a series of bumps on the dorsal ridge of the tail stock. The surface of the body behind the head tends to be wrinkled (Rice 1989). The flukes are broad and triangular, with an almost straight trailing edge.

Sperm whales are uniformly brownish-gray to black in color, with white areas around the mouth and often on the belly. On the ventral side, the flanks, and anterior around the mouth area are typically irregular whitish blotches. White scratches and scars are often observed on the bodies, especially the heads of adult males. These are assumed to be caused by both other sperm whales and the beaks of the cephalopods upon which they prey (Jefferson, Webber, and Pitman 2008).

Adult males are up to 18.3 m long and can weigh up to 57,000 kg. Females can reach lengths of 12 m and 24,000 kg. Sperm whales are sexually dimorphic, and males can weigh nearly three times as much as females (Rice 1989). Newborn sperm whales are 3.5 to 4.5 m long and weigh around 1,000 kg. There are 20 to 26 pairs of well-developed teeth in the mandibles (National Marine Fisheries Service 2006).

5.12.2 Status and Management

The sperm whale has been listed as endangered since 1970 under the precursor to the ESA (National Marine Fisheries Service 2009b), and is depleted under the MMPA. This species is also listed as vulnerable by the IUCN and falls under Appendix I CITES regulations. Sperm whales are divided into four stocks in the Pacific (Hawaiian, Alaskan, California Current, and eastern tropical Pacific). These stocks do not have range overlap with the MRA Study Area but sperm whales are known to have primary and secondary range within the MRA Study Area. No critical habitat has been designated for this species in the North Pacific. There are no annual deaths or serious injuries caused by fisheries in the Hawaiian stock (Carretta et al. 2012). For management purposes, the IWC has divided the North Pacific into two management regions defined by a zigzag line that starts at 150°W at the equator, is at 160°W between 40° to 50°N, and terminates at 180°W north of 50°N (Donovan 1991). It should be noted that the sperm whale's ESA status as endangered is somewhat political, and the species is actually in no immediate danger of global extinction (unlike some species, such as the North Pacific right whale).

Japanese scientific whaling permits continue to allow the capture and killing of sperm whales. From 1985 to 2011 special permits takes from pelagic and coastal Japanese waters have totaled 38 and 13 whales, respectively. From June 2010 to August 2010 three sperm whales were harvested from Japan's pelagic waters (International Whaling Comission 2012).

5.12.3 Population and Abundance

An estimated 21,200 to 22,700 sperm whales are present in the ETP Ocean (Wade and Gerrodette 1993), although population estimates are considerably uncertain (United Nations Environment Programme). The geographically nearest stock assessment was for the Hawaiian stock (estimated 6,919 whales [CV=0.81]) (Carretta et al. 2011r). Although many sperm whale populations have been depleted to varying degrees by past whaling activities, sperm whales remain one of the more globally common great whale species.

5.12.4 Biology, Ecology, and Behavior

Group Size. Sperm whales are highly social—perhaps an adaptation from feeding on highly dispersed prey (Ortega-Ortiz et al. 2011). The basic social unit is a mixed group consisting of usually 20 to 40 adult females, calves, and some juveniles (Rice 1989; Wade and Gerrodette 1993; Whitehead 2008). Males eventually leave these groups as juveniles or after reaching sexual maturity, after which they form "bachelor" groups. During their prime breeding period and old age, male sperm whales are essentially solitary, but they rejoin or find nursery groups during prime breeding season (Lettevall et al. 2002; Rice 1989). Females tend to be much more social and form stable, long-term group associations (Whitehead 2003). Sperm whales forage in small clusters and are known to raft (or group) together at the surface. Social structure does not seem correlated consistently with kinship, yet related pairs have been documented (Ortega-Ortiz et al. 2011). Social organization in the Atlantic Ocean differs from that in the Pacific Ocean, possibly due to predator pressures and prey abundance—necessitating site-specific consideration in predicting aspects of sperm whale socialization (Jaquet and Gendron 2009).

Predator/Prey Interactions. Sperm whales socialize for defense against predators and for foraging. Sperm whales feed on squid, other cephalopods, and bottom-dwelling fish and invertebrates (Davis et al. 2007; Marcoux, Whitehead, and Rendell 2007; Rice 1989). In a study in northeast Atlantic waters of sperm whale stomach contents, only cephalopod remains were identified, with over 26 species represented. Of this, over 50% of the biomass identified was composed of the squid *Histioteuthis bonnellii* (Spitz et al. 2011). It has been documented in the Southwest Atlantic that sperm whales remove Patagonian toothfish (*Dissostichus eleginoides*) from bottom-set longlines. Sperm whales were found in over 30% of hauls (Yamamoto, Ito, and Komaba 2001). Foraging behavior within high latitude feeding grounds can vary with depth: high density prey is targeted at depth and low density prey is captured in pelagic waters (Teloni et al. 2008). Exactly how sperm whales search for, detect, and capture their prey remains uncertain.

False killer whales, pilot whales, and killer whales have been documented harassing and on occasion attacking sperm whales (Baird 2009a).

Life History. In the Northern Hemisphere, the peak breeding season for sperm whales occurs between March/April and June (National Marine Fisheries Service 2009b). Studies show females are reproductive up to 40 years of age; males are reproductive at ages much greater than that. Females mature at 7 to 13 years of age; gestation lasts for over a year, possibly more than 15 months. Fighting between males has been observed, and studies show that this competitive behavior is for access to nursery groups (Jefferson, Webber, and Pitman 2008). As a result of selective whaling in the past, which targeted larger breeding males, a strong female bias remains within populations. This may in turn account for reduced birth rates (United Nations Environment Programme n.d.-b). Through observation, it was confirmed suckling occurs through the mouth and not the nasal cavity, as previously proposed (Johnson et al.

2010). In Caribbean waters, as mothers dive for food, other whales (males and females) can escort the calf, and in some instances these female escorts nurse the calf until the mother returns. In some populations, one female is escort to multiple calves, while in others, multiple females are seen caring for calves; variations seem to depend on specific social structure (Gero et al. 2009).

Migration. Sperm whales are somewhat migratory. General shifts occur during summer months for feeding and breeding, while in some tropical areas, sperm whales appear to be largely resident (Rice 1989; Whitehead 2003; Whitehead et al. 2008). Pods of females with calves appear to remain within breeding grounds throughout the year, between 40°N and 45°N (Rice 1989; Whitehead 2003), while males migrate between low-latitude breeding areas and higher-latitude feeding grounds (Pierce et al. 2007). In the Northern Hemisphere, "bachelor" groups (males typically 15 to 21 years old and bulls not taking part in reproduction) generally leave warm waters at the beginning of summer and migrate to feeding grounds that may extend as far north as the perimeter of the Arctic zone. In fall and winter, most return south, although some may remain in the colder northern waters during most of the year (Pierce et al. 2007).

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

Sperm whales produce short-duration (generally less than 3 s.), broadband clicks. These clicks include multiple pulses, representing the time of pulse travel between the air sacs at either end of the whale's head. The timing of such pulses can be correlated and used to approximate the individual's size or body length when no visual of the whale is obtained (Yamada 2001). This can occur through both manual and automated methods (Antunes, Rendell, and Gordon 2010). These clicks range in frequency from 100 Hz to 30 kHz, with dominant energy in two bands (2 to 4 kHz and 10 to 16 kHz). Generally, most of the acoustic energy is present at frequencies below 4 kHz, although diffuse energy exceeding 20 kHz has been reported (Thode et al. 2002). The source levels can be up to 236 dB re 1 µPa-m (Møhl et al. 2003). It has also been suggested that the acoustic directivity (angular beam pattern) from sperm whales must range between 10 and 30 dB in the 5 to 20 kHz region (Thode et al. 2002). The clicks of neonate sperm whales differ significantly from the usual clicks of adults in that these are of low directionality, long duration, and low-frequency (centroid frequency between 300 and 1,700 Hz), with estimated source levels between 140 and 162 dB re 1 µPa-m (Madsen et al. 2003). Clicks are heard most frequently when sperm whales engage in diving/foraging behavior (Miller, Johnson, and Tyack 2004; Whitehead and Weilgart 1991; Zimmer et al. 2005), when males produce clicks during 91% of the dive duration (Teloni et al. 2008). These may be echolocation clicks used in feeding, contact calls (for communication), and/or means of orientation during dives (the latter best suited for mid-range echolocations to locate small prey species with low reflectivity [squid]) (Andre 2009).

When sperm whales socialize, they tend to repeat series of clicks (codas), which follow a precise rhythm and may last for hours (Watkins and Schevill 1977). Codas are shared and repeated between individuals of a social unit, and are considered primarily for intragroup communication and for strengthening of social bonds (Rendell and Whitehead 2004; Schulz et al. 2008; Weilgart and Whitehead 1997). Still, because females live in long-term groups, some signals within the codas are thought to distinguish

individual whales (Winn and Perkins 1976). Research has shown that vocalizations are only occasionally individually specific. Most variations are shared by multiple, though not all, individuals in a group. These broader coda types have been shown to exist within populations, possibly for distinct communication functions such as reproductive status of females or identifications of mother and calf pairs (Schulz et al. 2008) (i.e., possibly not for singling out individual whales (Winn and Perkins 1976). Vocalizations may be a useful tool in localizing individual whales within a group, as explained further in (Hirotsu et al. 2010). Coda types can be broken down into "root," "three pulse," and "regular" calls—each auditorily distinguishable and correlating to specific whale behavior. "Roots" are short (less than 0.15 s.) codas, followed by one or two clicks after an interval of silence 2 to 10 times longer than the coda, and usually associated with surface time in altered dive cycles. The "three pulse" coda has evenly spaced clicks separated by 0.25 s. of inactivity, and correlates with ascents or descents during feeding dives. "Regular" coda type is characterized by three evenly spaced clicks with varying tempo during interaction among whales (Frantzis and Alexiadou 2008). Codas produced at breeding grounds are most often from mature females (Marcoux, Whitehead, and Rendell 2006).

Diving. Sperm whales are capable of dives deeper than 6,560 ft. (2,000 m), with durations greater than 60 min (Watkins et al. 1993). Males spend up to 83% of daylight hours underwater (Jaquet, Dawson, and Slooten 2000), while females spend prolonged periods of daylight hours at the surface (1 to 5 hours daily) without foraging (Amano and Yoshioka 2003; Whitehead and Weilgart 1991). During slow ascents and surface time, sperm whales have been seen drift-diving, a possible sleep pattern. Through these observations, researchers are led to believe bi-hemispheric sleep periods occur for this species (Miller et al. 2008). The average swimming speed is estimated as 0.7 m/s.. Dive descents for tagged individuals averaged 11 min, at a rate of 1.52 m/s. (Watkins et al. 2002). Ascents averaged 11.8 min, at a rate of 1.4 m/s.. Around the Ogasawara Islands, bursts of speed averaging 11 ft. per s. have been documented in one-third of deep dives greater than 400 m, indicating these rapid accelerations are not always correlated to prey capture. The bursts are characterized by a drastic acceleration with active stroking followed by a rapid deceleration and alteration in body orientation (Aoki et al. 2012). In this same area of Japan, significant diel variation in diving behavior was seen whereby day dives were deeper (853 m versus 496 m) and faster (2.0 m/s. versus 1.5 m/s.) (Aoki et al. 2007). Average surface time between dives was less than 4 min, with five to six blows per minute (Watkins et al. 2002).

5.12.5 Habitat and Distribution

Sperm whales strongly prefer deep waters (Rice 1989; Whitehead 2003). Their distribution is typically associated with waters over the continental shelf break, over the continental slope, and into deeper waters. However, in some areas, adult males are reported to consistently frequent waters with bottom depths less than 330 ft. (100 m) and as shallow as 130 ft. (40 m) (Gannier 2009; Jefferson, Webber, and Pitman 2008; Romero et al. 2001). Typically, sperm whale concentrations correlate with areas of high productivity. These areas are generally near drop offs and areas with strong currents and steep topography (Gannier and Praca 2007; Jefferson, Webber, and Pitman 2008). Off the coast of Italy, sperm whales were associated with habitats characterized by well-defined depth and slope gradient, on the shelf-edge and the upper and lower slope (Azzellino et al. 2008). The main sperm whaling feeding grounds correlate with increased primary productivity caused by upwelling. Sperm whales in the Gulf of Mexico aggregate at the mouth of the Mississippi River and along the continental slope in or near cyclonic (cold-core) eddies (Davis et al. 2007). This is thought to be the case worldwide in many other areas of steep topography and high productivity from upwelling (Jefferson, Webber, and Pitman 2008).

The sperm whale is thought to have a more extensive distribution than any other marine mammal except the killer whale. This species is found in polar to tropical waters in all oceans, from approximately 70°N to 70°S (Rice 1989). It ranges throughout all deep oceans of the world, essentially from equatorial zones to the edges of the polar pack ice. Historical accounts of whaling by Indigenous (1981 to 1986), British (1820 to 1840), and American (1825 to 1880) commercial vessels in Philippine waters may explain a reduction in range and abundance of sperm whales in this area (Acebes 2009).

As in many other aspects of sperm whale biology, the two sexes exhibit very different distribution patterns. Females are normally restricted to areas with sea-surface temperatures exceeding 15°C, whereas males, especially the largest males, can be found in waters bordering pack ice (Rice 1989). The thermal limits of female distribution are roughly around the 40° to 50˚ parallels, whereas bulls are often observed solitarily to the extreme north and south regions of their range (poleward of 40˚ and 50˚) (Jefferson, Webber, and Pitman 2008). In the Southern Ocean, adult males occur during the summer south to Antarctica (65° to 70˚). The limits of females in the North Atlantic are poorly documented but they probably range north to the Subpolar Convergence of the Gulf Stream and the Labrador Current (45° to 50˚N) (Romero et al. 2001). Sperm whale distribution includes semi-enclosed seas with deep entrances such as the Gulf of Mexico, Caribbean Sea, Gulf of California, Sea of Japan, and Mediterranean Sea (Jefferson, Webber, and Pitman 2008). In the North Pacific, sperm whales range into the South China Sea, the East China Sea, the Sea of Japan, the Okhtosk Sea, the Bering Sea, the Gulf of Alaska, and the Gulf of California (Rice 1989).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. This species is typically found in the temperate and tropical waters of the Pacific (Rice 1989). The secondary range includes the areas of higher latitudes (Jefferson, Webber, and Pitman 2008; Whitehead 2008). Sperm whale range is found within the North Central Pacific Gyre (Figure 5-23).

KUROSHIO CURRENT. They regularly occur throughout the entire Japan MRA Study Area (Figure 5-23). Sperm whales are expected to occur seaward of the shelf break in the Japan MRA Study Area, including in the south Sea of Japan and East China Sea . In some locales, sperm whales also may be found in waters less than 100 m deep (Croll 1999; Scott and Sadove 1997); sperm whales have frequently been sighted near coastal areas of Japan (Yoshioka et al. 1999).

EAST CHINA SEA. Sperm whales are expected to occur seaward of the shelf break in the Japan MRA Study Area, including in the south Sea of Japan and East China Sea (Figure 5-23 and Figure 5-24).

PHILIPPINE SEA. The Philippine Sea is included in sperm whale primary and secondary ranges, and is expected in this part of the MRA Study Area (Figure 5-23 and Figure 5-24).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Whaling catches off the Amami Islands were recorded during the whaling season of December to April (Miyazaki and Nakayama 1989). Some north-south movement is evident along the east coast of Japan; female groups are known to move north in the summer (to breed north of the Kuroshio/Oyashio front of the east coasts of Honshū and Hokkaidō) and return south during the fall and winter, possibly to the Ogasawara Islands, which may serve as a nursing ground (Kasuya 1971, 1999b; Mori 1999). Occurrence pattern is assumed similar throughout the year. Some encounters with this species are possible in shallow waters, although low sperm whale occurrence is expected from the

shoreline to the shelf break along the east coast of Japan and around the Ryukyu and Ogasawara Islands. Sperm whales are not expected in bays. They are found mainly offshore but are also seen in areas where the continental slope is close to shore, particularly off the coast of Cape Muroto, an area known for sperm whale watching (Figure 5-24) (Hoyt 1993).

Bōsō Peninsula, Izu Peninsula, and Izu Islands. Whaling grounds are located off the coast of Hokkaidō, Sanriku, Bōsō, and the Ogasawara Islands (Kasuya and Miyashita 1988).

MARIANA ARCHIPELAGO. Sperm whales are expected to occur seaward of the shelf break into waters with bottom depths similar to the open ocean (>200 m). They are expected in the Mariana Islands MRA Study Area and vicinity (Figure 5-25). Whaling records demonstrate sightings year-round around the Mariana Islands (Fulling, Thorson, and Rivers 2011; Townsend 1935; U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007). In some locales, sperm whales also may be found in waters less than 100 m deep (Croll 1999; Scott and Sadove 1997). Encounters with this species in shallow waters are somewhat possible, although sperm whale occurrence may be expected from the 50 m isobath to the shelf break (Figure 5-25). This occurrence prediction is based upon the possibility of finding this typically deepwater species in insular shelf waters closely proximate to deep water. As in other areas where sperm whales are found in shelf waters, this would likely be due to prey occurrence. Two stranding records for this area are available (Eldredge 1991, 2003; Kami and Lujan 1976). Sperm whale occurrence pattern is assumed similar throughout the year. North of the map extent shown on Figure 5-25, one sighting of three sperm whales occurred. This sighting was 8.3 km north of Anatahan during March 2003 (Vogt 2004). Twenty-one sperm whales were sighted in the Mariana Islands MRA Study Area during a 2007 survey (U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007), and acoustical recordings of the species in the area indicated the possibility that more individuals were present (Norris et al. 2011). Six sperm whales were sighted in the waters near the Challenger Deep at a depth of less than 8,000 m (Fulling, Thorson, and Rivers 2011). Details of sightings and behavior of these sighted whales are available in (U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007).

Pagan. Five sperm whales were sighted south of Pagan in 2007; three of these were 50-100 nm southwest of the island, and two were east-southeast 75-100 nm offshore (Fulling, Thorson, and Rivers 2011).

Saipan. A single sperm whale was sighted in a 2010 survey about 15 nm off the northern tip of Saipan (Ligon, Deakos, and U 2011). Two sperm whales were sighted north of Saipan in 2007 (Fulling, Thorson, and Rivers 2011).

Tinian. Three sperm whales were sighted south of Tinian in 2007 (Fulling, Thorson, and Rivers 2011).

Guam. In June 2001, a group of sperm whales that included a newborn calf was sighted off the west coast of Guam (Eldredge 2003). In 2007, a cetacean survey team spotted one sperm whale off the western coast of Guam, and another whale 100 nm east of the island (Fulling, Thorson, and Rivers 2011). In a 2012 survey, a single sperm whale was sighted close to the western coast of the island (HDR 2012).

Orote Peninsula Ecological Reserve Area – During a cetacean survey, one sperm whale was seen south of Orote Point (Ligon, Deakos, and U 2011).

CAROLINE ISLANDS. The Caroline Islands are included in sperm whale primary and secondary ranges, and they are expected in this part of the MRA Study Area; however, they are not likely to be found in coastal waters (Figure 5-23 and Figure 5-24).

5.12.6 Species-specific Threats

Sperm whales were the primary targets of whalers in the mid-18th to the mid-19th centuries, with an estimated 1,000,000 sperm whales taken. These massive mammals were hunted almost exclusively for the oil extracted from boiled-down blubber and from inside the head. A second phase of exploitation occurred from 1945 to 1988, and taking sperm whales virtually ceased with implementation of a moratorium against whaling by the IWC in 1988. Their abundance is currently estimated at one third the original numbers, although they are still directly hunted in a few regions, including a minor catch by primitive means in Lamalera, Indonesia, and takes by Japan identified as takes for scientific reasons (National Marine Fisheries Service). Some evidence also suggests illegal hunts of sperm whales in some parts of the world.

Among the current potential threats are collisions with vessels, entanglement in fishing gear, reduced prey as a result of overfishing, habitat degradation, disturbance from high-frequency noise, and the possibility of illegal or resumed legal whaling at biologically unsustainable rates. A study in the Gulf of Mexico revealed that sperm whales did not exhibit avoidance behavior when exposed to airgun arrays, but did change vocalizations associated with foraging and reduced predation attempts at received levels below the regulated thresholds of 160 dB re 1 µPa (Miller et al. 2009). Not only entanglements, but ingestion of marine debris such as ropes and miscellaneous plastics can be fatal for sperm whales, causing ruptured stomachs, gastric impaction, and starvation (Jacobsen, Massey, and Gulland 2010).

Stranding events have been recorded for sperm whales but at relatively low numbers. A stranded body can aid researchers in deciphering the cause of mortality, but may elucidate habitat preferences and population trends over time. A stranding survey from 1877 to 2005 in New Caledonia, the Loyalty Islands, and Vanuatu indicated that sperm whale strandings occurred more commonly in the spring and autumn (Borsa 2006). In a survey of the Adriatic Sea from 1555 to 2009, mortality events involving multiple individuals occurred 17% of the time; live strandings included multiple whales at least 29% of the time. The reasons for these strandings are largely unknown (Won and Yoo 2004). Autopsies were performed on three whales recovered from a 2009 stranding of seven individuals included in the (Won and Yoo 2004) survey. The seven whales in this study seem to have been from the same Mediterranean population but different groups (Terasawa et al. 1997). Skin copepods were present indicating poor health, and starvation was noted. Fishing nets were present in all digestive tracts, although lack of blockage precluded this as the cause of the stranding. It is still unknown why these seven whales beached themselves at the same time (Terasawa et al. 1997). In an analysis by Carvalho et al. (2010) of strandings off the coast of Brazil, sperm whales were shown susceptible to parasites. For more detailed information on specific host-parasite species identified through this study, refer to (Carvalho et al. 2010). Sperm whales are also susceptible to respiratory bacteria, and these may negatively impact overall animal health (Acevedo-Whitehouse, Rocha-Gosselin, and Gendron 2010). The possible effects of pollution on sperm whales remain poorly understood. Although published evidence indicates that levels of mercury, cadmium, and certain organochlorines in sperm whale's tissue were high enough to cause concern about toxicity, no clear link between contamination and strandings has been found (NMFS 2006). Hexavalent chromium, heavily used in industry and commercial products, has been found in sperm whale tissue at concentrations found in human, occupationally exposed workers who have lung cancer. Chromium was detected at greatest concentrations in sperm whales occurring within the waters off Kiribati, the Seychelles, and Sri Lanka (Wise et al. 2009). Cancer in sperm whales is attributed to environmental contaminants, although it is unknown whether those chromium concentrations would cause cancer in this species. Those chromium levels are known to be toxic to sperm whale skin cells and to the integrity of their genetic material (Yamada and Yamada 1999). Concentrations of butylin and

phenyltin were found in the organs and tissue of sperm whales off the coast of Thailand (Harino et al. 2007a).

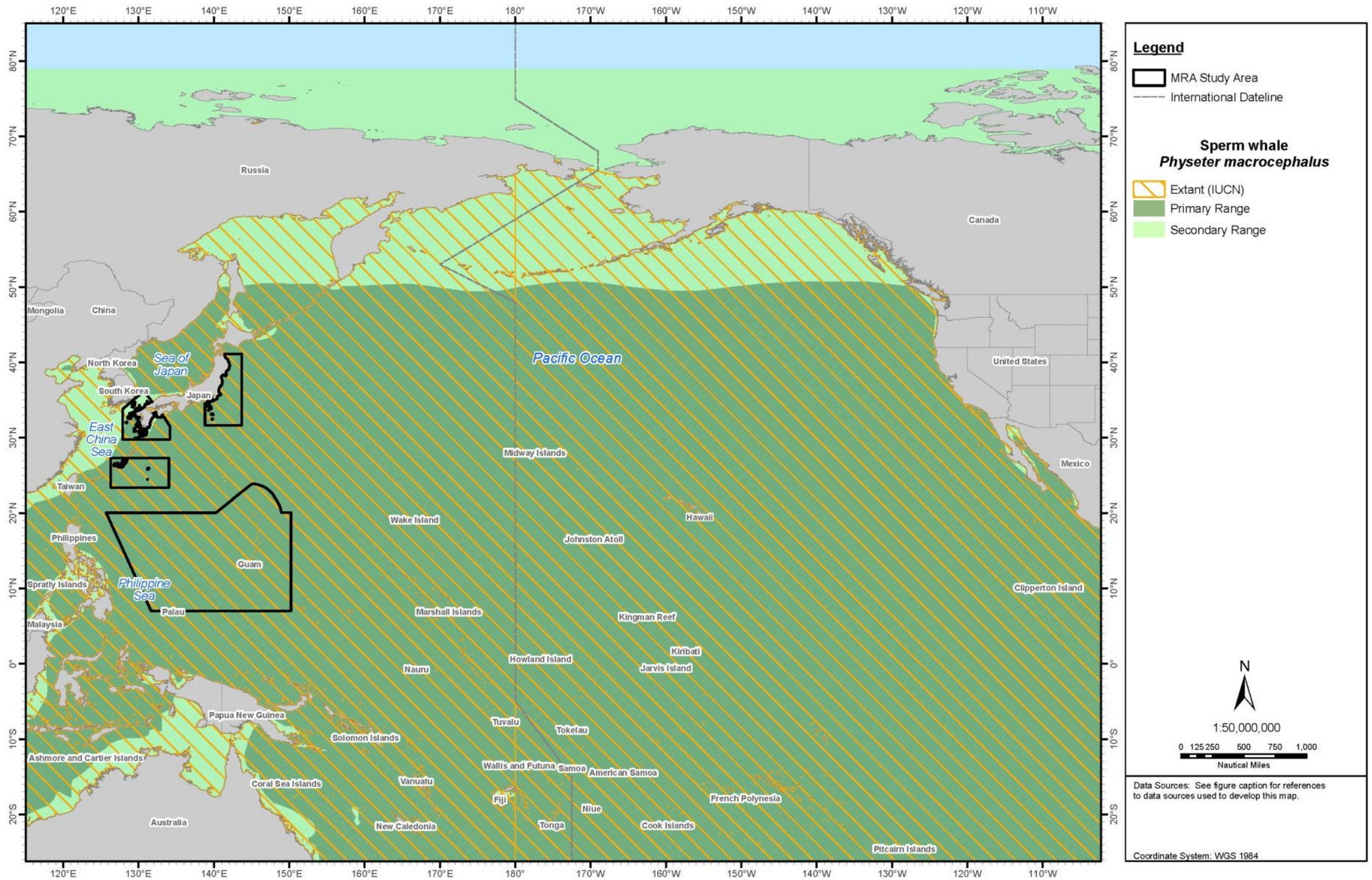

Figure 5-23: Geographic Range of the Sperm Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

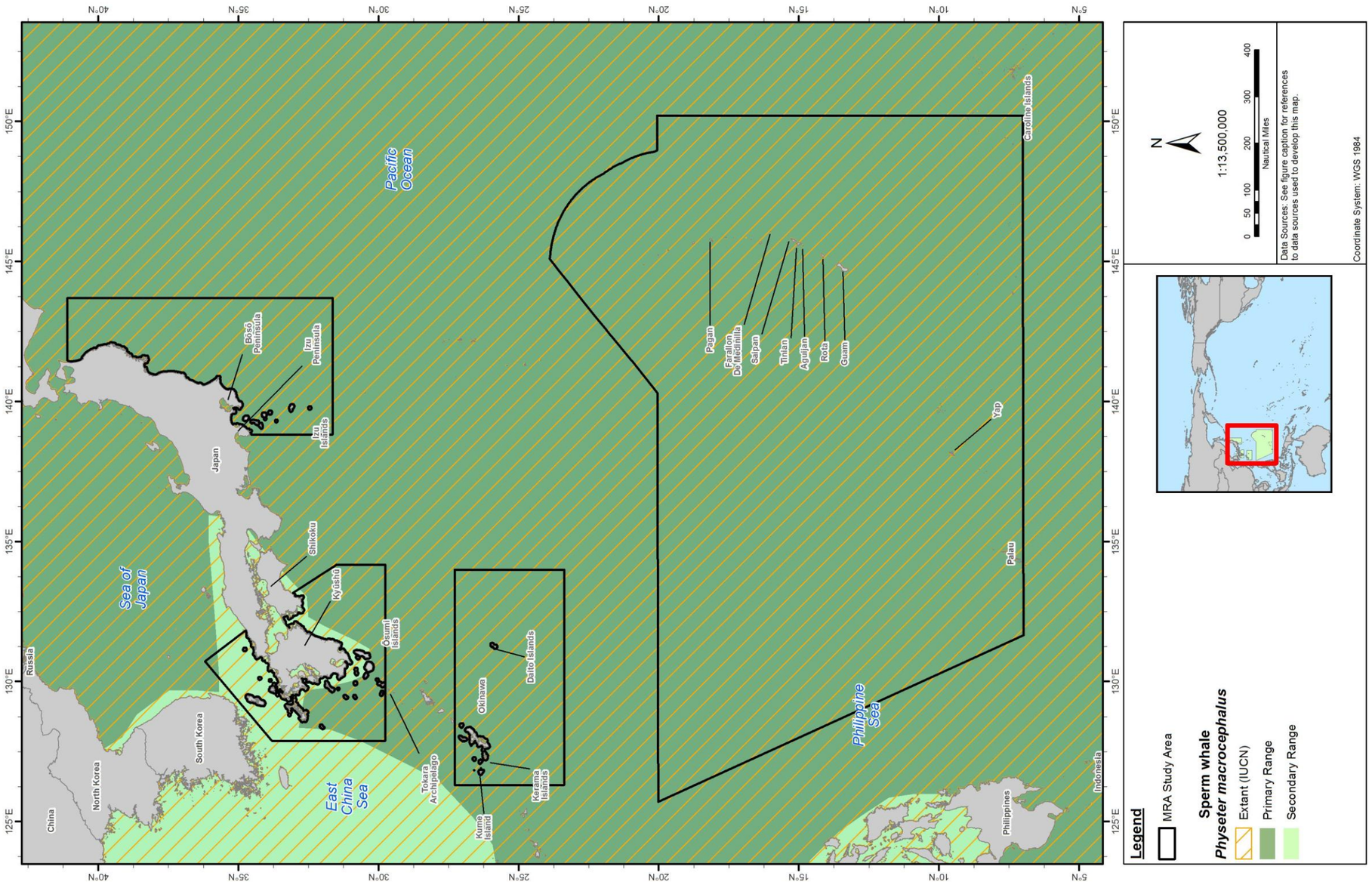

Figure 5-24: Geographic Range of the Sperm Whale in the MRA Study Area
Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

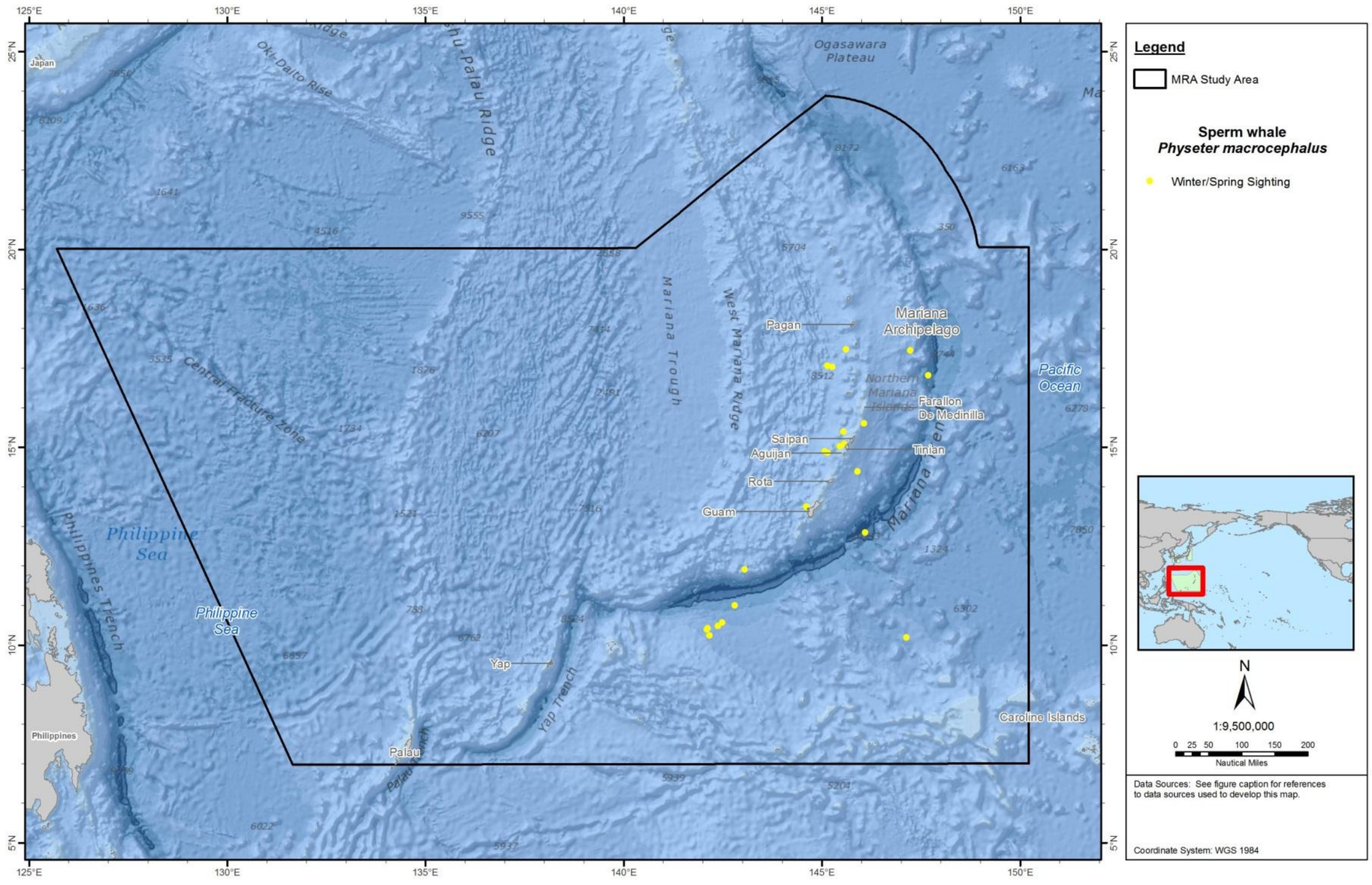

Figure 5-25: Sightings of the Sperm Whale in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented.
Sources: Fulling, Thorson, and Rivers (2011); HDR (2012); U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific (2007).

This Page Intentionally Left Blank.

5.13 PYGMY SPERM WHALE (*KOGIA BREVICEPS*)

5.13.1 Description

The two species of *Kogia* are the pygmy sperm whale (*Kogia breviceps*) and the dwarf sperm whale (*Kogia sima*). Before 1966, when morphological distinction was shown, they had been considered the same species (Handley 1966). Misidentifications of these two species are common (Jefferson, Webber, and Pitman 2008).

Pygmy sperm whales are difficult to observe and to identify except in very calm waters. They have an unusual body shape and look similar to a small sperm whale. Pygmy sperm whales are robust animals, with blunt, square heads that resemble the true sperm whale, and they appear somewhat shark-like. The head is thought to become squarer in older animals. Their bodies taper greatly behind the dorsal fin. The dorsal is strongly falcate, and a hump often appears between the blowhole and dorsal (Jefferson, Webber, and Pitman 2008).

This species is countershaded generally dark brownish-gray on the dorsal side, with a slightly lighter, whitish-pink belly. They have a white “bracket mark” or false gill slit on the head just behind the eye that gives the animal a shark-like appearance and is understood to be an adaptation mimicking their shark predators. A ring of darker color surrounds each eye.

Pygmy sperm whales are much larger than dwarf sperm whales, reaching body lengths of about 2.7 to 3.8 m. Females are slightly larger than males. Adults may reach weights of 450 kg. The lower jaw of the pygmy sperm whale contains 12 to 16 pairs of long, sharp, fang-like teeth that fit into the sockets in the upper jaw. The upper jaw has no teeth (Jefferson, Webber, and Pitman 2008).

5.13.2 Status and Management

The pygmy sperm whale is protected under the MMPA and is not listed under the ESA. This species is also listed as data deficient by the IUCN and falls under Appendix II CITES regulations In U.S. waters the pygmy sperm whale has been divided into four stocks: Hawaiian, California/Oregon/Washington, Northern Gulf of Mexico, and the Western North Atlantic (Carretta et al. 2010). There are no annual deaths or serious injuries caused by fisheries in the Hawaiian stock (Carretta et al. 2012). Although none of these stocks have range within the MRA Study Area, pygmy sperm whales are known to have primary and secondary range within the MRA Study Area.

5.13.3 Population and Abundance

The geographically nearest stock assessment was for the Hawaiian stock (estimated 7,138 whales [CV=1.12]). No trend data are available for the Hawaiian stock (Carretta et al. 2011r). No abundance estimates are available for *Kogia spp*. in the MRA Study Area.

5.13.4 Biology, Ecology, and Behavior

Very little is understood regarding the ecology and behavior of the pygmy sperm whale. Rare sightings indicate they are shy, and rarely active at the sea surface. They usually appear slow and sluggish, often resting motionless at the surface with no visible blow (Baird 2005; Jefferson, Webber, and Pitman 2008). Pygmy sperm whales are not often observed at sea, but they are one of the more frequently stranded cetaceans (Caldwell and Caldwell 1989; Jefferson, Webber, and Pitman 2008; McAlpine 2009).

Group Size. Generally, pygmy sperm whales congregate in small groups of less than five to six (Bloodworth and Odell 2008; Jefferson, Webber, and Pitman 2008).

Predator/Prey Interactions. Pygmy sperm whales feed on cephalopods and, less often, on deep-sea fishes and shrimps (Beatson 2007; Caldwell and Caldwell 1989). Stomach samples revealed an extreme diversity of cephalopod prey, with 38 species from 17 different families (West et al. 2009), in the northeastern Atlantic, stomach contents included 18 cephalopod species, 4 fishes, and 3 crustaceans (Spitz et al. 2011); this survey identified the most dominant prey species as the small squid, *Histioteuthis reversa* (Spitz et al. 2011). Pygmy sperm whales feed in four stages beginning with a preparation; then the jaw opens, followed by gular depression (closure of the gular grooves, a unique structure in the mouth of this species), and ending in closure of the jaw (Bloodworth and Marshall 2005).

Pygmy sperm whales have not been documented to be prey to any other species, although they are likely subject to occasional killer whale predation like other whale species.

Life History. Sexual maturity generally occurs at around 4 years of age in both sexes of this species; however, onset of sexual maturity in males has been reported as early as 2.5 years (Plon 2004). Sperm competition occurs among males (Plon 2004). Females can reproduce annually (Bloodworth and Odell 2008; Jefferson, Webber, and Pitman 2008). Pregnancy may last approximately a year, and calves nurse for almost a year (Caldwell and Caldwell 1989).

Migration. Little is known about possible migrations of this species. No specific information regarding routes, seasons, or resighting rates in specific areas is available.

Hearing/Vocalization. An auditory brainstem response study indicated that pygmy sperm whales have their best hearing between 90 and 150 kHz (Thomson and Richardson 1995).

Pygmy sperm whale clicks range from 60 to 200 kHz, with a dominant frequency of 120 kHz (Thomson and Richardson 1995).

Diving. Pygmy sperm whales are considered a deep-diving species, based on stomach contents, oxygen levels in the blood, and long dive durations (Bloodworth and Odell 2008; Wang et al. 2002). Stomach content analysis found that the depth to which juveniles feed is at least 500 m, and adults dive to depths of 650 to 1100 m. One of the main sources of prey for the pygmy sperm whale is the mysid (a small shrimp-like crustacean), *Gnathophausia ingens,* which has been recorded from depths of 210 to 3,915 m, although it is most common between 600 and 1,500 m (Beatson 2007). The pygmy sperm whale may dive deeper to feed on larger and deeper ranging squid than does the dwarf sperm whale (Barros and Duffield 2003; Plon 2004; Ross 1979).

5.13.5 Habitat and Distribution

Little is known of habitat preferences of this species. Pygmy sperm whales have been observed in both oceanic and coastal habitats, and are believed to move inshore during spring and summer months, presumably to feed (Sekiguchi, Klages, and Best 1992). However, several studies have suggested that this species generally occurs beyond the continental shelf edge (Bloodworth and Odell 2008; MacLeod, Hauser, and Peckham 2004). The pygmy sperm whale frequents more temperate habitats than the other *Kogia* species, which is more of a tropical species.

They are believed to have a circumglobal band of distribution across temperate and sub-Antarctic waters between the latitudes of 20°S and 55°S (Ivashin and Rovnin 1967).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. Records of this species from both the western (Japan) and eastern Pacific (California) suggest that the range of this species includes the North Pacific Central Gyre and North Pacific Transitional provinces (Carretta et al. 2010; Jefferson, Webber, and Pitman 2008; Katsumata, Ohishi, and Maruyama 2004; Marten 2000; Norman et al. 2004). Their range generally includes tropical and temperate warm water zones (Figure 5-26) and is not likely to extend north into subarctic waters (Bloodworth and Odell 2008; Jefferson, Webber, and Pitman 2008).

KUROSHIO CURRENT. The pygmy sperm whale generally prefers more temperate waters (Plon 2004). It is found mostly offshore of the continental shelf (Plon 2004). Therefore, occurrence of pygmy sperm whales in the Japan MRA Study Area is expected seaward of the shelf break, north of the southern tip of the main islands of Japan (Figure 5-27). Occurrence data from elsewhere off the shelf break, including in the Korean Strait and the Sea of Japan, are not available. Pygmy sperm whales are not expected from the shoreline to the shelf break around the Okinawa, Amami, and Ogasawara Islands. Occurrence pattern is assumed the same throughout the year.

EAST CHINA SEA. The East China Sea is a part of the known primary range of the pygmy sperm whale (Figure 5-26 and Figure 5-27).

PHILIPPINE SEA. The Philippine Sea is a part of the known primary range of the pygmy sperm whale (Figure 5-26 and Figure 5-27).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Although deep oceanic waters are the primary habitat for pygmy sperm whales, only a few oceanic sightings offshore have been recorded. However, this may be because of the difficulty of detecting and identifying these animals at sea (Caldwell and Caldwell 1989; Maldini, Mazzuca, and Atkinson 2005).

MARIANA ARCHIPELAGO. Only one stranding record of one pygmy sperm whale is available (Eldredge 1991, 2003; Kami and Lujan 1976; Reeves et al. 1999). *Kogia* are expected to occur from the vicinity of the shelf break to seaward of the Mariana Islands MRA Study Area and vicinity (Figure 5-26 and Figure 5-27). Occurrence of these two species is possible between the 50 m isobath and the shelf break in this area. Occurrence pattern is believed the same throughout the year.

Guam. During monitoring for Valiant Shield 07, three *Kogia* (dwarf or pygmy sperm whales) were detected about 8 nm east of Guam (Mobley 2007).

CAROLINE ISLANDS. The waters around the Caroline Islands are a part of the known primary range of the pygmy sperm whale, and they have been seen in coastal habitats; thus their occurrence is possible in this part of the MRA Study Area (Figure 5-27).

5.13.6 Species-specific Threats

The pygmy sperm whale has not been hunted to any significant degree, but has been taken incidentally in fisheries. They are occasionally victims of dolphin and small whale fisheries, or of gillnets and purse seine operations (Jefferson, Webber, and Pitman 2008). Instances of plastic debris ingestion or of ship strike-related mortalities have been recorded (Cardona-Maldonado and Mignucci-Giannoni 1999; Stamper, Whitaker, and Schofield 2006).

An analysis by Carvalho et al. (2010) of strandings off the coast of Brazil showed susceptibility of pygmy sperm whales to parasites. For more detailed information on specific host-parasite species identified through this study, refer to (Carvalho et al. 2010). Morbillivirus antigens were found in the lungs, lymph nodes, and spleen of a pygmy sperm whale in Taiwanese water (Yang et al. 2006). Concentrations of butyltin and phenyltin were found in the organs and tissue of pygmy sperm whales off the coast of Thailand (Harino et al. 2007a).

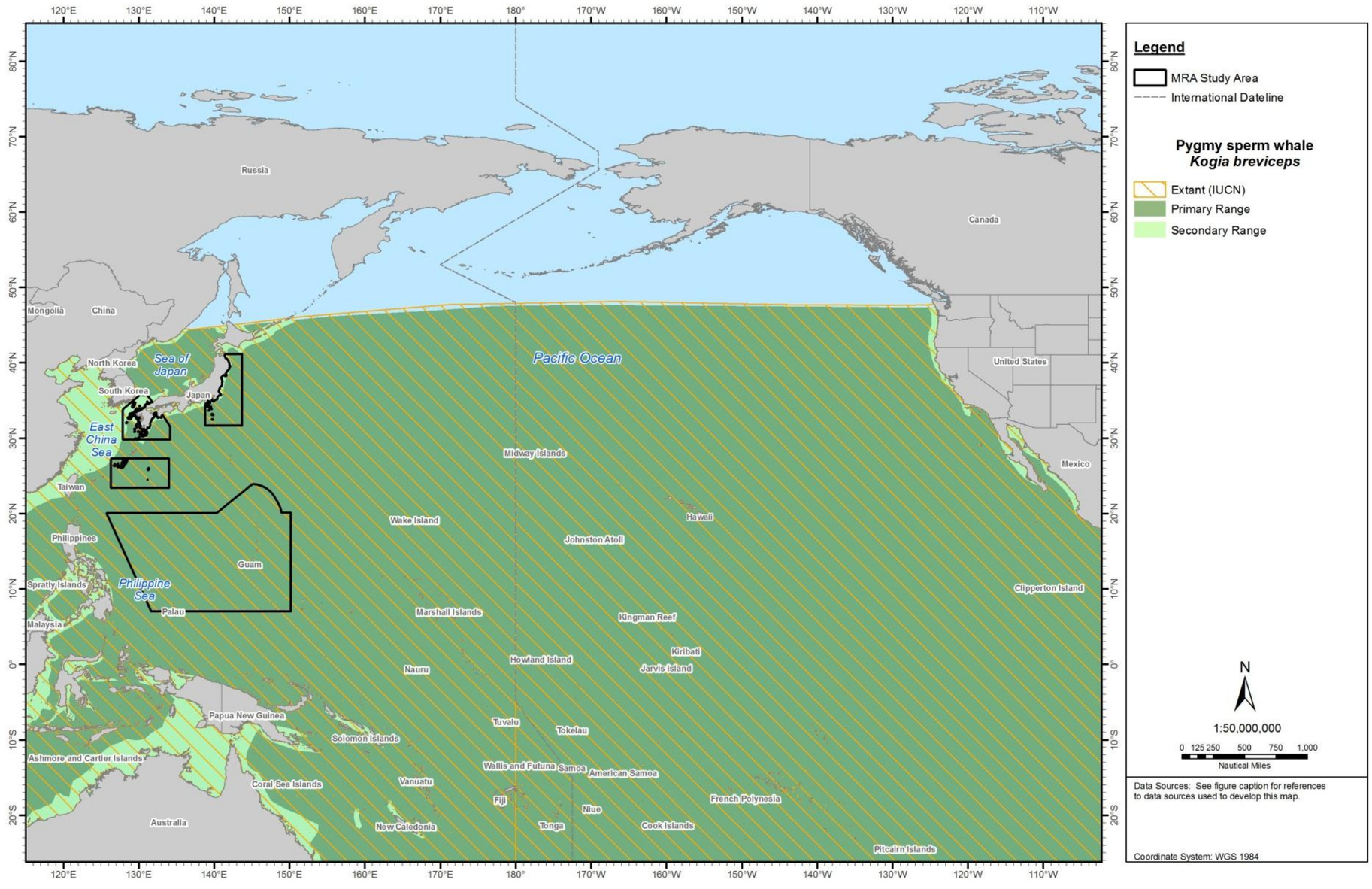

Figure 5-26: Geographic Range of the Pygmy Sperm Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

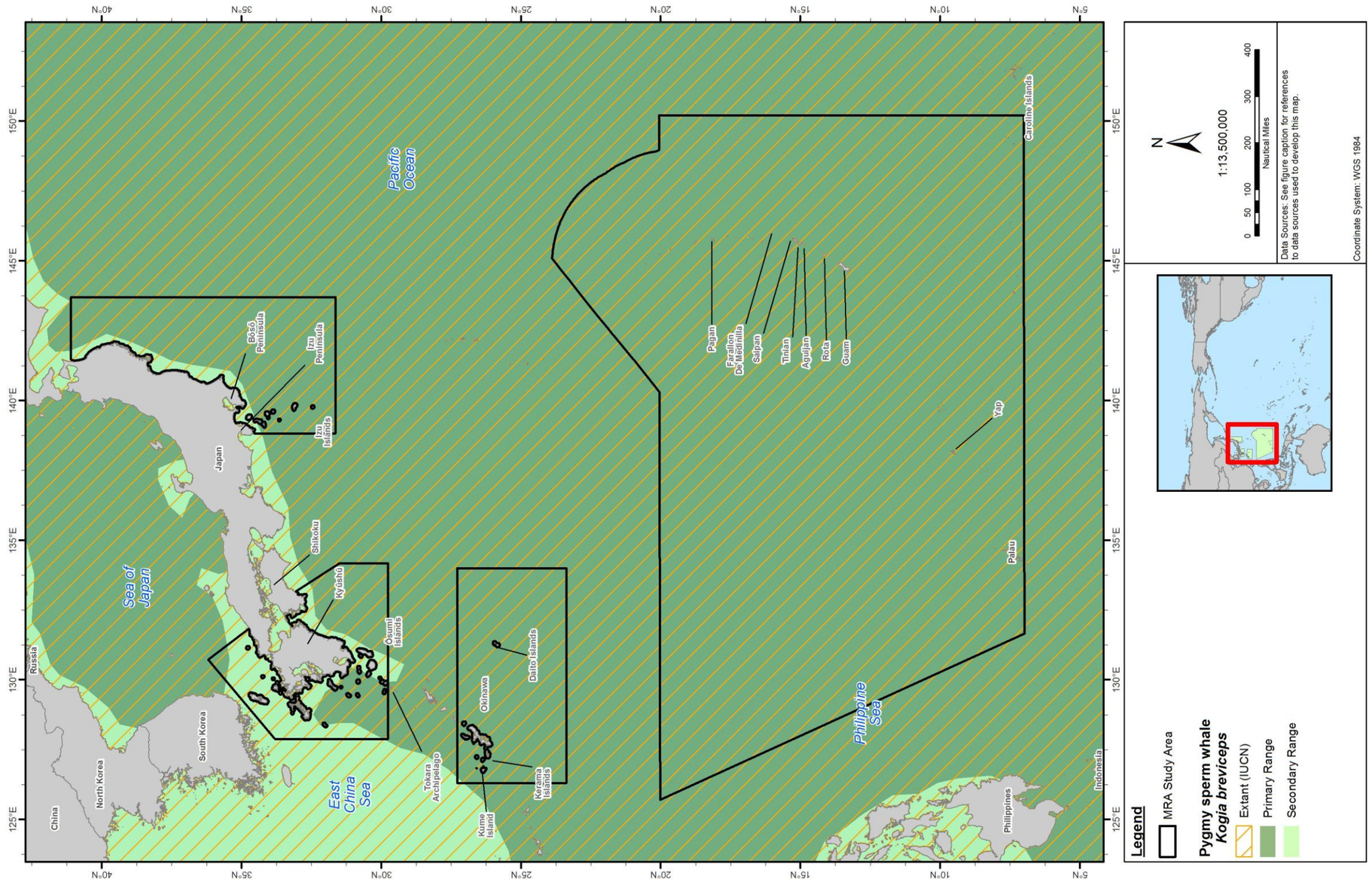

Figure 5-27: Geographic Range of the Pygmy Sperm Whale in the MRA Study Area
Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.14 DWARF SPERM WHALE (*KOGIA SIMA*)

5.14.1 Description

The two species of *Kogia* are the pygmy sperm whale and the dwarf sperm whale, which had been considered the same species until recently. Genetic evidence suggests the possibility of two separate species of dwarf sperm whales globally, one in the Atlantic and one in the Indo-Pacific (Jefferson, Webber, and Pitman 2008). Dwarf and pygmy sperm whales are difficult to distinguish from one another at sea, and sightings of both species are often categorized as the genus *Kogia* (*Kogia spp.*). Based on the cryptic behavior of these species and their small group sizes (much like that of beaked whales), as well as the similarity in appearance, many misidentifications have occurred (Jefferson, Webber, and Pitman 2008).

Dwarf sperm whales are robust animals, with blunt, squarish heads that resemble the true sperm whale. Their bodies taper greatly behind the dorsal fin. The dwarf sperm whale is similar in appearance to the pygmy sperm whale, but it has a relatively larger dorsal fin, generally set nearer the middle of the back. The dorsal fin is typically more dolphin-like than that of the pygmy sperm whale. The dwarf sperm whale also has a shark-like profile but with a more pointed snout than the pygmy sperm whale's (Jefferson, Webber, and Pitman 2008).

This species is countershaded, generally dark brownish-gray on the dorsal side, with a slightly-lighter, whitish-pink belly. They have a white "bracket mark" or false gill slit on the head just behind the eye that gives the animal a shark-like appearance. A ring of darker color surrounds each eye.

Dwarf sperm whales are much smaller than pygmy sperm whales, reaching body lengths of only about 2.7 m (Jefferson, Webber, and Pitman 2008). In the northwestern Atlantic, they do not exceed 2.5 m. They are thought to weigh up to 272 kg (Jefferson, Webber, and Pitman 2008).

5.14.2 Status and Management

The dwarf sperm whale is protected under the MMPA and is not listed under the ESA. This species is also listed as data deficient by the IUCN and falls under Appendix II CITES regulations. Dwarf sperm whales within the Pacific U.S. EEZ are divided into two separate areas: (1) waters off California, Oregon, and Washington; and (2) Hawaiian waters (Carretta et al. 2010). There are no annual deaths or serious injuries caused by fisheries in the Hawaiian stock (Carretta et al. 2012). Although none of these stocks have range within the MRA Study Area, dwarf sperm whales are known to have primary and secondary range within the MRA Study Area.

5.14.3 Population and Abundance

The closest stock assessment was completed for the Hawaiian EEZ (population of 17, 519 [CV=0.74], with minimum estimate of 10,043 animals). No trend data are available (Carretta et al. 2011e). No abundance estimates are available for *Kogia spp* within the MRA Study Area.

5.14.4 Biology, Ecology, and Behavior

Dwarf sperm whales are known to be shy and rarely active at the sea surface, similar to the pygmy sperm whale. Very little is known regarding the biology and behavior of this species.

Group Size. Generally, dwarf sperm whales occur in small groups of usually fewer than six, although they have sometimes been observed in groups of up to 10. Seasonal variations in group size have been documented in the Bahamas, where groups are larger (1 to 12 whales) in the winter and smaller (1 to 8 whales) in summer months (Dunphy-Daly, Heithaus, and Claridge 2008). They are often solitary or seen in pairs (Jefferson, Webber, and Pitman 2008; McAlpine 2009).

Predator/Prey Interactions. Dwarf sperm whales feed on cephalopods and, less often, on deep sea fishes and shrimps (Caldwell and Caldwell 1989; Sekiguchi, Klages, and Best 1992). In the northeastern Atlantic, a single whale stomach was surveyed, the contents of which included 44 individual small squid remains of the *Histioteuthis reversa* species and one swimming crab (Spitz et al. 2011). Dwarf sperm whales consume a variety of fishes, particularly lanternfish, in Japanese waters (Fitch and Brownell 1968). Dwarf sperm whales feed in four stages beginning with a preparation; then the jaw opens, followed by gular depression, and ending with closure of the jaw (Bloodworth and Marshall 2005). Dwarf sperm whales generally forage near the seafloor (McAlpine 2009).

Killer whales are predators of dwarf sperm whales (Dunphy-Daly, Heithaus, and Claridge 2008).

Life History. Sexual maturity is considered to occur at approximately 4 years of age in both sexes of this species. Sperm competition appears to occur among males. Pregnancy lasts about a year, and dwarf sperm whales have a lifespan of approximately 22 years (Caldwell and Caldwell 1989; Plon 2004; Ross 1979).

Migration. Little is known about possible migrations of this species. No specific information is available regarding routes, seasons, or resighting rates in the MRA Study Area.

Hearing/Vocalization. No data are available on dwarf sperm whale vocalizations or hearing capabilities.

Diving. Dwarf sperm whales are considered to be a deep-diving species, based on stomach contents, blood oxygen levels, and long dive durations (Bloodworth and Odell 2008; Wang et al. 2002). Dives of up to 53 min, with an average dive duration of 11 min, have been reported for the dwarf sperm whale (Willis and Baird 1998). The lungs of the dwarf sperm whale are smaller than the lungs of other cetaceans, occupying on average only 15% of their total thoracic cavity, and may have an evolutionary function during deep dives with a higher capability to expand (Piscitelli et al. 2010). Dwarf sperm whales generally feed on squid species found at depths that range between 400 and 1,500 m (Wang et al. 2002).

5.14.5 Habitat and Distribution

Dwarf sperm whales tend to occur over the outer continental shelf, and they may be relatively coastal in some areas with deep waters nearshore (MacLeod, Hauser, and Peckham 2004). Although the dwarf sperm whale appears to prefer more tropical waters than does the pygmy sperm whale, the exact habitat preferences of the species are not well understood. Dwarf sperm whales have been observed within both outer continental shelf and more oceanic waters.

Dwarf sperm whales apparently have a worldwide distribution in tropical and temperate waters from the equator to about 40° in both hemispheres (Jefferson, Leatherwood, and Webber 1993a). Stranding data provide most of the records that identify ranges of both dwarf and pygmy sperm whales, and therefore the true at-sea ranges of both species are not well known. They occur in waters along the continental shelf break and over the continental slope. Data from the Gulf of Mexico suggest that *Kogia*

may associate with frontal regions along the continental shelf break and upper continental slope, where higher epipelagic zooplankton biomass may enhance the densities of squids, their primary prey (Baumgartner et al. 2001). Dwarf sperm whales in the Bahamas were found in waters with bottom depths ranging from 94 to 883 m (MacLeod, Hauser, and Peckham 2004), where habitat use varied seasonally. Whales occupied deep habitats in the summer and in winter. Habitats along the slope, where vertical relief was highest, were preferred (Dunphy-Daly, Heithaus, and Claridge 2008).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. Records of this species from both the western Pacific and eastern Pacific suggest that its range includes the North Pacific Central Gyre (Carretta et al. 2010; Jefferson, Webber, and Pitman 2008; Wang and Yang 2006; Wang, Yang, and Liao 2001) (Figure 5-28).

KUROSHIO CURRENT. The Kuroshio Current is a known part of the dwarf sperm whale's primary and secondary ranges (Figure 5-28 and Figure 5-29).

EAST CHINA SEA. The East China Sea is a known part of the dwarf sperm whale's secondary range (Figure 5-28 and Figure 5-29).

PHILIPPINE SEA. The Philippine Sea is a known part of the dwarf sperm whale's primary range (Figure 5-28 and Figure 5-29).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Although deep oceanic waters may be the primary habitat for this species, very few oceanic sightings offshore have occurred. The lack of sightings may be a result of the difficulty of detecting and identifying these animals at sea (Jefferson, Webber, and Pitman 2008; Maldini, Mazzuca, and Atkinson 2005).

MARIANA ARCHIPELAGO. Only stranding records are available from the Mariana Islands MRA Study Area and vicinity—three have been documented for the dwarf sperm whale (Eldredge 1991, 2003; Kami and Lujan 1976; Reeves et al. 1999). *Kogia* are expected to occur from the vicinity of the shelf break to seaward of the Mariana Islands MRA Study Area and vicinity (Figure 5-29 and Figure 5-30). Any sightings in this archipelago would be most likely between the 50 m isobath and the shelf break. At the Society Islands, a dwarf sperm whale was sighted in relatively shallow waters (bottom depth of 120 m) (Gannier 2000), and MacLeod et al. (2004) reported sighting *Kogia* most often in waters with a bottom shallower than 200 m in the northern Bahamas. Occurrence pattern is believed the same throughout the year.

Saipan. A sighting of the dwarf sperm whale was recorded off the west coast of Marpi Reef (Hill et al. 2011).

CAROLINE ISLANDS. The waters around the Caroline Islands are a known part of the dwarf sperm whale's primary range, and they may occur coastally in some waters of the MRA Study Area (Figure 5-28).

5.14.6 Species-specific Threats

The dwarf sperm whale has not been hunted to any significant degree, but it has been taken opportunistically in whale fisheries in Japan, Indonesia, and the Lesser Antilles (Jefferson, Webber, and

Pitman 2008). Some individuals are also taken incidentally in fisheries, including by gillnets and purse seines, within various parts of their range. Ship strikes are another issue of concern, but little data are available regarding how frequently these occur. Based on the frequency of strandings, this species would not appear to be rare on a global basis. Parasites, such as the nematode *Anisakis paggiae*, are also found on dwarf sperm whales (Yamada 2002). An analysis by Carvalho et al. (2010) of strandings off the coast of Brazil showed susceptibility of dwarf sperm whales to parasites. For more detailed information on specific host-parasite species identified through this study, refer to (Carvalho et al. 2010). Ingestion of plastic debris is known to result in deaths of both *Kogia* species, although population-level impacts of this are not known.

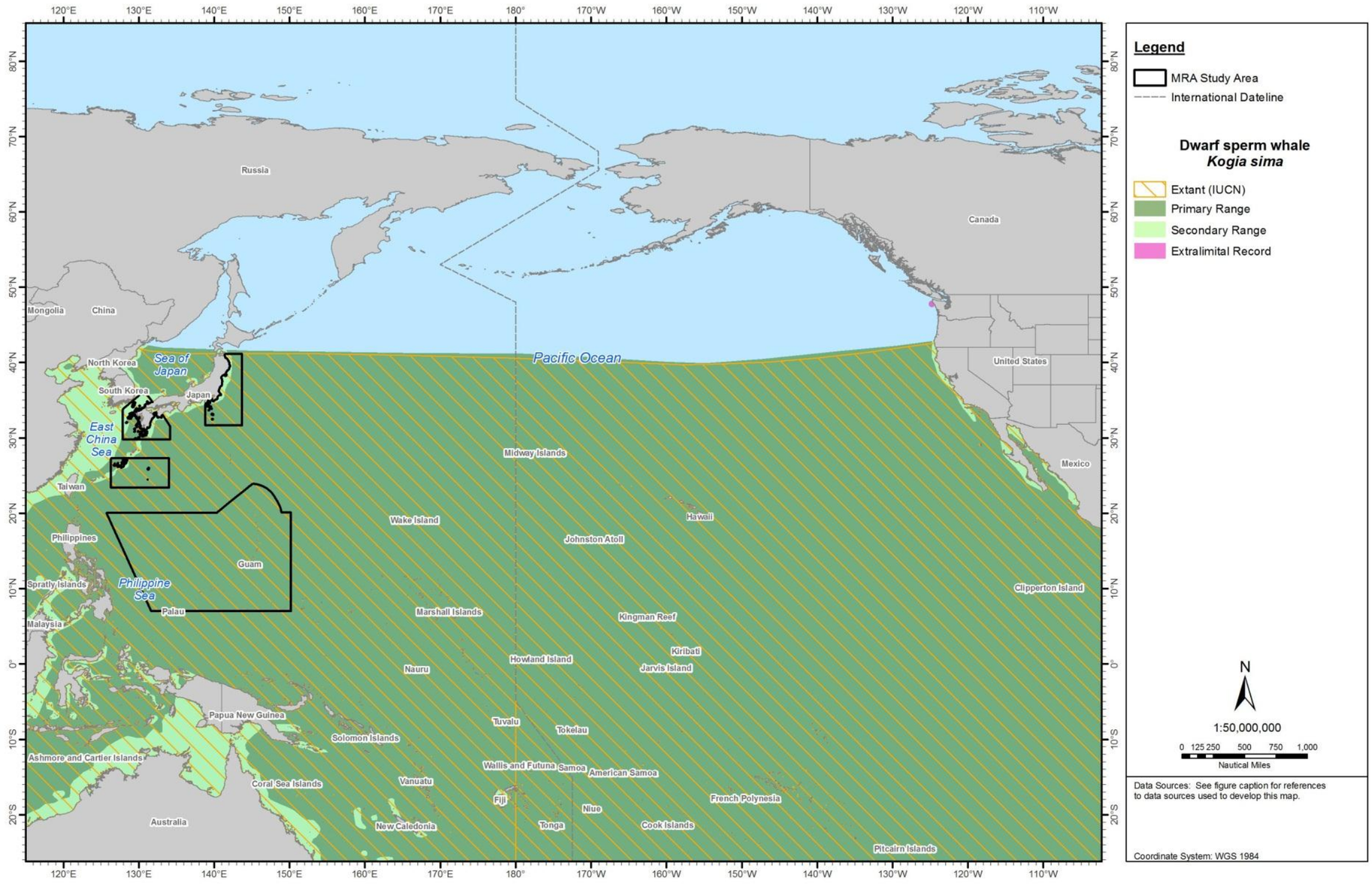

Figure 5-28: Geographic Range of the Dwarf Sperm Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

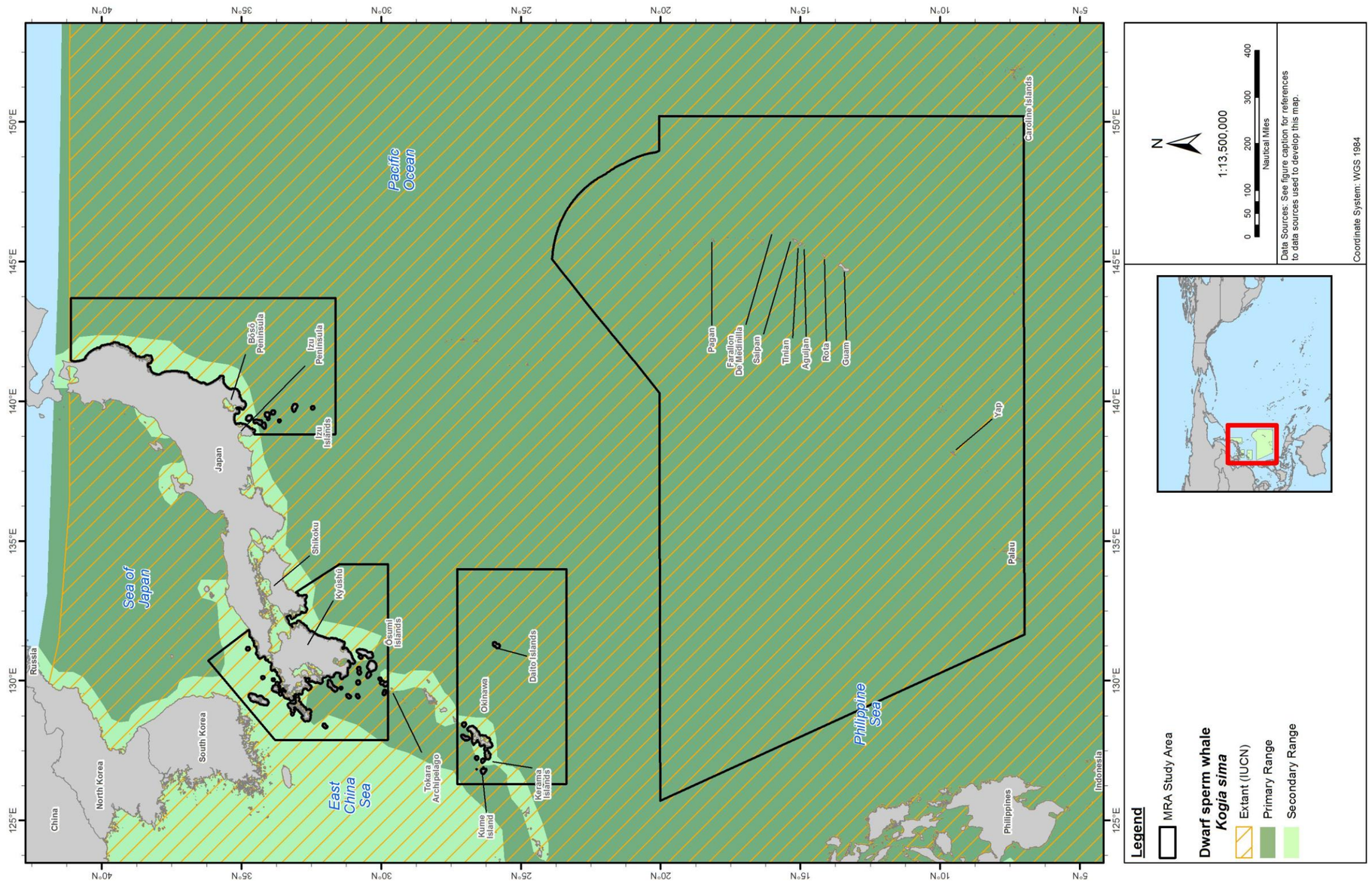

Figure 5-29: Geographic Range of the Dwarf Sperm Whale in the MRA Study Area

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

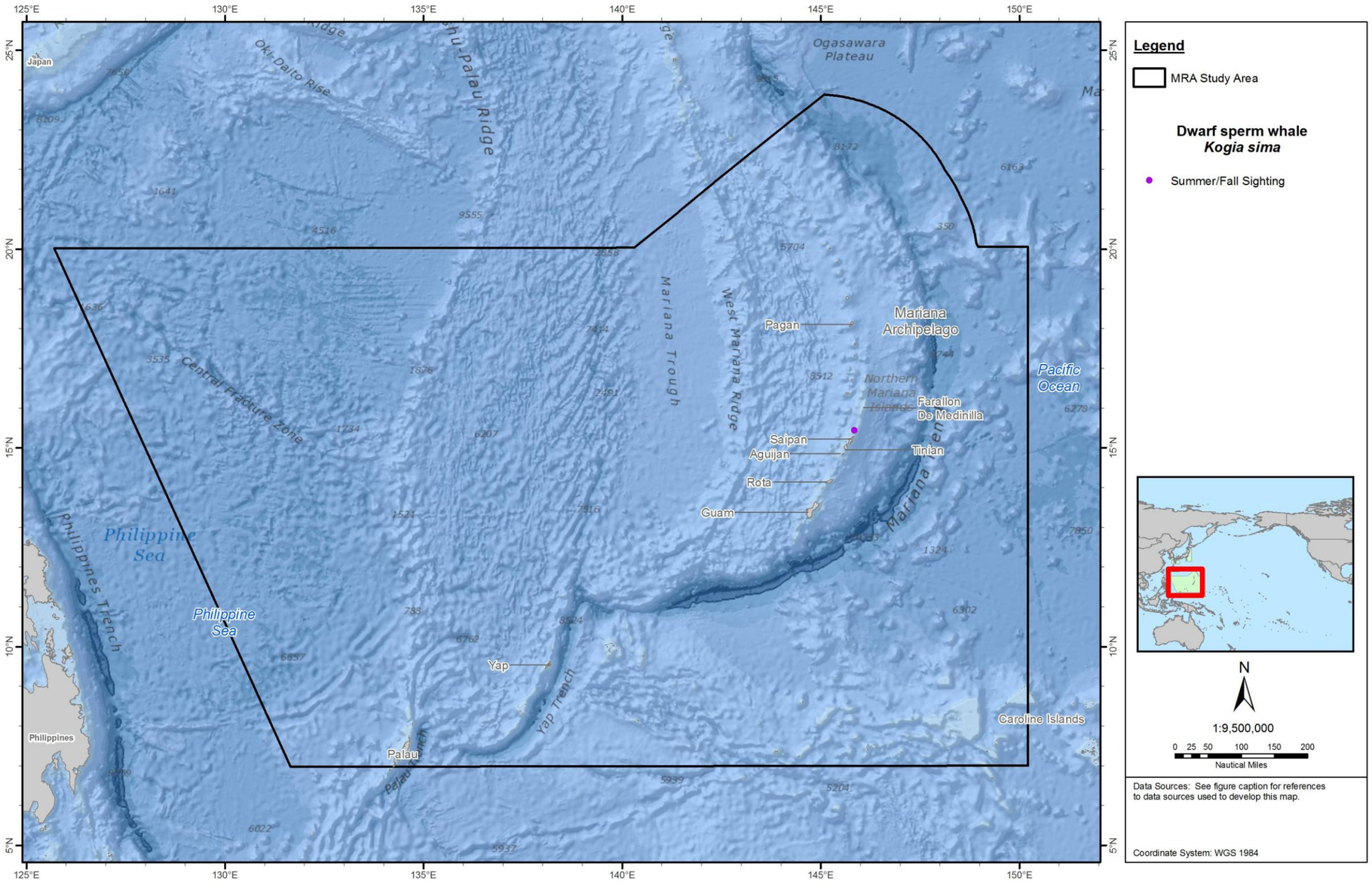

Figure 5-30: Sightings of the Dwarf Sperm Whale in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented.
Sources: Fulling, Thorson, and Rivers (2011); Hill et al. (2011).

This Page Intentionally Left Blank

5.15 CUVIER'S BEAKED WHALE (*ZIPHIUS CAVIROSTRIS*)

5.15.1 Description

Cuvier's beaked whales are relatively robust compared with other beaked whale species. They have a relatively short beak, which along with the curved jaw, somewhat resembles a goose beak. The body is spindle shaped; the flippers are small, tapered, and narrow, and can be tucked into slight depressions or pockets in the body wall. The dorsal fin is falcate and prominent, and is set two-thirds of the way back on the body (Heyning 1989; Jefferson, Webber, and Pitman 2008). The flukes are relatively large, and a fluke notch is sometimes present; barnacles are often found on both the flukes and dorsal fin.

Cuvier's beaked whales are generally dark gray to light rusty brown in color, often with lighter color around the head. In adult males, the head and much of the back can be light gray to white in color, and they also often have many light scratches and circular scars on the body, which can give the animal a slight mottled appearance. These scars are more prevalent in adult males, presumably from male to male conflict (Heyning 1989; Jefferson, Webber, and Pitman 2008).

This species of beaked whales may attain lengths of 7.5 m long for the male and 7.0 m for the female. The maximum recorded weight is 3,000 kg. Newborn Cuvier's beaked whales are typically around 2.7 m long and weigh between 250 to 300 kg (Jefferson, Webber, and Pitman 2008). Adult males have two teeth that erupt from the tip of the lower jaw and are typically visible outside the closed mouth; teeth in females remain unerupted (Heyning 1989).

Similar to other beaked whale species, this oceanic species generally occurs in waters past the edge of the continental shelf. This species occupies almost all temperate, subtropical, and tropical waters, as well as subpolar and even polar waters in some areas. Worldwide, beaked whales normally inhabit continental slope and deep oceanic waters (below 200 m). Cuvier's beaked whales are generally sighted in waters with a bottom depth greater than 200 m, and are frequently recorded at bottom depths greater than 1,000 m (Jefferson, Webber, and Pitman 2008).

5.15.2 Status and Management

Cuvier's beaked whale is protected under the MMPA and is not listed under the ESA. This species is also listed as least concern by the IUCN and falls under Appendix II CITES regulations. Cuvier's beaked whale stocks are defined as three separate areas within Pacific U.S. waters: (1) Alaska, (2) California/Oregon/Washington, and (3) Hawai'i (Carretta et al. 2010). There are no annual deaths or serious injuries caused by fisheries in the Hawaiian stock (Carretta et al. 2012). Although none of these stocks have range within the MRA Study Area, Cuvier's beaked whales are known to have primary and secondary range within the MRA Study Area.

5.15.3 Population and Abundance

An estimated 90,000 Cuvier's whales live in the eastern North Pacific (Jefferson, Webber, and Pitman 2008). The nearest stock assessment, geographically, occurred in the Hawaiian EEZ (estimate 15,242 [CV=1.43] whales with a population minimum of 6,269 whales). No information is available regarding the population trend within this stock assessment (Carretta et al. 2011d). No abundance estimates are available for any of the beaked whales in MRA Study Area.

5.15.4 Biology, Ecology, and Behavior

Cuvier's beaked whales, as all beaked whales, are not easily sighted (they are considered cryptic or to have "secretive" behavior at the surface). They are rarely seen at sea, although this species is one of the more commonly seen beaked whales and the most well-known. They are usually seen in pairs or small groups. All observed adult male Cuvier's beaked whales have had visible scars from fighting with other males (Cascadia Research 2009). They commonly strand, a source of some occurrence data on this species, and they seem vulnerable to acoustic impacts (Frantzis et al. 2002).

Group Size. Cuvier's beaked whales are most often observed in small groups of two to seven animals and are rarely observed alone. This species of beaked whale has a tendency to return to the same area repeatedly or a tendency to remain in an area for an extended period. This may apply to both breeding and feeding areas, and this site fidelity is more often observed in adult females (Falcone et al. 2009; McSweeney, Baird, and Mahaffy 2007).

Predator/Prey Interactions. Cuvier's beaked whales, similar to other beaked whale species, are apparently deepwater feeders. Stomach content analyses show that they feed mostly on deep-sea squid, fish, and crustaceans (Hickmott 2005; Santos et al. 2007). A study of whales in the northeast Atlantic showed Cuvier's beaked whales' stomach contents as mostly medium-sized squid, although a few fish remains and the remains of a giant octopod were identified (Spitz et al. 2011). They apparently use suction to swallow prey (Jefferson, Webber, and Pitman 2008; Werth 2006a).

Cuvier's beaked whales may be preyed upon by killer whales (Heyning and Mead 2008; Jefferson, Webber, and Pitman 2008).

Life History. Life history of the Cuvier's beaked whale is not well known. Calving season for this species is unknown (Jefferson, Webber, and Pitman 2008; Mead 1984).

Migration. Little is known about possible migration. Migration data might be inferred in certain areas from stranding data. Some summarized data from stranding records in the northeastern Pacific, ranging from Alaska to Baja California (Mitchell 1968), suggests that this species may show long-term site fidelity in certain areas. For example, repeated resightings of known individuals (primarily adult females) have occurred over a 15-year period from the west coast of the Island of Hawai'i (McSweeney, Baird, and Mahaffy 2007).

Hearing/Vocalization. Beaked whale ears are predominantly adapted to hear ultrasonic frequencies (MacLeod 1999). Based on the anatomy of the ears of beaked whales, these species may be more sensitive than other cetaceans to low frequency sounds; however, no direct evidence supports this speculation (MacLeod 1999). Sound enters the Cuvier's beaked whale's head below and between the lower jaw, passes through the lower mandible, and then passes through the internal mandibular pathways. This model also indicated this species can interpret directionality in beam reception (Cranford, Krysl, and Hildebrand 2008).

Very little information is available on characteristics of sound produced by beaked whales. It has been suggested that beaked whales use frequencies of between 300 Hz and 129 kHz for echolocation, and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication (MacLeod 1999). Click pulses of Cuvier's beaked whales recorded by (Frantzis et al. 2002) had a peak frequency between 13 and 17 kHz. In the Bahamas, vocalizations of Cuvier's and Blainville's beaked whales increased with prey abundance and vertical structure (upwelling) of the ocean (Antunes, Rendell, and Gordon 2010).

Vocalization can be detected at distances to 0.7 km over a 2.5 hour period (Zimmer et al. 2008).The anatomy of the hearing and vocalization structures of this species were mapped using remote imaging technology. This study found that the configuration of the forehead is homologous to the upside-down sperm whale nose, and therefore may function similarly. The anatomy of this species, along with simulated sound studies, leads researchers to believe that this whale is adapted to communication at deep dives and produces a bisonar signal (Cranford, Krysl, and Hildebrand 2008; Cranford et al. 2008).

Diving. Cuvier's beaked whales, similar to other beaked whale species, are known to be deep divers. Typically, this species feeds on fish found on the bottom or at mid-water of a body of water, and deep-sea squid are found in water depths exceeding 400 m (Gannon, Craddock, and Read 1998). Dives up to 40 min have been recorded for this species (Baird, Schorr, et al. 2006; Jefferson, Webber, and Pitman 2008). A tagging study in Hawaiian waters showed Cuvier's beaked whales made regular dives lasting between 48 and 68 min, and reached a depth of 1,450 m (Baird, Webster, et al. 2006). A more recent study in Hawaiian waters showed two tagged Cuvier's beaked whales made dives to depths over 1,700 m, with an average duration of 86.9 min during both the day and night (Baird et al. 2010a). Radio tagging has shown that Cuvier's beaked whales dive on average 1,070 m during foraging, and dive intervals range from 58 to 63 min (Tyack et al. 2006). Mid-water dives also occur, yet these dives get progressively shallower, and less time is spent in shallow depths during the day, possibly to reduce occurrence of visually oriented predation (Baird, Webster, Schorr, et al. 2008).

5.15.5 Habitat and Distribution

This species occupies almost all temperate, subtropical, and tropical waters of the world, as well as subpolar and even polar waters in some areas. Worldwide, beaked whales normally inhabit continental slope and deep oceanic waters. Cuvier's beaked whales are generally sighted in waters with a bottom depth exceeding 655 ft. (200 m), and are frequently recorded in waters with bottom depths exceeding 3,280 ft. (1,000 m) (Falcone et al. 2009; Jefferson, Webber, and Pitman 2008). Off the coast of Italy, Cuvier's beaked whales were associated with habitats characterized by well-defined depth and slope gradient, on the shelf-edge, and the upper and lower slope (Azzellino et al. 2008).

Cuvier's beaked whales have an extensive range that includes all oceans, from the tropics to the polar waters of both hemispheres. Similar to other beaked whale species, this oceanic species generally occurs in waters past the edge of the continental shelf.

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. Cuvier's beaked whales are widely distributed (Figure 5-31) in offshore waters of all oceans, and thus occur in temperate and tropical waters of the Pacific, including waters of the ETP (Ferguson 2005; Ferguson, Barlow, Feidler, et al. 2006; Jefferson, Webber, and Pitman 2008; Pitman et al. 1988).

KUROSHIO CURRENT. The Cuvier's beaked whale is believed to occur in deep waters seaward of the shelf break, as well as on the shelf in the Tsushima Strait, as deep waters are close to shore in this area (Yamada 2001). This species is not expected on the shelf area around island groups, such as the Ogasawara Islands (Figure 5-32). This occurrence pattern is believed to be similar year-round (Heyning 1989).

EAST CHINA SEA. The East China Sea is a known part of the Cuvier's beaked whale's secondary range (Figure 5-31 and Figure 5-32).

PHILIPPINE SEA. The Philippine Sea is a known part of the Cuvier's beaked whale's primary range (Figure 5-31 and Figure 5-32).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. The Cuvier's beaked whale is believed to occur in deep waters seaward of the shelf break (Figure 5-31). The atypical distribution of Cuvier's beaked whale strandings was similar to the beaked whale strandings in the Bahamas in 2000 during deployment of active mid-frequency sonar (Brownell et al. 2005; Brownell et al. 2004), suggesting that the Japanese mass strandings had an acoustic origin.

MARIANA ARCHIPELAGO. Beaked whales may be expected to occur in the area mostly seaward of the shelf break (Figure 5-31 and Figure 5-32). There is a low or unknown occurrence of beaked whales on the shelf between the 50 m isobath and the shelf break. Deep waters come very close to the shore in this area. In some locales, beaked whales can be found in waters over the shelf, so these whales possibly have similar habitat preferences here. Occurrence pattern is believed to be the same throughout the year.

Saipan. In August 2011, two stranded Cuvier's beaked whales were found on and near Micro Beach, Saipan (Saipan Tribune 2011). One whale was found deceased and the other was found alive. A necropsy conducted on the live stranded animal after euthanization exposed anomalies in the whale's kidneys and intestines. Further examination is needed to conclude if the strandings' cause should be characterized as natural or anthropogenic.

Guam. A solitary Cuvier's beaked whale was seen about 65 nm south of Guam at the edge of the Mariana Trench (Figure 5-33) (Mobley 2007).

CAROLINE ISLANDS. The Caroline Islands are a known part of the Cuvier's beaked whale's primary range, although this species is not usually associated with coastal waters (Figure 5-31 and Figure 5-32).

5.15.6 Species-specific Threats

Cuvier's beaked whales have never been hunted to a major extent, although small numbers have been taken in some whale fisheries in the past (especially those focusing on other beaked whale species). An estimated 3 to 35 Cuvier's beaked whales have been taken from Japanese waters in the Baird's beaked whales fishery (National Marine Fisheries Service). In the Republic of (South) Korea, "whale meat" markets still can buy and sell meat from stranded or bycaught marine mammals. A DNA surveillance study from 2003 to 2005 verified Cuvier's beaked whale meat in food markets (Baker et al. 2006). They have also been killed in some artisanal fisheries for small cetaceans (for example, in the Caribbean and Indonesia). They have occasionally been taken in deep water gillnets (Jefferson, Webber, and Pitman 2008).

The relationship between beaked whales and certain anthropogenic sounds remains poorly understood. In general, the only known threat is potential acoustic disturbance and tissue damage from seismic exploration and from military sonar activities (Aguilar Soto et al. 2006; Falcone et al. 2009; MacLeod 1999). There has been a single observation of altered foraging behavior in a Cuvier's beaked whale during passage of a loud vessel (Aguilar Soto et al. 2006). They suggest this species might be sensitive to increased anthropogenic ambient sound. A recent study suggested that the large number of strandings of Cuvier's beaked whales could result from their tendency to surface too quickly when exposed to

acoustic disturbances. Rapid surfacing involves the possibility of decompression sickness, and although not fully understood at this time, this response to anthropogenic noise is a potential threat to this species (Hooker, Baird, and Fahlman 2009).

This Page Intentionally Left Blank

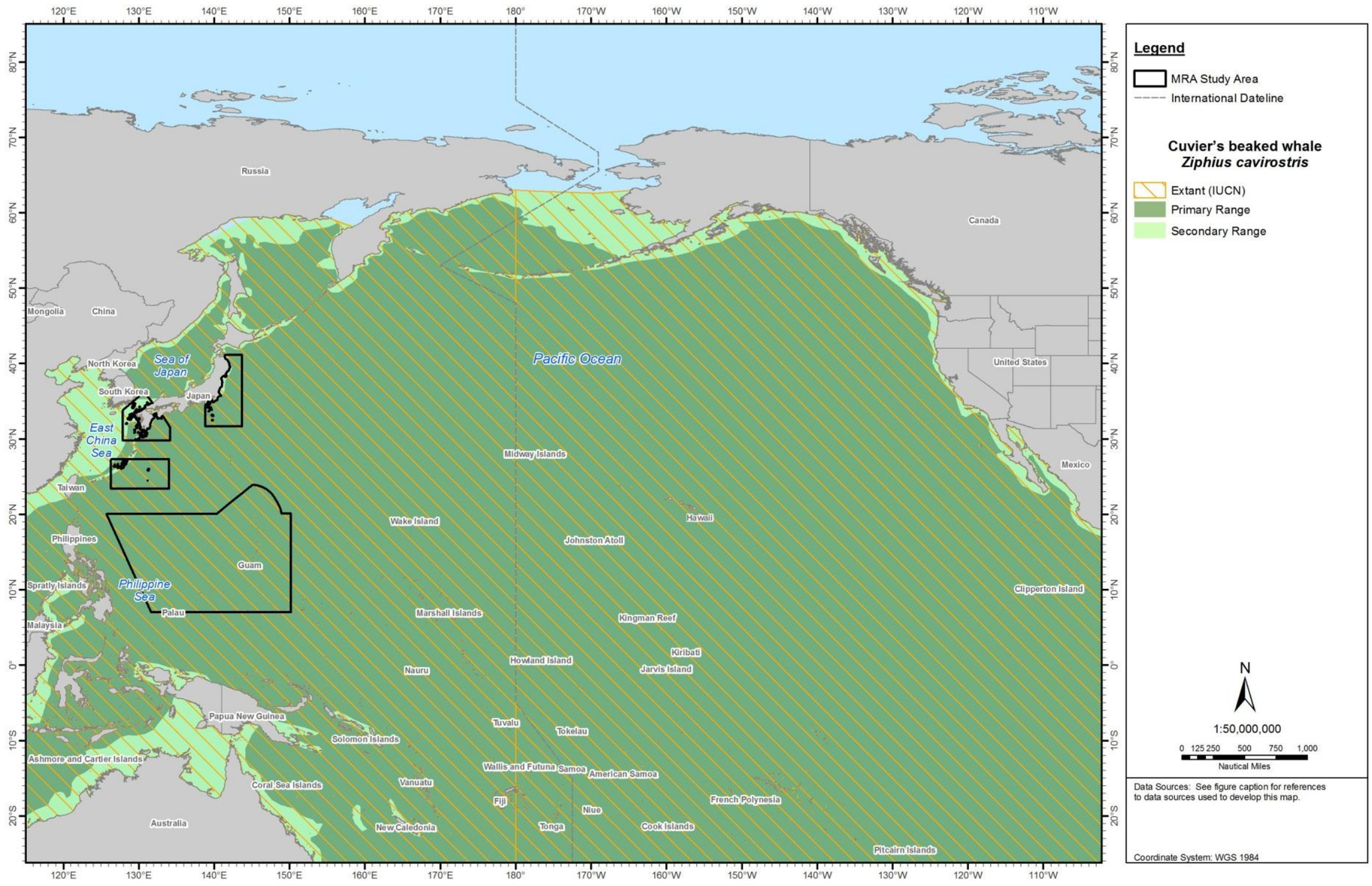

Figure 5-31: Geographic Range of Cuvier's Beaked Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

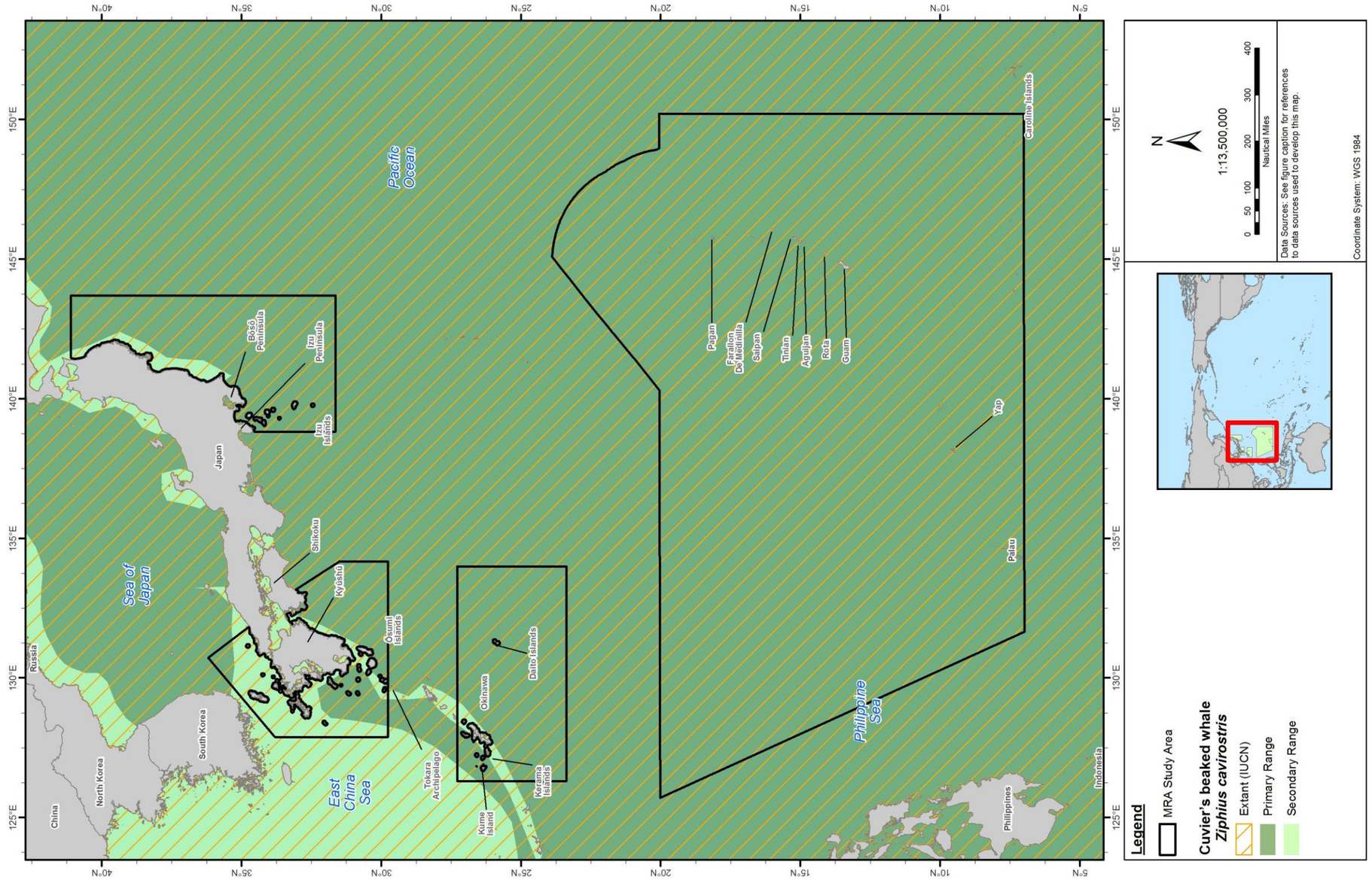

Figure 5-32: Geographic Range of Cuvier's Beaked Whale in the MRA Study Area

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

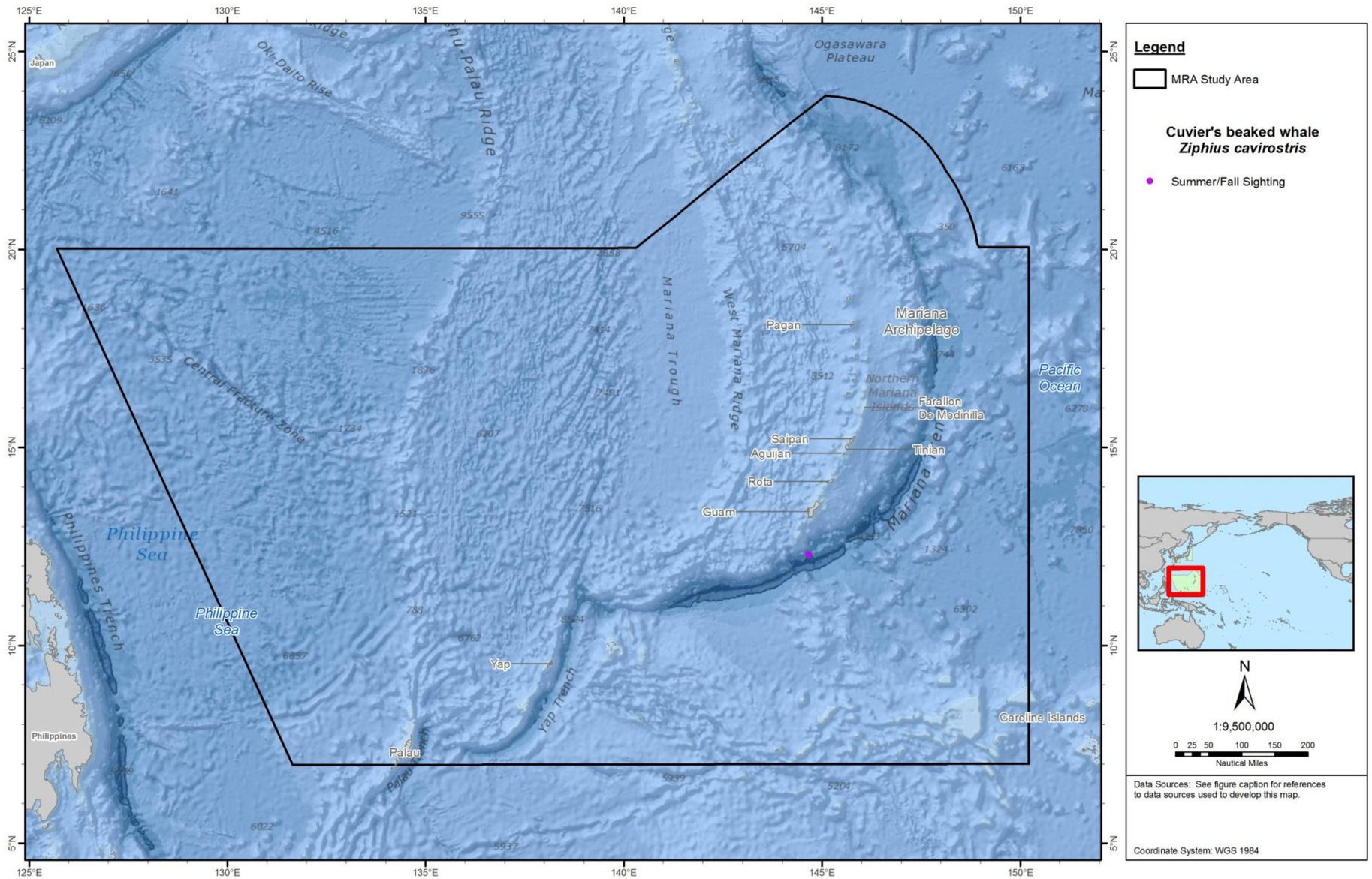

Figure 5-33: Sightings of the Cuvier's Beaked Whale in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented.
Sources: Fulling, Thorson, and Rivers (2011); Mobley (2007).

This Page Intentionally Left Blank

5.16 BLAINVILLE'S BEAKED WHALE (*MESOPLODON DENSIROSTRIS*)

5.16.1 Description

Blainville's beaked whales are one of the more distinctive of the *Mesoplodon* species. Blainville's beaked whales are characterized by a spindle-shaped body with a small head; small dorsal fin located two-thirds of the way back from the snout tip, small and narrow flipper and un-notched flukes. Their beak is moderately long in mature adults but shorter and stubbier in younger animals (Jefferson, Webber, and Pitman 2008). The posterior half of the lower jaw of this species is highly arched in both males and females. In bulls, these arches are massive, squarish, and wide, and flattened tusks erupt from the top of the arches, angled forward at about 45˚ (Jefferson, Webber, and Pitman 2008).

Blainville's beaked whales are normally brownish or blue-gray above and lighter on their ventral side. The darker areas of adult animals tend to have white scratches and scars. Paired scratches are assumed to be from other adult males. This species tends to show more white scratches than do most other *Mesoplodon* species. A yellowish-orange tinge often appears on the head and thorax; this is assumed to be from diatom films (Jefferson, Webber, and Pitman 2008).

Maximum size of Blainville's beaked whale is around 4.7 m for males and females; however, on average, females tend to be slightly larger than males. They are known to reach weights of up to 1,033 kg. The typical length of newborns is estimated to be between 2.0 and 2.5 m (Jefferson, Webber, and Pitman 2008). For a more detailed review of the Blainville's beaked whale, including genetics and evolution, see (Allen, Mead, and Brownell 2009).

5.16.2 Status and Management

Blainville's beaked whale is protected under the MMPA and is not listed under the ESA. This species is also listed as data deficient by the IUCN and falls under Appendix II CITES regulations. The Blainville's beaked whale in U.S. waters are separated into three stocks: Hawaiian, Northern Gulf of Mexico, and Western North Atlantic (National Marine Fisheries Service 2012b). There are no annual deaths or serious injuries caused by fisheries in the Hawaiian stock (Carretta et al. 2012). Although none of these stocks have range within the MRA Study Area, Blainville's beaked whales are known to have primary and secondary range within the MRA Study Area.

5.16.3 Population and Abundance

The geographically nearest stock assessments were for the Hawai'i stock (estimated 2,872 [CV=1.17] whales) (Carretta et al. 2011a). No abundance or population trend estimates are available for the Blainville's beaked whale in the MRA Study Area.

5.16.4 Biology, Ecology, and Behavior

This species of beaked whale has a tendency to return to the same area repeatedly or a tendency to remain in the area for an extended period. This may occur at both breeding and feeding areas, and this site fidelity is more often observed in adult females (McSweeney, Baird, and Mahaffy 2007).

Group Size. Blainville's beaked whales are observed in small groups of three to seven, although singles and pairs are more common (Baird et al. 2010a; Jefferson, Webber, and Pitman 2008).

Predator/Prey Interactions. This species preys on squid and possibly deepwater fish. Prey-capture occurred within the benthic boundary layer, although dive depths varied. Meso- and bentho-pelagic foraging occurred on these dives, and only active searching for prey occurred deep in the descent and when prey was identified within 2 min of echolocation. Hunting seemed to last for 4 hours per day, averaging 1.5 hours between dives. Foraging was aided by presence of steep undersea slopes and small spatial scales (Arranz et al. 2011). As other *mesoplodonts*, Blainville's beaked whales apparently use suction for feeding (Jefferson, Webber, and Pitman 2008; Werth 2006b).

This species has not been documented to be prey to any other species, although it is likely subject to occasional killer whale predation like other whale species.

Life History. Limited data are available on the life history of this species. A 9-year-old female Blainville's beaked whale specimen was examined and was determined to have just attained sexual maturity (Jefferson, Webber, and Pitman 2008; Mead 1989).

Migration. It is unknown whether this species makes specific migrations, and none has so far been documented. Populations studied in Hawaiʻi have evidenced some level of residency (McSweeney, Baird, and Mahaffy 2007).

Hearing/Vocalization. Beaked whale ears are predominantly adapted to hear ultrasonic frequencies (MacLeod 1999). Based on the anatomy of the ears of beaked whales, these species may be more sensitive than other cetaceans to low frequency sounds (MacLeod 1999). An audiogram testing of brainwaves of a sub-adult in Hawaiʻi indicated that the best hearing for the Blainville's beaked whale occurs between 5.6 and 160 kHz, with thresholds below 50 dB (Nachtigall 2011). Possible avoidance of multi-ship active sonar exercises has been documented for this whale; densities of these whales decreased during and shortly after sonar exercises (Moretti et al. 2010). During sonar exercises, Blainville's beaked whales were detected near the periphery of sonar range (average 16 km from transmissions), and once the sonar ceased, they repopulated the center of the range within 2-3 days. In the presence of military sonar, killer whale calls, and band limited noise, this species reacted at levels below 142 dB re µPa by halting echolocation and by conducting long, slow ascents from foraging dives (Tyack et al. 2011).

Beaked whales use frequencies of between 300 Hz and 129 kHz for echolocation, and between 2 and 10 kHz, and possibly up to 16 kHz, potentially for social communication (MacLeod 1999). Recently, an acoustic recording tag was attached to two Blainville's beaked whales in the Ligurian Sea (Johnson et al. 2004). This species was found to be highly vocal, producing high-frequency echolocation clicks with no significant energy below 20 kHz (Johnson et al. 2004). The source level of these clicks ranged from 200 to 220 dB re 1 µPa-m (Johnson and Tyack 2004). Interclick intervals of 300 to 400 ms have been recorded (Madsen et al. 2005). While searching and localizing prey, the -10 dB bandwidth and 26 to 51 kHz clicks have been shown to aid the whale in discriminating among prey types at differing depths (Jones et al. 2008). When receiving echolocation information, this species can adjust behaviors and vocalizations depending on prey type (Johnson et al. 2008). In the Bahamas, vocalizations of the Cuvier's and Blainville's beaked whales increased with prey abundance and with vertical structure (upwelling) of the ocean (Antunes, Rendell, and Gordon 2010). Under favorable conditions, a towed array can detect this species in the Atlantic Ocean at a distance of up to 7 km (von Benda-Beckmann et al. 2010).

Diving. As do other beaked whale species, Blainville's beaked whales appear to prefer deep waters for feeding. Blainville's beaked whales are known to be deep divers. Studies in Hawaiian waters showed

that Blainville's beaked whales can dive to a depth of 1,400 m and remain below the surface longer than 54 min (Baird, Webster, et al. 2006). Radio-tagging has shown that Blainville's beaked whales dive on average 835 m during foraging, and dives range from 47- to 92-min intervals (Tyack et al. 2006). Many mid-water dives are also made; yet these dives tend to get progressively shallower, and less time is spent in shallow depths during the day, possibly to reduce occurrence of visually oriented predation (Baird, Webster, Schorr, et al. 2008).

5.16.5 Habitat and Distribution

Similar to other beaked whale species, this oceanic species generally occurs in waters past the edge of the continental shelf. Typically Blainville's beaked whales inhabit waters between 200 and 1,000 m in depth.

Blainville's beaked whales are one of the most widely distributed of the distinctive toothed whales within the *Mesoplodon* genus (Jefferson, Webber, and Pitman 2008; MacLeod, Perrin, et al. 2006). Although they have not been recorded in some high-latitude areas, they are thought to have a continuous distribution throughout the tropical, sub-tropical, and warm-temperate waters of the world's oceans, with occasional occurrences in cold-temperate areas (MacLeod, Perrin, et al. 2006). They are known to inhabit enclosed seas with deep water, such as the Gulf of Mexico and Caribbean Sea. However, they are thought to only rarely occur in the Mediterranean Sea. Records of this species document presence along the eastern coast of the United States and Canada, from as far north as Nova Scotia south to Florida and the Bahamas (Mead 1989). Blainville's beaked whales are found mostly offshore in deeper waters along the California coast, Hawai'i, Fiji, Japan, and Taiwan, as well as throughout the ETP (Leslie et al. 2005; MacLeod and Mitchell 2006; Mead 1989). The Blainville's beaked whale occurs in temperate and tropical waters of all oceans (Jefferson, Leatherwood, and Webber 1993b). Strandings have been recorded at Japan (Kasuya and Nishiwaki 1971). The distribution of *Mesoplodon* species in the western North Atlantic may relate to water temperature (MacLeod 2000; Mead 1989), with Blainville's beaked whale generally occurring in warmer southern waters (MacLeod 2000).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. Blainville's beaked whale range is known to include the North Central Pacific Gyre (Jefferson, Webber, and Pitman 2008; Pitman 2008b).

KUROSHIO CURRENT. Identification to species level at sea is difficult for *Mesoplodon spp*. Therefore occurrence sightings and patterns for the Blainville's, Hubbs', Stejneger's, and ginkgo-toothed beaked whales are usually considered combined occurrences for *Mesoplodon spp.* MacLeod, Perrin, et al. (2006) (Figure 5-34).

EAST CHINA SEA. Some areas in the East China Sea are a part of the known secondary range of the Blainville's beaked whale (Figure 5-34 and Figure 5-35).

PHILIPPINE SEA. The Philippine Sea is included in the known primary range of the Blainville's beaked whale (Figure 5-34 and Figure 5-35).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. *Mesoplodon spp.* are believed to occur seaward of the shelf break, as well as on the shelf in the Tsushima Strait, as deep waters are close to shore in this area. This species is not expected on the shelf area around island groups, such as the Ogasawara Islands. There have been reports of recent live strandings of Blainville's and Hubbs' beaked whales in the MRA Study Area Yamamoto, Ito, and Komaba (2001). Resident populations may be present off the Japanese coast National Marine Fisheries Service (2012b).

MARIANA ARCHIPELAGO. Two *Mesopolodon spp.* whale sightings occurred during the 2007 survey of the Mariana Islands MRA Study Area, over the West Mariana Ridge; but the whales were not identified to the species level (Fulling, Thorson, and Rivers 2011). No additional, verified occurrence records of this species in the Mariana Islands MRA Study Area and vicinity are available, but this area is within the known distribution range of this species. Beaked whales are believed to occur in the area, including seaward of the shelf break. Beaked whales could occur on the shelf between the 50 m isobath and the shelf break, as deep waters come very close to the shore in this area. In some locales, beaked whales can be found in waters over the shelf, so beaked whales possibly have similar habitat preferences here. Occurrence patterns are believed the same throughout the year (Figure 5-35).

CAROLINE ISLANDS. Although the Caroline Islands are included in the Philippine Sea, a known area within the species' primary range, presence of this whale within the area of the Caroline Islands is not expected, except for transient individuals (Figure 5-35).

5.16.6 Species-specific Threats

This species is known to have been incidentally taken by Japanese fishing boats (Jefferson, Webber, and Pitman 2008). In the Republic of (South) Korea "whale meat" markets still can buy and sell meat from stranded or bycaught marine mammals. A DNA surveillance study from 2003 to 2005 found Blainville's beaked whale meat present in local area markets (Baker et al. 2006).

Naval sonar exercises have been correlated to beaked whale strandings, although as for many strandings, the true cause has not been identified definitively. Foraging activities of Blainville's beaked whales in the Bahamas may also be sensitive to multi-ship, mid-frequency, active sonar operations even though foraging continues when whales are exposed to sonar levels up to 157 dB re 1 µPa-m (Aoki et al. 2012). Foraging may be interrupted, however; during simulated sonar in this area, whales moved to the periphery of the sonar activity (16 km away from the source on average), returning 2 to 3 days after the noise had stopped. These foraging and movement reactions were similar to reactions of whales to military sonar, killer whales, and band-limited noise (Weller et al. 1999). When populations were exposed to acoustic signals of 115 and 240 kHz, vocalization activity and duration decreased. It was also observed that whale communication activity increased after the sonar transmission had ceased, but did not recover to pre-exposure levels.

Blainville's beaked whales are also known to be afflicted by some infections, including viruses. A stranded whale off the Atlantic coast of the United States revealed a novel case of a Ziphiid herpesvirus (Saliki et al. 2006).

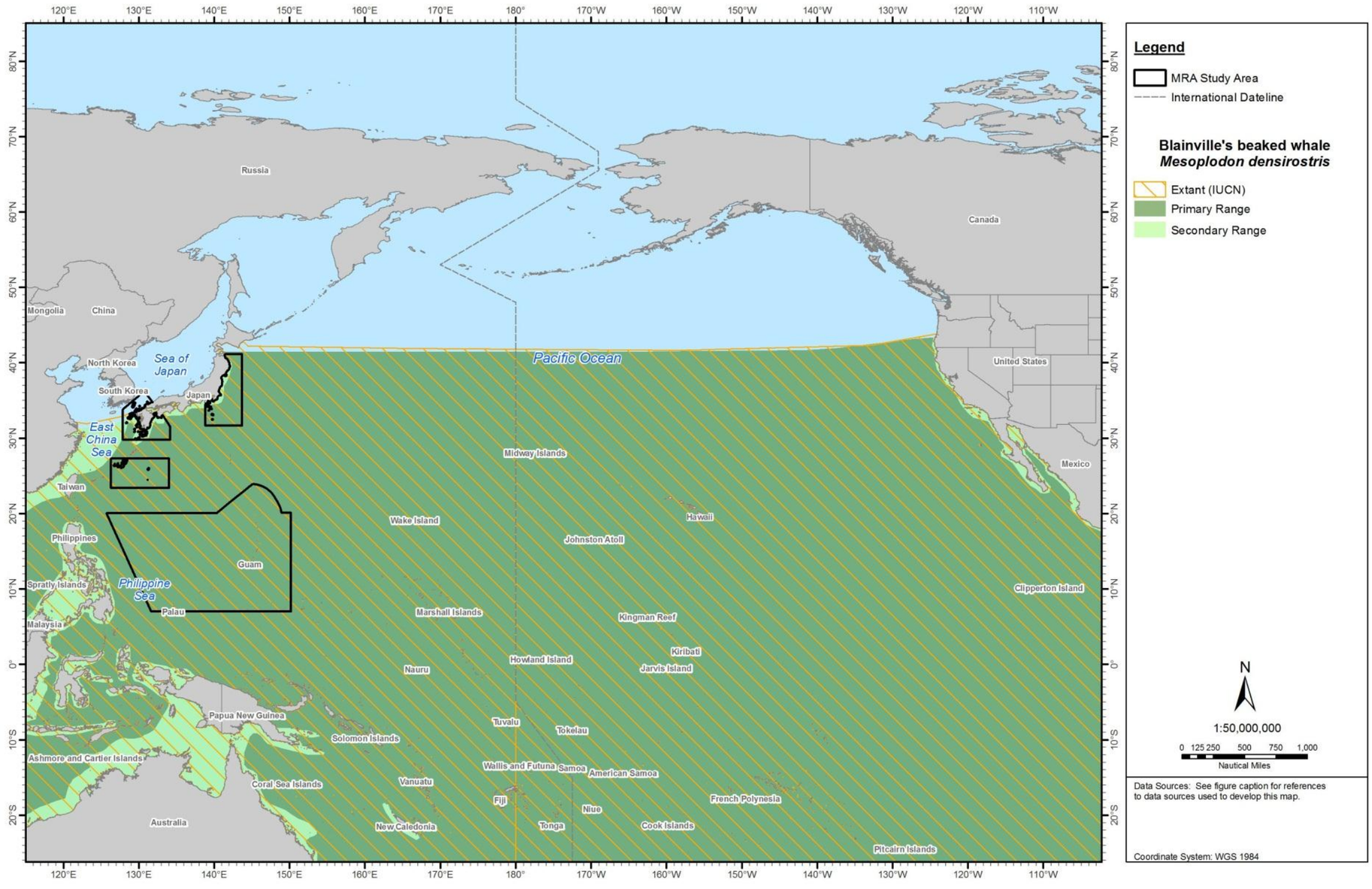

Figure 5-34: Geographic Range of Blainville's Beaked Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

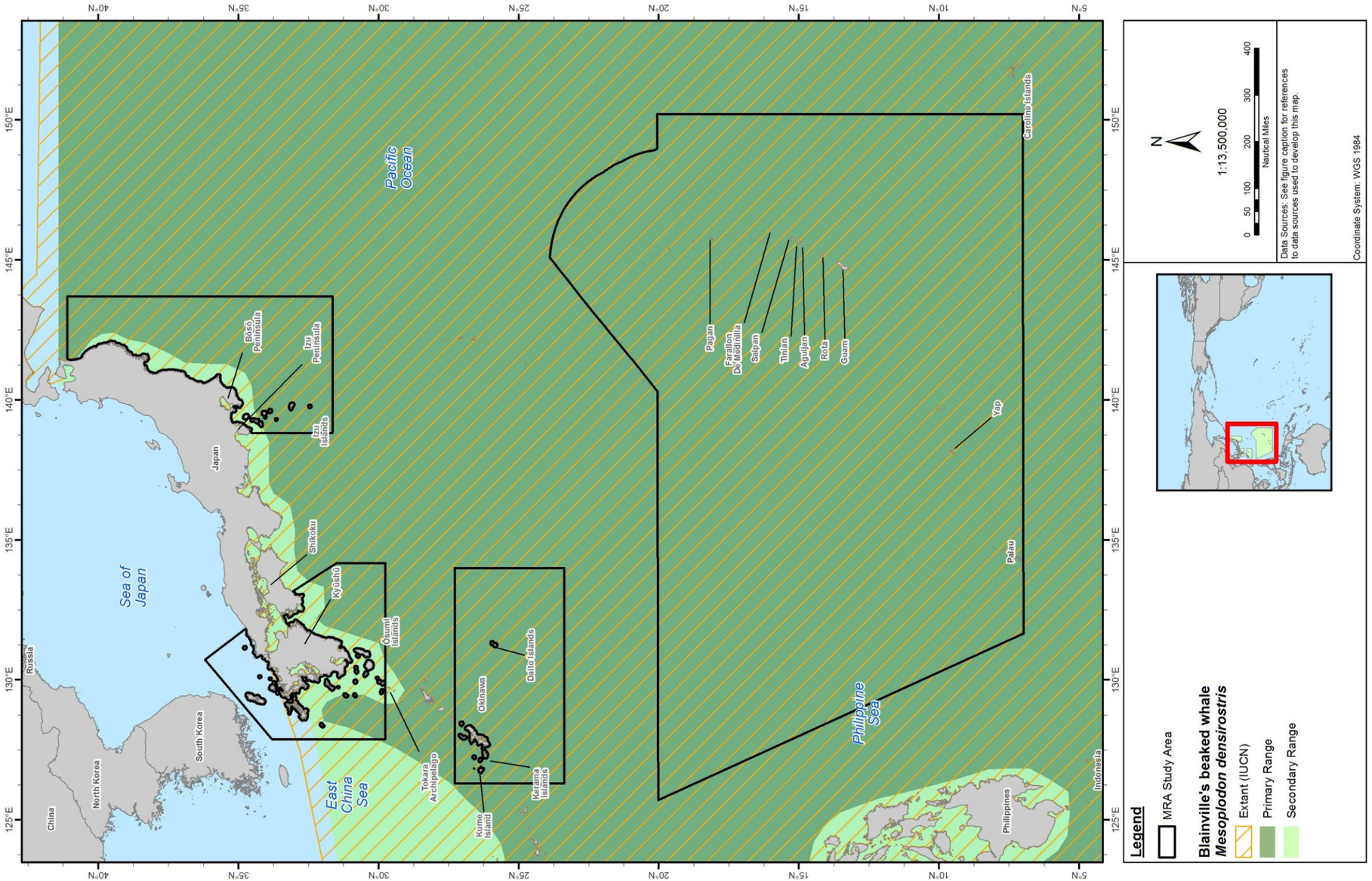

Figure 5-35: Geographic Range of Blainville's Beaked Whale in the MRA Study Area
Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.17 BAIRD'S BEAKED WHALE (*BERARDIUS BAIRDII*)

5.17.1 Description

Baird's beaked whales are dark brownish-gray, usually heavily scarred, and have light scratches or splotches on the back and often on the undersides (Jefferson, Webber, and Pitman 2008). The body is slender and has a small head, a low falcate dorsal fin, and small flippers. A pair of V-shaped throat grooves and a prominent rounded forehead with a long, tube-like beak are present (Balcomb 1989). Two pairs of teeth are located near the tip of the lower jaw. The forward pair (these teeth are large and triangular) in adults is visible at the tip of the lower jaw, even when the mouth is closed, and the second pair is smaller and peg-like in shape (Balcomb 1989). Baird's beaked whales are the largest beaked whales; males and females can attain lengths of 10.7 m and 11.1 m, respectively (Jefferson, Webber, and Pitman 2008). As adults, Baird's beaked whales can weigh approximately 26,400 lbs. (12,000 kg).

5.17.2 Status and Management

Baird's beaked whale is protected under the MMPA and is not listed under the ESA. This species is also listed as data deficient by the IUCN and falls under Appendix I CITES regulations. Baird's beaked whale stocks are defined as the two separate areas within Pacific U.S. waters where they are found: (1) Alaska and (2) California/Oregon/Washington (Carretta et al. 2010). Baird's beaked whales have a history of commercial harvesting in small numbers by the Russians, Canadians, and Americans. There are no annual deaths or serious injuries caused by fisheries in the California/Oregon/Washington stock (Carretta et al. 2012). Although none of these stocks have range within the MRA Study Area, Baird's beaked whales are known to have primary and secondary range within the Japan portion of the MRA Study Area.The Japanese fishery has historically been responsible for large numbers of deaths (Jefferson, Webber, and Pitman 2008).

5.17.3 Population and Abundance

The closest stock assessment geographically reports insufficient data, and therefore no stock estimates or trends are available (Allen and Angliss 2010b). The nearest stock assessment with reportable numbers was conducted for the California/Oregon/Washington stock (estimate of 907 [CV=0.49] individuals) (Carretta et al. 2012). No abundance estimates are available for these beaked whales in the MRA Study Area.

5.17.4 Biology, Ecology, and Behavior

Group Size. Baird's beaked whales occur in relatively large groups (for a beaked whale) of 6 to 30 individuals, although groups of up to 50 or more are occasionally observed (Balcomb 1989; Kasuya 2009). Groups often display surface-active behavior, including breaching and tail slapping (Pitman et al. 1988).

Predator/Prey Interactions. Baird's beaked whales feed mainly on bottom-dwelling fishes and cephalopods, but occasionally take open ocean fish, such as mackerel, sardine, and saury (Kasuya 2009; Ohizumi et al. 2003; Walker, Mead, and Brownell 2002). Stomach contents from specimens taken in whaling operations off Vancouver Island and off Central California included squid, octopus, various species of fishes, and skate egg cases (MacLeod, Santos, and Pierce 2003). Baird's beaked whales in Japan prey primarily on deepwater gadiform fishes and cephalopods, indicating that individuals there feed primarily at depths ranging from 800 to 1,200 m (Ohizumi et al. 2003; Walker, Mead, and Brownell

2002). Baird's beaked whale is known to forage for prey opportunistically at depths of about 3,280 ft. (1,000 m) or more (Ohizumi et al. 2003). This species has been documented to be prey for killer whales and sharks, as evidenced by wounds and scars observed on their bodies (Jefferson, Webber, and Pitman 2008; Kasuya 2009).

Life History. Baird's beaked whales have an unusual life history, with females remaining reproductive for the entirety of their lives. Calving peaks in March and April, and pregnancies last approximately 17 months (Jefferson, Webber, and Pitman 2008; Kasuya, Brownell, and Balcomb 1997). Males live longer than females (84 versus 54 years) (Kasuya, Brownell, and Balcomb 1997).

Migration. Although the specific migration of this species is unknown, Baird's beaked whales in the western North Pacific are known to move between waters of depths ranging from 3,280 to 9,840 ft. (1,000 to 3,000 m), where fish that live on or near the bottom of the ocean are abundant (Ohizumi et al. 2003).

Hearing/Vocalization. Beaked whales use frequencies of between 300 Hz and 129 kHz for echolocation, and between 2 and 10 kHz, and possibly up to 16 kHz, potentially for social communication (MacLeod 1999).

Both whistles and clicks have been recorded from Baird's beaked whales in the eastern North Pacific Ocean (Dawson, Barlow, and Ljungblad 1998). Whistles had fundamental frequencies between 4 and 8 kHz, with two to three strong harmonics within the recording bandwidth (Dawson, Barlow, and Ljungblad 1998). Pulsed sounds (clicks) had a dominant frequency around 23 kHz, with a second frequency peak around 42 kHz (Dawson, Barlow, and Ljungblad 1998). The clicks were most often emitted in irregular series of very few clicks; this acoustic behavior appears unlike that of many species that echolocate (Dawson, Barlow, and Ljungblad 1998).

Diving. Baird's beaked whales showed a maximum recorded diving depth of 1,777 m, and dives can be over an hour, with the longest dive duration at 67 min (Minamikawa, Iwasaki, and Kishiro 2007). Rommel et al. (2006) and (2005) reviewed aspects of beaked whale diving physiology and morphological/anatomical adaptations. Dives range from those near the surface, where the animals are still visible, to long deep dives. Prolonged dives by Baird's beaked whales for up to 67 min have been reported (Kasuya 2009), although dives of 25 to 35 m for about 45 min are more typical (Balcomb 1989; Von Saunder and Barlow 1999). The usual observed surface behavior for Baird's beaked whales is a tight group drifting along the surface spouting low bushy blows for 3 to 10 min, and then diving nearly synchronously (Balcomb 1989). Groups appear to stay together when diving and often resurface simultaneously. This can occur after dives of 30 min or more (Kasuya 2009; Minamikawa, Iwasaki, and Kishiro 2007; Pitman et al. 1988).

5.17.5 Habitat and Distribution

Baird's beaked whales appear to occur mainly in deep waters over the continental slope, near oceanic seamounts, and in areas with submarine escarpments. They may be seen close to shore where deep water approaches the coast (Jefferson, Webber, and Pitman 2008; Kasuya 2009).

The Baird's beaked whale is found only in the North Pacific and adjacent seas (Bering Sea, Okhotsk Sea, Sea of Japan, and the Gulf of California), mainly north of 34°N in the west and 28°N in the east (Kasuya and Miyashita 1997; Reeves et al. 2003). Distributional limits of Baird's beaked whales in the mid-Pacific, as well as their winter habitats, are not well known (Jefferson, Webber, and Pitman 2008). Baird's

beaked whales are sighted less frequently and are presumed to be farther offshore during the colder-water months of November through April (Carretta et al. 2010).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. The northern waters of the North Central Pacific Gyre may be included in this species' primary range (Figure 5-36).

KUROSHIO CURRENT. Seasonal movements in and out of shelf break regions of Japan throughout the year have been evidenced (Kasuya and Miyashita 1997). During summer-fall, occurrence of the Baird's beaked whale is expected off the Pacific coast of Japan north of 36° N from the shelf break to the 3,000 m isobath, (Kasuya and Miyashita 1997; MacLeod, Santos, et al. 2006; Reeves and Mitchell 1993). Their numbers increase toward summer, when whaling commences, and then decrease toward October (Kasuya and Miyashita 1997). Occurrence north of 36°N in the Sea of Japan is not likely (Perrin, Würsig, and Thewissen 2008). Low likelihood of occurrence is also expected in waters deeper than 3,000 m. During the winter-spring, the Baird's beaked whale may be found north of 34°N (seaward of the shelf break) along the Pacific coast of Japan. During this period, they are almost absent in waters farther offshore, having left these waters in December (Kasuya and Miyashita 1997); the exact locations of wintering grounds are not known (Perrin, Würsig, and Thewissen 2008).

EAST CHINA SEA. This species has no known occurrence in the East China Sea (Figure 5-36).

PHILIPPINE SEA. This species has no known occurrence in the Philippine Sea (Figure 5-36 and Figure 5-37).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Off the Pacific coast of Japan, Baird's beaked whales appear in May in waters with bottom depths of 1,000 to 3,000 m (Figure 5-36 and Figure 5-37) (Kasuya 1986; Kasuya and Miyashita 1997; Kasuya and Ohsumi 1984).

MARIANA ARCHIPELAGO. This species has no known occurrence in the Mariana Archipelago (Figure 5-37).

5.17.6 Species-specific Threats

The Baird's beaked whale is still hunted by fisheries in Japanese waters. A national quota of 66 animals has led to over 1,000 catches since 1987 National Marine Fisheries Service (2012a).

This Page Intentionally Left Blank

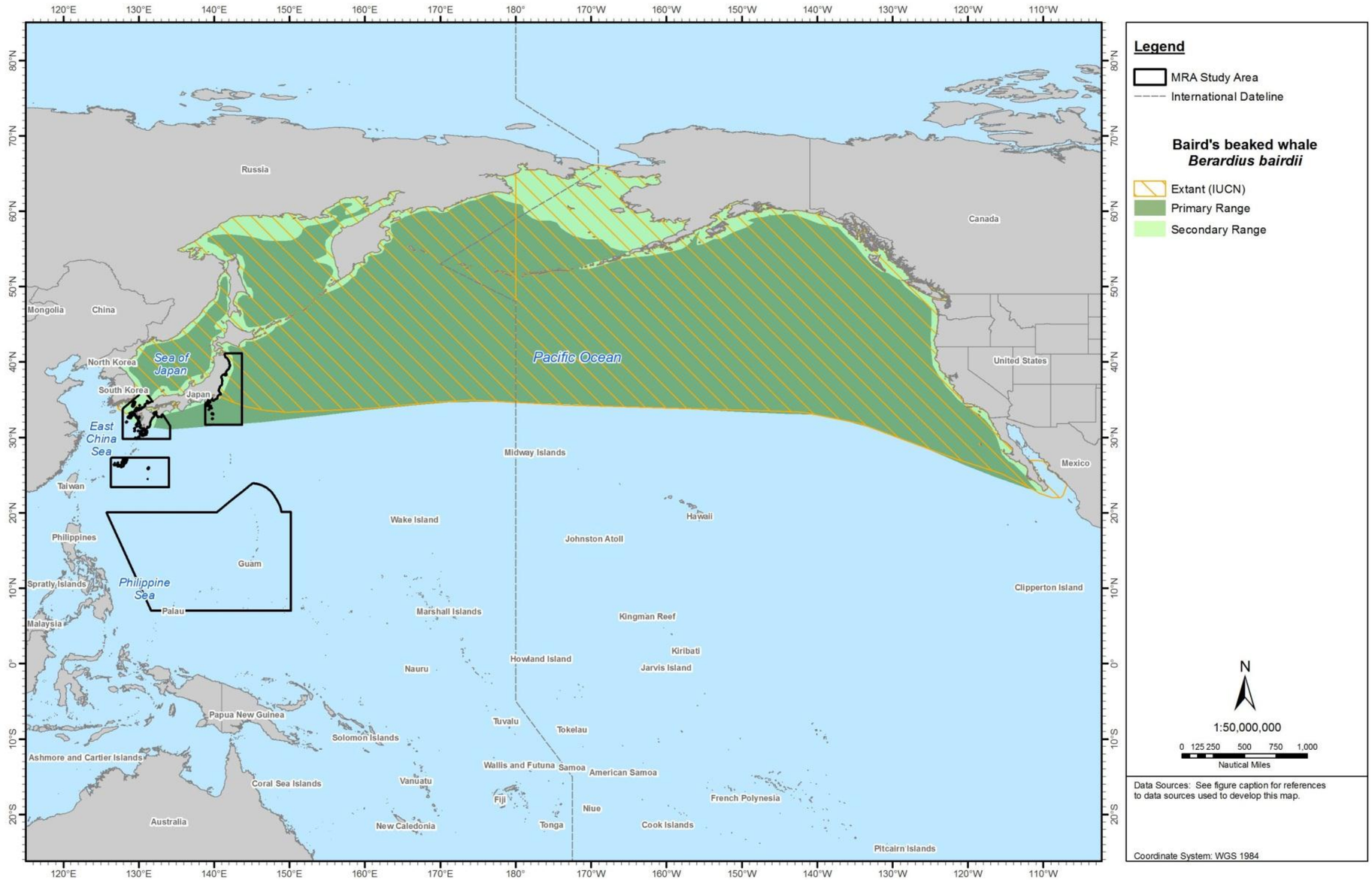

Figure 5-36: Geographic Range of Baird's Beaked Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

Figure 5-37: Geographic Range of Baird's Beaked Whale in the MRA Study Area
Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.18 LONGMAN'S BEAKED WHALE (*INDOPACETUS PACIFICUS*)

5.18.1 Description

In the past, this species was often referred to as the "tropical bottlenose whale" mainly because whales now known to be of this species had been sighted in various locations in the tropical/subtropical Indo-Pacific, but had not yet been identified to the species level (Pitman et al. 1999). At the time, this species was known only from a handful of skulls, and the external appearance of the species was undescribed. Until several stranded specimens were identified as Longman's beaked whales based on skull morphology and genetics, and the connection was made (Dalebout et al. 2003), the sighted whales had been thought to be members of the *Hyperoodon* genus (either far-ranging southern bottlenose whales or possibly an undescribed tropical species). We now know these animals to be, in fact, Longman's beaked whales.

The Longman's beaked whale looks very much like the southern bottlenose whale (*Hyperoodon planifrons*) in general shape and coloration but is more slender (Dalebout et al. 2003; Pitman et al. 1999). Longman's beaked whales ranging from an estimated 4 to 9 m in length have been sighted at sea (Jefferson, Webber, and Pitman 2008). Their weight is unknown. The tall, falcate dorsal fin is set far back on the body (Dalebout et al. 2003; Pitman et al. 1999). The head appears as a well-rounded melon in profile, and the beak length is variable, suggesting developmental changes in beak size (Dalebout et al. 2003; Pitman et al. 1999). This species has a single pair of teeth set close to the tip of the lower jaw; it is suspected that, as most other beaked whales species, only adult males have erupted teeth (Dalebout et al. 2003). The body color has been described as variable but is dominated by tan to grayish-brown tones (Pitman et al. 1999). Young animals are distinctively patterned; they are darker gray-brown above with conspicuous pale melon and white sides (Pitman et al. 1999). The light area on the head extends only as far back as the blowhole (Jefferson, Webber, and Pitman 2008).

5.18.2 Status and Management

Longman's beaked whale is protected under the MMPA and is not listed under the ESA. This species is also listed as data deficient by the IUCN and falls under Appendix II CITES regulations. Longman's beaked whale is a rare beaked whale species and, until recently, was considered the world's rarest cetacean; the spade-toothed whale now holds that position (Dalebout et al. 2003; Pitman 2008a). Only one Pacific stock, the Hawaiian stock, is identified (Carretta et al. 2010). There are no annual deaths or serious injuries caused by fisheries in the Hawaiian stock (Carretta et al. 2012). Although this stock does not have range within the MRA Study Area, Longman's beaked whales are known to have primary and secondary range within the MRA Study Area.

5.18.3 Population and Abundance

The geographically nearest stock assessments were for the Hawaiʻi stock (estimated 1,007 [CV=1.25] whales) (Carretta et al. 2012). No abundance estimates of this species in the MRA Study Area are available.

5.18.4 Biology, Ecology, and Behavior

This species is often observed swimming in tight groups and at times is associated with other species, such as pilot whales and spinner dolphins (Jefferson, Webber, and Pitman 2008; Pitman 2008b).

Group Size. Unlike other beaked whale species, Longman's beaked whale is generally found in moderately large groups, often greater than 10. In the Pacific, mean group size is 18.5 whales and ranges from 1 to 100 (Pitman 2008a). The average group size in Hawaiian waters is considered to be around 17, and group size in the Indian Ocean averages 7.2, ranging from 1 to 40 (Afsal et al. 2009; Anderson et al. 2006; Barlow et al. 2006).

Predator/Prey Interactions. Based on recent tagging data from Cuvier's and Blainville's beaked whales, Baird et al. (2005) suggested that feeding for this species might occur at mid-water rather than only at or near the bottom (Heyning 1989; MacLeod, Santos, and Pierce 2003).

This species has not been documented to be prey to any other species, although it is likely subject to occasional killer whale predation like other whale species.

Life History. Little information is available on life history and reproduction for this species. The length of a newborn calf has been measured at 2.9 m (Dalebout et al. 2003; Jefferson, Webber, and Pitman 2008).

Migration. Little information regarding the migration of this species is available, but it is believed widely distributed across the tropical Pacific and Indian Oceans (Jefferson, Webber, and Pitman 2008). Whether the Longman's beaked whale participates in a seasonal migration is unknown (Jefferson, Webber, and Pitman 2008; Pitman 2008a).

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

It has been suggested that beaked whales use frequencies of between 300 Hz and 129 kHz for echolocation, and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication (MacLeod and Claridge 1999). The only known recording of the Longman's beaked whale was taken during a shipboard survey of cetaceans in the Hawaiian Archipelago. The vocalization included clicks and burst pulses, categorized as a 15 KHz click, a 25 KHz click, and a 25 kHz pulse with an upsweep; 15k Hz and 25 kHz clicks lasted 181 and 144 ms, respectively. Upswept pulse were recorded at 288 ms, and burst pulses were 0.5-s. click trains consisting of around 240 clicks/s. (Aragones et al. 2010).

Diving. Dive durations of Longman's beaked whales are normally either relatively short (11 to 18 min) or long (20 to 23 min). The maximum reported dive time for Longman's beaked whales is 33 min (Anderson et al. 2006).

5.18.5 Habitat and Distribution

Worldwide, Longman's beaked whales normally inhabit continental slope and deep oceanic waters (depths greater than 200 m), and are only occasionally reported in waters over the continental shelf (Canadas, Sagarminaga, and Garcia-Tiscar 2002; Ferguson, Barlow, Reilly, et al. 2006; MacLeod, Perrin, et al. 2006; Pitman 2008a; Waring et al. 2001). Longman's beaked whales generally are found in warm tropical waters, with most sightings occurring in waters with sea surface temperatures warmer than 26°C (Anderson et al. 2006; MacLeod, Perrin, et al. 2006). Sighting records of this species in the Indian Ocean showed Longman's beaked whales typically found over deep slopes (655 to 6,560+ ft.) (Anderson et al. 2006).

Although the full extent of this species distribution is not fully understood, many recorded sightings have occurred at various locations in tropical waters of the Pacific and Indian Oceans (Afsal et al. 2009; Dalebout et al. 2002; Dalebout et al. 2003; Moore 1972). Ferguson et al. (2001) reported that all Longman's beaked whale sightings were south of 25°N. Records of this species indicate presence in the eastern, central, and western Pacific, including waters off the coast of Mexico.

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. The range of Longman's beaked whale generally includes the North Central Pacific Gyre (Gallo-Reynoso and Figueroa-Carranza 1995; Jefferson, Webber, and Pitman 2008; MacLeod, Perrin, et al. 2006).

KUROSHIO CURRENT. The Longman's beaked whale is believed to occur seaward of the shelf break south of 35°N, as well as on the shelf in the Tsushima Strait, as deep waters are close to shore in this area (Figure 5-38 and Figure 5-39). The occurrence pattern is believed similar year-round.

EAST CHINA SEA. Areas adjacent to the East China Sea are a part of both the primary and secondary ranges of this species (Figure 5-38 and Figure 5-39).

PHILIPPINE SEA. The Philippine Sea is included in the Longman's beaked whale's known primary range (Figure 5-38 and Figure 5-39).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. This species is not expected on the shelf area around island groups, such as the Ogasawara Islands (Figure 5-39). One of the few confirmed records for this species in the western North Pacific is an individual that stranded in July 2002 at Nishikata beach, Sendai-shi, Kagoshima-ken, Japan (Crane and Lashkari 1996). This is the only recorded stranding of this species in Japan (Crane and Lashkari 1996).

MARIANA ARCHIPELAGO. No occurrence records exist for this species in the Mariana Islands MRA Study Area and vicinity, but that area is within the known distribution range of this species (Figure 5-389). Beaked whales may occur in the area including around seaward of the shelf break. Beaked whales may occur on the shelf between the 50 m isobath and the shelf break, as deep waters come very close to the shore in this area. In some locales, beaked whales can be found in waters over the shelf, so beaked whales possibly have similar habitat preferences here.

CAROLINE ISLANDS. The waters around the Caroline Islands are included in the Longman's beaked whale primary range, although they are not expected to occur around island groups (Figure 5-389).

5.18.6 Species-specific Threats

In general, beaked whales may be sensitive to underwater noise such as that produced through Navy sonar and seismic studies (Cox T. M. et al. 2006). A novel case of polydactyly was noted in an immature Longman's beaked whale (i.e., a sixth digit contained within the sheath of the fin). This is believed to cause little hindrance to swimming (Watson et al. 2008).

This Page Intentionally Left Blank

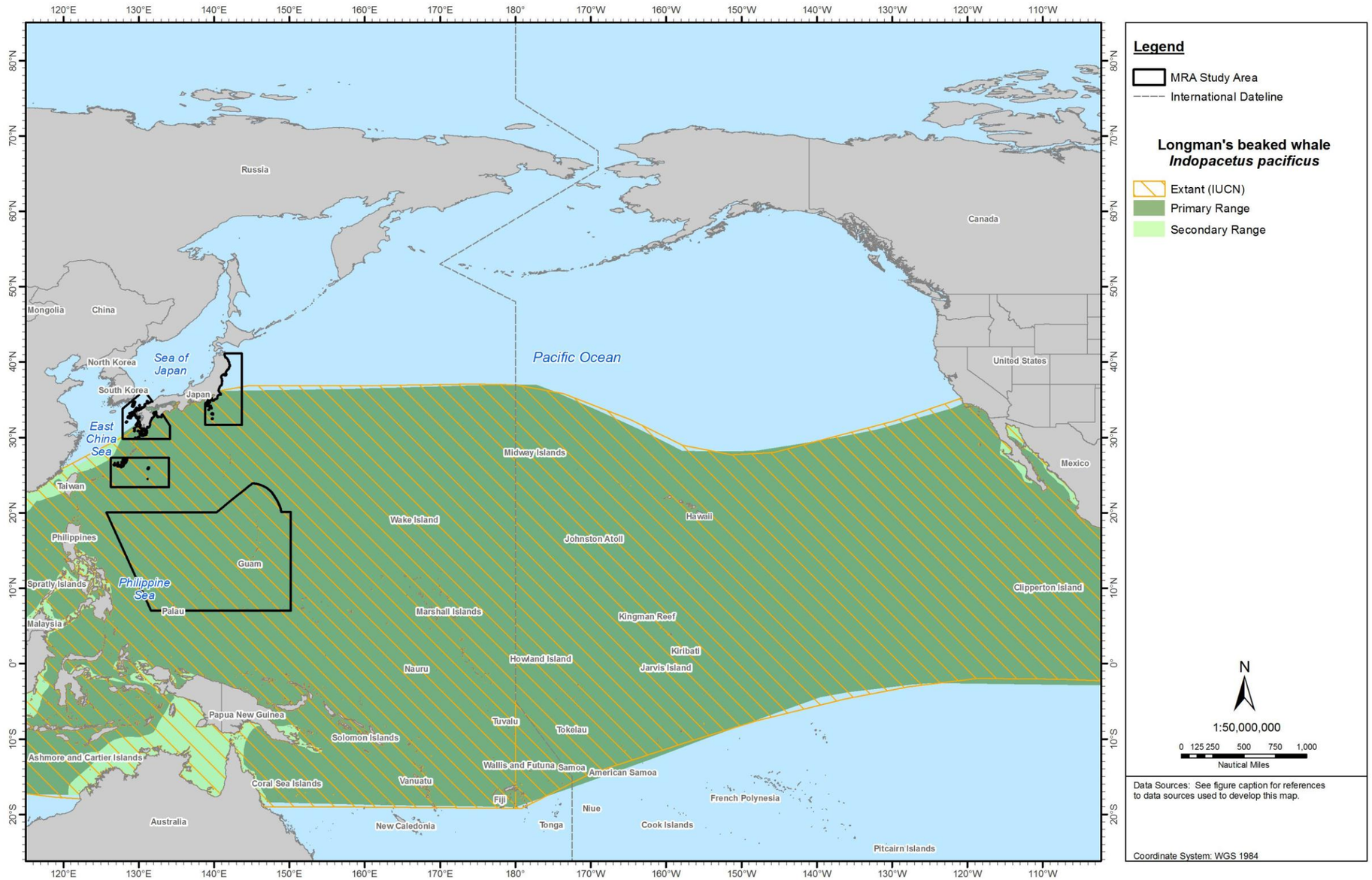

Figure 5-38: Geographic Range of Longman's Beaked Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

Figure 5-39: Geographic Range of Longman's Beaked Whale in the MRA Study Area

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.19 HUBBS' BEAKED WHALE (*MESOPLODON CARLHUBBSI*)

5.19.1 Description

Because of morphological similarities between this species and other *Mesoplodonts*, distinguishing the Hubb's beaked whales from other *Mesoplodon* species at sea is not straightforward. Hubb's beaked whales can grow up to 5.4 m and may weigh as much as 1,500 kg (The Beaked Whale Resource 2012b). Calves may be up to 2.5 m long (The Whale and Dolphin Conservation Society 2010). They are generally dark in coloration with a contrasting white beak and, in males, a white cap or what has been termed the "beanie" cap. This is a distinctive marking on the head. Males also have large teeth halfway along the jaw, and typically show excessive scarring as do other beaked whale males. Three distinctive features of the male's raised white forehead render them easier to identify at sea: the white cap, a stocky white elongated beak, and a strongly arched lower jaw with two large tusks in the middle. These are clearly visible when the mouth is closed. The male is dark grey to black in color, and the skin is scratched with long, white scars.

Females are harder to identify and less distinctive than the males. They have a longer beak than do the males, exhibit typical counter shading (i.e., lighter and darker below), and also lack the scarring seen in males. The female also lacks the white forehead and has a less strongly arched jaw from which the teeth do not erupt. Both the females and immature whales are medium grey with pale grey undersides. Both sexes have a moderately long beak and a rounded melon. This latter feature is helpful for at-sea identifications. Hubb's beaked whales have longer beaks than the similar looking Stejneger's, a more rounded melon, and a rotund, spindle-shaped body similar to many other beaked whale species. The flippers and dorsal fin are relatively small.

5.19.2 Status and Management

Hubbs' beaked whale is protected under the MMPA and is not listed under the ESA. This species is also listed as data deficient by the IUCN and falls under Appendix II CITES regulations. As a result of difficulty in distinguishing the different *Mesoplodon* species from one another, the U.S. management unit is defined to include all *Mesoplodon* species that occur in the area. Hubb's beaked whale has been combined with other *Mesoplodon* species to make up the California/Oregon/Washington stock (Carretta et al. 2010).

5.19.3 Population and Abundance

No abundance estimates are available for the Hubbs' beaked whale in the MRA Study Area.

5.19.4 Biology, Ecology, and Behavior

Adult male Hubbs' beaked whales may fight each other, although this has not been directly observed. It is inferred from the scars and scratches found on their bodies (Heyning 1984; Jefferson, Webber, and Pitman 2008).

Group Size. Group sizes are generally considered small, ranging from 1 to 15, as in other species in the genus *Mesoplodon* (MacLeod and D'Amico 2006).

Predator/Prey Interactions. All beaked whales probably feed at or close to the bottom in deep oceanic waters (Heyning 1989; Heyning and Mead 1996; MacLeod, Santos, and Pierce 2003). However, feeding may also occur at mid-water, based on tagging data on Cuvier's and Blainville's beaked whales (Baird et al. 2004). Stomach content analyses of Hubbs' beaked whales indicated squid beaks, fish ear bones, and other fish bones (MacLeod, Santos, and Pierce 2003; Mead, Walker, and Houck 1982). *Mesoplodonts* occupy an ecological niche distinct from that of Cuvier's beaked whales by feeding on smaller squids, allowing the different beaked whale species to coexist (MacLeod 2005; MacLeod, Santos, and Pierce 2003). This species has not been documented to be prey to any other species, although it is likely subject to occasional killer whale predation like other whale species.

Life History. Little information is available on life history and reproduction of this species. Based on sightings in the North Pacific, calving likely occurs in the summer. Measured length of Hubbs' beaked whales at birth has been 2.5 m (Jefferson, Webber, and Pitman 2008; Mead 1984).

Migration. Little information regarding the migration of this species is available. Whether Hubbs' beaked whale is restricted to the North Pacific or participates in a seasonal migration is unknown (Jefferson, Webber, and Pitman 2008; Pitman 2008b).

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

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

Diving. Little information is available on diving for this species, but dive durations of *Mesoplodon* species are typically longer than 20 min, and this species is known to dive to significant depths (Baird, Webster, et al. 2006; Barlow 1999).

5.19.5 Habitat and Distribution

Worldwide, beaked whales normally inhabit continental slope and deep oceanic waters (depths greater than 655 ft. [200 m]) and are occasionally reported in waters over the continental shelf (Canadas, Sagarminaga, and Garcia-Tiscar 2002; Ferguson, Barlow, Reilly, et al. 2006; MacLeod, Perrin, et al. 2006; Pitman 2008a; Waring et al. 2001).

Along the Pacific coast of North America, Hubbs' beaked whale distribution is generally associated with the deep subarctic current system (Mead 1989; Mead, Walker, and Houck 1982). The Hubbs' beaked whale appears to be restricted to the North Pacific Ocean (Houston 1990; Mead, Walker, and Houck 1982). Nearly all records to date have come from strandings along the west coast of North America and in Japan (Mead, Walker, and Houck 1982).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. The northern boundaries of the North Central Pacific Gyre may include part of the primary range of this species (Figure 5-40).

KUROSHIO CURRENT. Identification of species at sea is generally difficult for *Mesoplodon spp.*, so occurrence patterns for the Blainville's, Hubbs', Stejneger's, and ginkgo-toothed beaked whales are typically recorded as a combined occurrence of *Mesoplodon spp.* (Figure 5-40) (MacLeod et al. 2006). However, this species does have distinctive markings that render it easier to identify at sea. *Mesoplodon spp.* are believed to occur seaward of the shelf break, as well as on the shelf in the Tsushima Strait, as deep waters are close to shore in this area.

EAST CHINA SEA. The East China Sea is not included in the known range of this species (Figure 5-40 and Figure 5-41).

PHILIPPINE SEA. The Philippine Sea is not included in the known range of this species (Figure 5-40 and Figure 5-41).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Live strandings of Blainville's and Hubbs' beaked whales in the MRA Study Area have been documented (Yamamoto, Ito, and Komaba 2001).

MARIANA ARCHIPELAGO. No occurrence records are available for this species in the Mariana Islands MRA Study Area and vicinity (Figure 5-40 and Figure 5-41). Beaked whales may occur in the area including and seaward of the shelf break. These beaked whales may occur on the shelf between the 50 m isobath and the shelf break because deep waters come very close to the shore in this area. In some locales, beaked whales can be found in waters over the shelf, so beaked whales possibly have similar habitat preferences here. Occurrence pattern is believed the same throughout the year. The range of the Hubbs' beaked whale is not well-known. While occurrence of this species in the Mariana Islands MRA Study Area and vicinity is possible, its apparent preference for colder waters suggests that any occurrence would be extralimital.

CAROLINE ISLANDS. The waters around the Caroline Islands are not included in the known range of this species (Figure 5-40 and Figure 5-41).

5.19.6 Species-specific Threats

The IUCN reports the major threats for the Hubb's beaked whale include direct and indirect takes by Japanese fisheries to be sold in meat markets (Taylor et al. 2007). This species may also be susceptible to the same harmful effects other beaked whales experience regarding anthropogenic sound (Cox T. M. et al. 2006).

This Page Intentionally Left Blank

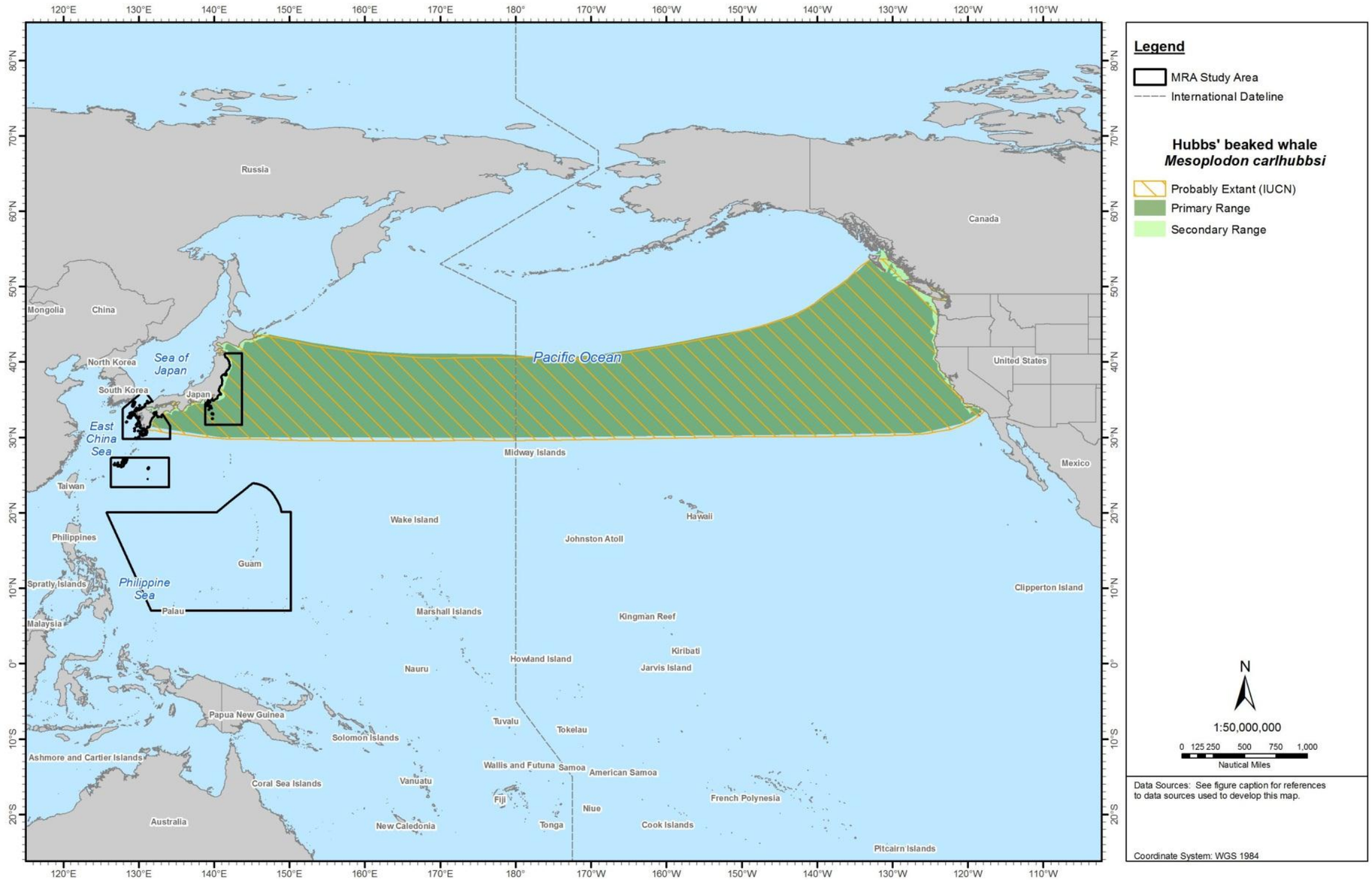

Figure 5-40: Geographic Range of Hubb's Beaked Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

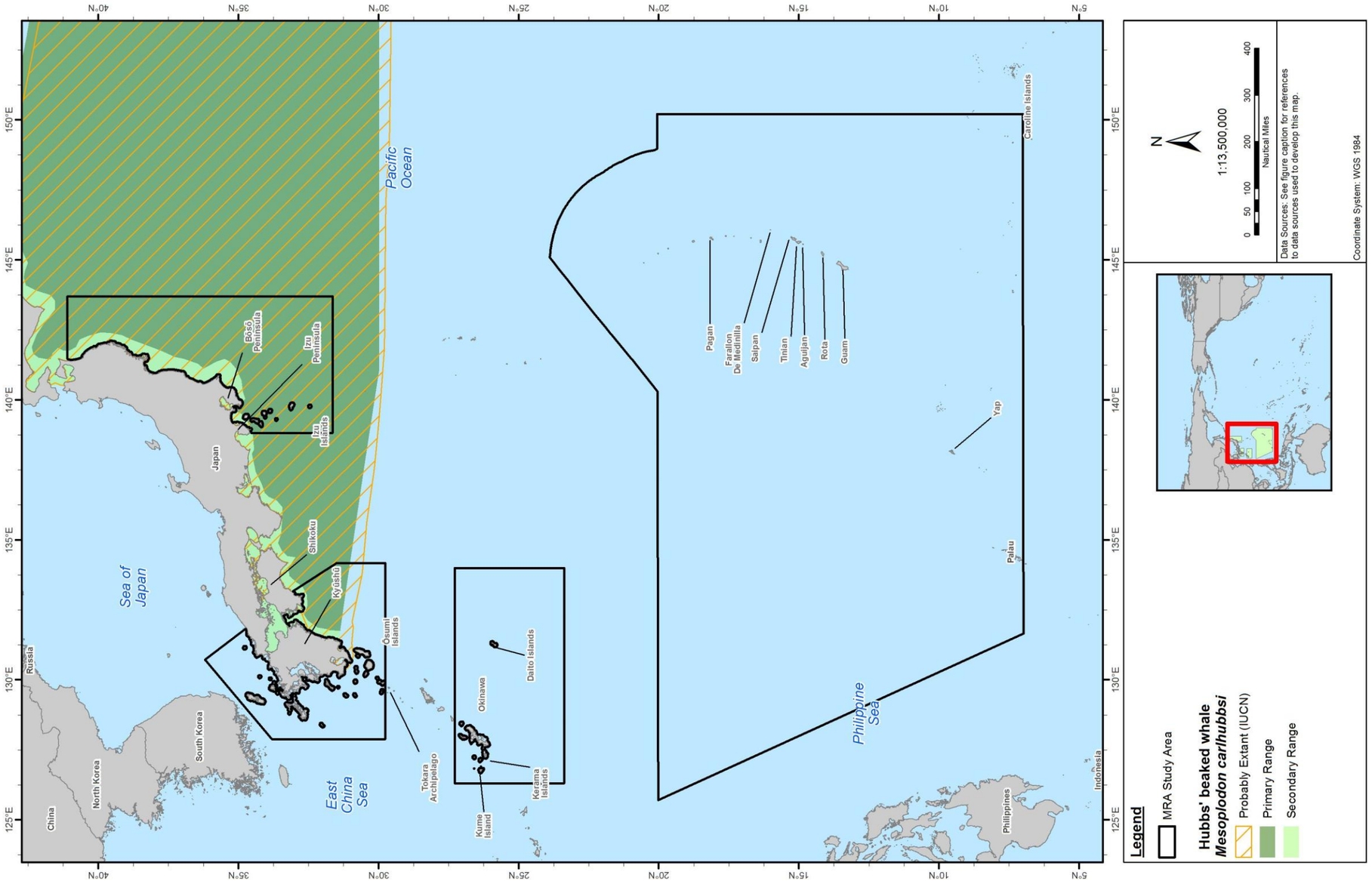

Figure 5-41: Geographic Range of Hubb's Beaked Whale in the MRA Study Area
Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.20 GINKGO-TOOTHED BEAKED WHALE (*MESOPLODON GINKGODENS*)

5.20.1 Description

The level of morphological similarities between this species and other *Mesoplodonts* renders the ginkgo-toothed beaked whale virtually indistinguishable at sea from other *Mesoplodon* species. Their length is approximately 5 m and weight is unknown. They are poorly described generally but have a moderate beak with arched jaw line and a round melon. As in other *Mesoplodonts*, the male has an extruding tooth halfway along the jaw line. White markings may be here, but generally the coloration of this species is dark (The Beaked Whale Resource 2012a).

5.20.2 Status and Management

The ginkgo-toothed beaked whale is protected under the MMPA and is not listed under the ESA. This species is also listed as data deficient by the IUCN and falls under Appendix II CITES regulations. Because of the difficulty in distinguishing the different *Mesoplodon* species from one another, the U.S. management unit is defined to include all *Mesoplodon* species that occur in the area (Carretta et al. 2010; Jefferson, Webber, and Pitman 2008). The ginkgo-toothed beaked whale has been combined with other *Mesoplodon* species to make up the California/Oregon/Washington stock (Carretta et al. 2010).

5.20.3 Population and Abundance

No abundance estimates are available for the ginkgo-toothed beaked whale in the MRA Study Area.

5.20.4 Biology, Ecology, and Behavior

Fewer than 30 records of this species exist—all from stranding records; therefore, very little is known regarding the ecology and behavior of this species. This species has never been reliably identified in the wild (MacLeod and Mitchell 2006). Most beaked whales are difficult to approach and tend to avoid aircraft and vessels (Barlow et al. 2006; Wursig et al. 1998).

Group Size. Group sizes are assumed small, ranging from 1 to a maximum of 15, as in other species in the genus *Mesoplodon* (MacLeod and D'Amico 2006).

Predator/Prey Interactions. Although no published stomach content analysis is available, ginkgo-toothed beaked whales presumably prey on squid and possibly fish, similar to other *Mesoplodon* species. *Mesoplodonts* occupy an ecological niche distinct from Cuvier's beaked whales by feeding on smaller squids, allowing the different beaked whale species to coexist (MacLeod 2005; MacLeod, Santos, and Pierce 2003). Current thinking is that all beaked whales probably feed at or close to the bottom in deep oceanic waters taking suitable prey opportunistically or as locally abundant, typically by suction feeding (Heyning 1989; Heyning and Mead 1996; MacLeod, Santos, and Pierce 2003). However feeding may also occur at mid-water, based on tagging data on Cuvier's and Blainville's beaked whales (Baird et al. 2004).

This species has not been documented to be prey to any other species, although it is likely subject to occasional killer whale predation like other whale species.

Life History. No specific information is available on life history and reproduction for this species, although gingko-toothed beaked whales likely range in length from 6.6 to 8.2 ft. at birth (Jefferson, Webber, and Pitman 2008; Mead 1984).

Migration. This species probably occurs only in the temperate and tropical waters of the Indo-Pacific; however, no specific information regarding migration is available (Jefferson, Webber, and Pitman 2008; MacLeod and D'Amico 2006).

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

Beaked whalesmay use frequencies between 300 Hz and 129 kHz for echolocation, and frequencies from 2 to 10 kHz, and possibly up to 16 kHz, for social communication (MacLeod 1999). No information is available regarding ginkgo-toothed whale vocalizations.

Diving. No specific information on diving is available for this species, but dive durations for *Mesoplodon* species are typically more than 20 min (Baird, Webster, et al. 2006; Barlow 1999).

5.20.5 Habitat and Distribution

Beaked whales normally inhabit continental slope and deep ocean waters (depths greater than 655 ft. [200 m]) and are only occasionally reported in waters over the continental shelf (Canadas, Sagarminaga, and Garcia-Tiscar 2002; Ferguson, Barlow, Reilly, et al. 2006; MacLeod, Perrin, et al. 2006; Pitman 2008a; Waring et al. 2001).

The handful of known records of the ginkgo-toothed beaked whale are from strandings, all of which are limited to the Pacific and Indian Oceans (Jefferson, Webber, and Pitman 2008; MacLeod and D'Amico 2006). The majority of the published records are from Japan; however, strandings have also been recorded in China, Taiwan, California, Mexico, and the Galapagos Islands (Mead 1989; Wang and Yang 2006).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. The distribution of the ginkgo-toothed beaked whale is thought to include the North Central Pacific Gyre (Figure 5-42).

KUROSHIO CURRENT. The ginkgo-toothed beaked whale is known only from strandings (no sightings have been confirmed) in temperate and tropical waters of the Pacific and Indian Oceans (MacLeod, Perrin, et al. 2006; Mead 1989; Palacios 1996; Wang and Yang 2006). Most records are from Japan, where this species was first described (Figure 5-42) (Nishiwaki et al. 1972).

EAST CHINA SEA. The secondary distribution of the ginkgo-toothed beaked whale is thought to include the East China Sea (Figure 5-42 and Figure 5-43).

PHILIPPINE SEA. The primary distribution of the ginkgo-toothed beaked whale is thought to include the Philippine Sea (Figure 5-42 and Figure 5-43).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. The primary distribution of the ginkgo-toothed beaked whale is known to include the Japan Archipelago (Figure 5-42 and Figure 5-43).

MARIANA ARCHIPELAGO. No occurrence records are available for this species in the Mariana Islands MRA Study Area and vicinity, but this area is within the known distribution range of this species. Beaked whales may occur in the area including and seaward of the shelf break (Figure 5-42 and Figure 5-43). Beaked whales may occur on the shelf between the 50 m isobath and the shelf break, as deep waters come very close to the shore in this area. In some locales, beaked whales can be found in waters over the shelf, so beaked whales possibly have similar habitat preferences here. Occurrence pattern is expected to be the same throughout the year.

CAROLINE ISLANDS. The distribution of the ginkgo-toothed beaked whale is thought to include the waters around the Caroline Islands, although no information regarding this species is available from these nearshore waters (Figure 5-42 and Figure 5-43).

5.20.6 Species-specific Threats

No species-specific threats to the ginkgo-toothed whale are known.

This Page Intentionally Left Blank

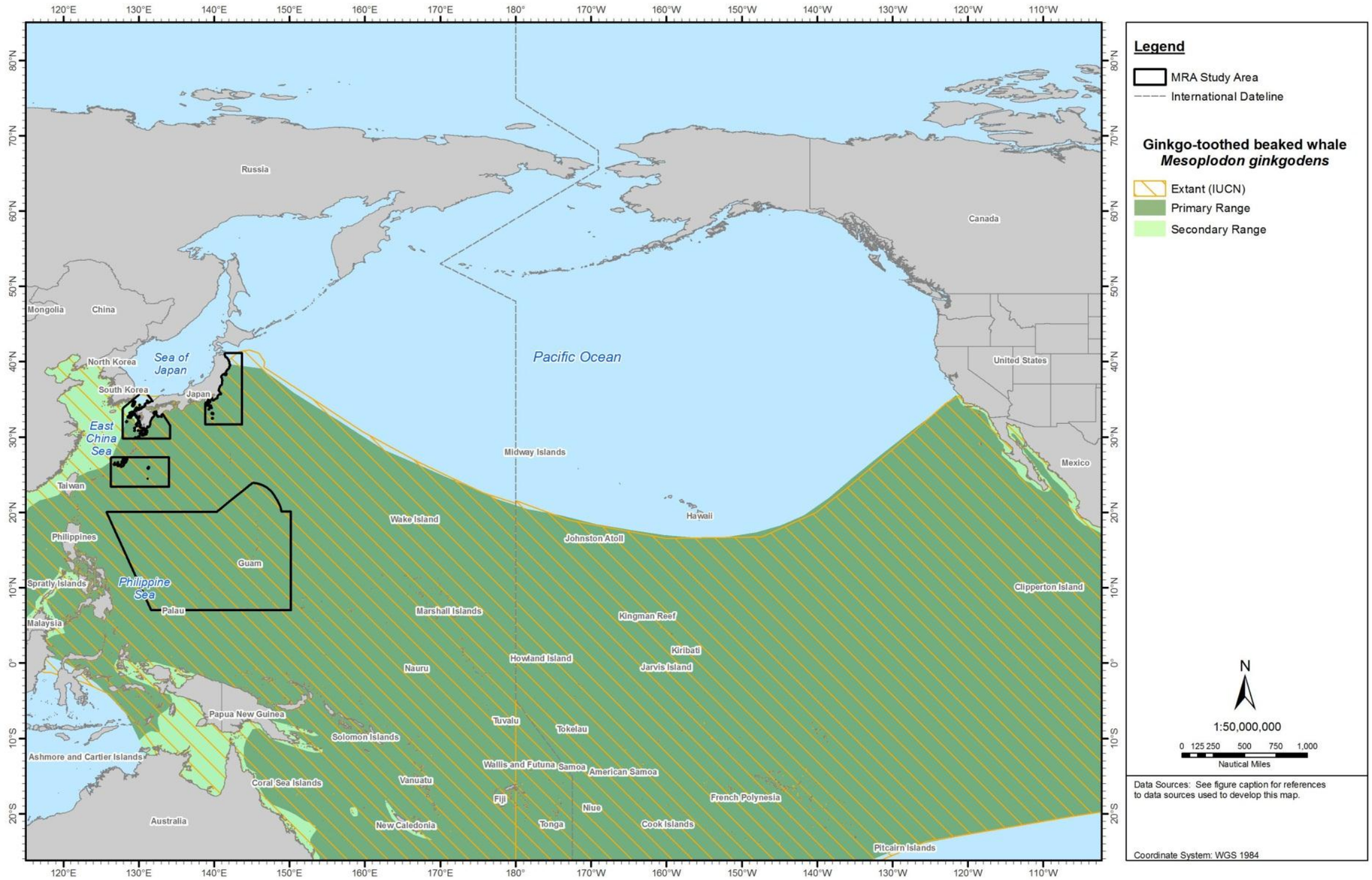

Figure 5-42: Geographic Range of the Gingko-toothed Beaked Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

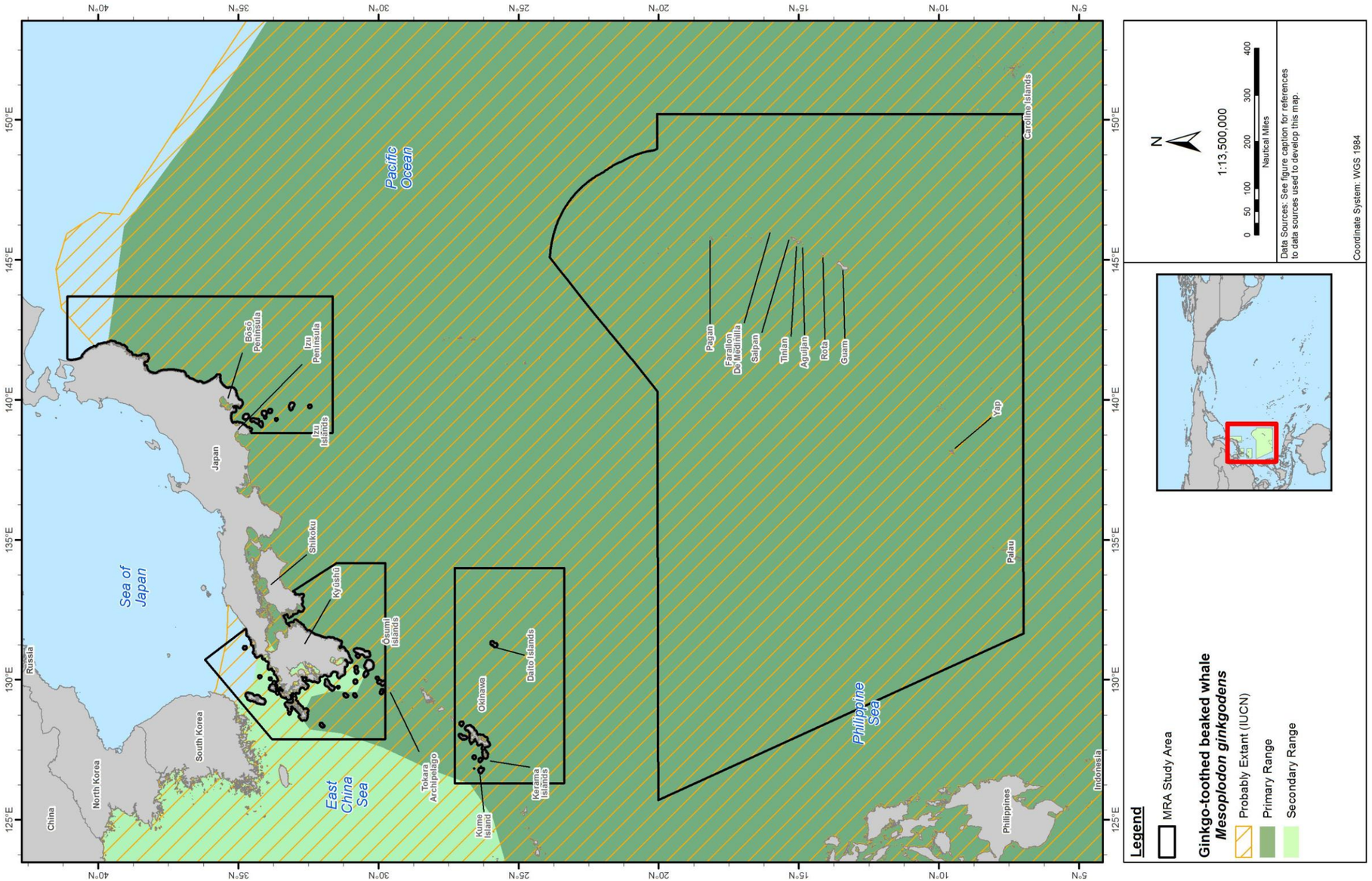

Figure 5-43: Geographic Range of the Gingko-toothed Beaked Whale in the MRA Study Area
Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.21 STEJNEGER'S BEAKED WHALE (*MESOPLODON STEJNEGERI*)

5.21.1 Description

Stejneger's beaked whale was initially described in 1885 from a skull, and nothing more of the species was known for nearly a century. Several strandings occurred in the late 1970s, but not until 1994 was the external appearance well described from fresh (stranded) specimens.

The Stejneger's beaked whale reaches lengths of at least 5.7 m (Jefferson, Webber, and Pitman 2008). Weight is unknown. This species has a typical *Mesoplodon* body shape, but the lower jaw of the adult male is highly arched with a large tusk sitting atop each arch (Mead 1989). The coloration is not very distinctive, except for some interesting white striations around the base of the tail (Walker and Hanson 1999) and a dark "hood' on the top of the head (Jefferson, Webber, and Pitman 2008).

5.21.2 Status and Management

Stejneger's beaked whale is protected under the MMPA and is not listed under the ESA. This species is also listed as data deficient by the IUCN and falls under Appendix II CITES regulations. Because of the difficulty in distinguishing the *Mesoplodon* species, the U.S. management unit is usually defined to include all *Mesoplodon* species that occur in the area. The Alaska Stejneger's beaked whale stock is recognized separately from *Mesoplodon* species off California, Oregon, and Washington (Allen and Angliss 2010a). Although these stocks do not have range within the MRA Study Area, Stejneger's beaked whales are known to have primary and secondary range within the Japan portion of the MRA Study Area.

5.21.3 Population and Abundance

The geographically nearest stock assessment was for the Alaskan stock, but no abundance or trend estimates were reported (Houston 1990). No abundance estimates are available for any of the beaked whales in the MRA Study Area, although the Stejneger's beaked whale is thought to be the most abundant *Mesoplodon* species in Japanese waters (Yamada and Yamada 1999).

5.21.4 Biology, Ecology, and Behavior

Most sightings of beaked whales are brief because these whales are difficult to approach and they avoid aircraft and vessels (e.g., Wursig et al. 1998).

Group Size. Stejneger's beaked whales have been observed in groups of 5 to 15, often containing individuals of various sizes (Jefferson, Webber, and Pitman 2008; Pitman 2008b).

Predator/Prey Interactions. Stejneger's beaked whales are known to feed primarily on squids of the families Gonatidae and Cranchiidae, typically in mid-water to near bottom depths. Stomach contents analyses of this species also have identified deep-sea fish (Jefferson, Webber, and Pitman 2008; Walker and Hanson 1999; Yamada 1998).

This species has not been documented to be prey to any other species, although it is likely subject to occasional killer whale predation like other whale species.

Life History. Little information is available on the life history of this species (Loughlin and Perez 1985). What is known is from fetuses that have been examined after strandings. This species may reach sexual maturity when individuals attain lengths of approximately 15 ft. (4.5 m), and calving likely occurs from spring to early fall in the North Pacific. Stejneger's beaked whale may live to at least 36 years, based on the aging of seven specimens (Arai, Yamada, and Takano 2004; Jefferson, Webber, and Pitman 2008).

Migration. The specific migration of this species is not known, but high stranding rates in the winter and spring along the Pacific coast suggest that Stejneger's beaked whales migrate north during summer (Jefferson, Webber, and Pitman 2008; Pitman 2008b).

Hearing/Vocalization. Beaked whales use frequencies of between 300 Hz and 129 kHz for echolocation, and between 2 and 10 kHz, and possibly up to 16 kHz, potentially for social communication (MacLeod 1999). No species specific information is available regarding Stejneger's beaked whale vocalizations and/or hearing.

Diving. No specific information is available on diving for this species, but dive durations of *Mesoplodon* species are typically more than 20 min (Baird, Webster, et al. 2006; Barlow 1999).

5.21.5 Habitat and Distribution

Worldwide, beaked whales normally inhabit continental slope and deep oceanic waters (depths greater than 656 ft. [200 m]) (Canadas, Sagarminaga, and Garcia-Tiscar 2002; Ferguson, Barlow, Reilly, et al. 2006; MacLeod, Perrin, et al. 2006; Pitman 2008a; Waring et al. 2001). They are occasionally reported in waters over the continental shelf (Pitman and Stinchcomb 2002).

Stejneger's beaked whale appears to prefer cold to temperate and subpolar waters (Loughlin and Perez 1985; MacLeod, Perrin, et al. 2006). This species has been observed in waters ranging in bottom depths from 2,395 to 5,120 ft. (730 to 1,560 m) on the continental slope (Loughlin and Perez 1985).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. The primary distribution of this species runs adjacent to the northern boundary of this oceanic area (Figure 5-44).

KUROSHIO CURRENT. This species is common in the Sea of Japan (Hiraguchi et al. 2001; Honma et al. 1999). *Mesoplodon spp.* are expected to occur seaward of the shelf break, as well as on the shelf in the Tsushima Strait, as deep waters are close to shore in this area (MacLeod, Perrin, et al. 2006). Stejneger's beaked whale is represented by the most records—a fairly large number (10 to 20) of strandings mainly along the west coast, but no sightings have been confirmed. The occurrence pattern is believed similar year-round (Figure 5-44).

EAST CHINA SEA. The distribution of this species does not include the East China Sea (Figure 5-44 and Figure 5-45).

PHILIPPINE SEA. The distribution of Stejneger's beaked whale does not include the Philippine Sea (Figure 5-44 and Figure 5-45).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. During the winter-spring season, strandings of *Mesoplodon spp.* are frequent along the coasts of the Sea of Japan. The expected range of the Stejneger's beaked whale is as far south as Miyagi Prefecture (Yamada 2001). During one stranding, a novel case of amyloidosis (abnormal proteins in organs or on tissues) was documented in this cetacean (Tajima et al. 2007).

MARIANA ARCHIPELAGO. The distribution of the Stejneger's beaked whale does not include the coastal waters around the Mariana Archipelago, yet other members of *Mesoplodon spp.* are expected in the area (Figure 5-44 and Figure 5-45).

CAROLINE ISLANDS. The distribution of Stejneger's beaked whale does not include the waters around the Caroline Islands (Figure 5-44 and Figure 5-45).

5.21.6 Species-specific Threats

The Stejneger's beaked whale has been directly hunted in Japanese waters in the local beaked whale fishery. This whale has also been documented in bycatch through entanglement in driftnet and gillnet fishing gear in the Sea of Japan (National Marine Fisheries Service). In the Republic of (South) Korea, "whale meat" markets still can buy and sell meat from stranded or bycaught marine mammals. A DNA surveillance study from 2003 to 2005 found Stejneger's beaked whale meat present in such food markets (Baker et al. 2006).

Other threats to this species includes accidental ingestion of marine debris in the form of plastic bags and string (Jefferson, Webber, and Pitman 2008). Underwater sounds may have the same effects on this species as on other beaked whales National Marine Fisheries Service (2012q).

An analysis of a Stejneger's beaked whale stranded off the coast of western Japan indicated presence of amyloidosis. Liver tissue appeared swollen, fragile, and pale, and kidneys were found to have amyloid deposits as well. Many nematodes were also found near the amyloids (Tajima et al. 2007).

This Page Intentionally Left Blank

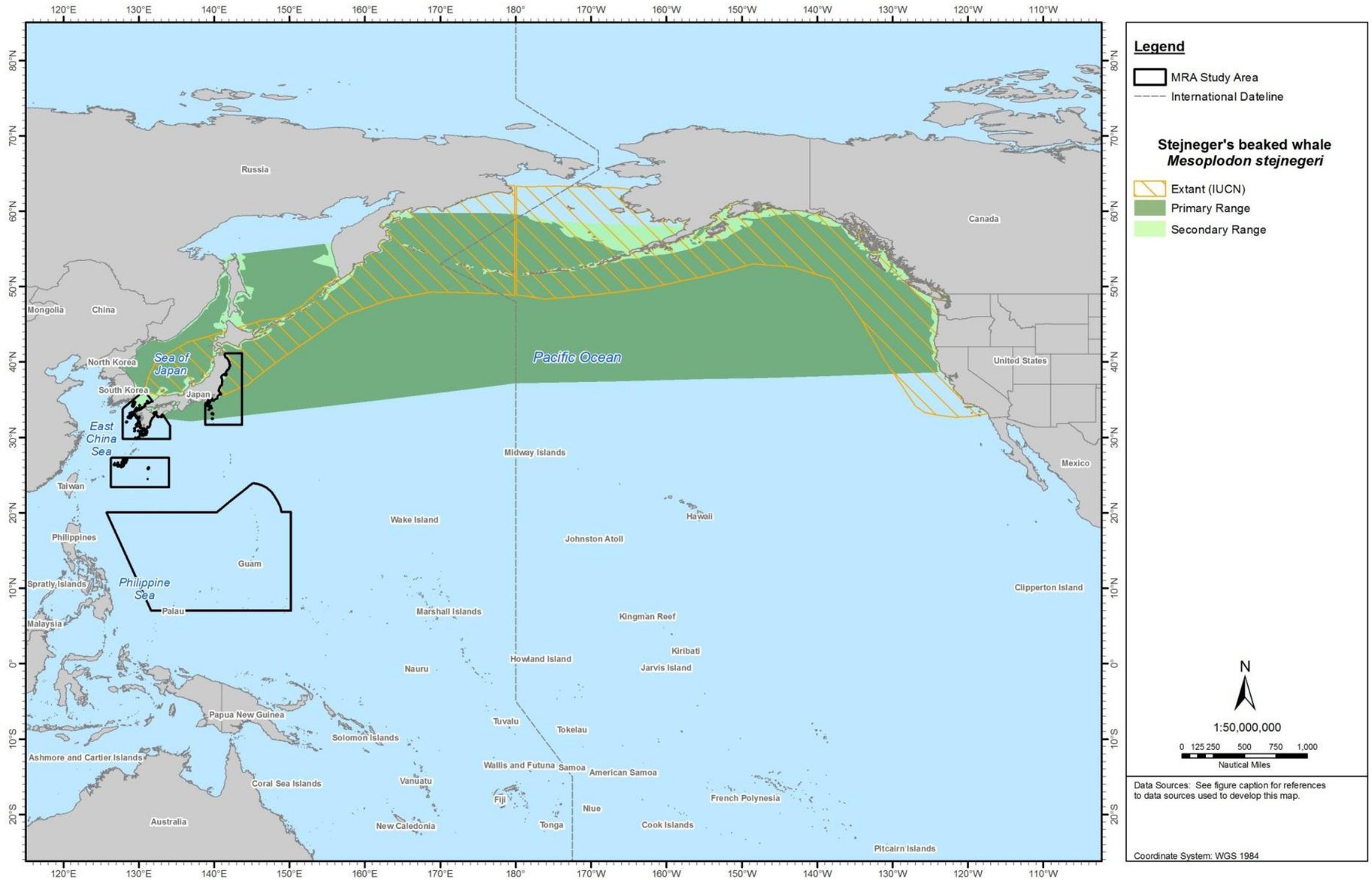

Figure 5-44: Geographic Range of Stejneger's Beaked Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

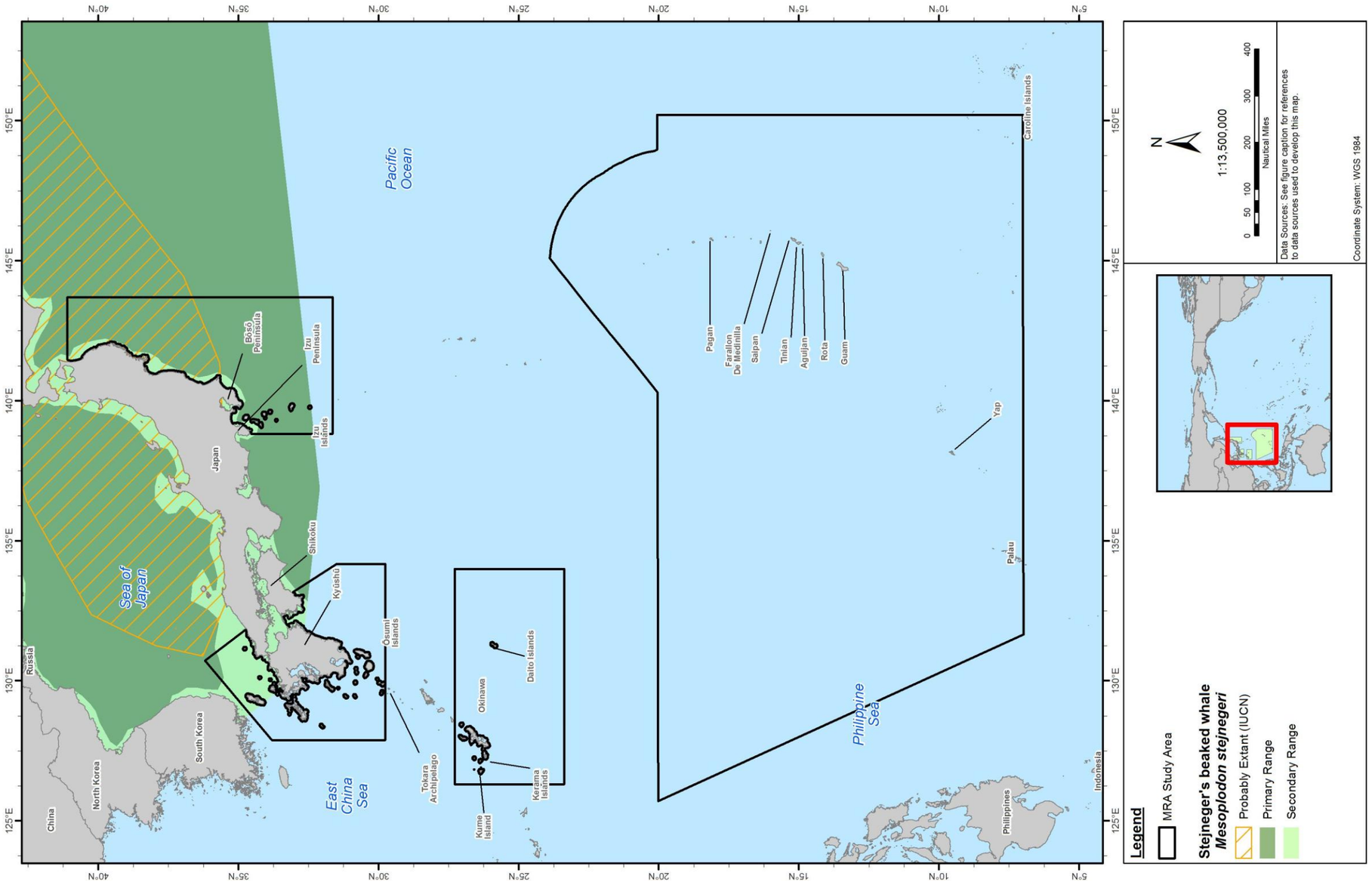

Figure 5-45: Geographic Range of Stejneger's Beaked Whale in the MRA Study Area
Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.22 ROUGH-TOOTHED DOLPHIN (*STENO BREDANENSIS*)

5.22.1 Description

Rough-toothed dolphins are relatively robust. They have a long, conical head with no demarcation between the gently-sloping melon and the moderately-long beak. This is unique among oceanic dolphins, and gives them a somewhat-reptilian appearance. Rough-toothed dolphins have large flippers (that look oversized for the animal), which are set farther back on the body than in most other dolphin species. The dorsal fin is tall and slightly falcate. Adult male rough-toothed dolphins may have an enlarged post-anal hump of connective tissue (Jefferson, Webber, and Pitman 2008; Miyazaki and Perrin 1994).

Rough-toothed dolphins have a color pattern that is generally three-tone. The back is dark gray, with a prominent, narrow dorsal cape that dips slightly down onto the side and tail stock below and behind the dorsal fin. The undersides and lips are usually white, sometimes with a pinkish cast. A dark eye patch may be hard to see. The sides are an intermediate shade of gray. White scratches and spots are often present on the bodies of older individuals—apparently caused mostly by bites of cookie-cutter sharks and probably other dolphins. Calves and juveniles are lighter in color than adults, with a muted, less contrasting color pattern; they generally lack the white spots of adults (Jefferson, Webber, and Pitman 2008; Miyazaki and Perrin 1994).

Adult rough-toothed dolphins can be up to 2.65 m long (with males slightly larger than females), and they may occasionally reach 2.8 m. They can attain weights of up to 155 kg. Length at birth is not well known. The mouth contains 19 to 28 heavy teeth in each row. The teeth have subtle, but detectable, vertical wrinkles or ridges (and this gives the species its common name).

5.22.2 Status and Management

This species is protected under the MMPA and is not listed under the ESA. This species is also listed as least concern by the IUCN and falls under Appendix II CITES regulations. Rough-toothed dolphins are among the most widely distributed species of tropical dolphins, but little information is available regarding population status (Jefferson 2009b; Jefferson, Webber, and Pitman 2008). A single Pacific management stock includes only animals found within the U.S. EEZ of the Hawaiian Islands (Carretta et al. 2010). An unknown number of annual deaths or serious injuries caused by fisheries are estimated for the Hawaiian stock (Carretta et al. 2012). Although this stock does not have range within the MRA Study Area, rough-toothed dolphins are known to have primary range within the MRA Study Area.

5.22.3 Population and Abundance

Rough-toothed dolphins are common in tropical areas, but not nearly as abundant as some other dolphin species (Reeves, Stewart, et al. 2002). Nothing is known about stock structure for the rough-toothed dolphin in the North Pacific (Carretta et al. 2004). Geographically, the nearest stock assessment was for the Hawaiian stock (estimated 8,709 [CV=0.45] dolphins) (Houston 1990). A 2007 cetacean survey estimated the number of this species in Guam and the CNMI at 166 individuals (Fulling, Thorson, and Rivers 2011).

5.22.4 Biology, Ecology, and Behavior

Rough-toothed dolphins often associate with other whale species (Miyazaki and Perrin 1994). They are also known to companion floating objects in the ETP and Gulf of Mexico (Fulling, Mullin, and Hubard 2003; Pitman and Stinchcomb 2002). Rough-toothed dolphins can perform a variety of leaps and breaches, and have been observed to move at high speeds, skimming the water's surface with only their heads and necks visible above the water. They are known to swim ahead of boats (bowride) but appear to prefer slower boats than do many other dolphin species.

Group Size. Small groups of 10 to 20 rough-toothed dolphins are most common, with pods (groups) up to several hundred reported (Baird, Webster, Mahaffy, et al. 2008; Jefferson, Webber, and Pitman 2008; Miyazaki and Perrin 1994).

Predator/Prey Interactions. Prey of rough-toothed dolphins includes fish and cephalopods. They are known to feed on large fish species, such as mahi mahi or the common dolphinfish (Miyazaki and Perrin 1994; Pitman and Stinchcomb 2002). They also prey on reef fish, as Perkins and Miller (1983) noted that parts of reef fish had been found in the stomachs of stranded rough-toothed dolphins in Hawai'i. Gannier and West (2005) observed rough-toothed dolphins feeding during the day on near-surface fishes, including on flying fishes.

Rough-toothed dolphins have not been documented to be preyed upon by any other species. They may be subject to predation by killer whales.

Life History. Very little is known about the reproductive biology of this species outside of Japan, where research has been conducted using specimens killed in direct hunts. Research in Japan indicated that males reach sexual maturity at approximately 14 years old and 2.25 m in length, and females reach sexual maturity at 10 years and 2.10 to 2.20 m in length. Calving apparently occurs throughout the year. Maximum age may be around 36 years (Miyazaki and Perrin 1994). One documentation of the behaviors of rough-toothed dolphins in response to the death of a calf, supports the belief that these dolphins form long-term associations and bonds within populations (Ritter 2007).

Migration. No evidence indicates that the rough-toothed dolphin migrates. No information regarding routes, seasons, or resighting rates in the MRA Study Area is available.

Hearing/Vocalization. No published information is available regarding hearing ability of this species.

The vocal repertoire of the rough-toothed dolphin includes broad-band clicks, barks, and whistles (Yu 2003). Echolocation clicks of rough-toothed dolphins are in the frequency range of 0.1 to 200 kHz, with a peak of about 25 kHz (Miyazaki and Perrin 1994; Yu 2003). Whistles show a wide frequency range: 0.3 to >24 kHz (Yu 2003). When these dolphins travel in synchronized groups, echolocation by more than one animal decreases, leading (Gotz, Verfuss, and Schnitzler 2006) to conclude dolphins within the group gain information from listening to the echolocation of other dolphins, a practice known as "eavesdropping."

Diving. Rough-toothed dolphins can conduct deep dives of up to 15 min (Baird, Webster, Mahaffy, et al. 2008; Jefferson 2009b). They have been recorded to dive to between 200 and 300 m (Lodi and Hetzel 1999; Wells 2008).

5.22.5 Habitat and Distribution

The rough-toothed dolphin is regarded as an offshore species that prefers deep water, but it can occur in waters of variable bottom depth (Gannier and West 2005; West, Mead, and White 2012). It rarely occurs close to land, except around islands with steep drop-offs nearshore (Gannier 2009; Gannier and West 2005). In some areas, this species may frequent coastal waters and areas with shallow bottom depths (Davis et al. 1998; Fulling, Mullin, and Hubard 2003; Lodi and Hetzel 1999; Mignucci-Giannoni 1998; Ritter 2002). At the Society Islands, rough-toothed dolphins were sighted in waters with bottom depths ranging from less than 330 ft. (100 m) to more than 9,845 ft. (more than 3,000 m), although they apparently favored the 1,640 to 4,920 ft. (500 to 1,500 m) range (Gannier 2000).

Rough-toothed dolphins are found in tropical to warm-temperate waters globally, rarely ranging north of 40°N or south of 35°S (Miyazaki and Perrin 1994). However, in some areas (such as off the coast of Brazil and West Africa), rough-toothed dolphins may occur in more shallow coastal waters. They are found in many semi-enclosed bodies of water adjacent to tropical oceans (such as the Gulf of Mexico, Caribbean Sea, Red Sea, and Gulf of California), but only occasionally in the Mediterranean Sea.

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. In the Pacific, occurrence of this species is well known in deep oceanic waters off southern Japan, in the South China Sea, off Hawai‘i, and in the ETP (Au and Perryman 1985; Baird, Webster, Mahaffy, et al. 2008; Carretta et al. 2010; Ferguson 2005; Miyashita et al. 1996) (Figure 5-46).

KUROSHIO CURRENT. South of approximately 34°N on the Pacific coast is the area of expected occurrence for the rough-toothed dolphin, seaward of the shelf break (Figure 5-46 and Figure 5-47). This takes into consideration the species’ latitudinal distribution, as shown in (Miyazaki and Perrin 1994), as well as a number of offshore records for the species provided by (Miyashita et al. 1996). The rough-toothed dolphin normally occurs in deep waters off the east coast of Japan, with some individuals making their way into the Sea of Japan (Miyazaki and Perrin 1994). Occurrence pattern is believed similar throughout the year.

EAST CHINA SEA. The East China Sea is included in the known primary range of this species (Figure 5-46 and Figure 5-47).

PHILIPPINE SEA. The Philippine Sea is included in the known primary range of this species (Figure 5-46 and Figure 5-47).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Occurrence is expected from the shore to seaward of the MRA Study Area in the Tsushima Strait, as deep waters are very close to shore here. Occurrences of this species are less likely between the shore and the shelf break. This species is not expected to occur within the bays.

MARIANA ARCHIPELAGO. As an oceanic species, the rough-tooth dolphin is expected to occur from the shelf break to seaward of the Mariana Islands MRA Study Area (Figure 5-48). Rough-toothed dolphins may occur from the coastline (including harbors and lagoons) to the shelf break (Figure 5-48), consistent with data on distribution the pattern for this species at other tropical locales in nearshore waters. Two dolphins were visually identified during a 2007 cetacean survey swimming in the waters around the

island of Guguan (Fulling, Thorson, and Rivers 2011; U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007). Through acoustic recordings and visual sightings the occurrence of rough-toothed dolphins north of the archipelago has been documented (Norris et al. 2011). Occurrence pattern is believed the same throughout the year.

Rota. July 2004, a sighting of a few rough-toothed dolphins was documented, along with a school of an estimated 500 to 700 melon-headed whales, at Sasanhayan Bay (Rota) in waters with a bottom depth of 249 ft. (75.9 m) (Jefferson et al. 2006).

Guam. An assembly of eight rough-toothed dolphins was seen approximately 102 nm east of Guam (Mobley 2007).

CAROLINE ISLANDS. The waters around the Caroline Islands are included in the known primary range of this species. They may occur from the coastline (excluding harbors and lagoons) to the shelf break (Figure 5-46 and Figure 5-47), although no sightings have been documented.

5.22.6 Species-specific Threats

Although they are generally not the main target species, rough-toothed dolphins have been taken directly in small cetacean fisheries in Japan, Sri Lanka, Indonesia, the Caribbean, Papua New Guinea, and the Solomon Islands. Small numbers may be taken directly in fisheries in West Africa as well. Incidental catches also have been documented in purse seines and gillnets in the ETP, Sri Lanka, Brazil, and the offshore North Pacific (Best 2007; Jefferson, Webber, and Pitman 2008). Hearing defects have been reported in stranded rough-toothed dolphins severely entangled in fishing gear. Of the dolphins surveyed, 36% showed reductions in hearing equivalent to severe or profound hearing loss documented in humans (Mann et al. 2010).

In an analysis by Carvalho et al. (2010) of strandings off the coast of Brazil, rough-toothed dolphins were shown susceptible to parasites. For more detailed information on specific host-parasite species identified through this study, refer to Carvalho et al. (2010).

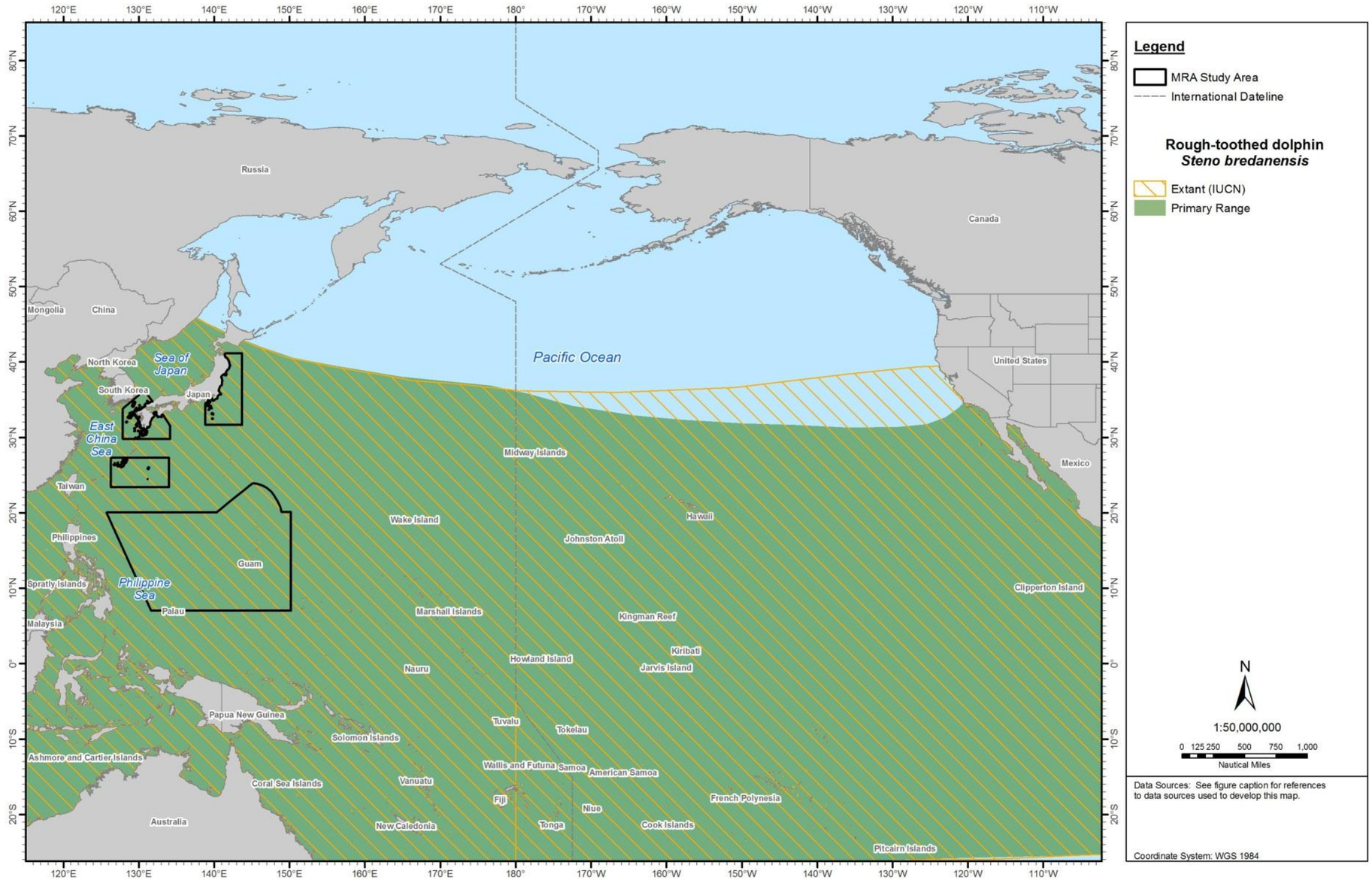

Figure 5-46: Geographic Range of the Rough-toothed Dolphin in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

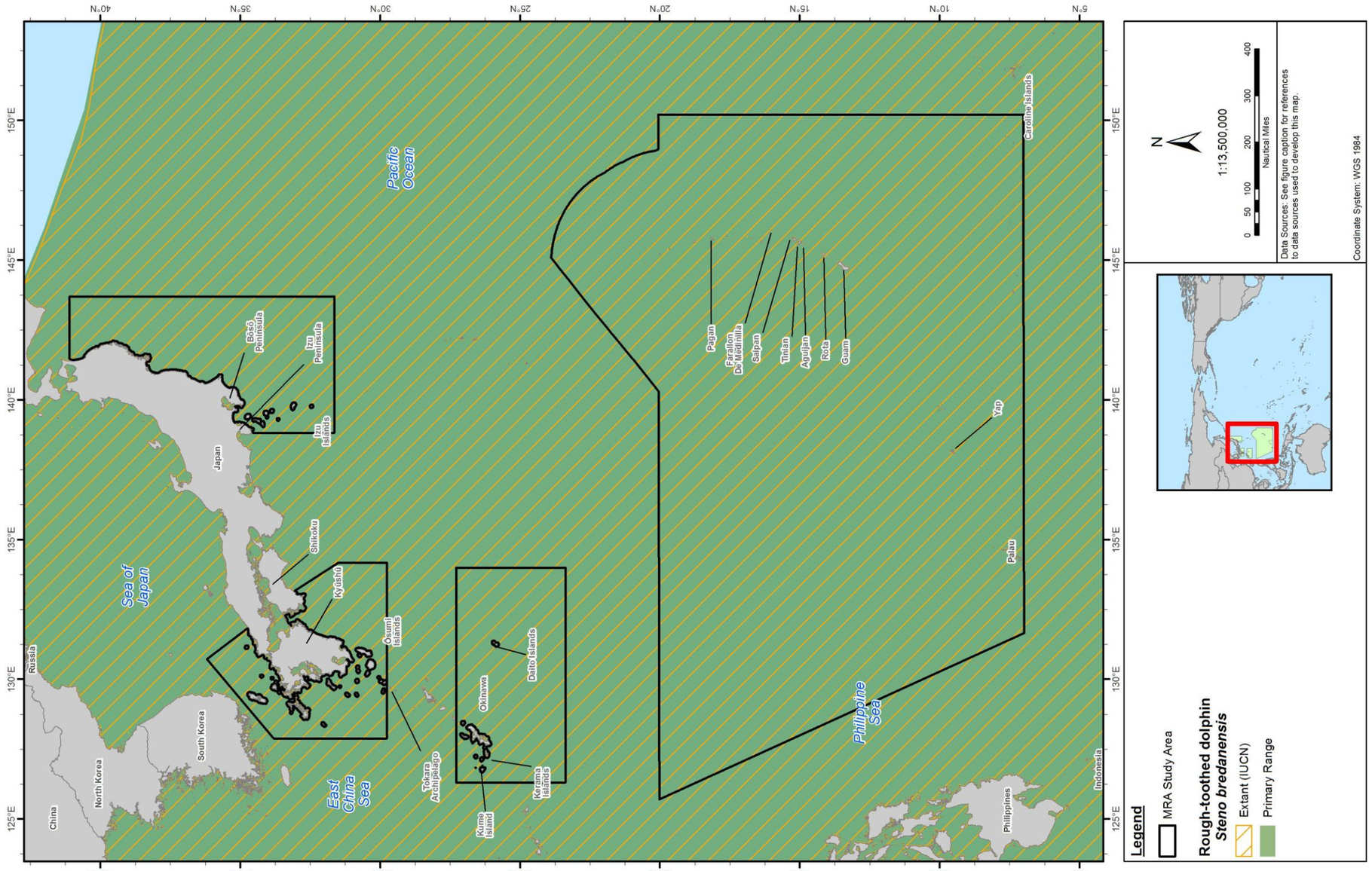

Figure 5-47: Geographic Range of the Rough-toothed Dolphin in the MRA Study Area
Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

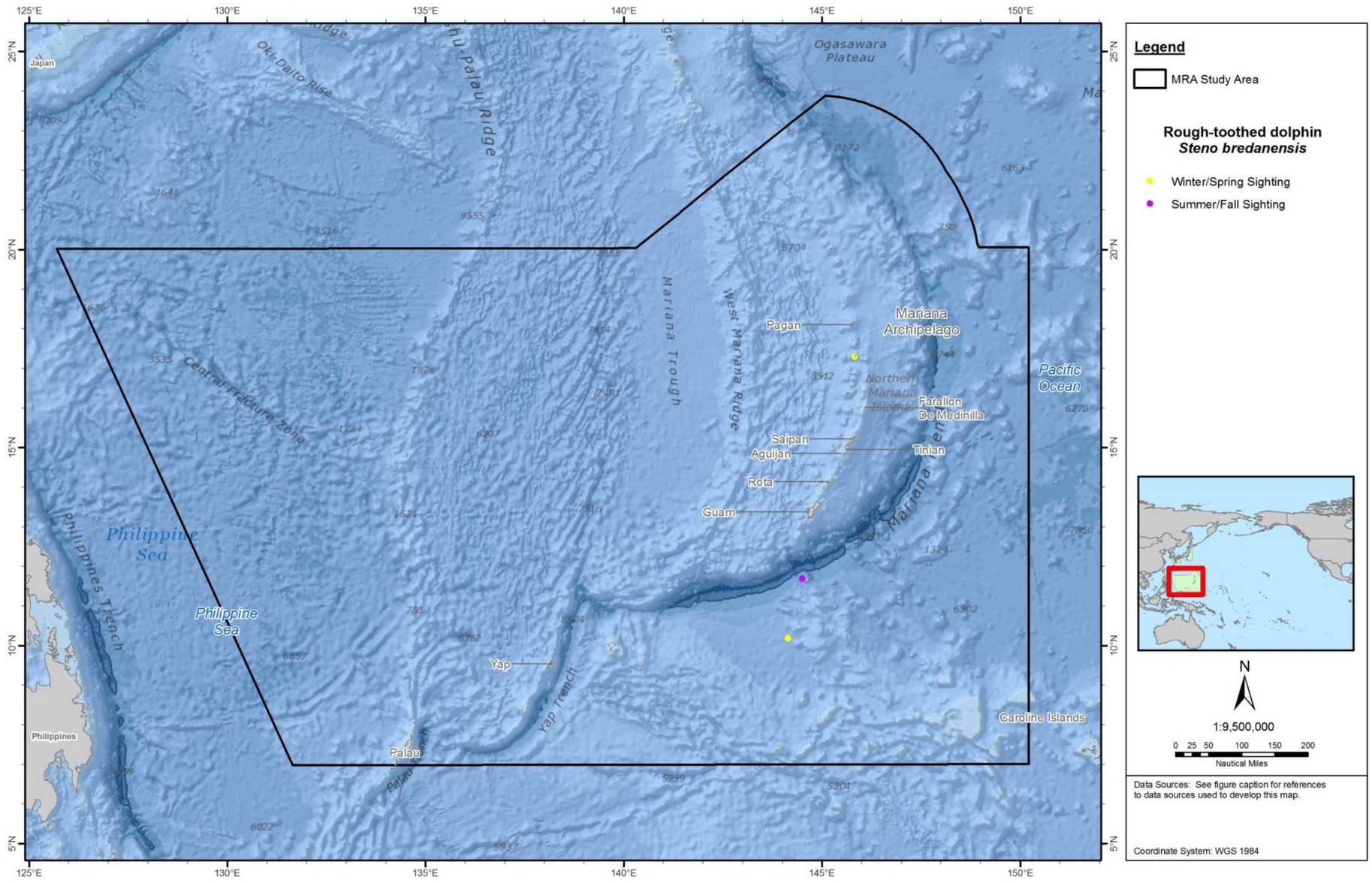

Figure 5-48: Sightings of the Rough-toothed Dolphin in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented.
Sources: Fulling, Thorson, and Rivers (2011); Mobley (2007); U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific (2007).

This Page Intentionally Left Blank.

5.23 COMMON BOTTLENOSE DOLPHIN (*TURSIOPS TRUNCATUS*)

5.23.1 Description

Classification of the genus *Tursiops* continues to be in question, as two species are recognized: the common bottlenose dolphin (*Tursiops truncatus*) and the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) (Rice 1998). Additional species are likely to be recognized via future analyses (Natoli, Peddemors, and Hoelzel 2004). The subspecies living in the Pacific Ocean is *Tursiops truncates gilli*.

The common bottlenose dolphin is a large, relatively-robust species (it is the largest of the "beaked dolphins"). The shape of the body is generic for a dolphin, but body shape and coloration vary significantly geographically. It has a short to moderate length, stocky beak distinctly set off from the melon by a deep crease. The mouthline is gently curved and dips down from the tip of the beak, then back up, and finally down again at the gape (gives the appearance of a smile). The dorsal fin is tall and falcate, and relatively narrow. It is set near the middle of the back. The flippers are wide, recurved, and somewhat pointed at the tips. The fluke is generic for dolphins (Jefferson, Webber, and Pitman 2008). In Japan, a live-captured, female bottlenose dolphin was found to have additional, fin-shaped hind appendages located near the genital opening (Ohsumi and Kato 2008).

The color pattern is relatively simple at first glance, yet is complex. It varies from light gray to nearly black on the back and sides, fading to white (sometimes with a pinkish tinge) on the belly. The belly and lower sides are rarely spotted. When spots are present, they are generally very small flecks. The back is generally dark gray. A faint dorsal cape on the back is common, yet generally visible only at close range and in good lighting. A faint spinal blaze may also be present (Jefferson, Webber, and Pitman 2008; Wells and Scott 1999). Potentially visible longitudinal stripes are formed by small ridges along the animal's circumference. Stripes can vary because of differences in ridge size, orientation, and shape (Gnone et al. 2008). A wide, but very faint, stripe frequently extends forward from the flipper and connects to the gape. A light patch on the side of the melon is often present, bordered by dark stripes from the blowhole to the apex of the melon eye, extending to the apex of the melon. A slight throat chevron and genital patch may be present. Brushings of gray often appear on the body, especially on the face. A generalized delphinid "bridle" consisting of blowhole and eye stripes is present, but highly variable in intensity (Jefferson, Webber, and Pitman 2008; Wells and Scott 1999). Bottlenose dolphins have 18 to 27 pairs of stout, pointed (unless worn) teeth in each jaw.

Adult common bottlenose dolphins range from 1.9 to 3.8 m, with males tending to be somewhat larger than females. All aspects of morphology vary significantly geographically. Common bottlenose dolphins often occur as two morphotypes (or forms): a nearshore (coastal) and an offshore ecotype (Hersh and Duffield 1990; Hoelzel, Potter, and Best 1998). Clear differences are evident between the forms of the bottlenose dolphin in the western North Atlantic and western North Pacific, suggesting eventual recognition of multiple species (Curry and Smith 1997). Maximum weight is at least 650 kg, although most bottlenose dolphins are much smaller. Length at birth is about 1.0 to 1.3 m.

5.23.2 Status and Management

The common bottlenose dolphin is protected under the MMPA and is not listed under the ESA. This species is also listed as least concern by the IUCN and falls under Appendix II CITES regulations For the MMPA stock assessment reports, bottlenose dolphins within the Pacific U.S. EEZ are divided into three stocks: (1) California coastal stock; (2) California, Oregon, and Washington offshore stock; and (3) Hawaiian stock (Carretta et al. 2010). An unknown number of annual deaths or serious injuries

caused by fisheries are estimated for the Hawaiian stock (Carretta et al. 2012). Although none of these stocks have range within the MRA Study Area, common bottlenose dolphins are known to have primary and secondary range within the MRA Study Area.

5.23.3 Population and Abundance

In the ETP, an estimated 243,500 common bottlenose dolphins occur. Through a stock assessment of the populations in the Hawaiian Islands EEZ and Four Islands Region stock (nearest stock assessments to MRA Study Area—arguably the same population as that found around Japan), it has been (Barlow 2006) estimated this population is at the high end of the range between 2,006 and 3,178 individuals (Carretta et al. 2011c) and 153 (CV=0.24) animals, respectively (Carretta et al. 2010). No population trend estimates are available for this stock. Approximately 168,000 dolphins are in the vicinity of Japan. Although an estimated 37,000 or so of these occupy more inshore waters, no stock-specific estimates are available for what are known as the "inshore" and "offshore" forms (Jefferson, Webber, and Pitman 2008; Miyashita 1993a; Wade and Gerrodette 1993). In some areas, both inshore and offshore ecotypes are present, and these populations differ genetically and morphologically. Nothing is known of stock structure around the Mariana Islands. One estimate for the area north of the Mariana Islands was 31,700 animals (Miyashita 1993b). A 2007 cetacean survey (Fulling, Thorson, and Rivers 2011), estimated the number of this species in Guam and the CNMI at 122 individuals.

A growth and survival trend study covering the years 1995 to 2008 showed the New Zealand population in slight decline (growth ratio not exceeding 1 for the study dates). This statistic can be primarily attributed to negative impacts reducing recruitment in individuals less than 3 years of age (Currey et al. 2011). On a smaller scale, photo-identification studies have shown that the population in the Bay of Islands, New Zealand may be on the rise (Berghan et al. 2008). These studies do not allude to global population trends, yet they highlight area-specific population trends for this species.

5.23.4 Biology, Ecology, and Behavior

This species frequently rides bow waves of vessels, ranging from small outboards to huge container and cruise ships. A few cases of interspecific activity, theorized to constitute play, have been documented between humpback whales and bottlenose dolphins in the Hawaiian islands. In one instance, the whale was photographed lifting the dolphin out of the water (Deakos et al. 2010). Bottlenose dolphins are highly intelligent and demonstrate self-awareness. The imitation of other dolphins and also of humans had led scientists to believe dolphins have a mirror-neuron system like that found in humans and monkeys (Herman 2012).

Group Size. Common bottlenose dolphins are social and are typically found in groups of up to 15, although groups of up to 100 or more have been reported in some areas (Shane, Wells, and Wursig 1986; Wells and Scott 2008). Ferguson (2006) reported the average group size of common bottlenose dolphins in the ETP at approximately 24 individuals. Based partly on photo-identification techniques using dorsal fin shapes and markings (Wursig and Jefferson 1990), it is well known that *Tursiops* has a fluid social organization (Connor et al. 2000). Habitat structure, in terms of complexity and water depth, is generally a major factor in *Tursiops* groupings (Shane, Wells, and Wursig 1986; Wells et al. 2009). Shallow-water areas typically have smaller group sizes than open oceanic areas (Scott and Chivers 1990; Wells, Irvine, and Scott 1980). In contrast, semi-open habitats often sustain larger school sizes, diminished levels of site fidelity, and more expansive home ranges (Defran and Weller 1999). Off Southern California, an increase in group size occurs from inshore to offshore waters (Defran and Weller

1999). This segregation seems more prevalent in the Pacific ocean (Tezanos-Pinto et al. 2009), yet, in some areas, inshore and offshore groups do not segregate habitat use (Silva et al. 2008). It has also been shown that after hurricane events (resulting in large-scale emigration or death), a typical population splints into two distinct populations. Following the split, dolphins closely associate with members in the newly formed group but rarely associate across groups (Preen 1995b).

Predator/Prey Interactions. Bottlenose dolphins are opportunistic feeders. It has been shown that acute fasting and re-feeding can alter hormone levels and behavior (Ortiz et al. 2010). Habitat concentration areas for this species are associated with ocean currents, fronts, eddies, and steep seabed gradients. This is likely because these areas have high prey predictability, although the direction of the current may alter the utility of the different sites at various times (Bailey and Thompson 2010). Common bottlenose dolphins feed on a wide variety of fishes, cephalopods, and shrimps (Wells and Scott 1999), and use a variety of feeding strategies (Shane 1990). In addition to applying echolocation, bottlenose dolphins may also use a passive listening technique whereby dolphins detect and orient to fish prey by listening for the sounds the prey species produce (Barros and Myrberg 1987; Barros and Wells 1998). Nearshore bottlenose dolphins prey predominantly on coastal fish and cephalopods, while offshore individuals prey on open ocean cephalopods and a large variety of near-surface and mid-water fish species (Mead and Potter 1995). Pacific coast bottlenose dolphins feed primarily on surf perches (family Embiotocidae) and croakers (family Sciaendae) (Wells and Scott 1999). Common bottlenose dolphins feed in two ways: open gape and closed gape (gape increases only when nearing prey) (Bloodworth and Marshall 2005).

This species is known to be preyed upon by killer whales and sharks (Wells and Scott 2008). As many as half the observed common bottlenose dolphins in Florida exhibit scars from shark attacks. Primary shark predators are considered to be the bull, tiger, great white, and dusky sharks (Wells and Scott 2008).

Life History. Bottlenose dolphins go through three life stages: a preliminary early life stage (characterized by rapid growth), a secondary slower growth phase, and a spurt of moderate growth later in life. Females grow faster than males in the first year of life, with males growing more quickly between 3 and 4 years of age. Growth for both sexes is reported to stop around 15 years of age (McFee et al. 2010). Longevity may be well over 50 years (Wells 2000). Bottlenose dolphins typically reach sexual maturity at 7 years for females and 13 years for males (Mead and Potter 1995). Gestation is 1 year (Caldwell and Caldwell 1972; Wells 2000). During the later stages of pregnancy, mothers have reduced top speeds, due to their frontal surface area increasing by over 50%. This physical change can double drag closer to delivery. Increased buoyancy and reduced fluke sweep associated with late-stage pregnancy can also negatively affect diving capabilities (Wiggins et al. 2004). Calving seasons are likely timed in response to seasonally available local resources. Newborn calves are seen year round off Southern California, but in most areas, calving is seasonal with peaks in spring/summer (Wells and Scott 1999). Whistle rates can increase ten-fold at the birth of a calf and subsequently decrease steadily to a normal rate in the 3 weeks after delivery. Signature maternal calls also increase during this time, possibly teaching calves to identify their mothers (Fripp and Tyack 2008). During the first few months of the calf's life, mothers are extremely active and attentive with continuous monitoring, increased wakefulness, and reduced rest postpartum (Lyamin et al. 2007). Calves typically remain with the female for 3 to 6 years (Wells 2000; Wells, Scott, and Irvine 1987) and demonstrate a diverse set of mother-calf interactions (von Streit, Ganslosser, and von Fersen 2011).

Migration. Although in most areas bottlenose dolphins do not migrate (especially where they occur in bays, sounds, and estuaries), seasonal shifts in abundance do occur in many areas (Griffin and Griffin

2004). Several stocks off the Atlantic coast of the United States migrate north for the warmer months and south along the coast for the colder months (Kenney 1990; Waring et al. 2009a).

Hearing/Vocalization. The bottlenose dolphin has a functional high-frequency hearing limit of 160 kHz (Au 1993) and can hear sounds at frequencies as low as 40 to 125 Hz (Turl 1993). Hearing thresholds were also estimated from jawbone experiments, and carrier frequencies were between 10 to 160 kHz (Finneran et al. 2008). Audiogram upper cut-off frequencies were above 113 kHz (Finneran 2008). Inner ear anatomy of this species has been described (Ketten 1992b). Electrophysiological experiments suggest that the bottlenose dolphin brain has a dual analysis system: one specialized for ultrasonic clicks and the other for lower-frequency sounds, such as whistles (Ridgway 2000). The audiogram of the bottlenose dolphin shows that the lowest thresholds occurred near 50 kHz at a level around 45 dB re 1 µPa-m (Nachtigall, Lemonds, and Roitblat 2000). Jawbone tests also illustrated low frequency thresholds at 40 and 60-115 kHz in Pacific bottlenose dolphins (Houser, Gomez-Rubio, and Finneran 2008). Below the maximum sensitivity, thresholds increased continuously up to a level of 137 dB at 75 Hz. Above 50 kHz, thresholds increased slowly up to a level of 55 dB at 100 kHz, then increased rapidly above this to about 135 dB at 150 kHz. Scientists have reported a range of best sensitivity between 25 and 70 kHz, with peaks in sensitivity occurring at 25 and 50 kHz at levels of 47 and 46 dB re 1 µPa-m (Nachtigall, Lemonds, and Roitblat 2000). (Richardson 1995) noted that the differences between the reported audiograms for these two studies might be attributable in part due to performance of the experiments in tanks. A neurophysiological method was used to determine the high-frequency audiograms (5 to 200 kHz) of five bottlenose dolphins (Richardson 1995). Temporary threshold shifts (TTS) in hearing have been experimentally induced in captive bottlenose dolphins (Nachtigall, Pawloski, and Au 2003; Ridgway et al. 1997; Schlundt et al. 2000). Two areas in the melon tip correspond to differing hearing sensitivities. Areas associated with the bulla and auditory meatus received sounds between 16 and 22.5 kHz, whereas areas corresponding to the lower jaw received sounds from 32 to 128 kHz (Popov et al. 2008). (Ridgway et al. 1997) observed changes in behavior at the following minimum levels for 1-s. tones: 186 dB at 3 kHz, 181 dB at 20 kHz, and 178 dB at 75 kHz (all re 1 µPa-m). TTS levels were 194 to 201 dB at 3 kHz, 193 to 196 dB at 20 kHz, and 192 to 194 dB at 75 kHz (all re 1 µPa-m). When bottlenose dolphins were exposed to intense tones (0.4, 3, 10, 20, and 75 kHz) the animals demonstrated altered behavior at source levels of 178 to 193 dB re 1 µPa-m, with TTS after exposures generally between 192 and 201 dB re 1 µPa-m (although one dolphin exhibited TTS after exposure at 182 dB re 1 µPa-m) (Schlundt et al. 2000). A threshold for a 7.5 kHz pure tone stimulus has been determines (Nachtigall, Pawloski, and Au 2003). No shifts were observed at 165 or 171 dB re 1 µPa-m, but when the noise level reached 179 dB re 1 µPa-m, the animal showed the first sign of TTS. Recovery apparently occurred rapidly, with full recovery apparently within 45 min following noise exposure. TTS measured between 8 and 16 kHz (negligible or absent at higher frequencies) occurred after 30 min of noise exposure (4 to 11 kHz) at 160 dB re 1 µPa-m (Nachtigall et al. 2004). It was demonstrated that emitting tonal signals at 50 kHz continuously could successfully deter this species from a particular area (Niu et al. 2012). Hearing range is known to decrease with age in this species (Houser, Gomez-Rubio, and Finneran 2008).

Sounds emitted by bottlenose dolphins have been classified into two broad categories: pulsed sounds (including clicks and burst-pulses) and narrow-band continuous sounds (whistles), which usually are FM. Whistle characteristics play a vital role in social behavior and have been shown to coincide with particular behaviors. Whistles may be an indicator of stress (Esch et al. 2009). Undisturbed dolphins had whistle rates of 0.3 whistles/min, and during capture-release activities or pregnancy stages, had a rate of 14.3 whistles/min (Fripp and Tyack 2008). Whistle rates also increased in social situations of fewer dolphins in the group. Increased whistle rates also resulted in a decrease in coordinated surface swimming. This may be a way to avoid signal masking (Quick and Janik 2008). High peak frequency

whistles over long duration may correlate to foraging activities (Bearzi 2005). Clicks and whistles have a dominant frequency range of 110 and 130 kHz (33 to 109 kHz in the wild, averaging between 26.7 and 36.7 kHz) with a source level of 177 and 228 dB re 1 µPa-m and a duration of 8 to 72 microseconds (Au 1993; Baumann-Pickering et al. 2010; Szczepaniak, Webber, and Jefferson 1992); and 3.5 to 14.5 kHz and 125 to 173 dB re 1 µPa-m, respectively (Ketten 1998). Thomson and Richardson (1995) recorded whistles ranging in frequency from 0.8 to 24 kHz. Clicks have served to maintain contact between two individuals (i.e., one click release by the first animal was followed by a short response from the other individual) (Nakahara and Miyazaki 2011; Watwood et al. 2005). When a response did not occur, the first caller was likely to produce additional whistles (Bearzi, Pierantonio, et al. 2011). Clicks and burst-pulses are highly directional. The dolphin can "steer" and modify the range of the echolocation beam, which may in turn increase the quality of information transmitted back during echolocation. Directionality may also provide information between and among dolphins during socialization (Branstetter et al. 2012; Moore, Dankiewicz, and Houser 2008). The range of bottlenose dolphin communication is estimated at approximately 750 m on average but can range up to 5,740 m (Jensen et al. 2012). (van der Woude 2009) recorded extremely low frequencies in a bottlenose dolphin living in the Black Sea. The calls were well below 500 Hz, lasting 0.2 to 8.7 s., similar to baleen whale "moans." The type of call used may depend on the habitat in which the dolphin is foraging (Nowacek 2005).

In echolocation, the dolphin emits target clicks and then releases a pulse train. Then, receiving the echoes, dolphins can interpret whether the object is food or a predator. Calculations have indicated that the response times are very rapid for tones and pulse trains. In the youngest, fastest dolphins, echolocation responses occur within 175 to 213 ms (tones) and within 213 to 275 ms (pulse trains) (Rowntree et al. 1980). It has also been documented that some dolphins do not wait to receive all of the echolocation information before sending response vocalizations, indicating that different pathways for echolocations and response vocalizations exist (Ridgway 2011).

Diving. Captive Navy bottlenose dolphins have been trained to reach maximum diving depths of about 300 m (Ridgway and Harrison 1986; Ridgway, Scronce, and Kanwisher 1969). Dives for durations up to 15 min have been recorded for trained dolphins (Ridgway, Scronce, and Kanwisher 1969). Typical dives, however, are shallower and shorter. Deep-sea fish in the stomachs of some offshore bottlenose dolphins suggest that they dive to more than 500 m. Relatively large lungs in bottlenose dolphins (taking up 37% of the total thoracic cavity) may allow gas exchange throughout their rapid, shallow dives (Piscitelli et al. 2010).

5.23.5 Habitat and Distribution

Common bottlenose dolphins are found mostly in coastal and continental shelf waters of tropical and temperate regions of the world. They live around many oceanic islands and atolls, and over shallow offshore banks and shoals (Gannier 2009; Wells et al. 1999). They occur in most enclosed or semi-enclosed seas. The species inhabits shallow, murky, estuarine waters and also deep, clear offshore waters in oceanic regions (Jefferson, Webber, and Pitman 2008; Wells et al. 2009). Common bottlenose dolphins are often found in bays, lagoons, channels, and river mouths, and are known to occur in very deep waters of some ocean regions. In the ETP and elsewhere, open ocean populations occur far from land. However, population density appears to be higher in nearshore areas (Scott and Chivers 1990). Off the coast of Italy, bottlenose dolphins were associated with habitats characterized by well-defined depth and slope gradient, on the shelf-edge and the upper and lower slope (Azzellino et al. 2008). Nearshore habitat use can be predicted by prey source assemblages, yet because of heterogeneity, fine-

scale nearshore habitat preferences are better predicted using predator data (Torres, Read, and Halpin 2008).

The overall range of the common bottlenose dolphin is worldwide (Atlantic, Pacific, and Indian oceans) in tropical to temperate waters. This is one of the most widely-distributed dolphin species. *Tursiops* generally do not range poleward of 45°, except around the United Kingdom (UK) and northern Europe, and possibly around the southern tip of South America (Jefferson, Webber, and Pitman 2008); Wells and Scott 2009). A southern extension of documented range in the Pacific Ocean has been suggested (Olavarria et al. 2010).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. The range of this species is known to include waters of the North Central Pacific Gyre (Figure 5-49). Although typically thought to be more of a coastal species, the common bottlenose dolphin's secondary range includes all offshore waters of the Pacific (Au and Perryman 1985; Carretta et al. 2010; Miyashita 1993b; Wang and Yang 2006). Bottlenose dolphins found in nearshore waters around the main Hawaiian Islands are island-associated, with all sightings occurring in relatively nearshore and shallow waters (<200 m), and no apparent movement between the islands (Baird, Gorgone, and Webster 2002; Baird, McSweeney, et al. 2003). Based on sighting data, the possibility of a second population of bottlenose dolphins in the Hawaiian Islands with a preference for deeper waters (bottom depth of 400 to 900 m) has been noted (Baird, McSweeney, et al. 2003).

KUROSHIO CURRENT. Comparatively little specific information regarding bottlenose dolphins around Japan is available, but general knowledge of the highly diverse habitat preferences of bottlenose dolphins in other parts of the world (such as the eastern North Pacific) should be considered when evaluating the species' distribution patterns. Little or no evidence suggests major seasonal differences in distribution off Japan. The common bottlenose dolphin is believed to occur everywhere in the MRA Study Area (Figure 5-50), based on evidence of presence in the western North Pacific of both a coastal population (which may occur along the shore and even into shallow enclosed bays) and offshore populations (which may extend very far offshore into truly oceanic waters) (Kishiro and Kasuya 1993; Miyashita 1993a). Occurrence pattern is believed similar throughout the year. Individuals radio-tracked after release off Taiji, Japan, tended to stay within 30 nm (56 km) of land, although two moved as far as 200 nm (370 km) offshore (Tanaka 1987). This suggests that the oceanic and coastal stocks may have largely distinct areas of distribution, although this remains to be confirmed (Miyashita 1993a). Two other individuals tagged at Taiji in January 2001 moved into waters with a bottom depth of about 2,400 m (approximately 57 nm [106 km] south of Omaezaki) and 4,300 m (approximately 142 nm [263 km] due south of Daio), respectively (Iwasaki et al. 2001).

EAST CHINA SEA. The primary range of this species is known to include the waters of the East China Sea (Figure 5-49 and Figure 5-50); thus its occurrence is expected in this part of the MRA Study Area. A DNA study reported in (Yang et al. 2005) indicated that common bottlenose dolphins had been found primarily in the Yellow Sea and the northern East China Sea. The similar Indo-Pacific bottlenose dolphin had been found mostly in southern Chinese Waters. Range overlap exists in the Taiwan Strait and possibly in adjacent waters, yet reproductive isolation is likely.

PHILIPPINE SEA. The primary and secondary ranges of this species are known to include the waters of the Philippine Sea (Figure 5-49 and Figure 5-50).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Common bottlenose dolphins in the western North Pacific occur in both coastal and far offshore waters (Kasuya et al. 1997; Miyashita 1993a).

Bōsō Peninsula, Izu Peninsula, and Izu Islands. A female bottlenose dolphin was caught for display off the coast of Higashimuro District, in the Wakayama Prefecture. This individual had fin-shaped hind appendages on either side of the genital opening (Ohsumi and Kato 2008).

MARIANA ARCHIPELAGO. Through visual sightings, four common bottlenose dolphins in this area were identified (U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007). Additional individuals may have been documented through acoustic recordings (Norris et al. 2011). The dolphins were found primarily along the northern shelf of the Mariana Trench (Fulling, Thorson, and Rivers 2011). In other sightings reports, all sightings of bottlenose dolphins in the western Pacific have been of a larger, unspotted type (presumably the common bottlenose dolphin, as opposed to the Indo-Pacific bottlenose dolphin) (Miyashita 1993a). Possibly, bottlenose dolphins do not occur in great numbers in this island chain. A 2007 cetacean survey reported two dolphins in offshore waters south of Guam in the area around the Challenger Deep where oceanic depths were less than 5,000 m (Fulling, Thorson, and Rivers 2011). The absence of large densities of bottlenose dolphins at the Marquesas Islands have been attributed to the area's lack of a significant shelf component (Gannier 2002). A similar situation could exist in the Mariana Islands MRA Study Area and vicinity (Figure 5-51).

Saipan. A sighting of bottlenose dolphin in Lualua Bay has been reported (HDR 2011).

Tinian. A sighting of a bottlenose dolphin was documented Tinian's northern point (HDR 2011).

Rota. A single sighting of a bottlenose dolphin off the north coast of Guam at Rota Bank was recorded in a 2010 survey (HDR 2011).

Guam. Interestingly, no stranding records are available for this species in the Mariana Islands MRA Study Area and vicinity, and reports only idicate that bottlenose dolphins occur in coastal waters of Guam (Trianni and Kessler 2002). One group that may have been common bottlenose dolphins was sighted about 10 km northwest of Tumon Bay off the coast of west Guam in 2010 (HDR 2011).

CAROLINE ISLANDS. The Caroline Islands are known to be a secondary range of the common bottlenose dolphin. They have been seen in nearshore environments here (Figure 5-49 and Figure 5-50).

5.23.6 Species-specific Threats

Common bottlenose dolphins have been hunted directly in several areas. The largest takes in recent years have been in the Black Sea, but large numbers have occasionally been taken in drive fisheries in Japan and Taiwan as well (the Taiwanese fishery is illegal). Some animals have also been taken in small cetacean fisheries in the Caribbean, Peru, Sri Lanka, West Africa, and Indonesia. In the past (late 1800s and early 1900s), bottlenose dolphins were hunted on the east coast of the United States. Finally, significant numbers have been taken in live-capture fisheries for display, research, and for use by the military. Although bans on small cetacean takes are now in place, DNA analyses in 2006 and 2007 of meats sold in Peru fish markets revealed meat from many small cetaceans was available, including from the common bottlenose dolphin, proving these are still caught and sold (Tzika et al. 2010). In the Republic of (South) Korea, "whale meat" markets still can buy and sell meat from stranded or bycaught

marine mammals. A DNA surveillance from 2003 to 2005 proved that common bottlenose dolphin meat was present in such markets (Baker et al. 2006). This species continues to be collected for captive display and research in some parts of the world (although not in the United States, where this is now illegal). Coastal bottlenose dolphins are susceptible to habitat destruction and degradation from human activities.

Common bottlenose dolphins interact with fisheries throughout their range, and are often seen following behind and feeding from shrimp trawlers. In Brazil, they have a cooperative hunting relationship with local fisherman, whereby the catch yield is greater when the dolphins lead boats to mullet assemblages (Shirakihara 2005). In North Carolina, when fishing efforts increase, a higher percent of stranded dolphins have net lesions (Byrd et al. 2008). In some areas in the Atlantic Ocean, increased depredation is associated with lags in red tide and from increased boat traffic during tourist seasons. Dolphins who have followed fishing vessels in the past are more likely to exhibit changes in their natural activities and behaviors, and become more habituated to behaviors with fishing vessels (Rock 1993). Incidental catches are also known from throughout the species' range, in gillnets, driftnets, purse seines, trawls, and on hook-and-line gear. Mortality related to recreational fishing has also been documented with increasing frequency in recent years, in some cases exceeding commercial catches. This species has suffered larynx strangulation through ingestion of fishing gear (Gomercic et al. 2009; Levy et al. 2009). Hearing defects have been reported in stranded bottlenose dolphins severely entangled in fishing gear; 57% of dolphins surveyed showed reductions in hearing equivalent to that considered severe or profound in humans (Mann et al. 2010). Noise from vessel traffic or from other anthropogenic noise sources (such as pile-drivers, or general increases in background noise in the ocean can harmfully affect dolphin communication. Behavioral changes or avoidance in some areas during high vessel traffic times has been documented (Lusseau 2005). It has been found, small boats traveling at 5 knots can reduce the range of bottlenose dolphin communication by 26% when in shallow waters 50 m from the animals (Jensen et al. 2009). When exposed to a sequence of tones (four 3-kHz tones for 16 s. at 192 dB re 1 µPa separated by 224 s. of silence) accumulation of hearing loss was documented, yet some hearing was recovered during silent periods (Finneran and Schlundt 2010). When tones were between 3 and 20 kHz, results showed frequency-specific differences in the TTS onset and growth. Fatigue increased after 3 kHz exposure (Finneran and Schlundt 2010).

Several mass die-offs of bottlenose dolphins have occurred in recent decades, and these have been linked to the noxious effects of biotoxins of natural or anthropogenic origin. Some toxins are associated with harmful algal blooms, such as the brevetoxin-producing dinoflagellate *Karenia brevis* and the diatom *Pseudo-nitzschia spp* producing DA, causing eosinophilia (Schwacke et al. 2010). During a mass stranding in California in 2002, common bottlenose dolphins were also found intoxicated with DA correlated to both inshore and offshore foraging (de la Riva et al. 2009). Some bacterium can cause adverse health effects in this species. Natural bacterial infections causing respiratory illness are thought to be the primary cause of death in *Tursiops truncates* (Johnson et al. 2009). Also, *Brucella spp*, a bacterium, has been documented in the reproductive tissues of a captive bottlenose dolphin and can cause reproductive lesions associated with abortions (Nymo, Tryland, and Godfroid 2011). Bacterial infections, including from *Erysipelothrix rhusiopathiae*, *Streptococcus agalactiae*, and *Lactococcus garvieae,* cultured from tissue samples have been found in bottlenose dolphins (Evans et al. 2006; Melero et al. 2011). *Erysipelothrix rhusiopathiae* can cause skin lesions and often proves fatal. Yet, this infection is more prevalent in captive individuals and often enters the body through ill-preserved fish (Melero et al. 2011). *Mycobacterium chelonae* has also been isolated from tissue biopsies in this species and may be responsible for panniculitis, possibly causing lyphadentis, pneumonia, and scoliosis (Wunschmann et al. 2008). For an in-depth analysis in the Atlantic ocean of risk to the bottlenose

dolphin of mortality by bacterial pathogens, reference (Venn-Watson, Smith, and Jensen 2008). Chronic fungal skin infections like lobomycosis, caused by a form of yeast also found in humans, may be more prevalent in estuary habitats than coastal areas (Bermudez et al. 2009; Murdoch et al. 2010). Other fungal infections documented in strandings of bottlenose dolphins can cause hemorrhages—for example, the novel case of the common plant pathogen *Fusarium oxysporu* (Staggs et al. 2010). Viral infections can also cause lesions on many parts of the body. A biopsy of a lesion on the tongue of a dolphin identified the novel bottlenose dolphin enterovirus, causing abnormally high blood protein levels and hyperglobulinemia (Nollens et al. 2009). Other viruses, such as a novel strain of a parainfluenza virus, have also been proposed as the cause of death of some individuals with respiratory diseases (Nollens et al. 2008). Parasites can cause systemic, chronic health problems for many animals, including bottlenose dolphins (Carvalho et al. 2010). Mother-calf transmission of lung nematodes in Australian waters, known to compromise the animal's health, have been documented in carcasses of this species. Prevalence of the nematode is relative to year, season, age class, and geographic range (Tomo, Kemper, and Lavery 2010)). Four species of the parasite Microsporidia were found in dolphins off Atlantic coasts—three associated with potential prey fishes, and one associated with humans and other terrestrial mammals (Fayer et al. 2008). The stomach parasite *Pholeter gastrophilius*, known to affect primarily coastal species (varying with prey preferences), has been documented in stranded common bottlenose dolphins off the coast of Norway (Aznar et al. 2006). Additional parasites, such as *Toxoplasma gondii (*commonly associated with cats, which also can cause neurological affects in humans), have been found in bottlenose dolphins (Dubey et al. 2005; Dubey et al. 2008). For more detailed information on specific host-parasite species identified through this study, refer to Carvalho et al. (2010). Anthropogenic contaminants taken in by the common bottlenose dolphin are serious concerns. Although scientists are just beginning to understand the true impact contaminants can have on marine animals, contaminants have been documented to affect the immune and reproductive systems of some individuals (Jefferson, Webber, and Pitman 2008). PCBs found in bottlenose dolphin blubber have been correlated to reduced hormone levels, as well as reduced innate immunity (increased susceptibility to infectious diseases). High levels of PCBs found in the blubber and liver of a bottlenose dolphin in Spain were suggested to be associated with lymphoma found in the animal (Jaber et al. 2005). All effects may be further amplified with increasing trophic levels (Scott and Sadove 1997; Yordy et al. 2010). Along with PCBs, OCP and PBDE have been detected in the blubber and milk of common bottlenose dolphins at concentrations that differed among populations and life stages (Yordy et al. 2010). Concentrations of butylin and phenyltin were found in the tissue of common bottlenose dolphins off the coast of Thailand. The highest concentrations were found in the liver, wherein concentrations of the contaminants increased in successive animals with respectively larger body lengths (Harino et al. 2007a).

This Page Intentionally Left Blank

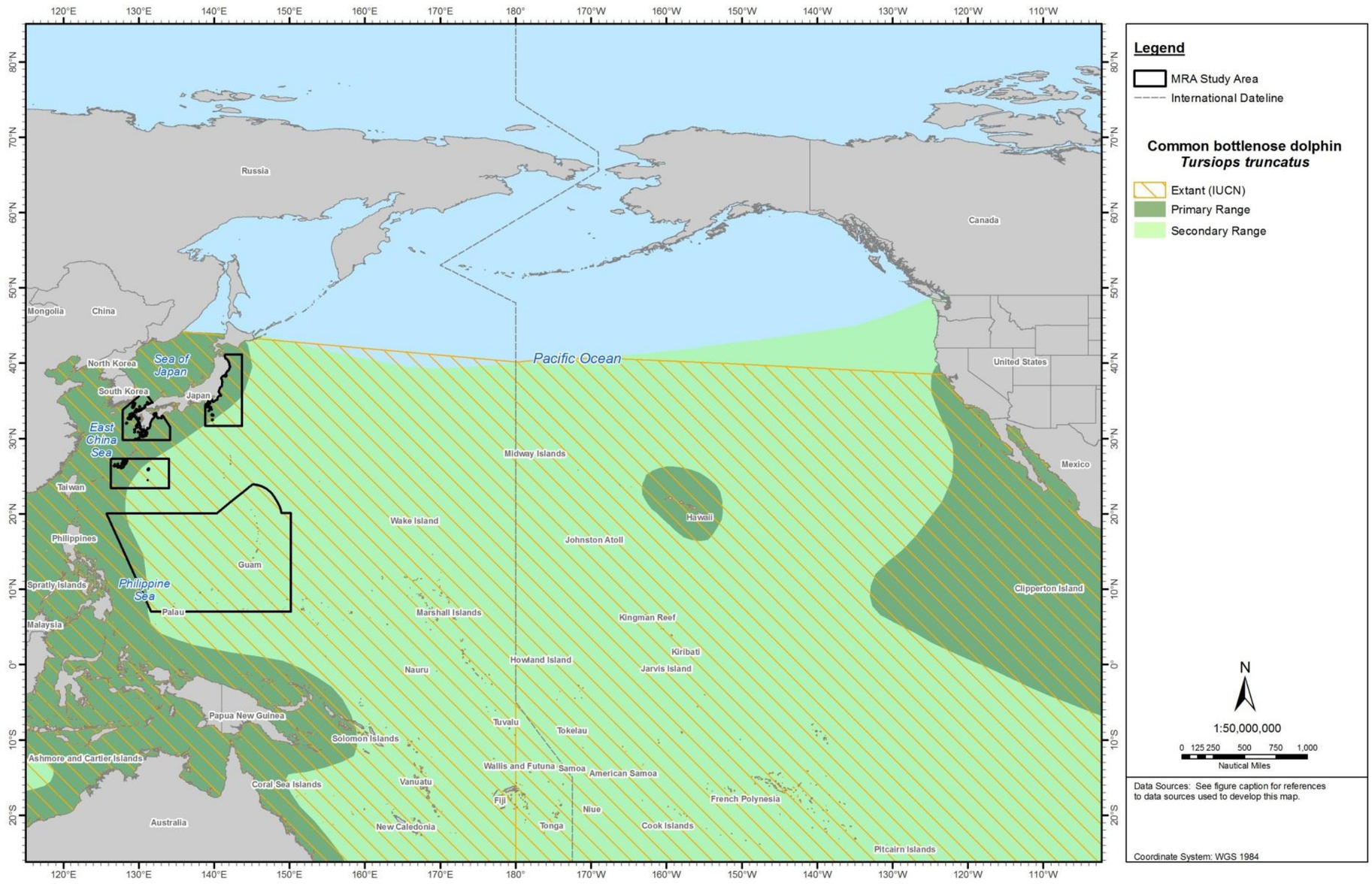

Figure 5-49: Geographic Range of the Common Bottlenose Dolphin in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature (2009).

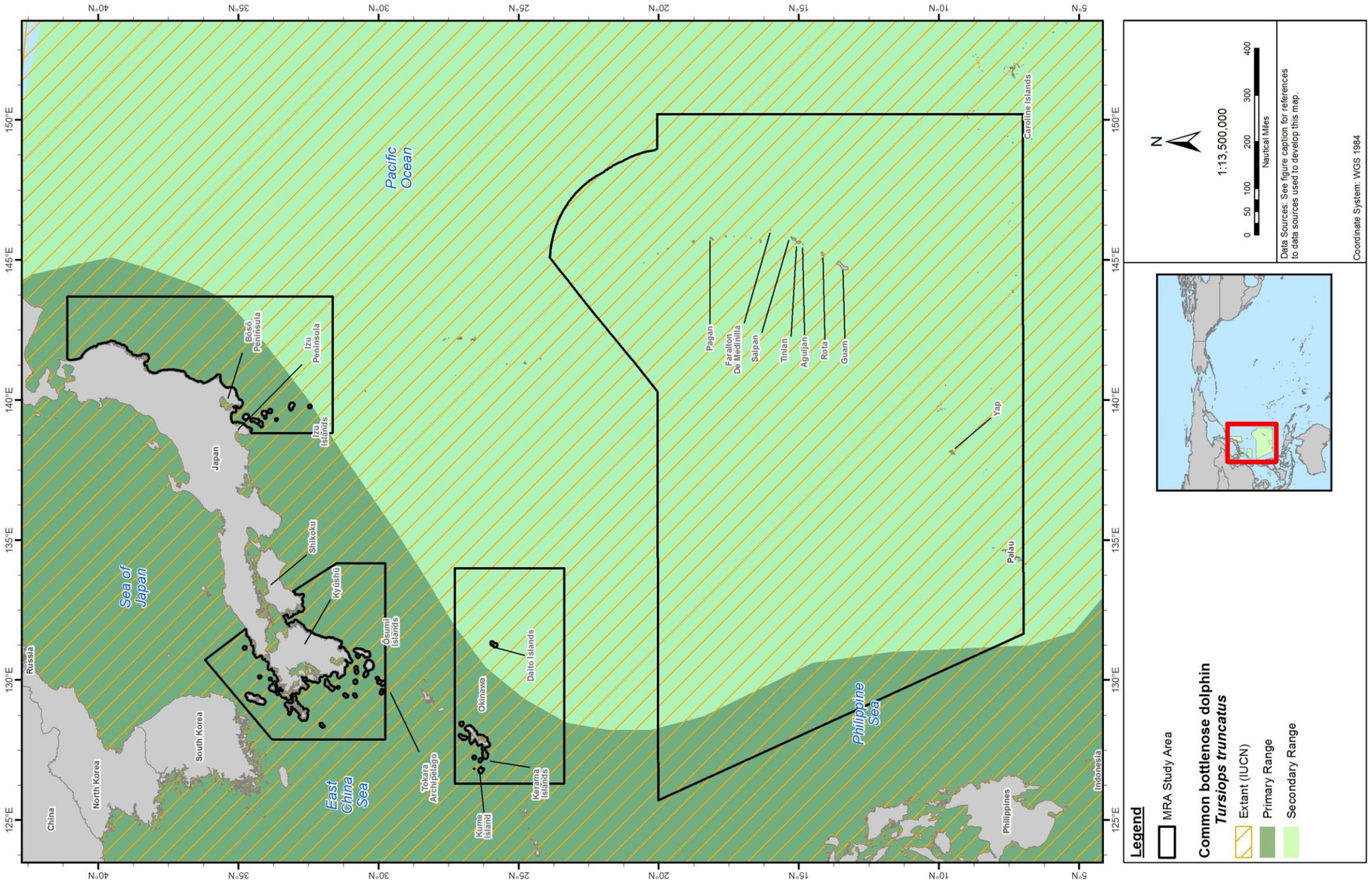

Figure 5-50: Geographic Range of the Common Bottlenose Dolphin in the MRA Study Area
Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature (2009).

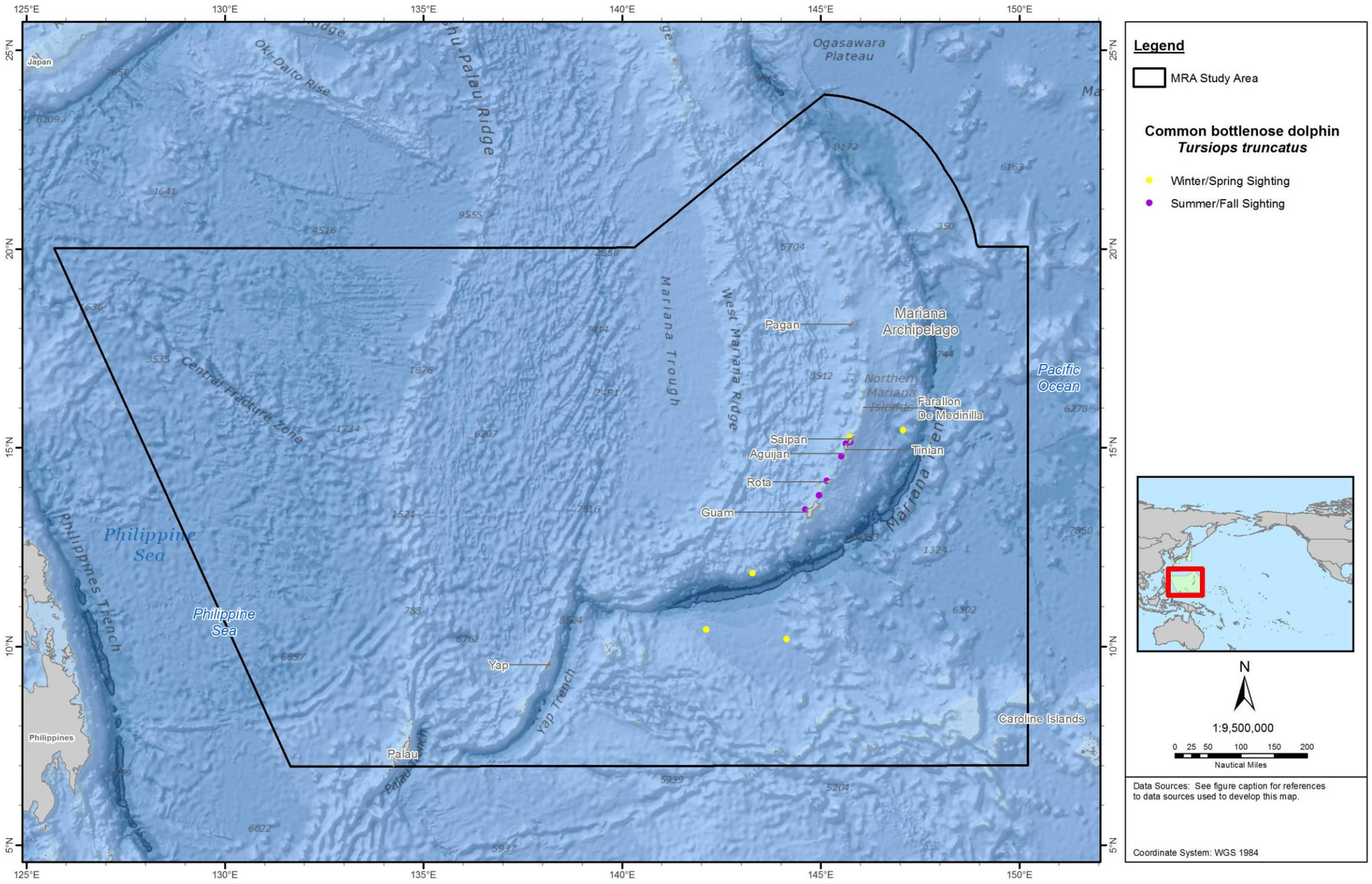

Figure 5-51: Sightings of the Common Bottlenose Dolphin in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented.
Sources: Fulling, Thorson, and Rivers (2011); HDR (2012); Hill et al. (2013); Hill et al. (2011); U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific (2007).

This Page Intentionally Left Blank

5.24 LONG-BEAKED COMMON DOLPHIN (*DELPHINUS CAPENSIS*)

5.24.1 Description

Only recently have long-beaked common dolphins been recognized as a species distinct from short-beaked common dolphins (Heyning and Perrin 1994). Both long-beaked and short-beaked common dolphins share the same basic body plan and shape, but the long-beaked common dolphins tend to be more slender. A tall, slightly falcate dorsal fin is present, and the flippers are falcate and pointed at the tips. They have longer beaks than short-beaked common dolphins (up to at least 9.7% of total length), and long-beaked common dolphins also have a somewhat flatter shape to the melon, which rises at a relatively shallow angle. A deep crease is between the melon and beak. Some individuals (apparently adult males) have a prominent ventral “keel” or post-anal hump of connective tissue (Heyning and Perrin 1994; Jefferson, Webber, and Pitman 2008).

Long-beaked common dolphins are distinctively marked, with a V-shaped saddle caused by a dip in the cape below the dorsal fin, yielding an hourglass pattern on the side of the body (Jefferson, Webber, and Pitman 2008). The back is dark brownish-gray, the belly is white, and the anterior flank patch is tan to cream in color. The lips are dark; a dark stripe extends from the eye to the apex of the melon, and another one (often so wide and extensive that it contacts the gape) extends from the chin to the flipper (Heyning and Perrin 1994). A dark band often appears on the lower flank, from the flipper area to the anus (Heyning and Perrin 1994; Jefferson and Van Waerebeek 2002; Perrin et al. 2009).

Most measured adults have been between 2.02 and 2.54 m (males), and 1.93 and 2.22 m (females) long, although some dolphins may reach lengths of over 2.60 m. Weights of at least 235 kg can occur. Sharp pointed teeth in each tooth row number 47 to 67—higher tooth counts than in any other species of delphinid (though with strong overlap with several other species).

5.24.2 Status and Management

This species is protected under the MMPA and is not listed under the ESA. This species is also listed as data deficient by the IUCN and falls under Appendix II CITES regulations.The only stock within U.S. waters is the California stock. Although this stock does not have range within the MRA Study Area, long-beaked common dolphins are known to have primary range within the Japan portion of the MRA Study Area.

5.24.3 Population and Abundance

The geographically closest stock assessment was for the California stock of this species (estimated 11,714 [CV=0.99] individuals and 62,447 [CV=0.80]). No conclusive evidence has emerged for population trend (Carretta et al. 2011j). No abundance estimates are available for the long-beaked common dolphin in the MRA Study Area.

5.24.4 Biology, Ecology, and Behavior

Long-beaked common dolphins are fast and agile, often leaping out of the water while moving at high speeds in large splashing herds. These dolphins are frequent bowriders and also commonly demonstrate breaches and acrobatic leaps. They sometimes associate with other cetacean species (Perrin 2008a).

Group Size. Extremely social, long-beaked common dolphins congregate in schools of fewer than a dozen to several thousand (Jefferson, Webber, and Pitman 2008; Perrin 2008a). Ferguson et al. (2006) reported the average group size of long-beaked common dolphins in the ETP at around 400. Little information is available about school composition, but some degree of age and sex segregation is possible because these segregations have been well documented for short-beaked common dolphins (and for members of the genus *Stenella*).

Predator/Prey Interactions. Stomach contents of *Delphinus* species from California waters revealed 19 species of fish and two species of cephalopods. *Delphinus* species feed primarily on organisms in the ocean zones, usually composed of marine organisms that have diel migration patterns (Evans 1994).

This species has not been documented to be prey to any other species. It is probably subject to predation by killer whales.

Life History. The small amount of information available regarding this species generally comes from areas where the two species of *Delphinus* overlap, and may actually apply to short-beaked common dolphin populations (off Southern California and West Africa). Sexual maturity is believed to occur when the species grows to a length of about 2 m. This species has a more tropical distribution than the other *Delphinus* species, possibly leading to less specific reproductive seasonality (Jefferson, Webber, and Pitman 2008; Perrin 2008a). The peak calving season in southern California is spring and early summer (Forney 1994).

Migration. The long-beaked common dolphin is not a migratory species, but seasonal shifts in abundance (mainly inshore/offshore) are known within some regions of its range (Neumann 2001).

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

Diving. *Delphinus* dives have been reported to range from 30 to 60 m (Evans 1971). Evans (1971) found a link between common dolphin dive behavior and the deep scattering layer (DSL), with maximum dive depths consistently occurring below the depth of the DSL. However, this information was obtained before the species were distinguished, and may mainly apply to the short-beaked species.

5.24.5 Habitat and Distribution

Common dolphins occupy a wide range of habitats, including waters over the continental shelf, along the continental shelf break, and over prominent underwater topography (e.g., escarpments and seamounts) (Evans 1994; Hui 1979). The long-beaked common dolphin appears to be restricted to waters relatively close to shore (Jefferson and Van Waerebeek 2002; Perrin 2008a), apparently preferring shallower and warmer water than does the short-beaked common dolphin (Perrin 2008a). Long-beaked common dolphins are commonly found within 60 miles (93 km) of the coast (Carretta et al. 2010). In tropical regions, where common dolphins are routinely sighted, they are generally found in upwelling zones with nutrient rich waters (Au and Perryman 1985; Ballance and Pitman 1998; Jefferson, Webber, and Pitman 2008). During warm-water periods, rare sightings of long-beaked dolphins have

been documented farther north (British Columbia) than their range previously had been thought to extend (Ford 2005). This may be a future trend for this species within a changing global climate.

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. Typically, the long-beaked common dolphin occurs in coastal and offshore waters of the northeastern Pacific, from the equator to about 36°N (Evans 1982; Jefferson and Van Waerebeek 2002). The western boundary of the North Central Pacific Gyre is adjacent to the known primary range of this species (Figure 5-52).

KUROSHIO CURRENT. Distribution in this area is based mostly on information in Amaha (1994) and Jefferson and Van Waerebeek (2002), both of which separated records of dolphins of the genus into long-beaked and short-beaked forms. No seasonal differences are known for the long-beaked common dolphin in Japanese waters. Occurrence pattern is believed similar throughout the year.

EAST CHINA SEA. The East China Sea is included in the known primary range of this species (Figure 5-52). The species is also believed to occur in the Tsushima Strait.

PHILIPPINE SEA. The northern boundary of the Philippine Sea is adjacent to the known primary range of this species (Figure 5-52).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Distribution in this area is based mostly on information in Amaha (1994) and Jefferson and Van Waerebeek (2002), both of which distinguished records of dolphins of the genus into long-beaked and short-beaked forms. This is a relatively shallow-water, warm-temperate to tropical species. Occurrence is expected from the shore (but not including the enclosed bays) from 35°N, to the south and extending about 100 nm (185 km) offshore of the mainland and main islands (Figure 5-53). The long-beaked common dolphin is unlikely to occur in bays and inshore seas, as the species apparently does not often come into enclosed shallow bays such as these.

MARIANA ARCHIPELAGO. This species tends to occur in upwelling modified waters of the ETP (Au and Perryman 1985). Absence of known areas of major upwelling in the western tropical Pacific suggests that common dolphins would not be found there, although some reports of sightings of this species have been received (Masaki and Kato 1979). However, these records of species identification have not been confirmed, and are in doubt. Occurrence pattern is believed the same throughout the year.

CAROLINE ISLANDS. The Caroline Islands are not included in the known primary range of this species (Figure 5-523).

5.24.6 Species-specific Threats

This species is only occasionally involved in the ETP tuna fishery. They are sometimes taken in drive fisheries off Japan (National Marine Fisheries Service), and concern increases about the growing problem of direct kills off Peru. Although bans on small cetacean takes are in place, DNA analysis in 2006 and 2007 on meats sold in Peru fish markets revealed that many small cetaceans including the long-beaked common dolphin are still caught and sold (Tzika et al. 2010). A large direct kill has occurred off northern Venezuela, but current status of the species there is unknown. In the Indian Ocean and Chinese waters, long-beaked common dolphins are among many species of small cetaceans taken in

gillnets, trawls, and purse seines. Some dolphins of this species have been live-captured for display, but they do not do very well in captivity (Jefferson, Webber, and Pitman 2008; Perrin et al. 2009).

The barnacle *Xenobalanus* has been found on this animal in the ETP, indicating attachments to fast-swimming host is possible (Kane et al. 2008). In a survey of 930 stranded long-beaked common dolphins encompassing years 1985 to 2000 in the southeast Pacific where various lesions on 120 of the animals have been documented (Van Bressem et al. 2006). The most common lesion on the skull was from ostolysis (absorption of bone into the bloodstream) caused by tooth infections and the roundworm *Crassicauda sp*. Worn and damaged teeth, alveolar lesions, bone fractures, and skin lesions (possibly from fishing gear), trunk malformations, and complications from parasite infections were also documented in this survey. During a mass stranding in California in 2002, long-beaked common dolphins were found intoxicated with DA, associated with harmful algal blooms and correlated with both inshore and offshore foraging (Torres de la Riva et al. 2009). Long-beaked common dolphins, including individuals found in Korean waters, are known to bioaccumulate toxins such as butylins, which have been used in antifouling paint on fishing hulls, fishing nets, and marine platforms, and may cause immunosuppression (Choi et al. 2011). PFCs used in industrial polymers, stain repellants, paper coatings, and cosmetics were also found (Moon, Kannan, Yun, et al. 2010). Concentrations of butylin and phenyltin were found in the tissue of long-beaked common dolphins off the coast of Thailand. The highest concentrations were found in the liver, where concentrations of the contaminants increased with body length (Harino et al. 2007a). Dioxins exceeding threshold levels in long-beaked common dolphins have been documented within Korean waters, and may adversely affect health of the animals (Moon, Kannan, Choi, An, et al. 2010).

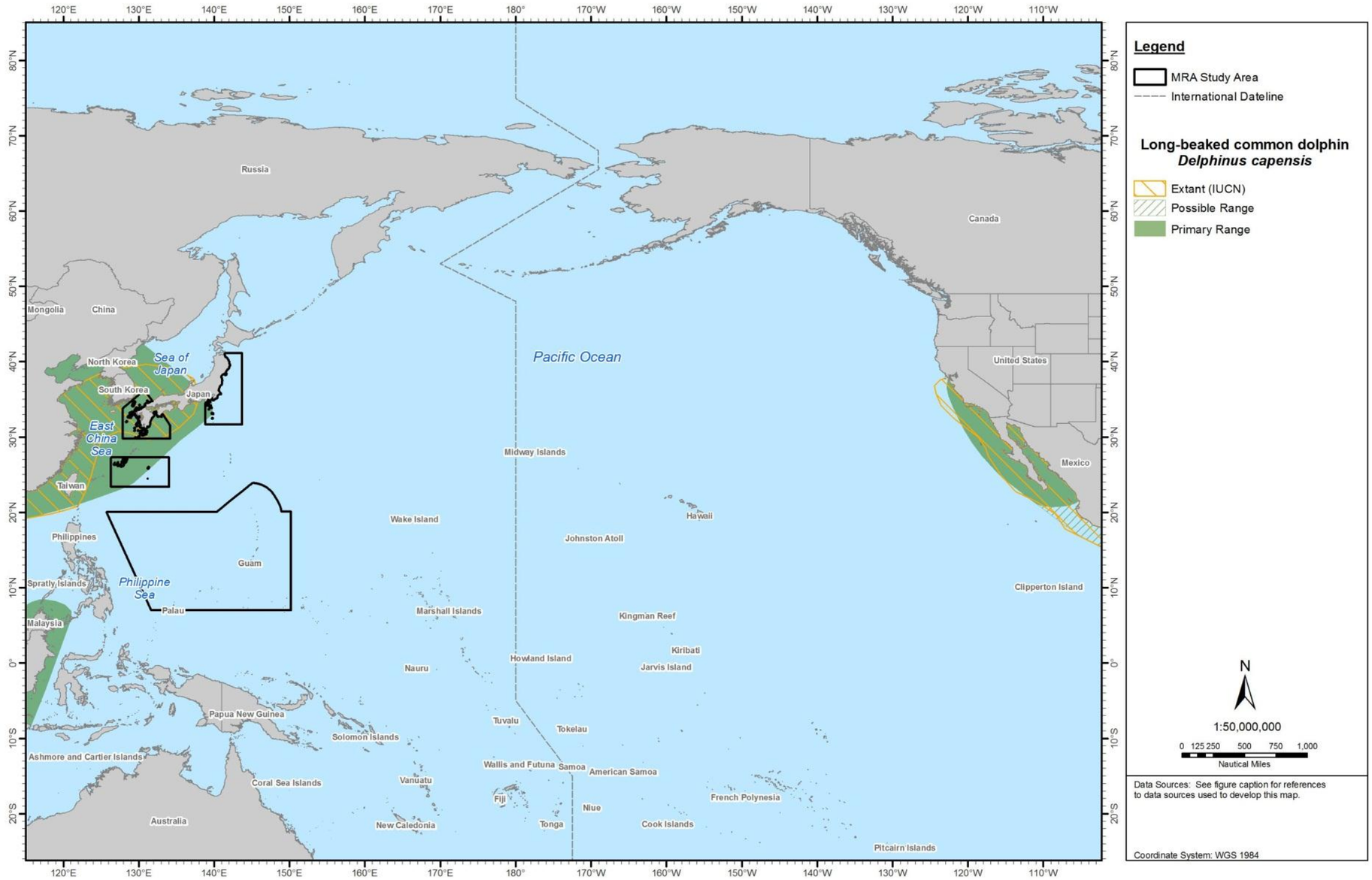

Figure 5-52: Geographic Range of the Long-beaked Common Dolphin in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

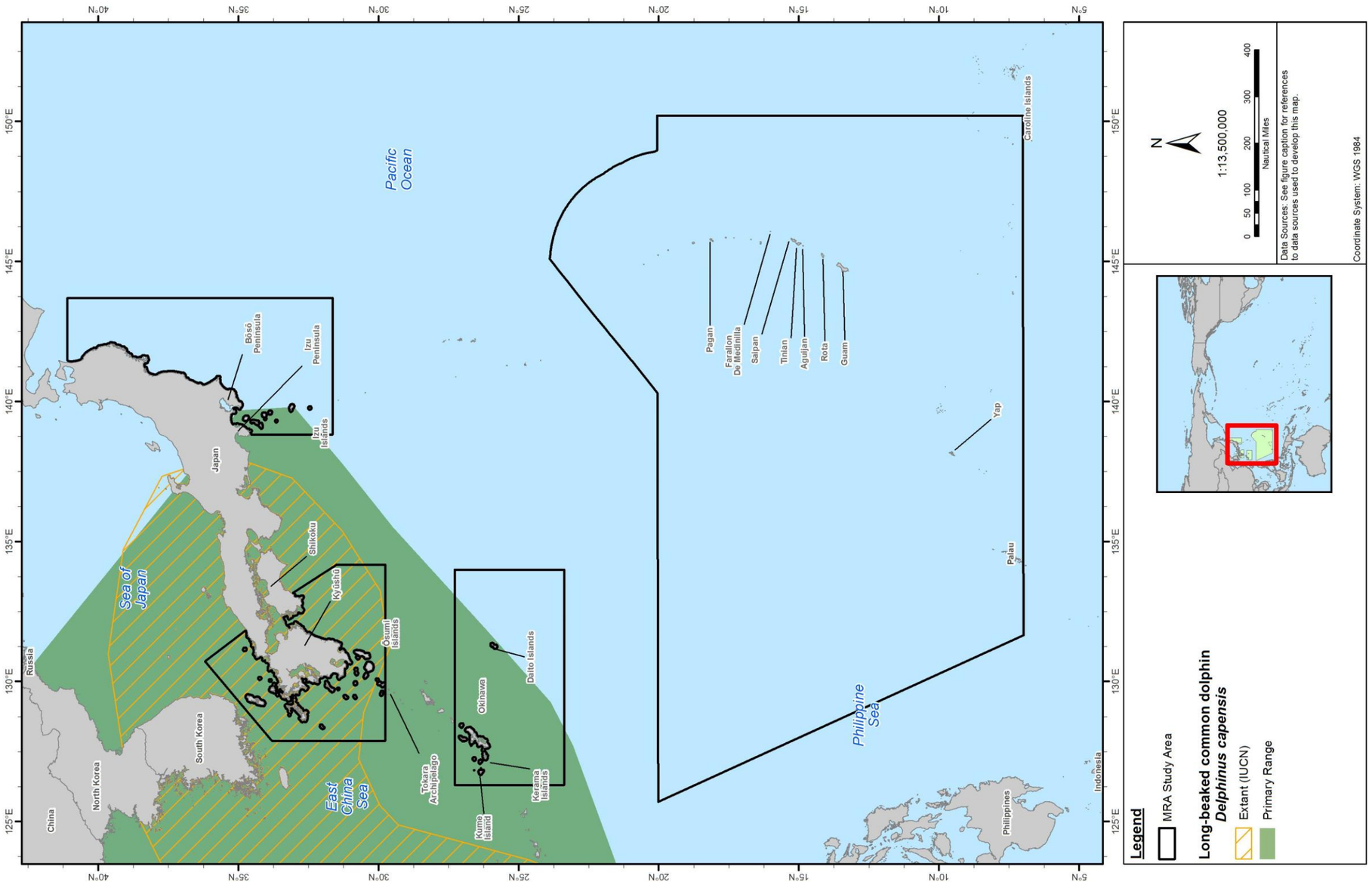

Figure 5-53: Geographic Range of the Long-beaked Common Dolphin in the MRA Study Area
Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.25 SHORT-BEAKED COMMON DOLPHIN (*DELPHINUS DELPHIS*)

5.25.1 Description

Common dolphins now include two species—short-beaked common dolphin (*Delphinus delphis*) and long-beaked common dolphin (*Delphinus capensis*)—rather than a single species, as previously believed. Therefore, much of the biological information regarding dolphins of the genus *Delphinus* cannot be reliably applied to one or the other, especially in regions where the two species overlap (Heyning and Perrin 1994).

The short-beaked common dolphin tends to be somewhat more robust than the long-beaked species, with a shorter (but still moderately long) beak, and a more rounded, bulging melon (Heyning and Perrin 1994). A deep crease extends between the melon and beak, as is common in many delphinids. Short-beaked common dolphins have tall, slightly falcate dorsal fins, with pointed tips. The flippers are slender, recurved, and pointed at the tips—the typical shape for dolphins. Some individuals (apparently mostly adult males) have a prominent post-anal hump of connective tissue that forms a ventral “keel” (Jefferson, Webber, and Pitman 2008).

The color pattern of short-beaked common dolphins is highly variable. They are strikingly marked, with a dark brownish-gray back, white belly, and thoracic patch of tan to ochre. The thoracic patch dips below the dorsal fin and merges with an area of streaked light gray on the tail stock to produce an hourglass pattern on the side—the common dolphins' most characteristic feature. In short-beaked common dolphins, the thoracic patch is relatively light, contrasting strongly with the dark cape. A flipper-to-anus stripe is rarely present (this is generally well-developed in the long-beaked species), and when present tends to be faint. The flippers and dorsal fin range from completely dark to almost entirely white, but most often have a light patch in the center. The chin-to-flipper stripe does not approach the gape, and it narrows anterior to the eye. The lips of short-beaked common dolphins are black, and a dark stripe runs from the apex of the melon to the eye. The upper surface of the beak is generally light gray, with a black tip, and a dark line that runs from the tip to the apex of the melon. A light-colored blowhole stripe runs from the apex to the blowhole (Jefferson, Webber, and Pitman 2008; Perrin et al. 2009).

In the eastern Pacific, lengths of adult short-beaked common dolphins are 1.6 to 2.2 m (females) and 1.7 to 2.3 m (males), with occasional specimens attaining a length of 2.35 m. Those in the northeast Atlantic appear to grow much larger, up to about 2.50 m; some individuals may reach nearly 2.70 m, and may weigh up to 200 kg. Short-beaked common dolphins are about 80 to 90 cm long at birth. Small, sharp, pointed teeth number 41 to 57 in each tooth row.

5.25.2 Status and Management

This species is protected under the MMPA and is not listed under the ESA. This species is also listed as least concern by the IUCN and falls under Appendix II CITES regulations. The MMPA stock assessment reports specify a single Pacific management stock including only animals found within the U.S. EEZ of California, Oregon, and Washington (Carretta et al. 2010). Although this stock does not have range within the MRA Study Area, short-beaked common dolphins are known to have primary range within the Japan portion of the MRA Study Area.

5.25.3 Population and Abundance

Short-beaked common dolphins occur in very high densities within their primary range of temperate waters of the Atlantic and Pacific Oceans. Although some populations are threatened by human activities, no global population estimates have been produced. It is considered one of the most abundant dolphin species in the world. The geographically nearest stock assessment was for the California stock (estimated 411,211 dolphins [CV=0.21]). A history of decline and increase in this population may correlate to certain oceanic conditions such as El Niño events (Carretta et al. 2011q). Apparently, no abundance estimates have been published for the short-beaked common dolphin in the MRA Study Area.

5.25.4 Biology, Ecology, and Behavior

Short-beaked common dolphins are highly active and are often observed moving at high speeds in large groups. They have been noted near schools of long-beaked common dolphins, but the two species do not appear to intermix often. Associations with other marine mammal species, pilot whales in particular, are not uncommon (Carretta et al. 2010; Jefferson, Webber, and Pitman 2008).

Group Size. Schools range widely in size from approximately 10 to more than 10,000 animals and are frequently segregated by age and sex (Jefferson, Webber, and Pitman 2008; Perrin 2008a). DNA analysis of stranded pods in the English Channel does not support a matriarchal system, and individuals within a pod are not necessarily related (Viricel et al. 2008).

Predator/Prey Interactions. Stomach contents of *Delphinus* from California waters revealed 19 species of fish and two species of cephalopods. Stomach contents from the Bay of Biscayne showed sardine, anchovy, sprat, and horse mackerel as the most important prey species. Composition of stomach contents varied seasonally in species composition and size with the age and sex of the dolphin (Meynier et al. 2008). Short-beaked common dolphins have been shown to select high-energy prey over low-energy prey, even when the latter is more abundant (Spitz et al. 2010). *Delphinus* feed primarily on organisms in upwelling currents. *Delphinus* species fluctuate in vocal activity, with more vocal activity during late evening and early morning, apparently linked to feeding on the DSL, which rises in this same time frame (Goold 2000). It has been shown that rostrum length variation within this species results in variations in use of habitat among individuals. Individuals with longer beaks either feed at higher trophic levels and/or inhabit farther offshore waters than their shorter beaked counterparts (Wilson et al. 1987).

Predation by killer whales on this species has been observed (Leatherwood et al. 1973).

Life History. Age at sexual maturity varies considerably among populations (3 to 12 years for males, 2 to 7 years for females). Through the analysis of testes from stranded males off the Irish and French coasts from 1991 to 2000, sexually mature males were measured at 1.95 to 2.33 m in length and an average of 11.86 years of age (Murphy, Collet, and Rogan 2005). Mating seasons in this area are believed to occur from May to September where females mate with multiple, competing partners. Pregnancy apparently lasts 10 to 11 months. The peak calving season off the California coast is spring and early summer (Forney 1994). These data are further supported through analyses of peak testosterone concentrations in mature males found during summer months (Kellar et al. 2009). Reported calving intervals for short-beaked common dolphins are from 1 to 3 years. Longevity is at least 25 years (Jefferson, Webber, and Pitman 2008). Often, intraspecific genetic diversity is confined by physical barriers, however, genetic structure in this highly mobile species seems to be correlated with marine productivity and sea surface

temperature with divergence to be driven by isolation over great distances (Amaral et al. 2012). Life history has not been studied in detail in Japan.

Migration. Although short-beaked common dolphins are not truly migratory, their abundance off California varies with seasonal and year-to-year changes in oceanographic conditions; movements may be north-south or inshore-offshore (Barlow 1995; Carretta et al. 2010; Forney and Barlow 1998).

Hearing/Vocalization. Recorded auditory brainstem responses from a short-beaked common dolphin were U-shaped with a steeper high-frequency branch. The audiogram bandwidth was up to 128 kHz at a level of 100 dB above the minimum threshold. The minimum thresholds were observed at frequencies of 60 to 70 kHz (Popov and Klishin 1998).

Recorded short-beaked common dolphin vocalizations include whistles, chirps, barks, and (Ketten 1998). Clicks and whistles have dominant frequency ranges of 23 to 67 kHz and 0.5 to 18 kHz, respectively (Ketten 1998).

Diving. *Delphinus* dives have been reported to range from 30 to 60 m (Evans 1971; Hooker and Baird 2001). Evans (1971) found a link between common dolphin dive behavior and the DSL, with maximum dive depths consistently below the depth of this layer. An individual tagged and tracked off San Diego, California, most often dove within the range of 9 to 50 m; however, other tagging studies have recorded feeding dives as deep as 200 m (Hooker and Baird 2001; Jefferson, Webber, and Pitman 2008).

5.25.5 Habitat and Distribution

Common dolphins in some populations apparently prefer to travel along bottom topographic features, such as escarpments and seamounts (Bearzi 2003; Evans 1994; Hui 1979). Short-beaked common dolphins are routinely sighted in upwelling-modified waters of the ETP (Au and Perryman 1985; Ballance and Pitman 1998; Reilly 1990). This species prefers areas with large seasonal changes in surface temperature and thermocline depth (the point between warmer surface water and colder water) (Au and Perryman 1985). Although short-beaked common dolphins primarily occur in deep waters beyond the edge of the continental shelf, they do come into continental shelf waters in some areas and seasons (Jefferson, Webber, and Pitman 2008; Perrin 2008a). The distribution of this species in Portuguese waters was found correlated most strongly with chlorophyll concentrations, reflecting prey availability of pelagic schooling fishes (Moura, Sillero, and Rodrigues 2012). In the Azores, seamounts shallower than 400 m were sites of high seasonal aggregations of common dolphins, and may be concentration areas for marine life (Morato et al. 2008). Canadas and Hammond (2008) observed a preference for more coastal waters among groups of short-beaked common dolphins with calves and groups that were feeding.

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. The short-beaked common dolphin occurs from southern Norway to West Africa in the eastern Atlantic (including the Mediterranean and Black seas), from Newfoundland to Florida and Venezuela to Argentina in the western Atlantic, and from southern Canada to Chile along the coast and pelagically in the eastern Pacific. It occurs in the central North Pacific; from central Japan to Taiwan and around New Caledonia, New Zealand, and southern Australia in the western Pacific; and is possibly absent from much of the South Atlantic and Indian oceans (Jefferson et al. 2009; Perrin et al. 2009) (Figure 5-54).

KUROSHIO CURRENT. Unfortunately, most older records of common dolphins from Japanese waters do not distinguish between long-beaked or short-beaked dolphins. The following assessment is based mostly on information in Amaha (1994) and Jefferson and Van Waerebeek (2002), both of which distinguished records of dolphins of the genus into long-beaked and short-beaked forms.

No known seasonal differences are evident in distribution within Japanese waters. This is a relatively deepwater, cool-temperate species. An area of expected occurrence is seaward of the shelf break to far offshore [ca. 500 nm (926 km)], including in the Tsushima Strait (Figure 5-54 and Figure 5-55).

EAST CHINA SEA. The East China Sea is a part of the known primary range of this species (Figure 5-54). Short-beaked common dolphin may occur in areas including in the Tsushima Strait.

PHILIPPINE SEA. The northern boundary of the Philippine Sea is adjacent to the known primary range of this species (Figure 5-54 and Figure 5-55).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Short-beaked common dolphin may occur here (including in the Tsushima Strait), except for the bays and inland seas along the Japanese mainland. They may occur on the shelf area around island groups, such as Okinawa and the Amami and Ogasawara islands.

MARIANA ARCHIPELAGO. They may occur from the shelf break to seaward of the Mariana Islands MRA Study Area and vicinity (Figure 5-55) (Au and Perryman 1985). The absence of known areas of major upwelling in the western tropical Pacific suggests that common dolphins will not be found there, although there have been some reports of sightings of this species (Masaki and Kato 1979). However, the species identification of these records is not confirmed, and therefore is in doubt. Occurrence pattern is assumed to be the same throughout the year.

CAROLINE ISLANDS. Short-beaked common dolphin may occur from the shelf break to seaward of the Mariana Islands MRA Study Area and vicinity, including in the waters surrounding the Caroline Islands but it is not included in its primary range (Figure 5-54 and Figure 5-55).

5.25.6 Species-specific Threats

Many fisheries worldwide take short-beaked common dolphins, either directly or indirectly. Very large direct catches formerly occurred in countries bordering the Black Sea. Common dolphin stocks there have declined and the fishery has not operated since 1983. Some direct hunting still occurs off Japan and in the Mediterranean (National Marine Fisheries Service). Although bans on small cetacean takes are in place, DNA analysis in 2006 and 2007 on meats sold in Peru fish markets revealed many small cetaceans were available, including the short-beaked common dolphin, verifying that these are still caught and sold (Tzika et al. 2010).

The recent short-beaked common dolphin decline in the Mediterranean Sea appears to have been primarily caused by prey depletion and poor habitat quality. The ETP tuna fishery incidentally takes short-beaked common dolphins from several stocks, and some of these stocks may have been depleted by past levels of mortality. Incidental catches also occur in various other fisheries, particularly via gillnets and pelagic trawls, throughout the range (Jefferson, Webber, and Pitman 2008; Perrin et al. 2009). In south Australia, a 1-year survey estimated 1,728 encirclements by fishery nets (21.3% of them ending in death after fishers responded to entangled animals) and 377 mortalities as a result of the Sardine

Fishery (Hamer, Ward, and McGarvey 2008). In northwestern Spain, Fernandez-Contreras et al. (2010) surveyed bycatch and noted possible bycatch avoidance of trawlers operating in waters deeper than 300 m. Bycatch of common dolphins from gillnet entanglements can subject the animal to abnormally rapid ascent, causing many subsequent health problems including accumulation of gas bubbles in tissues (Moore et al. 2009).

Common dolphins are often afflicted with diseases similar to those found in humans and other mammals. A novel case of a brain tumor (*Microcystic meningioma*) was documented, in this species, off the French Atlantic coast (Miclard et al. 2006). Mother-calf transmissions of lung nematodes in Australian waters, known to compromise the animal's health, have been documented in carcasses of this species in. Prevalence of nematodes is relative to year, season, age class, and geographic range (Tomo, Kemper, and Lavery 2010). Other parasites (nematodes, acanthocephalans, and digeneans) have been found in the gastrointestinal tracts of short-beaked common dolphins off the coast of Patagonia (Beron-Vera et al. 2007). During a mass stranding in California in 2002, short-beaked common dolphins were found intoxicated with DA, associated with harmful algal blooms and correlated with both inshore and offshore foraging (de la Riva et al. 2009). Anthropogenic pollution can also affect dolphin populations. In Spain, organochlorine contaminants have been found in the blubber of the short-beaked common dolphin (Tornero et al. 2006). Southern Australian common dolphins had higher metal and selenium concentrations in bone and liver tissue than did bottlenose dolphins in the same area, correlating to coastal habitat and pelagic prey preferences (Lavery et al. 2008). Concentrations of these pollutants, as well as cadmium, copper, mercury, selenium, and zinc, were found to be transmitted from mother to fetus (Lahaye et al. 2007). PCBs concentrations in the blubber of Atlantic dolphins have been loosely correlated to deaths by infection or disease (Pierce et al. 2008).

This Page Intentionally Left Blank

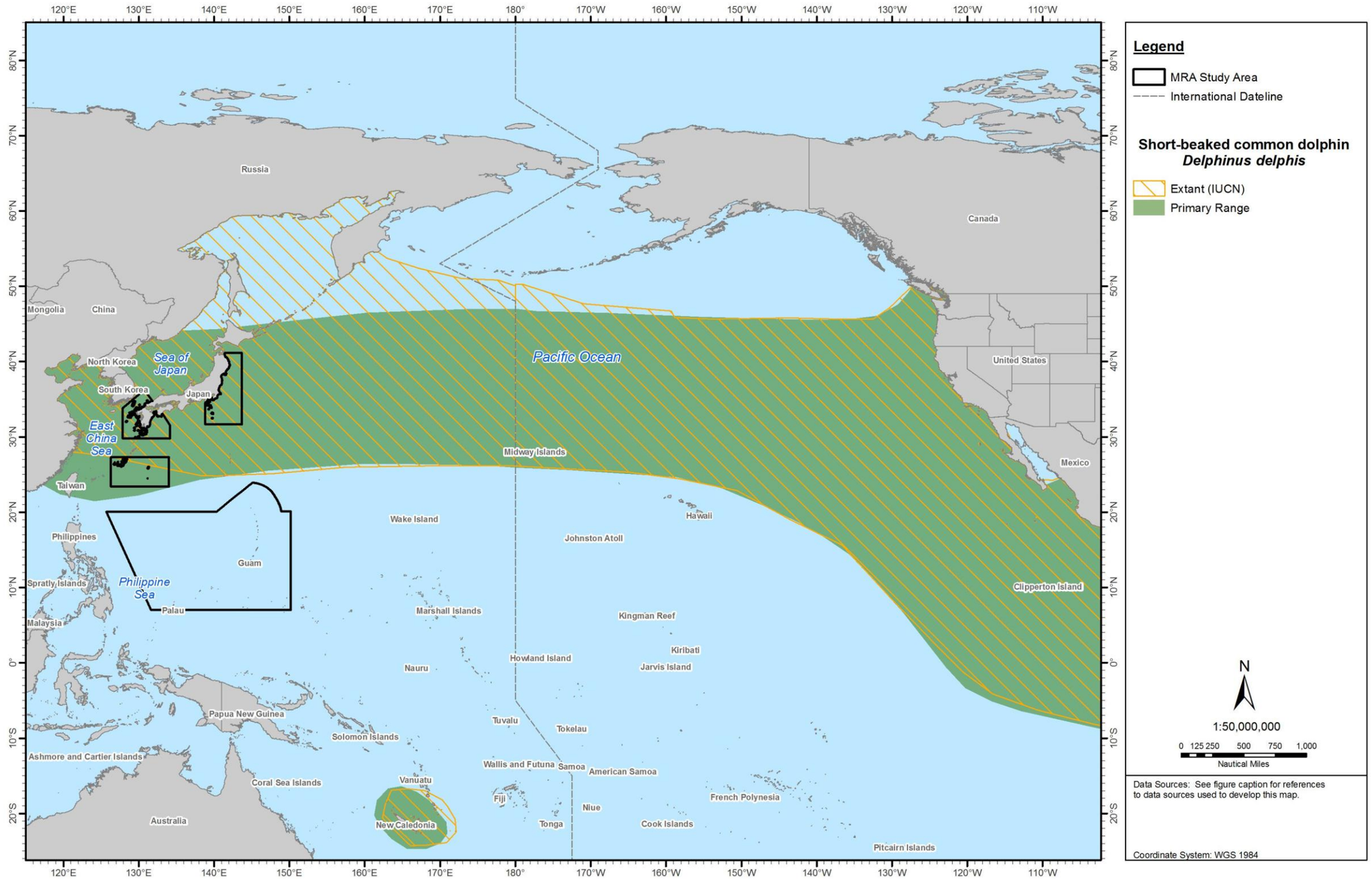

Figure 5-54: Geographic Range of the Short-beaked Common Dolphin in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

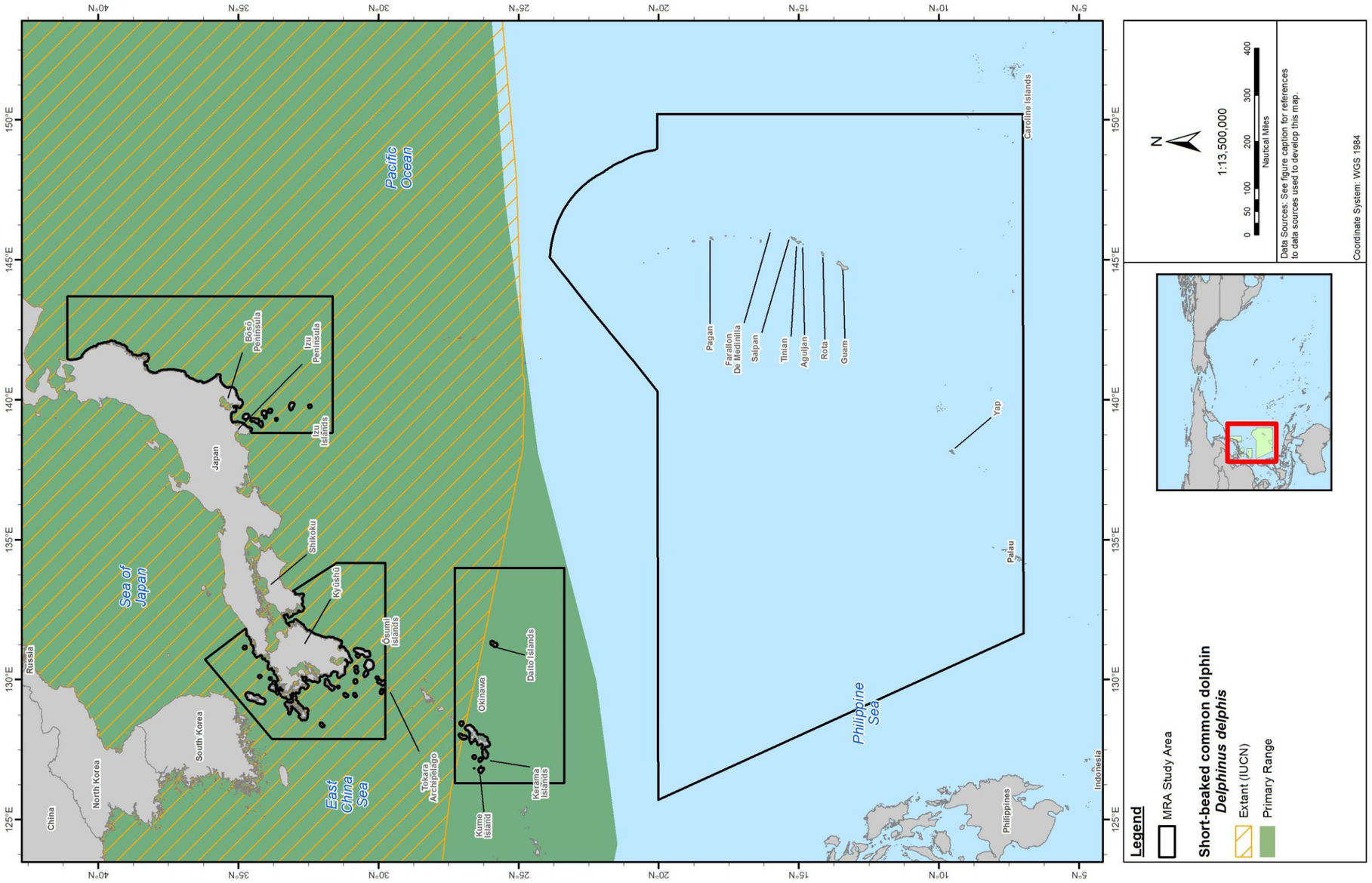

Figure 5-55: Geographic Range of the Short-beaked Common Dolphin in the MRA Study Area
Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.26 PANTROPICAL SPOTTED DOLPHIN (*STENELLA ATTENUATA*)

5.26.1 Description

Pantropical spotted dolphins have cigar-shaped bodies, and are usually fairly slender and streamlined. However, the coastal spotted dolphin subspecies in the ETP is moderately robust. The pantropical spotted dolphin has a long, slender beak, separated from the melon by a distinct crease. The dorsal fin in this species is very narrow, falcate, and usually pointed at the tip. The flippers are slender and strongly recurved, with a continuous curve along the leading edge. Some individuals (apparently adult males) have a small postanal hump or protuberance (Jefferson, Webber, and Pitman 2008; Perrin and Hohn 1994).

Adult pantropical spotted dolphins have varying degrees of white mottling on the dark cape. The spotting ranges from very slight (or even non-existent) in offshore animals to heavy enough to obliterate the cape in the coastal subspecies (this is the reason they are sometimes called "spotters"). In adults, the lower sides and belly are gray, and the lips and beak tip are usually brilliant white. Younger, subadult animals may have extensive dark ventral spotting. They are unspotted at birth, with a simple countershaded pattern. Actually, the most distinctive color pattern component of the pantropical spotted dolphin is the dark dorsal cape, the margin of which is high above the flipper and sweeps very low on the side below the dorsal fin. The tail stock, behind the upsweep of the cape, is often streaked with extensions of the light ventral field. A dark gray patch encircles the eye, and continues forward to the apex of the melon as a narrow eye stripe. Pantropical spotted dolphins also have a dark gape-to-flipper stripe (Perrin et al. 2009; Perrin and Hohn 1994).

Adults of this species are 1.6 to 2.4 m (females) or 1.6 to 2.6 m (males) long, depending on the population. They can reach weights of 119 kg. Newborn pantropical spotted dolphins are about 80 to 85 cm long. In each tooth row are 34 to 48 slender, sharply pointed teeth.

5.26.2 Status and Management

The species is depleted (Pacific Northeastern Offshore Stock) under the MMPA and is not listed under the ESA. This species is also listed as least concern by the IUCN and falls under Appendix II CITES regulations. Three subspecies are recognized in the Pacific Ocean. One inhabits nearshore waters around the Hawaiian Islands, another occurs in offshore waters of the ETP, and a third occurs in coastal waters between Baja California and the northwestern coast of South America (Reeves, Stewart, et al. 2002). There are no annual deaths or serious injuries caused by fisheries are estimated in the Hawaiian stock (Carretta et al. 2012). Several stocks of pantropical spotted dolphins may occur in the western Pacific (Miyashita 1993a), although this has not been confirmed.

5.26.3 Population and Abundance

The western and southern offshore stock, which has been less affected by fishery interactions, numbers about 800,000 (Perrin 2001). A stock assessment for the Pacific Islands estimated is 8,978 (CV=0.48) dolphins in the Hawaiʻi EEZ, and between 1,414 and 37,535 near Palmyra. No trend data are available for these stocks (Carretta et al. 2011m). An estimated 440,000 spotted dolphins were in the waters surrounding Japan in 1993 (Miyashita 1993a); an estimated 127,800 spotted dolphins were in the waters surrounding the Mariana Islands (Miyashita 1993b). Some stocks are not demonstrating clear signs of recovery, despite the dramatic decline in fishery bycatch deaths over recent years, but nonetheless, this is a relatively abundant species (Jefferson, Webber, and Pitman 2008).

5.26.4 Biology, Ecology, and Behavior

Pantropical spotted dolphins are social animals and are fast swimmers. The species is a frequent bowrider and may swim at speeds of at least 22 km/hr. In a study of purse-seine catches, spotted dolphin adults were able to swim much faster than neonates during bursts (6 m/s. compared to 3 m/s.) and during sustained swimming periods (2.5 m/s. over 1 m/s.) (neonates require 3.5 times the energy as adults to swim at the same speed) (Edwards 2006).

Group Size. Group size of pantropical spotted dolphins may range from just a few animals to large schools (groups) of several thousand (Jefferson, Webber, and Pitman 2008; Perrin 2008b). School sizes of the coastal form are generally less than 100, but offshore schools may number in the thousands. Schools may be segregated to some degree by age and sex. Observations of dolphin groups caught in tuna purse seines in the ETP revealed subgroups containing mother-calf pairs, adult males, or juveniles (Pryor and Shallenberger 1991).

Predator/Prey Interactions. Pantropical spotted dolphins prey on near-surface fish, squid, and crustaceans, and on some mid-water species (Perrin and Hohn 1994). Results from various tracking and food habit studies suggest that pantropical spotted dolphins in the ETP and off Hawaiʻi feed primarily at night on surface and mid-water species that rise with the DSL toward the water's surface after dark (Baird et al. 2001; Robertson and Chivers 1997). Pantropical spotted dolphins may be preyed upon by killer whales and sharks, and have been observed fleeing killer whales in Hawaiian waters (Baird, McSweeney, et al. 2006). Other predators may include the pygmy killer whale, false killer whale, and occasionally the short-finned pilot whale (Perrin 2008b).

Life History. Sexual maturity is attained at ages of 9 to 11 years in females and 12 to 15 years in males. Pantropical spotted dolphins are known to breed year round, but in the ETP, where this species has been studied most thoroughly, two calving peaks occur (one in spring and one in fall). Pregnancy lasts about 11.5 months (Perrin and Hohn 1994). Periods between pregnancies are usually 2 to 3 years, and age at weaning varies widely among populations.

Migration. Although pantropical spotted dolphins do not migrate, extensive movements are known in the ETP (although these have not been strongly linked to seasonal changes) (Scott and Chivers 2009).

Hearing/Vocalization. No published hearing data are available regarding pantropical spotted dolphins (Ketten 1998). Anatomy of the ear of the pantropical spotted dolphin has been studied (Ketten 1992a; Ketten 1997). As do other delphinids studied, the pantropical spotted dolphin has a Type II cochlea with 2.5 turns (Ketten 1997).

Pantropical spotted dolphin whistles have a dominant frequency range of 6.7 to 17.8 kHz (Ketten 1998). Click source levels between 197 and 220 dB have been recorded for pantropical spotted dolphins (Schotten et al. 2004).

Diving. Dives during the day generally are shorter and shallower than dives at night; rates of descent and ascent are higher at night than during the day (Baird et al. 2001). Similar mean dive durations and depths have been obtained for tagged pantropical spotted dolphins in the ETP and off Hawaiʻi (Baird et al. 2001). Dives of up to 3.4 min have been recorded for this species (Baird et al. 2001; Jefferson, Webber, and Pitman 2008; Scott and Chivers 2009). A study in Hawaiian waters found that average dive depths and durations were shallower and shorter than those of other similar-sized dolphins and toothed whales, but were similar to those reported for pantropical spotted dolphins from the ETP. Dives in

Hawaiian waters were found to be deeper at night, with a mean depth of 57 m, ± 24 m and a maximum depth of 215 m. During the day, the mean depth was 13 m ± 2 m, with a maximum depth of 120 m (Baird et al. 2001). Average dive depth of tagged pantropical spotted dolphins in the ETP was 14 m, maximum dive depth was 200 m, and maximum dive duration was 5.4 min (Scott and Chivers 2009).

5.26.5 Habitat and Distribution

Studies have shown large variability in habitat for this species. Although coastal populations occur in shallow nearshore waters of Central America, most pantropical spotted dolphins there are present in deep oceanic waters of the upper continental slope and deeper waters away from the slope. Most sightings of this species in the Gulf of Mexico, Caribbean, and off Brazil occur over the lower continental slope (Mignucci-Giannoni et al. 2003; Moreno et al. 2005). Pantropical spotted dolphins in the offshore Gulf of Mexico do not appear to prefer any one habitat type (within the Loop Current, inside cold-core eddies, or along the continental slope) (Baumgartner et al. 2001).

The species is much more abundant in the lower latitudes of its range. It is found mostly in deeper offshore waters but does approach the coast in some areas (Jefferson, Webber, and Pitman 2008; Perrin 2001). They are known to occur in some enclosed seas, such as the Gulf of Mexico, Persian Gulf, and Red Sea (Perrin 2001).

In the eastern Pacific, this species ranges from 25°N (Baja California, Mexico) to 17°S (southern Peru) (Perrin and Hohn 1994). Pantropical spotted dolphins are associated with warm tropical surface water in the ETP (Au and Perryman 1985; Reilly 1990). Au and Perryman (1985) noted that the species occurs primarily north of the Equator, off southern Mexico, and westward along 10°N. In the ETP, the pantropical spotted dolphin is an inhabitant of the tropical, equatorial, and southern subtropical water masses characterized by a sharp thermocline at less than 50 m depth, surface temperatures greater than 25°C, and salinities less than 34 parts per thousand (Au and Perryman 1985). In some areas, such as in the Philippines, pantropical spotted dolphins occur in deep waters close to shore (Perrin 2001). In other locales, pantropical spotted dolphins may also be sighted in relatively shallow waters near the edge of the continental shelf (Gannier 2002; Peddemors 1999).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. The pantropical spotted dolphin is distributed in offshore tropical and subtropical waters of the Pacific, Atlantic, and Indian Oceans between about 40°N and 40°S (Baldwin, Gallagher, and Van Waerebeek 1999; Perrin 2008b) (Figure 5-56).

KUROSHIO CURRENT. Pantropical spotted dolphins occur (and are hunted) in several areas along the Pacific coast of Japan, including off Taiji (Kii Peninsula) (Miyazaki, Kasuya, and Nishiwaki 1974). The occurrence pattern of the pantropical spotted dolphin in the MRA Study Area is based on fishing and sighting data, and this species' preference for pelagic and coastal waters is influenced by the Kuroshio Current (Miyazaki, Kasuya, and Nishiwaki 1974). During the summer-fall period, pantropical spotted dolphins are expected seaward of the shelf break. This area of expected occurrence extends north to 38°N along the east coast of Japan and north to 35°N along the west coast of Japan (Figure 5-56).

EAST CHINA SEA. Short-beaked common dolphins may occur from the shelf break to seaward of the Mariana Islands MRA Study Area and vicinity (Figure 5-57).

PHILIPPINE SEA. The Philippine Sea is a part of the known primary range of the pantropical spotted dolphin (Figure 5-56 andFigure 5-57).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. This species may occur from the shoreline to the shelf break off the south coast of Kyūshū, the Ryukyu Islands, and the Ogasawara Islands (Figure 5-57). Pantropical spotted dolphins are not expected in enclosed bays and channels.

Okinawa Island, Kerma Island, Kume Island, and Daito Islands. During the winter-spring period, pantropical spotted dolphins are expected to occur south of 33°N and seaward of the shelf break along the coasts of Japan and Okinawa (Figure 5-58).

Bōsō Peninsula, Izu Peninsula, and Izu Islands. Pantropical spotted dolphins are known from (and hunted in) several areas along the Pacific coast of Japan, including Arari (west Izu Peninsula), Kawana (Bōsō Peninsula), and Futo (east Izu Peninsula) (Miyazaki, Kasuya, and Nishiwaki 1974). Pantropical dolphins have also been captured at Arari for public display (Nishiwaki 1967).

MARIANA ARCHIPELAGO. The pantropical spotted dolphin is primarily an oceanic species (Jefferson, Leatherwood, and Webber 1993a). Based on the known habitat preferences of the pantropical spotted dolphin, this species is expected to occur seaward of the shelf break (200 m isobath) (Figure 5-58). The pantropical spotted dolphin may also occur from the coastline (in harbors and lagoons) to the shelf break (Figure 5-58). This is based on sightings of pantropical spotted dolphins reported in coastal waters of Guam by (Trianni and Kessler 2002) and coastal populations of pantropical spotted dolphins in tropical locations, such as off Central America and Hawai'i. Sixteen dolphins were seen offshore of the archipelago (U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007). Five dolphins were associated with the waters around the West Mariana Ridge, and six others were over 200 nm offshore south of the island chain (Fulling, Thorson, and Rivers 2011). Therefore, although they do occur in coastal waters, this is not a preferred habitat for the species. Occurrence pattern is believed the same throughout the year.

Farallon de Medinilla. One dolphin was reported in a 2007 survey off the east coast of the island of FDM (Fulling, Thorson, and Rivers 2011).

Saipan. A single sighting of the pantropical spotted dolphin was recorded off the west coast of Saipan during a 2010 survey (HDR 2011). Another two dolphins were seen in a 2012 survey off the west coast of the island (HDR 2012).

Guam. A single pantropical spotted dolphin was seen during a survey by Ligon, Deakos, and U (2011) about 10 nm west of Tumon bay, the west coast of Guam. One dolphin was reported during a 2007 survey off the east coast of Rota (Fulling, Thorson, and Rivers 2011). Two sightings of the Pantropical spotted dolphin, off the west coast of Guam, between Tumon Bay and Ritidian Point, were recorded during a 2010 survey (HDR 2011). Through acoustic recordings and visual sightings, an occurrence of Pantropical spotted dolphin south of the archipelago and along the West Marian Ridge in flowing shallow waters associated with the ridge we recorded (Norris et al. 2011).

CAROLINE ISLANDS. The waters around the Caroline Islands are a part of the known primary range of the pantropical spotted dolphin, and this species has been seen in nearshore waters in other areas (Figure 5-56 and Figure 5-57).

5.26.6 Species-specific Threats

Pantropical spotted dolphins are taken incidentally in a number of purse seine, gillnet, and trawl fisheries throughout the range. Large hunts occur sporadically in the Japanese small cetacean drive and harpoon fisheries, and much-smaller direct kills have occurred in the dolphin fisheries of the Caribbean, Sri Lanka, Philippines, Indonesia, St. Helena, and the Laccadive and Solomon island groups. Most of these takes have not been adequately monitored, and the effects of most of these on the populations are not known. The greatest mortality of this species has been in the ETP tuna purse seine fishery, where it is the main species of dolphin involved in bycatch. Since the interaction between dolphin and tuna was first documented in the late 1960s, millions of spotted dolphins have died in these nets (from 1959 to 1972, about 3,000,000 offshore spotted dolphins were killed). Current mortality in this fishery has been greatly reduced by years of modifications to the fishing practices, fleet changes, and U.S. and international legislation. Major concerns currently focus on possible effects of fishery-related stress, and the role of this in preventing recovery of the populations. In addition, this species has been live-captured in some areas, and some individuals have survived for a short time in captivity (Jefferson, Webber, and Pitman 2008).

A possible encounter between an individual of this species and an active seismic gun array was documented off Liberia in March 2009: physical exhaustion, possibly associated with internal acoustic injury, was possibly worsened by the full power seismic airgun. The distressed animal died. This event highlights the need for precaution during these situations, especially in known dolphin habitat (Zimmer et al. 2005). Concentrations of butylin and phenyltin were found in the tissue of pantropical spotted dolphins off the coast of Thailand. The highest concentrations were found in the liver, where concentrations of the contaminants increased with body length (Harino et al. 2007a).

This Page Intentionally Left Blank

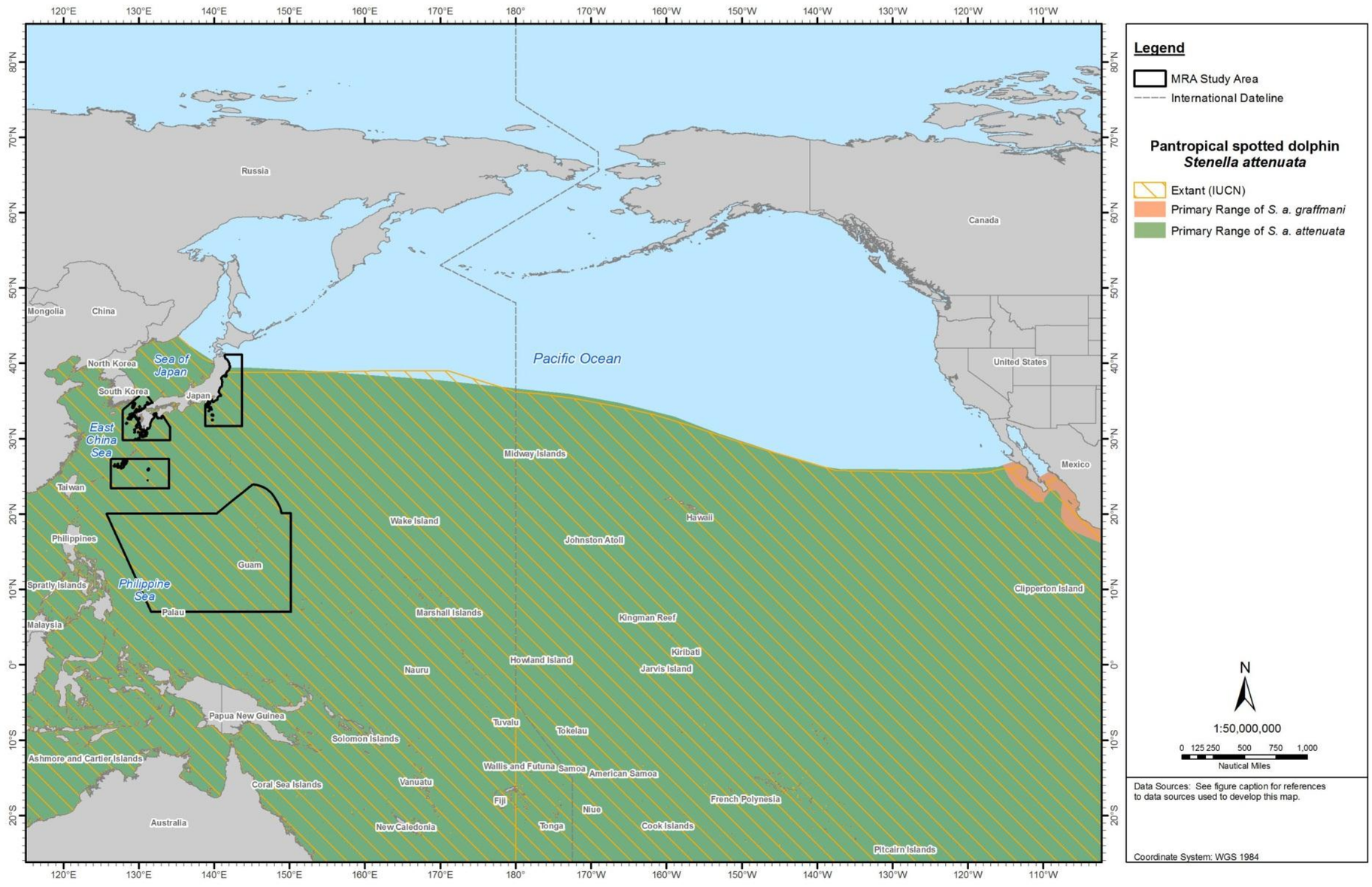

Figure 5-56: Geographic Range of the Pantropical Spotted Dolphin in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

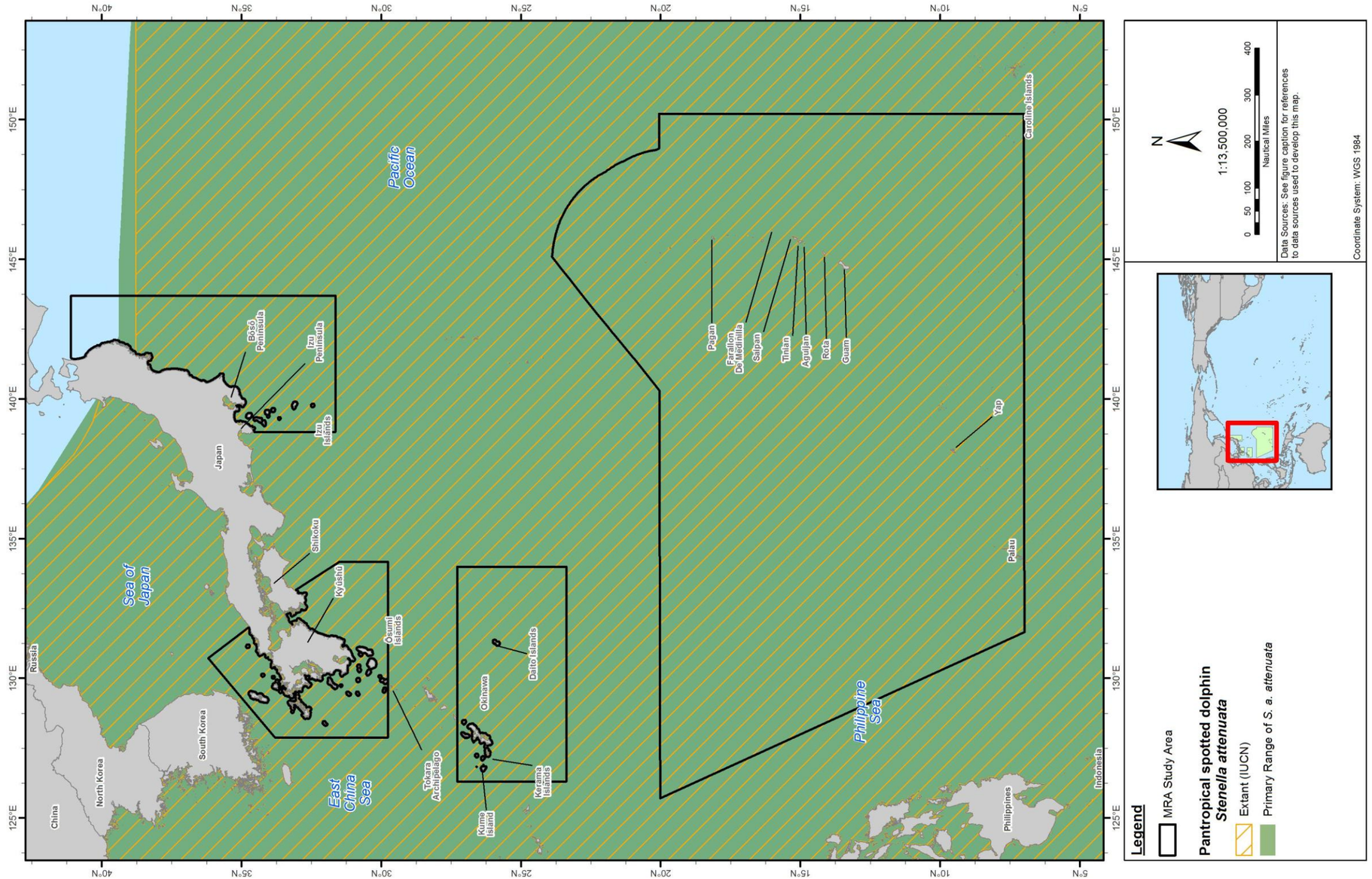

Figure 5-57: Geographic Range of the Pantropical Spotted Dolphin in the MRA Study Area
Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

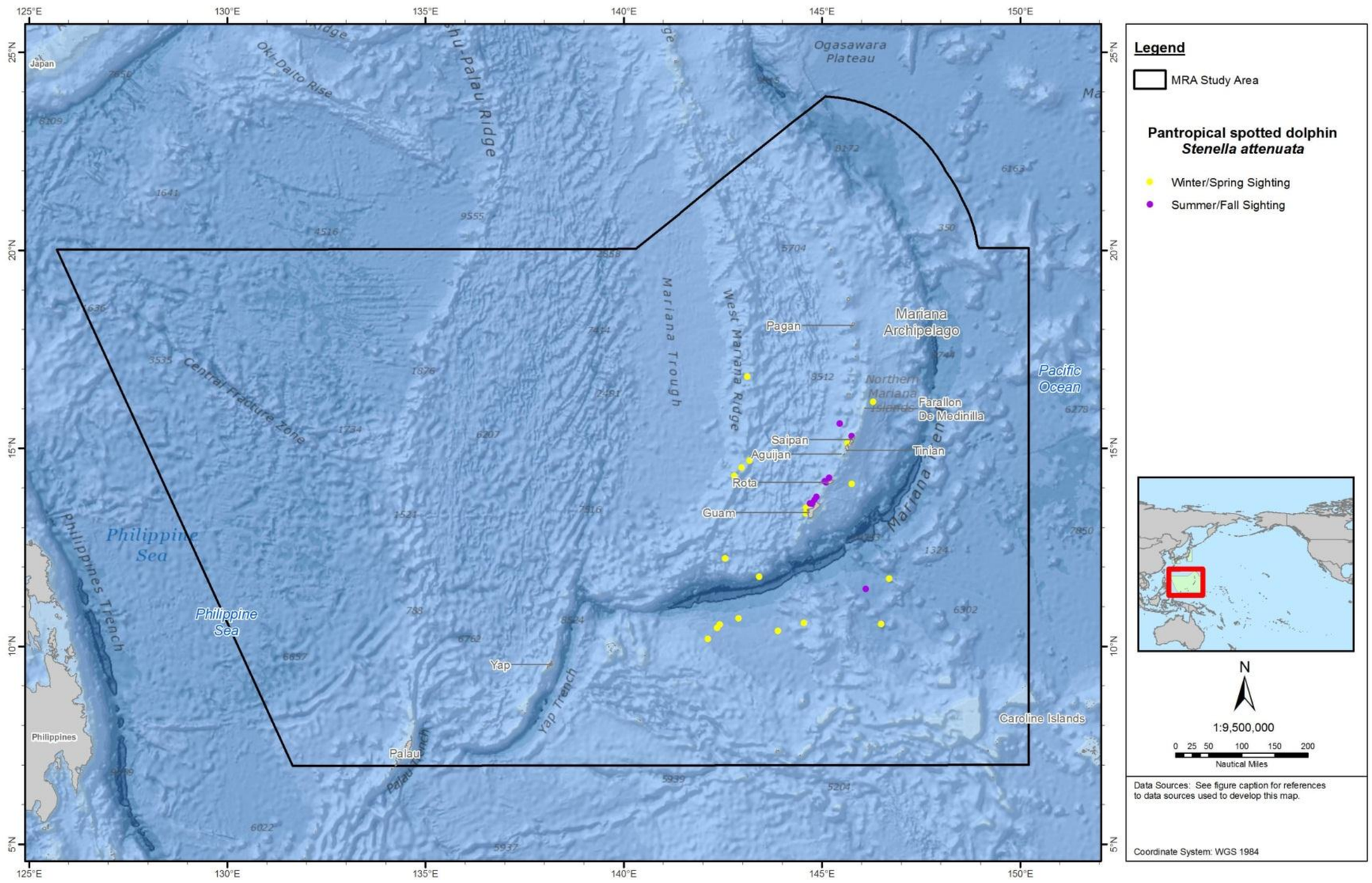

Figure 5-58: Sightings of the Pantropical Spotted Dolphin in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented.
Sources: Fulling, Thorson, and Rivers (2011); HDR (2012); Hill et al. (2013); Hill et al. (2011); Mobley (2007); U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific (2007).

This Page Intentionally Left Blank

5.27 SPINNER DOLPHIN (*STENELLA LONGIROSTRIS*)

5.27.1 Description

Four well differentiated geographical forms of spinner dolphins have been described as separate subspecies: *Stenella longirostris longirostris* (Gray's spinner dolphin) and *Stenella longirostris longirostris* (white belly hybrid) are two forms of the same subspecies; the others are *Stenella longirostris orientalis* (eastern spinner dolphin), *Stenella longirostris centroamericana* (Central American spinner dolphin), and *Stenella longirostris roseiventris* (dwarf spinner dolphin).

The spinner dolphin is very slender, with an extremely long, narrow beak. The forehead is very slender at the apex of the melon. The flippers are also narrow and recurved. The dorsal fin of spinner dolphin ranges from slightly falcate to erect and triangular. In adult males of some subspecies, however, the dorsal fin may be so canted forward that it looks as if it were backwards. The tail stock becomes relatively deeper (taller) over time, and this correlates with an enlarged post-anal hump (often called a keel) of connective tissue. The tips of the flukes may also curl upwards somewhat in males. These three features are developmentally correlated, and reach their greatest extents in eastern and Central American spinners (Jefferson, Webber, and Pitman 2008; Perrin 1998; Perrin, Dolar, and Robineau 1999).

Individuals of most spinner dolphin populations have a three-part color pattern—dark gray cape, light gray sides, and white belly, with only slight differences between males and females. This includes Gray's spinner dolphins (*S. l. longirostris*) and dwarf spinners (*S. l. roseiventris*). In these animals, the upper beak is dark, and most of the lower jaw is white; the beak tip and lips are dark. In the ETP, three other forms with different color patterns are found; they are more monotone in their color patterns with only some light patches on the belly. Spinners generally have dark eye-to-flipper stripes, although these may be hard to see in the ETP forms. Geographical variation in spinner dolphins exists, but has not been as well described for most areas outside the eastern Pacific (Perrin et al. 2009; Perrin and Gilpatrick 1994).

Adults attain lengths of 2.0 m (females) and 2.35 m (males), with much geographical variation. For instance, dwarf spinner dolphins reach maximum lengths of only about 1.58 m. From records taken from bycatch, the eastern spinner dolphin measured 79.7 cm at birth, 121.5 cm at 1 year, and at adulthood averaged 171.5 cm (Larese and Chivers 2009). The white belly spinner dolphins are slightly over 80 cm at birth, 122.5 cm at 1 year, and 177.1 cm fully grown. Spinners are known to reach weights of at least 82 kg (although dwarf spinners can be mature at 25 kg). Males appear to be somewhat larger than females in all subspecies and forms. Spinner dolphin neonates are about 75 to 80 cm long. Very fine, pointed teeth number 40 and 62 in each tooth row, with modal differences among subspecies. Length-weight ratios have been found for this species. Calculations of these ratios are reported in (Perrin et al. 2005).

5.27.2 Status and Management

The spinner dolphin is listed as depleted (Eastern Stock in the ETP) under the MMPA, and the species is not listed under the ESA. This species is also listed as data deficient by the IUCN and falls under Appendix II CITES regulations. The eastern spinner dolphin (*Stenella longirostris orientalis*) is listed as depleted under the MMPA. Four subspecies of spinner dolphins are known, and probably others are undescribed (Perrin 1998; Perrin, Dolar, and Robineau 1999). These four include a globally-distributed nominal subspecies, which occurs in Japanese waters (*S. l. longirostris*).

5.27.3 Population and Abundance

The geographically nearest stock assessments were for the Hawai‘i pelagic stock (estimated 3,351 [CV=0.59] dolphins in Hawaiian waters). An unknown number of annual deaths or serious injuries caused by fisheries are estimated for the Hawaiian stock (Carretta et al. 2012). No abundance estimates have been reported for the new American Samoa Stock (Carretta et al. 2012). From a 2007 cetacean survey Fulling, Thorson, and Rivers (2011) reported the number of this species in Guam and the CNMI as 1,803 individuals.

5.27.4 Biology, Ecology, and Behavior

Spinner dolphins are well known for leaping high into the air and spinning, and they are also frequent bowriders. This activity is thought to produce enough force to knock remoras off of the individual (Fish, Nicastro, and Weihs 2006). Spinners in the Atlantic occasionally have been sighted and stranded in association with Clymene dolphins (*Stenella clymene*) and pantropical spotted dolphins (Fertl et al. 2003; Jefferson and Lynn 1994). In the ETP, spinner dolphins are often seen with pantropical spotted dolphins.

Group Size. Group sizes range from fewer than 50 to several thousand (Jefferson, Webber, and Pitman 2008; Perrin 2008c). Some assemblages are characterized by a dynamic social structure within groups with low gene flow between populations, whereas others have long-term stable social organizations with relatively high gene flow between groups (Andrews et al. 2010). Reported group sizes in the Mariana Islands range from 1 to 120 individuals, with most groups consisting of less than 30 individuals (Trianni and Kessler 2002). Seasonal and geographic variations in group size have been recorded (Norris et al. 1985; Perrin 2008c). In the offshore ETP, some segregation by age and sex is evident among dolphin groups (Perrin and Gilpatrick 1994).

Predator/Prey Interactions. Spinner dolphins feed primarily on small mid-water fishes, squids, and shrimp, and they dive to at least 200 to 300 m (Perrin and Gilpatrick 1994). They forage primarily at night, when the mid-water community migrates toward the surface and the shore (Benoit-Bird 2004; Benoit-Bird et al. 2001). Spinner dolphins track the horizontal migrations of their prey (Benoit-Bird and Au 2003), thus increasing foraging efficiencies (Benoit-Bird 2004; Benoit-Bird and Au 2003). Horizontal migrations are associated not only with solar activity but with lunar phases as well, and dolphin abundance increases with lunar illumination (Benoit-Bird, Dahood, and Wursig 2009). In Hawai‘i, they have been observed feeding in cooperation to maximize prey catch. Dolphins were seen herding schools of fish, utilizing the prey species’ natural avoidance tendencies by swimming in parallel groups close to the shoreline where the potential prey swam. The dolphin groups slowly closed in on the schooling prey and eventually formed a circle, trapping the fish inside. Once the dolphins successfully aggregated the fish, they took turns, often in pairs, feeding from the center of the circle (Benoit-Bird and Au 2009). It has been suggest this cooperative tactic may be essential for energy acquisition in an energy-poor, homogeneous environment (Au and Benoit-Bird 2008). In a complementary study, differences in communication were heard among the varying foraging stages (Benoit-Bird and Au 2009). Data suggest clicks were mainly used between foraging locations to locate other dolphins and organize cooperative activities.

Spinner dolphins may be preyed upon by sharks, killer whales, pygmy killer whales, and short-finned pilot whales (Perrin 2008c).

Life History. The life history of the spinner dolphin has been well described for the ETP, where the species has been taken in large numbers in tuna purse seine nets, but is not as well known in other areas

reviewed in Perrin (1998). Sexual maturity of females occurs at about 4 to 7 years and of males at about 7 to 10 years. Pregnancy lasts approximately 10 months, and lactation is from about 1 to 2 years. Calving among different populations peaks from late spring to fall (Jefferson, Webber, and Pitman 2008; Perrin and Gilpatrick 1994). The eastern spinner dolphin attains sexual maturity at 8.7 years, and the mean annual pregnancy rate is 0.351 with a calving interval of 2.84 years. The white belly spinner dolphin reaches sexual maturity at 8.4 years, with a mean annual pregnancy rate of 0.329 and a calving interval of 3.04 years. For both subspecies, the reproductive potential is less than previously estimated, possibly correlating to low population growth rates (Larese and Chivers 2009).

Migration. The spinner dolphin is not considered a migratory species.

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

Diving. Most feeding generally occurs in shallow waters; however, this species may dive to over 600 m when pursuing prey (Benoit-Bird and Au 2003; Jefferson, Webber, and Pitman 2008). The distribution and mid-water feeding habits of spinner dolphins indicate that this species is probably not an extremely deep diver (Dolar et al. 2003). Spinner dolphins are known to feed at night on mid-water fishes and invertebrates typically in the upper 200 m and occasionally to as deep as 1, 400 m (Dolar et al. 2003).

5.27.5 Habitat and Distribution

Throughout much of their range, spinner dolphins are found in the open ocean. Spinner dolphins occur in both oceanic and coastal environments. Many sightings of this species have been associated with inshore waters, islands, or banks (Perrin and Gilpatrick 1994). Coastal populations are usually found in island archipelagos, where they are tied to trophic and habitat resources associated with the coast (Gannier 2009; Norris and Dohl 1980; Poole 1995). Habitat use, specifically within bays, varies between wet and dry seasons off the Brazilian coast, where the number of dolphins, aerial activity, and reproduction was observed reduced during the wet season (Silva and Da Silva 2009). Open ocean populations, such as those in the ETP, often are found in waters with a shallow thermocline (rapid temperature difference with depth) (Au and Perryman 1985; Perrin 2008c; Reilly 1990). Concentrated in and above the thermocline are sea organisms on which spinner dolphins feed. In the ETP, spinner dolphins are associated with tropical surface waters typified by extensive stable thermocline ridging and relatively little annual variation in surface temperature (Au and Perryman 1985; Perrin 2008c).

Spinner dolphins are pantropical, ranging through oceanic tropical and subtropical zones in both hemispheres (the range is nearly identical to that of the pantropical spotted dolphin). Northern and southern limits are near 40°N and 40°S. Spinner dolphins occur in the Gulf of Mexico, Caribbean Sea, the east coast of Africa to the Red Sea and the Persian Gulf, but not in the Mediterranean Sea. The dwarf spinner dolphin is found only in shallow waters in Southeast Asia and Northern Australia (Perrin, Dolar, and Robineau 1999).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. The primary range of Gray's spinner dolphin is known to include waters of the North Central Pacific Gyre and the southern waters of the North Pacific Transitional provinces (Figure 5-59). Its range generally includes tropical and subtropical oceanic waters south of 40°N, continuously across the Pacific (Jefferson, Webber, and Pitman 2008; Perrin and Gilpatrick 1994). The eastern spinner dolphin is known to be distributed through offshore waters of the ETP (Jefferson, Webber, and Pitman 2008; Perrin and Gilpatrick 1994).

KUROSHIO CURRENT. Spinner dolphin occurrence in the Japan MRA Study Area changes seasonally. During the winter-spring period, spinner dolphins are expected to occur south of 31°N, seaward of the shelf break along the coast of Japan and Okinawa (Figure 5-59). During the summer-fall period, spinner dolphins are expected to occur south of 35°N.

EAST CHINA SEA. Spinner dolphins are expected to occur on the shelf break in the East China Sea for the winter-spring and summer-fall periods (Figure 5-59).

PHILIPPINE SEA. The Philippine Sea is included in the known range of Gray's spinner dolphin (Figure 5-59 and Figure 5-60).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Spinner dolphins use the coastal waters of the Ogasawara Islands for resting during the daytime (Mori 1999). Therefore, an area of expected occurrence extends from the shoreline to the shelf break around the Ogasawara Islands. A low occurrence is expected from the shoreline to the shelf break along the east coast of Japan, southern part of Kyūshū (not including bays), and around the Ryukyu Islands (Figure 5-60).

MARIANA ARCHIPELAGO. Spinner dolphins travel among the CNMI island chain, using coastal, protected waters (Trianni and Kessler 2002). Further research efforts, including from boats and aerial surveys, are likely to identify other areas of the Mariana Islands MRA Study Area and vicinity as high-usage habitat. One dolphin was seen during a 2007 survey off the Mariana Islands (U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007). Additionally, acoustical recordings of the species in this area may indicate presence of more individuals (Norris et al. 2011). Occurrence pattern is believed the same throughout the year (Figure 5-60 and Figure 5-61).

Farallon de Medinilla. Spinner dolphins have been seen at FDM (Trianni and Kessler 2002). On March 20th, 2006 a pod of approximately 10 spinner dolphins were identified 400 m east of FDM (Vogt 2008).

Saipan. In the Mariana Islands, dolphins are reported in Saipan Lagoon at Saipan nearly every year (Trianni and Kessler 2002). Typically, these sightings are from the northern part of the lagoon, referred to as Tanapag Lagoon (Trianni and Kessler 2002). On July 28th, 2007 a pod of aproxaimaely 30 spinner dolphins was seen 50 km north of Saipan (Vogt 2008). A survey in 2010 of cetacean sightings around Saipan and Tinian recorded 10 group sightings with an average group size of 22 individuals (Oleson and Hill 2010). Six spinner dolphins were sighted near Naftan Cliff, west of Managaha Island, two sightings occurred on the east coast of Marpi Reef, and another off Tank beach (Ligon, Deakos, and U 2011). Sightings of spinner dolphins also are documented near Tank Beach, Naftan Cliff, Marpi Reef, and at the southwest end of the island (HDR 2011). Norris et al. (2011) identified, through acoustic recordings and visual sightings, spinner dolphins off the coast of Saipan.

Tinian. Sightings of spinner dolphins around Tinian are documented along the southeast coast of the island (HDR 2011).

Aguijan. A single sighting of a spinner dolphin around Aguijan occurred on the northeast coast of the island (HDR 2011).

Rota. During a 2010 survey, sightings occurred at Rota Bank, in Inarajan Bay, on the north and east banks of Pati Point, and around the cost of Rota (HDR 2011).

Guam. Spinner dolphins occur off the waters of Guam (Trianni and Kessler 2002). High-use areas at Guam include Bile Bay, Tumon Bay, and Double Reef (Amesbury et al. 2001; Eldredge 1991). A survey in 2010 of Guam cetacean sightings recorded nine spinner dolphin group sightings with an average group size of 68 individuals (Oleson and Hill 2010). Seven groups of spinner dolphins were sighted off the coast of west Guam in 2010. One sighting of a spinner dolphin occurred on the west coast of Guam, at Tumon Bay, during a 2010 survey (HDR 2011). During a 2012 survey a spinner dolphin was sighted close to the coast of western Guam (HDR 2012).

Apra Harbor - The spinner dolphin is expected to occur throughout the entire Mariana Islands MRA Study Area and vicinity, except within Apra Harbor, where it is unlikely to occur (Figure 5-61). Spinner dolphins are behaviorally sensitive and avoid areas with much anthropogenic usage, which is why this species is unlikely to occur in Apra Harbor.

Agat Bay - High-use areas at Guam also include north Agat Bay (Amesbury et al. 2001; Eldredge 1991). During a cetacean survey , eight spinner dolphins were seen in Agat Bay and south of Facpi Point (Ligon, Deakos, and U 2011). Five additional sightings occurred in Agat Bay, one in Hagatna, and another in Tumon Bay (HDR 2011).

Cocos Lagoon - Lagoons are high-usage habitat for resting by spinner dolphins: spinner dolphins are expected to concentrate in at least Saipan and Cocos Lagoons (Figure 5-61) for that purpose during the day (as they do in other locales, such as Hawai‘i and French Polynesia).

CAROLINE ISLANDS. The waters around the Caroline Islands are included in the known range of Gray’s spinner dolphin, and this species occurs in coastal environments (Figure 5-59 and Figure 5-60).

5.27.6 Species-specific Threats

Direct kills of this species occur in several areas, including the Caribbean, Sri Lanka, the Philippines, Indonesia, and occasionally Japan. They may also take place in West Africa. Spinners are taken by the ETP tuna purse seine fishery; this species is the second-most impacted species of dolphin (after the pantropical spotted dolphin) in that fishery. Estimated reduction of eastern spinner dolphin population in the ETP via the tuna fishery mortality is to less than one-third of its original size. Although current kills have been greatly reduced, the population is not recovering at its expected potential, and fishery-related stress may be at least partially responsible for this (Jefferson, Webber, and Pitman 2008). Other incidental catches occur throughout the range in a number of different fisheries, including in driftnets, purse seines, and trawls. Dwarf spinners are taken incidentally in shrimp trawls in the Gulf of Thailand. Human use of bycaught dolphins has led to some direct hunting. The spinner dolphin’s habit of resting in coastal waters has led to harassment of them by dolphin-watchers and by swim-with-dolphin boat tourists in many areas. Some spinner dolphins have been captured for public display, but they generally do not do well in captivity (Jefferson, Webber, and Pitman 2008).

The barnacle *Xenobalanus* has been found on this animal in the ETP, indicating attachments to a fast-swimming host are possible (Kane et al. 2008). An analysis by (Carvalho et al. 2010) of strandings off the coast of Brazil showed susceptibility of spinner dolphins to parasites. For more detailed information on specific host-parasite species identified through this study, refer to (Carvalho et al. 2010). Other infections, including presence of cutaneous nodules and enlarged lymph nodes caused by the yeast *Cryptococcus gattii*, have been documented in this species (Rotstein et al. 2010). Anthropogenic pollution can affect this species, as it does other marine mammal species. Some pollutants such as trace levels of PCBs have been detected in blubber samples of spinner dolphins (Mwevura et al. 2010). Concentrations of butylin and phenyltin were found in the tissue of spinner dolphins off the coast of Thailand. The highest concentrations were found in the liver, where concentrations of the contaminants increased with body length (Harino et al. 2007a).

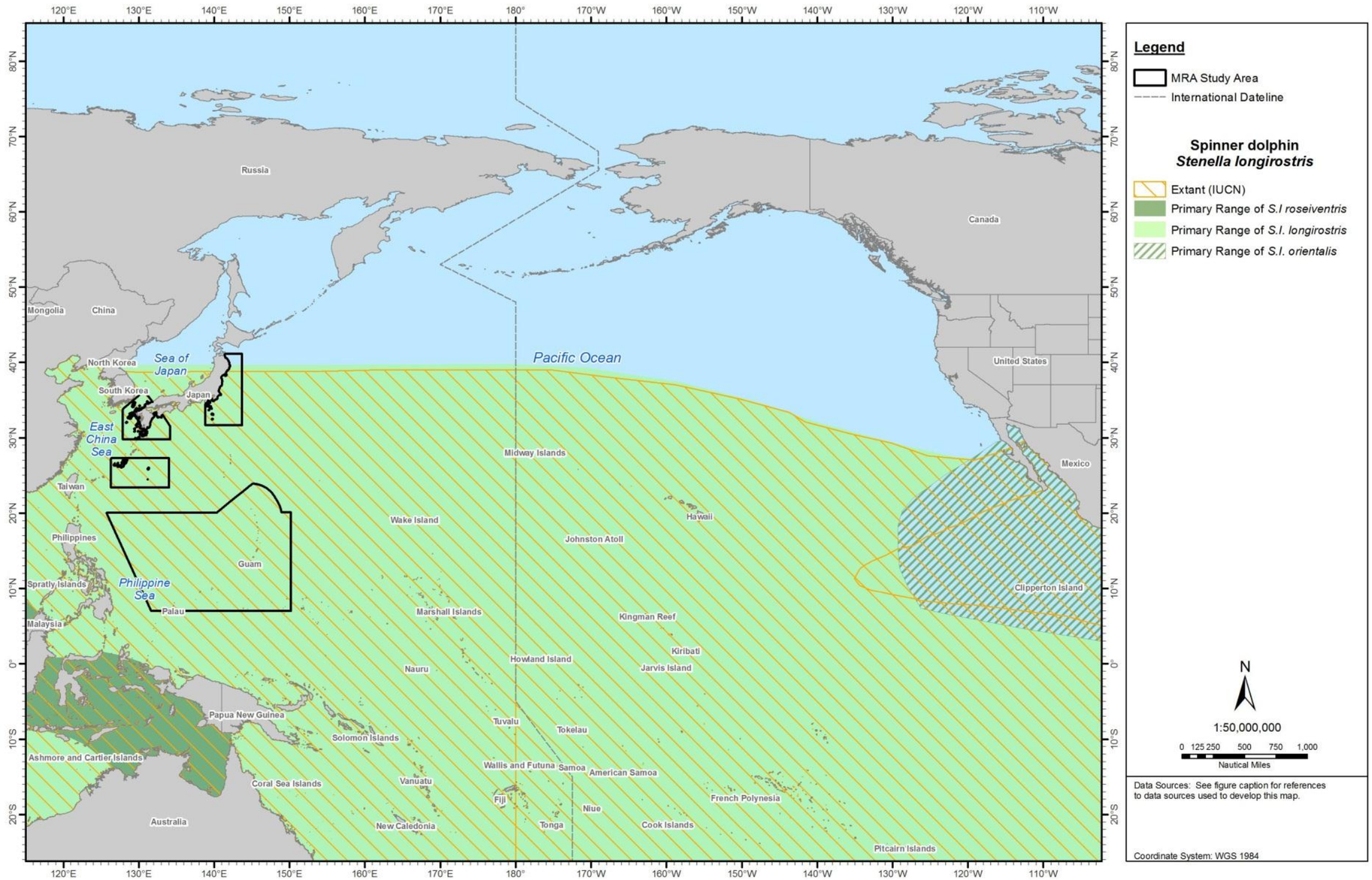

Figure 5-59: Geographic Range of the Spinner Dolphin in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

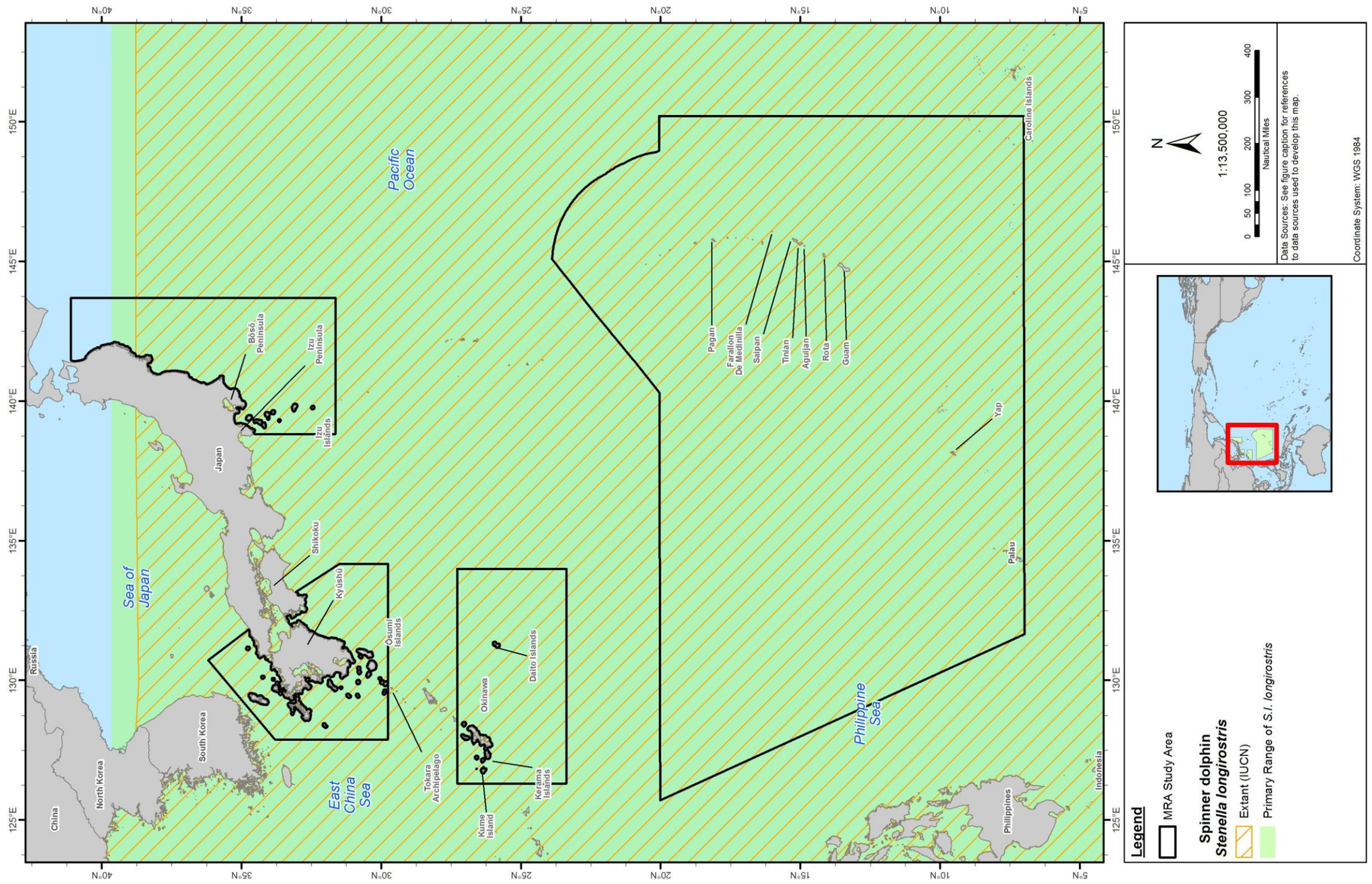

Figure 5-60: Geographic Range of the Spinner Dolphin in the MRA Study Area
Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

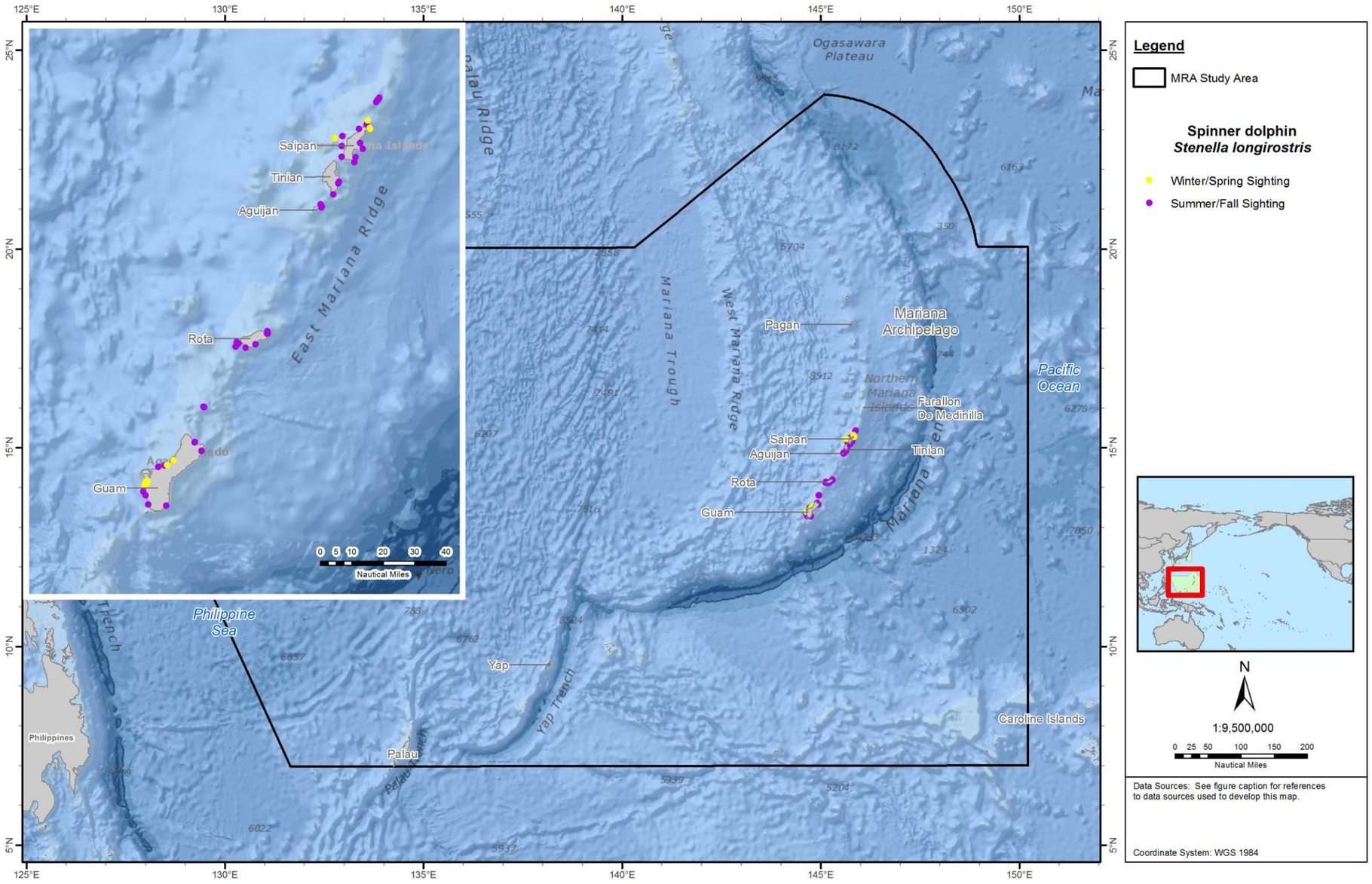

Figure 5-61: Sightings of the Spinner Dolphin in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented.
Sources: Fulling, Thorson, and Rivers (2011); HDR (2011, 2012); Hill et al. (2013); Hill et al. (2011); U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific (2007).

This Page Intentionally Left Blank.

5.28 STRIPED DOLPHIN (*STENELLA COERULEOALBA*)

5.28.1 Description

The striped dolphin is relatively robust (especially in the thoracic region), and is somewhat more heavy-bodied than is typical of most other species in the *Stenella/Delphinus* group. The beak is moderately long; a distinct crease separates the melon and beak. The dorsal fin of the striped dolphin is tall and slightly falcate. The flippers are recurved and pointed (they have the typical dolphin shape). The flukes have slender blades and acutely-rounded tips, and are not notably different from those of other species in the genus (Archer 2009; Jefferson, Webber, and Pitman 2008).

The striped dolphin has a beautiful, complex color pattern. The mostly-black beak sends back a dark stripe, which encircles the eye and then widens and runs back to the anus (this is the basis for the species' common name). An eye-to-flipper stripe is present, and usually a short accessory stripe is between the other two. It has a white belly (often with a pinkish tinge) and dark gray dorsal cape that may appear bluish-gray. The belly and back are separated by a light gray flank. A light gray spinal blaze (highly variable in extent and intensity) extends into the cape, to just under the dorsal fin. The dorsal fin, flippers, and flukes are all dark gray to black (Jefferson, Webber, and Pitman 2008). Phenotypic differences seem smaller when dolphins are in small groups. Phenotypic variations related to group size are addressed at more depth in (Rosso, Moulins, and Wurtz 2008).

Males grow slightly larger than females (with significant geographical variation in the size of adults from different populations). Adult striped dolphins can be up to 2.56 m long. Calves are about 93 to 100 cm long at birth. Maximum weight is about 156 kg. Slender pointed teeth in each tooth row number 40 to 55.

5.28.2 Status and Management

This species is protected under the MMPA and is not listed under the ESA. This species is also listed as least concern by the IUCN and falls under Appendix II CITES regulations. In the western North Pacific, three migratory stocks are recognized. In the eastern Pacific, NMFS divides striped dolphin management stocks within the U.S. Pacific EEZ into two separate areas: waters off California, Oregon, and Washington; and waters around Hawai'i (Carretta et al. 2010). An unknown number of annual deaths or serious injuries caused by fisheries are estimated for the Hawaiian stock (Carretta et al. 2012). Although these stocks do not have range within the MRA Study Area, striped dolphins are known to have primary range within the MRA Study Area.

5.28.3 Population and Abundance

An estimated 570,000 striped dolphins occur in the western North Pacific (mostly around Japan). In the ETP/eastern North Pacific (the west coast of North America), a population of 1.5 million striped dolphins is estimated. Evidence suggests presence of a coastal stock, a northern offshore stock in Japanese waters, and a southern offshore stock. The abundance estimates for these putative stocks are as follows: 19,631 (coastal stock), 497,725 (northern offshore stock), and 52,682 (southern offshore stock) (Miyashita 1993a). The geographically nearest stock assessment in U.S. waters was for the Hawaiian stock (estimated 13,143 [CV=0.46] dolphins). No trend data are available for the Hawaiian stock (Carretta et al. 2011s).

5.28.4 Biology, Ecology, and Behavior

Striped dolphins are fast moving and very acrobatic, performing frequent breaches and other jumps. They are well known in the ETP, where they have frequently been observed at sea, for their habit of fleeing from vessels in low leaps and at high speeds (Archer and Perrin 1999). Visual tests have shown a right-eye monocular preference when these animals inspect unfamiliar targets (Siniscalchi et al. 2012).

Group Size. Most striped dolphin schools are composed of several dozen to 500 individuals, although they sometimes form large herds numbering in the thousands. Indication of age and sex segregation of herds off Japan has been noted, whereby individuals interchange among juvenile, adult, and mixed schools. Wade and Gerrodette (1993) noted a mean group size of 61 in the ETP, and Smith and Whitehead (1999) reported a mean group size of 50 in the Galápagos.

Predator/Prey Interactions. Striped dolphins often feed in open sea or sea bottom zones along the continental slope or just beyond it in oceanic waters. Most of their prey possess light-emitting organs, suggesting that striped dolphins may be feeding at great depths, possibly diving to 200 to 700 m (Archer and Perrin 1999). Striped dolphins may feed at night in order to take advantage of the DSL's diurnal vertical movements. Small mid-water fishes (in particular lanternfishes) and squids are the predominant prey (Perrin, Wilson, and Archer 1994). From results of analyses of nutrient isotopes in tissue samples, Abbot, Premus, and Abbot (2010) suggest that, although males and females feed in the same areas, with increased benthic prey consumption with age, females prefer larger prey at higher trophic levels. These data may suggest nutrient requirements differ between male and female striped dolphins (Abbot, Premus, and Abbot 2010). This assessment also may indicate a dietary shift within the last few decades from a primarily hake and sardine diet to one much more diverse, possibly induced by change in food availability (Abbot, Premus, and Abbot 2010).

Striped Dolphins may be subject to predation by killer whales. This species has been documented to be preyed upon by sharks (Ross 1971).

Life History. Life history information is based mostly on western North Pacific specimens and those from the Mediterranean Sea (Archer and Perrin 1999). Males reach sexual maturity between 7 and 15 years, at an average body length of 2.2 m. Females become sexually mature between 5 and 13 years (Archer and Perrin 1999). Males likely have more than one mate (Archer 2009; Jefferson, Webber, and Pitman 2008). Gestation lasts an estimated 12 to 13 months. Off Japan, where their biology has been well studied, two calving peaks occur: one in summer and one in winter (Perrin, Wilson, and Archer 1994).

Migration. Striped dolphins are not known to formally migrate; yet off the coast of Japan, striped dolphins congregate at the periphery of the Kuroshio Current, where warm water meets cold water (Miyazaki, Kasuya, and Nishiwaki 1974).

Hearing/Vocalization. The striped dolphin's range of most sensitive hearing (defined as the frequency range with sensitivities within 10 dB of maximum sensitivity) was determined to be 29 to 123 kHz using standard psycho-acoustic techniques; maximum sensitivity occurred at 64 kHz (Kastelein et al. 2003). Hearing ability became less sensitive below 32 kHz and above 120 kHz (Kastelein et al. 2003).

Striped dolphin whistles range from 6 to 24+ kHz, with dominant frequencies ranging from 8 to 12.5 kHz (Thomson and Richardson 1995).

Diving. The striped dolphin is estimated to dive to depths of 200 to 700 m while foraging, typically in regions of the continental slope (Archer 2009; Ringelstein et al. 2006).

5.28.5 Habitat and Distribution

Although primarily a warm-water species, the range of the striped dolphin extends higher into temperate regions than those of any other species in the genus *Stenella* (spotted and spinner/Clymene dolphins), and striped dolphins have been shown to prefer colder waters (21 to 24°C) (Panigada et al. 2008). Striped dolphins also are generally restricted to oceanic regions and are seen close to shore only where deep water approaches the coast. In some areas (the ETP), they are mostly associated with convergence zones and regions of upwelling (Au and Perryman 1985; Reilly 1990) or areas with elevated chl *a* (Panigada et al. 2008). In the ETP, striped dolphins inhabit areas with large seasonal changes in surface temperature and thermocline depth, as well as seasonal upwelling (Au and Perryman 1985; Reilly 1990). In some areas, this species appears to avoid waters with sea temperatures less than 68°F (20°C) (Van Waerebeek et al. 1998).

Northern and southern limits are about 50°N and 40°S, although extralimital records exist from the Kamchatka Peninsula, southern Greenland, the Faroe Islands, and the Prince Edward Islands, as well as one sub-adult stranding in the Atlantic off the coast of Argentina around 43°S (Yoshida and Trono 2004).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. The northern limits for this species are the Sea of Japan, Hokkaidō, Washington State, and along roughly 40°N across the western and central Pacific (Figure 5-62) (Reeves, Stewart, et al. 2002). The striped dolphin regularly occurs around the Hawaiian Islands, although sightings are relatively infrequent (Carretta et al. 2010). The striped dolphin occurs primarily seaward at a depth of about 547 fathoms, based on sighting records and the species' known preference for deep waters. Striped dolphins are occasionally sighted closer to shore in Hawai'i; therefore, an area of secondary occurrence is expected from a depth range of 55 to 547 fathoms. Occurrence pattern is believed the same throughout the year (Mobley et al. 2000).

KUROSHIO CURRENT. Striped dolphins are the most common dolphins found in Japanese waters; however, their numbers have decreased due to directed catches (Kasuya, Tobayama, and Matsui 1984). Striped dolphins prefer pelagic and coastal waters influenced by the Kuroshio current (Miyazaki, Kasuya, and Nishiwaki 1974). Occurrence of striped dolphins throughout the Japan MRA Study Area varies seasonally. During the winter-spring period, striped dolphins are expected to occur south of 36°N and seaward of the shelf break. Expected occurrence includes the southern edge of the Sea of Japan (Figure 5-62). During the summer-fall period, expected occurrence of striped dolphins extends further north along the east coast of Japan and includes the area seaward of the shelf break along the coast of Japan and Okinawa.

EAST CHINA SEA. Expected occurrence also extends into the southern part of the Sea of Japan and over the shelf break in the East China Sea (Figure 5-62).

PHILIPPINE SEA. Primary range also extends into the Philippine Sea (Figure 5-62 and Figure 5-63).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Drive fisheries at Kawana, Futo, and Taiji catch striped dolphins off the Pacific coast of Honshū (Miyazaki 1983). They may occur from the shoreline to the shelf break along the east coast of Japan, the southern tip of Kyūshū, and the Ryukyu and Ogasawara Islands (Figure 5-63). Strandings have been documented at Gogo-shima and Taiji (Isobe et al. 2009). Striped dolphins are not expected in bays.

Kyūshū Island, Ōsumi Islands, and Tokara Archipelago. They may occur from the shoreline to the shelf break along the east coast of Japan, the southern tip of Kyūshū, and the Ryukyu and Ogasawara Islands. Striped dolphins are not expected in bays.

MARIANA ARCHIPELAGO. One record of a stranded striped dolphin occurrence in the Mariana Islands MRA Study Area and vicinity occurred in July 1985 (Eldredge 1991, 2003; Wilson et al. 1987). (Eldredge 1991) erroneously reported that an additional record, aside from the stranding he documented, had appeared in (Wilson et al. 1987); it is actually the same record. Striped dolphins may occur in this area seaward of the 100 m isobath (Figure 5-64)—this is an oceanic species. A 2007 survey recorded 10 striped dolphins visually identified in this part of the MRA Study Area (U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007). Fulling, Thorson, and Rivers (2011) reported 10 sightings of striped dolphin, many associated with the West Mariana Ridge and waters near the Mariana trench where waters are at depths between 2,500 to 5,000 ft. Two groups (one of 6 and one of 12 dolphins) were sighted in 2010 in the waters southeast of the Challenger Deep at 11.384°N and 143.800°E, and 10.286°N 143.800°E, respectively (Oleson and Hill 2010). Through acoustic recordings and visual sightings, striped dolphins along the West Mariana Ridge and at the shelf bordering the Mariana Trench were recorded. Occurrence pattern is believed the same throughout the year (Norris et al. 2011).

Fallon de Medinilla. Fulling, Thorson, and Rivers (2011) reported a sighting of this species off the west coast of FDM.

Guam. One dolphin was reported less than 100 nm off the west and another off the east coast of Guam (Fulling, Thorson, and Rivers 2011).

CAROLINE ISLANDS. The waters around the Caroline Islands are a part of the known primary range of this species, which has been known to frequent deep, coastal areas (Figure 5-62 and Figure 5-63).

5.28.6 Species-specific Threats

This species was formerly caught in large numbers in pelagic driftnets in the Mediterranean and the North Pacific, and catches are known from pelagic trawls and driftnets in western Europe. Striped dolphins are the main dolphin species involved in small cetacean harpoon and drive fisheries in Japanese waters (National Marine Fisheries Service). Catch levels there vary widely, but in some years over 20,000 were taken, although the takes generally have been much lower (less than 1,000 per year) in recent years. Despite the recent reductions, the population(s) in Japan (more than one population may be involved) are thought to be seriously depleted (United Nations Environment Programme n.d.-a). This species has also been hunted in smaller numbers in the Caribbean, Sri Lanka, and occasionally in the Mediterranean. Incidental catches occur throughout the range in various types of fishing gear, especially purse seines and driftnets (United Nations Environment Programme n.d.-a).

A massive die-off of this species in the Mediterranean Sea from 1990 to 1992 is thought to have been at least partly related to lowered immunity to morbillivirus disease from high levels of environmental contaminants (especially organochlorines like PCBs) (Jefferson, Webber, and Pitman 2008). In the Mediterranean Ocean, stranded striped dolphin tested positive for herpesvirus and morbillivirus antibodies (Soto et al. 2012). Strandings occurred on the coast of Italy between 2007 and 2008. Subsequent autopsies found meningo-encephilitis in the brains of three dolphins. Two of these three brains also harbored cysts associated with *Toxoplasma gondii*, a single-celled organism thought to cause abortion and systematic disease (Di Guardo et al. 2010). Other infections have been documented in this species, including in dolphins displaying swimming disorders (characteristic of neurological syndromes) later attributed to *Brucella spp* (Gonzalez-Barrientos et al. 2010; Hernandez-Mora et al. 2008). The stomach parasite, *Pholeter gastrophilius*, known to affect primarily coastal species with varying prey preferences, has been documented in stranded striped dolphins off the coast of Norway (Aznar et al. 2006). An analysis by Carvalho et al. (2010) of strandings off the coast of Brazil showed susceptibility of striped dolphins to parasites. For more detailed information on specific host-parasite species identified through this study, refer to Carvalho et al. (2010). Striped dolphins stranded in Japan tested positive for significant levels of anthropogenic contaminants, causing disrupted endocrine systems. PCBs, DDT, and hexachlorocyclohexane were found in the dolphins' tissues. Concentrations of these contaminants were not found progressively higher in biopsies conducted in 1978, 1979, 1986, and 1992. In contrast, hexabromocyclododecanes and PBDEs were encountered at significantly increased levels (Isobe et al. 2009). Concentrations of butylin and phenyltin were found in the tissue of striped dolphins off the coast of Thailand. The highest concentrations were found in the liver, where concentrations increased with body length (Harino et al. 2007a). Mercury selenide has been found in the liver, kidney, lung, pancreas, spleen, muscle, and brain of some striped dolphins (Rogers 1994). Off the coast of Japan, concentrations of vanadium, chromium, manganese, iron, cobalt, copper, zinc, selenium, rubidium, strontium, molybdenum, silver, cadmium, antimony, cesium, barium, thallium, mercury, and lead were found in liver samples—at levels that varied with age and presence of trace element; but these concentrations did not correlate with sex of the dolphin (Agusa et al. 2008). Nineteen trace elements were found from the liver of striped dolphin in coastal Japan from 1977 to 1982 (Agusa et al. 2008).

This Page Intentionally Left Blank

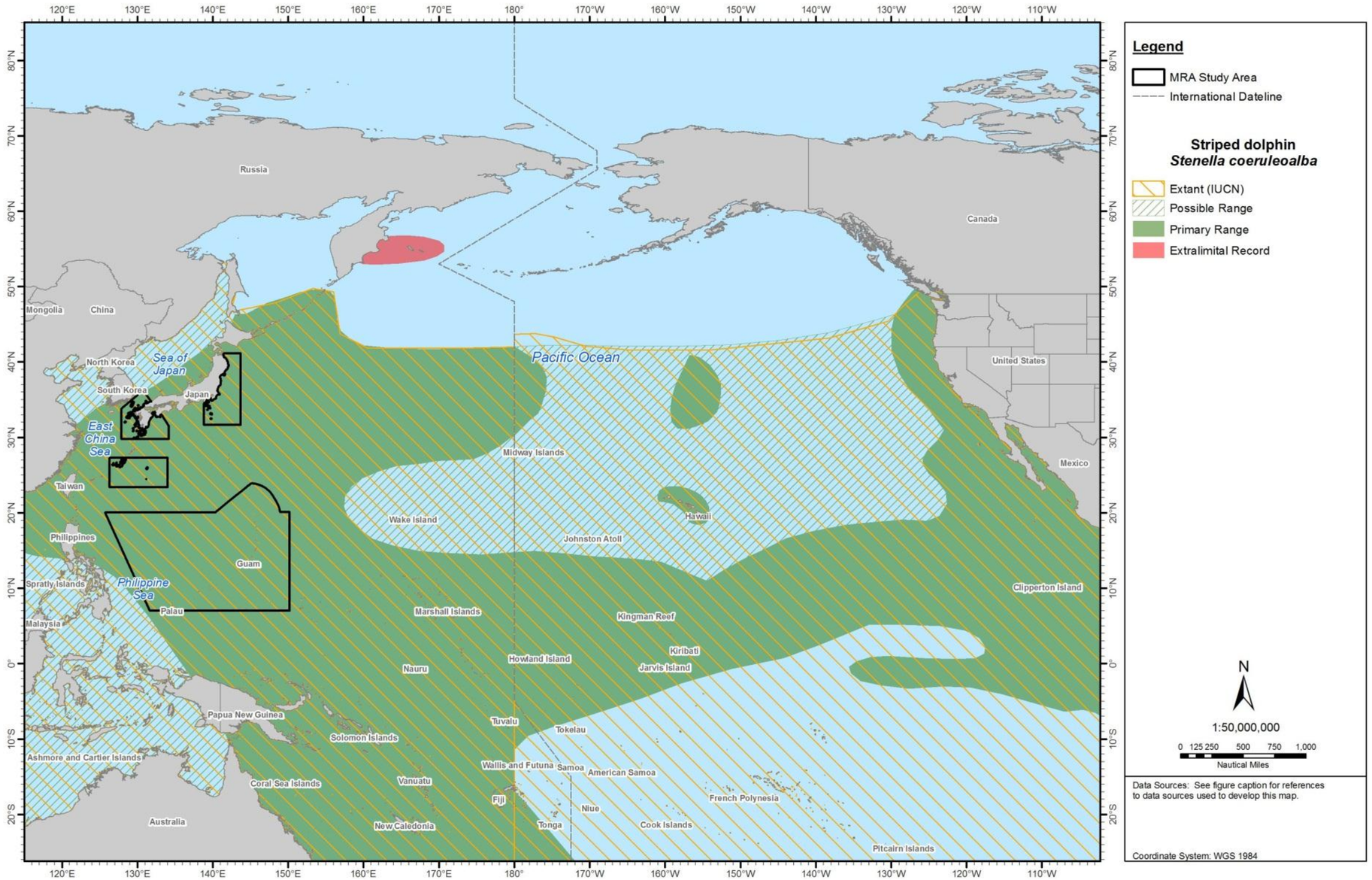

Figure 5-62: Geographic Range of the Striped Dolphin in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

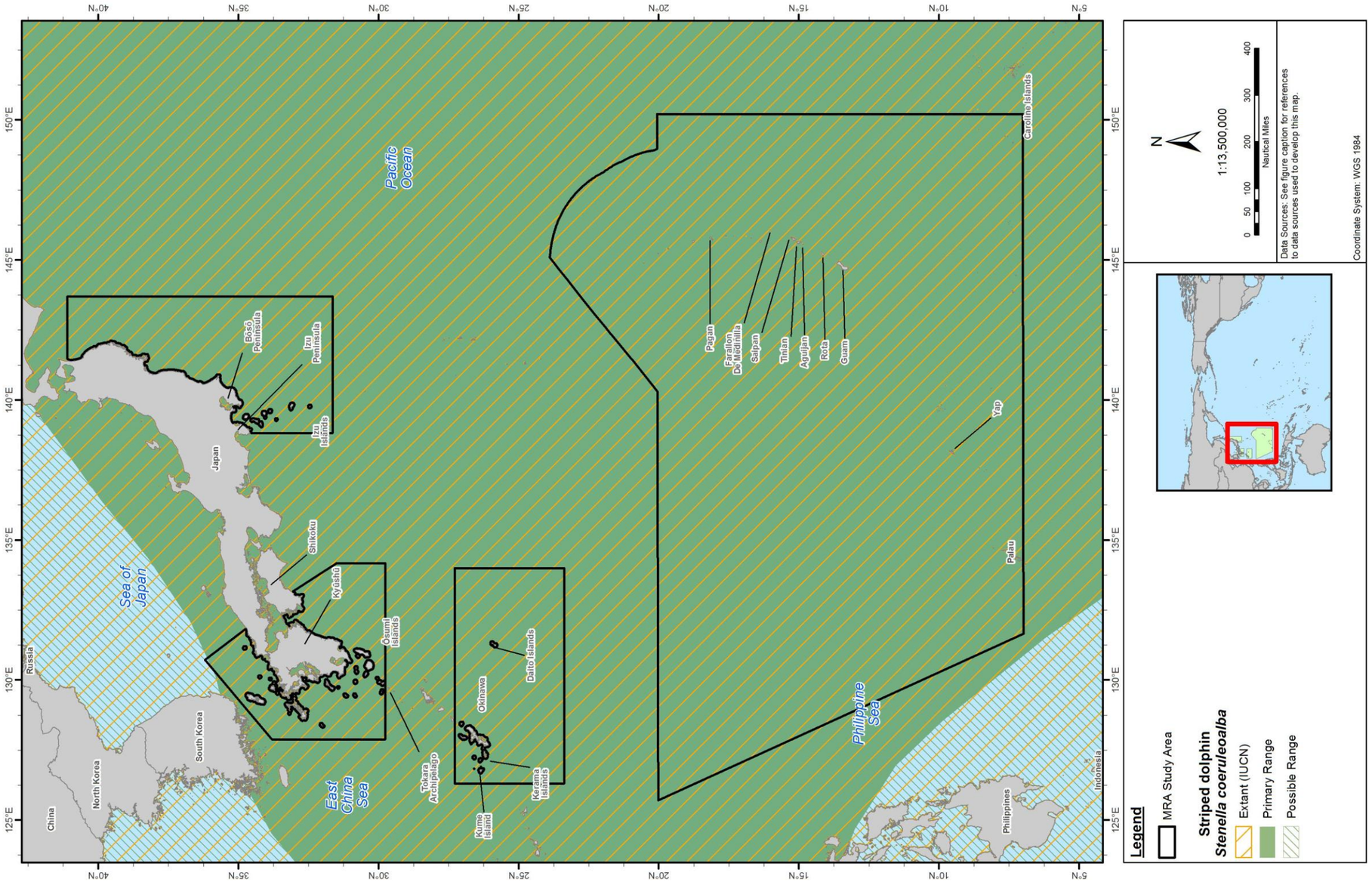

Figure 5-63: Geographic Range of the Striped Dolphin In the MRA Study Area

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

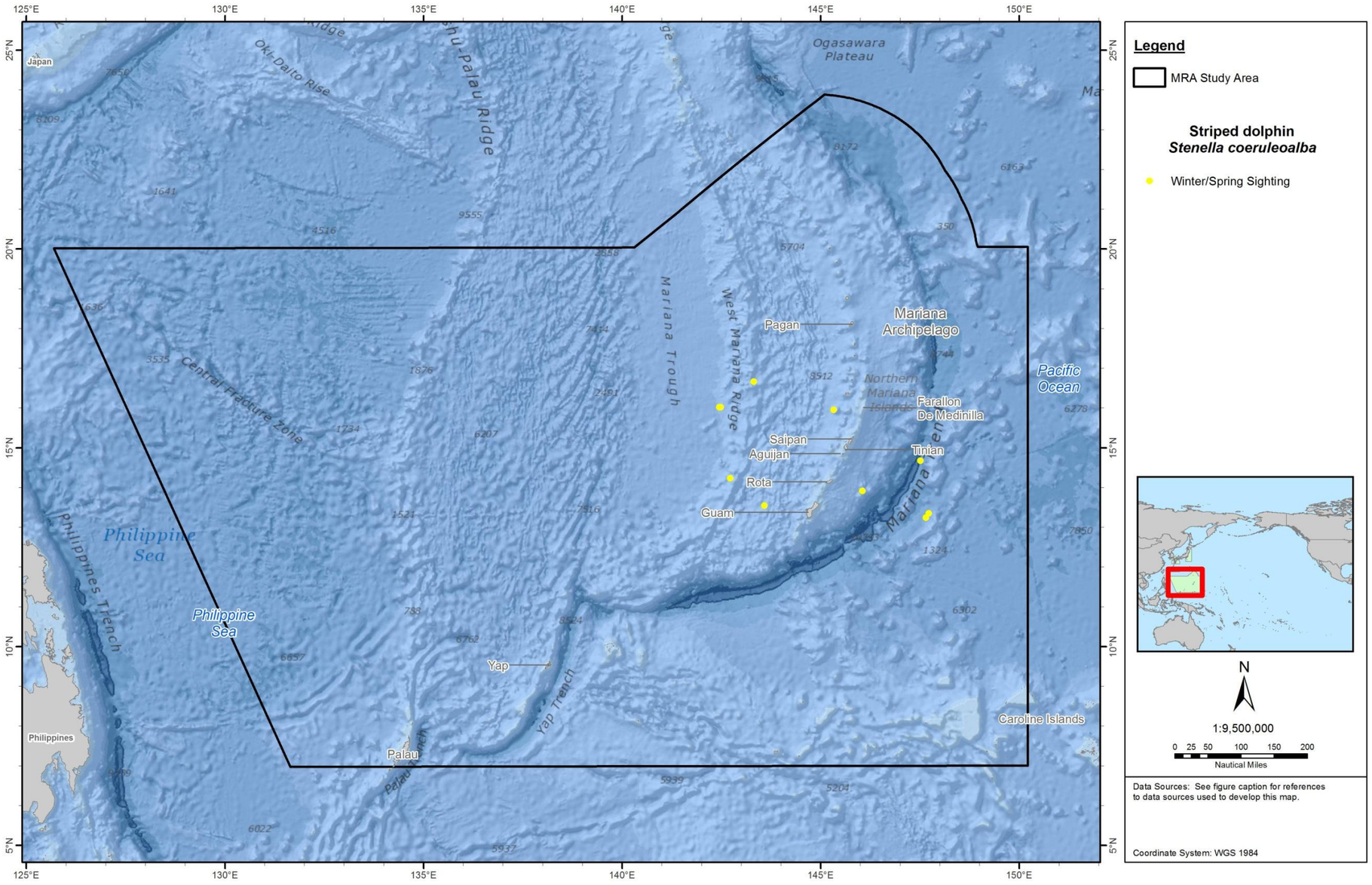

Figure 5-64: Sightings of the Striped Dolphin in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented.
Sources: Fulling, Thorson, and Rivers (2011); U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific (2007).

This Page Intentionally Left Blank

5.29 FRASER'S DOLPHIN (*LAGENODELPHIS HOSEI*)

5.29.1 Description

Following discovery of the Fraser's dolphin in 1956, it was known only from skeletal specimens until once again identified in the early 1970s (Perrin et al. 1973). Although it is still one of the least-known species of cetaceans, much better descriptions of the Fraser's dolphin have occurred in recent years.

Fraser's dolphin is a very distinctive dolphin, with an extremely stocky body and very small appendages (relatively smaller than in all other tropical dolphins). The dorsal fin is short (less than 9.5% of total length) and its shape is triangular or slightly falcate. It tends to be more erect in adult males than in females or young. The short flippers are pointed at the tips, and the flukes are typical of dolphins. The beak is very short (less than 3% of total length) and stubby, but is well-defined. Many adult male Fraser's dolphins have a large post-anal hump or keel, composed of connective tissue (Jefferson, Webber, and Pitman 2008).

The Fraser's dolphin's color pattern can be striking; its most distinctive feature (when present) is a dark band of varying thickness that runs from the face to the anus (in some parts of the world, the band is not well developed, however). This band is weakly developed on young animals, and it widens and darkens with age in some animals, especially adult males (Jefferson et al. 1997). A stripe starts at the lower jaw and runs to the insertion of the flipper. In some individuals, the lateral stripe is so wide that it merges with the flipper stripe, creating a dark "bandit mask." The back of the body is dark brownish-gray, the lower sides are cream-colored, and the belly is white or pink. Young Fraser's dolphins may have particularly pinkish bellies. The tip of the beak and lips are dark in color, and a dark stripe runs from the tip of the upper jaw to the apex of the melon (Dolar 2008; Jefferson, Webber, and Pitman 2008).

Maximum size for Fraser's dolphin is at least 2.7 m (males) and 2.6 m (females). They may reach weights of more than 210 kg. Estimated length of newborns is 1.0 to 1.1 m. Pairs of teeth in each jaw number 38 to 44.

5.29.2 Status and Management

Fraser's dolphin is protected under the MMPA and is not listed under the ESA. This species is also listed as least concern by the IUCN and falls under Appendix II CITES regulations. Fraser's dolphins are divided into three stocks: Hawaiian, Northern Gulf of Mexico, and Northern Atlantic. The MMPA stock assessment reports include a single Pacific management stock with animals found only within the U.S. EEZ of the Hawaiian Islands (Carretta et al. 2010). There are no annual deaths or serious injuries caused by fisheries are in the Hawaiian stock (Carretta et al. 2012). Although none of these stocks have range within the MRA Study Area, Fraser's dolphins are known to have primary and secondary range within the MRA Study Area. Fraser's dolphin is not considered extremely abundant in any region in the world, although its global conservation status is stable enough to elicit little concern (Dolar 2008; Jefferson, Webber, and Pitman 2008).

5.29.3 Population and Abundance

The closest stock assessment was for the Hawaiian Stock (estimated at 10,226 [CV=1.16] dolphins), with no information on the population trend for this stock (Carretta et al. 2011h; Carretta et al. 2012). No abundance estimates are available for the Fraser's dolphin in the MRA Study Area.

5.29.4 Biology, Ecology, and Behavior

Individuals have commonly been seen in mixed-species aggregations associated with melon-headed whales in the ETP (Jefferson and Leatherwood 1994), where the two species sometimes partition prey and space (Sylvestre 1988). They ride bow waves of ships, except in areas where they have been harassed or hunted (such as areas in the ETP and some parts of the Philippines).

Group Size. Fraser's dolphins are usually seen in large, fast-moving "splashy" groups. Most sightings have been of groups ranging from between 100 and 1,000 animals (Jefferson and Leatherwood 1994). Ferguson (2006) reported the average group size of Fraser's dolphin in the ETP as more than 440.

Predator/Prey Interactions. Fraser's dolphin feeds on mid-water fishes, squids, and shrimps, and has not been documented to be prey to any other species (Jefferson and Leatherwood 1994; Perrin, Leatherwood, and Collet 1994). Nonetheless, as with other marine mammals, it may be subject to predation by killer whales.

Life History. Very little is known of the life history and reproduction of this species. Sexual maturity in Japanese waters occurs at about 7 to 10 years and at lengths of 2.2 to 2.3 m for males, and 5 to 8 years and 2.1 to 2.2 m for females. Available data do not show strong evidence of calving seasonality, but slight peaks may occur in spring, summer, or fall. Longevity is at least 18 years (Jefferson and Leatherwood 1994).

Migration. This does not appear to be a migratory species, and little is known about its possible migrations. No specific information regarding routes, seasons, or resighting rates in specific areas is available.

Hearing/Vocalization. No hearing data are available for this species.

Very little is known of the acoustic abilities of the Fraser's dolphin. Fraser's dolphin whistles have a frequency range of 7.6 to 13.4 kHz (Leatherwood et al. 1993). In the Pacific, a towed hydrophone array and sonobuoy recorded whistles from 6.6 to 23.5 kHz (Oswald, Rankin, and Barlow 2007). Duration of these whistles ranged from 0.06 to 0.93 s.. These dolphins were notably less vocal than those recorded in Leatherwood (1993), and the reason for this difference is unclear.

Diving. No direct information regarding diving depth for Fraser's dolphins is available, but, based on prey items and the species' physiological characteristics, this dolphin is considered a relatively deep diver. Most Fraser's dolphins feed in waters up to 600 m, but they have been observed to feed near the surface as well (Jefferson, Webber, and Pitman 2008; Watkins et al. 1994). Based on the vertical distribution of their prey, they may be capable of diving to 1,970 ft. (600 m) or more (Dolar 2008). During an abundance survey comparing the Marquesas and the Society Islands, many species of cetaceans, including the Fraser's dolphin, were found more abundant near the Marquesas, possibly due to increased primary productivity associated with presence of a narrow shelf (Gannier 2009).

5.29.5 Habitat and Distribution

Fraser's dolphin is found in tropical and subtropical waters around the world, typically between 30°N and 30°S (Dolar 2008; Dolar et al. 2003; Jefferson, Webber, and Pitman 2008). Strandings in temperate areas are generally considered extralimital and usually are associated with unusually warm water temperatures (Perrin, Leatherwood, and Collet 1994).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. The range of this species includes waters of the North Central Pacific Gyre. In the Pacific, occurrence of this species is well known in deep oceanic waters off southern Japan, off Taiwan, off Hawai'i, and in the ETP (Aguayo and Sanchez 1987; Ferguson 2005; Miyazaki and Wada 1978a; Tobayama, Nishiwaki, and Yang 1973) (Figure 5-65). In the offshore ETP, this species is distributed mainly in upwelling-modified waters (Au and Perryman 1985; Reilly 1990).

KUROSHIO CURRENT. The expected occurrence of the Fraser's dolphin in the MRA Study Area is just to the south of 30°N, seaward of the shelf break (Perrin, Leatherwood, and Collet 1994). (Miyazaki and Wada 1978a) list records of sporadic whaling catches for this species that include the MRA Study Area; and (Amano, Miyazaki, and Yanagisawa 1996) reported on catches at Taiji of this species in the dolphin fishery there. The Fraser's dolphin may occur in the area beginning north of Taiji in Honshū on the Kii Prefecture, following the warm water current that moves past this area. Occurrence pattern is believed to be the same throughout the year.

EAST CHINA SEA. Known parts of this species' primary and secondary ranges extend into the East China Sea (Figure 5-65).

PHILIPPINE SEA. The Philippine Sea is included in the primary range of the Fraser's dolphin (Figure 5-65 and Figure 5-66).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Fraser's dolphins may occur from the shore to the shelf break around Okinawa. In some locales, as noted earlier, Fraser's dolphins approach closer to shore, particularly at locations where the shelf is narrow and deep waters are nearby (Figure 5-66).

MARIANA ARCHIPELAGO. No occurrence records are available for this species in the Mariana Islands MRA Study Area and vicinity, but this area is within the known distribution range of this species. The Fraser's dolphin is an oceanic species. In the Gulf of Mexico, this species has been seen in waters over the abyssal plain (Leatherwood et al. 1993). Therefore, the Fraser's dolphin is expected to occur from the shelf break to seaward of the Mariana Islands MRA Study Area and vicinity (Figure 5-66). In some locales, as noted earlier, Fraser's dolphins approach closer to shore, particularly at locations where the shelf is narrow and deep waters are nearby, so they may occur from the 100 m isobath to the shelf break. Occurrence pattern is believed to be the same throughout the year.

CAROLINE ISLANDS. The primary range of this species does include oceanic waters around the Caroline Islands, although it does not frequent coastal environments (Figure 5-65 and Figure 5-66).

5.29.6 Species-specific Threats

Incidental catches of Fraser's dolphins in purse seines (ETP and the Philippines), gillnets, driftnets (South Africa, Ghana, Japan, the Philippines, and Sri Lanka), and trap nets (Japan) are known (Weir et al. 2008). Direct hunting has also been documented in Japan, the Lesser Antilles, Sri Lanka, Indonesia, and the Philippines. Their primary range in tropical, oceanic waters probably subjects them to fewer problems related to habitat degradation than those encountered by most other species of dolphins (Jefferson, Webber, and Pitman 2008).

An analysis by Carvalho et al. (2010) of strandings off the coast of Brazil showed susceptibility of Fraser's dolphins to parasites. For more detailed information on specific host-parasite species identified through this study, refer to Carvalho et al. (2010).

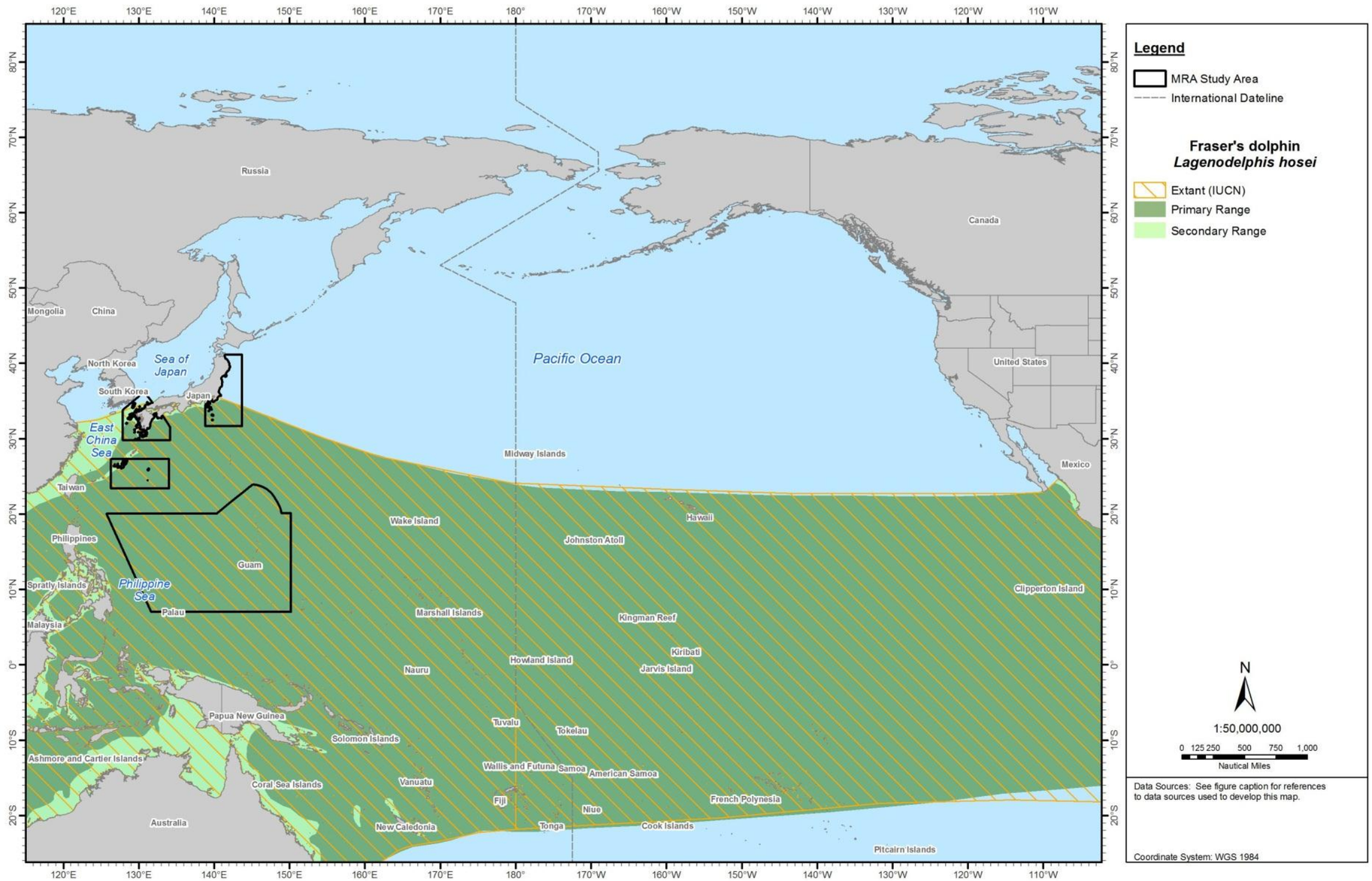

Figure 5-65: Geographic Range of Fraser's Dolphin in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

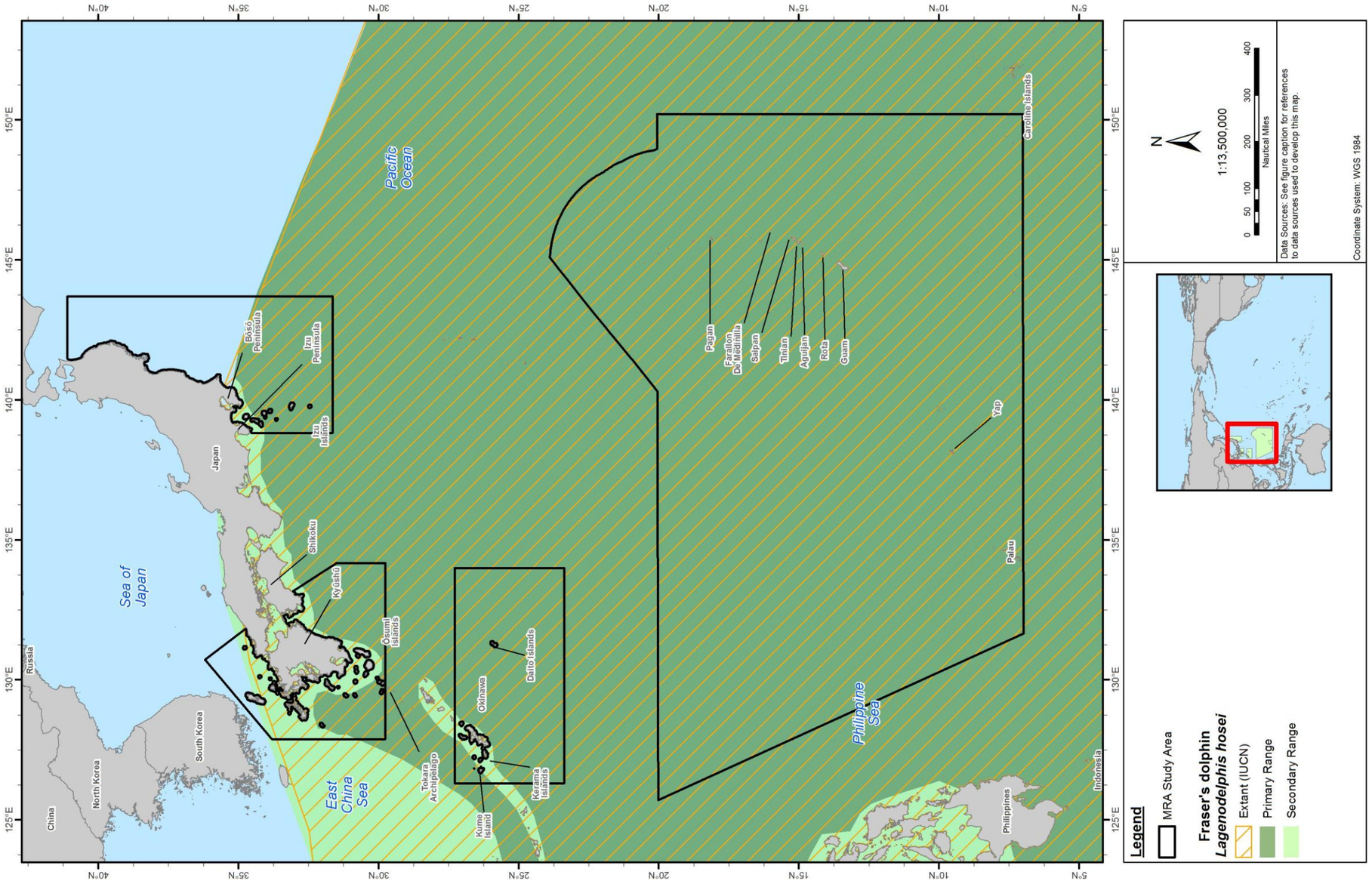

Figure 5-66: Geographic Range of Fraser's Dolphin in the MRA Study Area

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.30 RISSO'S DOLPHIN (*GRAMPUS GRISEUS*)

5.30.1 Description

Risso's dolphins are robust, blunt-headed animals without distinct beaks. The forehead is bulging, but is not rounded (it has a more squarish profile than that of most other small cetaceans). A vertical crease on the front of the melon is one of the most diagnostic features of this species. Risso's dolphins have mouthlines that slope upward. The flippers are long, recurved, and pointed at the tips. The tall and slender dorsal fin is somewhat falcate, and is generally pointed at the tip. The tail stock is generally very shallow, especially directly just ahead of the flukes, giving the animal the appearance of having most of its bulk ahead of the dorsal fin (Baird, McSweeney, et al. 2003; Jefferson, Webber, and Pitman 2008).

Adult Risso's dolphins range from dark gray to nearly white, but are typically covered with white scratches, spots, and blotches (these are thought to result from the beaks and suckers of squid, their major prey, but others may be caused by the teeth of conspecifics). The patterns of scars and scratches are unique, and can be used in conjunction with dorsal fin markings to identify individuals. The thorax has a whitish anchor-shaped patch, and another white patch of variable extent is around the urogenital area. The fins and flukes tend to be darker than the rest of the body. Calves and juveniles range from light gray to dark brownish-gray and are relatively unscarred. Young animals also have a dark cape that extends down over the eye, and dips slightly below the dorsal fin. The cape is generally obscured by scratches and scars in adults (Jefferson, Webber, and Pitman 2008; Kruse, Caldwell, and Caldwell 1999).

Adult Risso's range up to at least 3.8 m long; little or no sexual dimorphism is apparent in adult length. Average size of Risso's dolphins taken by small-type whaling off the Pacific coast of Japan was reported to be 2.8 m for males and 2.7 m for females (Kishiro 2001), but they can grow to 3.8 m (Jefferson, Webber, and Pitman 2008). Weights of up to 400 kg have been recorded, with the maximum near 500 kg. At birth, Risso's dolphins are 1.1 to 1.5 m long. The teeth of this species are also unique; two to seven heavy, pointed teeth are in the front of each lower tooth row, and usually none (but occasionally one to two pairs) is in the upper jaw.

5.30.2 Status and Management

Risso's dolphin is protected under the MMPA and is not listed under the ESA. This species is also listed as least concern by the IUCN and falls under Appendix II CITES regulations. MMPA stock assessment reports include Risso's dolphins within the Pacific U.S. EEZ, divided into two separate areas: waters off California, Oregon, and Washington; and Hawaiian waters (Carretta et al. 2010). There are no annual deaths or serious injuries caused by fisheries are in the Hawaiian stock (Carretta et al. 2012). Although neither of these stocks have range within the MRA Study Area, Risso's dolphins are known to have primary range within the MRA Study Area.

5.30.3 Population and Abundance

This is a widely distributed species that occurs in all major oceans, and although no global population estimates are available, it is generally considered to be one of the most abundant of the large dolphins. Risso's dolphins are fairly abundant in many cool temperate regions, and are not considered threatened or endangered on a global scale (Baird et al. 2009; Jefferson, Webber, and Pitman 2008). The geographically nearest stock assessment for U.S. waters was for the Hawaiian stock (estimated 2,372 [CV=0.97] dolphins). Trend data are not available for the Hawaiian stock (Carretta et al. 2011o). An estimated 85,000 individuals occur in the waters off Japan, the western North Pacific, and the East China

Sea (Jefferson, Webber, and Pitman 2008; National Marine Fisheries Service 2012l). Assuming that several stocks may be present there, Japanese survey data was used to estimate that about 7,000 Risso's dolphins occur in the area to the north of the Mariana Islands (Miyashita 1993a).

5.30.4 Biology, Ecology, and Behavior

This species commonly associates with other cetacean species, especially smaller dolphin species (Cetacean and Turtle Assessment Program 1982; Frantzis and Herzing 2002; Kruse, Caldwell, and Caldwell 1999). These dolphins breach and leap with some frequency and sometimes ride bow waves of larger vessels, although overall this species is considered slow moving and somewhat sluggish (Jefferson, Webber, and Pitman 2008; Kruse, Caldwell, and Caldwell 1999).

Group Size. Risso's dolphins are quite social; groups usually average about 30 individuals but can range to more than several hundred or even several thousand (Baird 2008; Cetacean and Turtle Assessment Program 1982; Kruse, Caldwell, and Caldwell 1999).

Predator/Prey Interactions. Cephalopods and crustaceans are the primary prey for the Risso's dolphins (Clarke 1996), which feed mainly at night (Baird 2008; Jefferson, Webber, and Pitman 2008). An analysis of the stomach contents of Risso's dolphins in the northeastern Atlantic revealed cuttlefish and octopods with a few salps as well (Spitz et al. 2011).

This dolphin may be preyed upon by both killer whales and sharks, although no documented reports of predation by either species have been received (Weller 2008).

Life History. Not many life history studies involving large numbers of specimens have been conducted, and so little is known about this species. An autopsy survey in Taiwan of strandings from 1994 to 2008 showed that females reached sexual maturity with a body length between 240 and 255 cm, and males did so with a body length of 253 to 265 cm. For both sexes, this correlated to roughly 10 years of age (Whiting 2002b). Age of first reproduction is estimated around 11 years, and the animals give birth every 2.4 years. The oldest recorded reproductive female was 38 years old (Taylor et al. 2007). In the Mediterranean, gestation is recorded to be around 14 months (Yoshida 2002). In the North Pacific, off California, calving peaks in either summer/fall or fall/winter. In Taiwan, it has been suggested Risso's dolphin has a summer-fall calving season (Whiting 2002b). Most births in Japanese waters occur from summer to fall; these newborns are between 3.5 and 5.5 ft. long, weighing around 45 lbs. This dolphin has an estimated lifespan of 35 years (National Marine Fisheries Service).

Migration. Risso's dolphin does not migrate, although schools may range over very large distances, and seasonal shifts in centers of abundance are known for some regions.

Hearing/Vocalization. Nachtigall et al. (1995) conducted baseline audiometric work. Because of the natural background noise (the study was conducted in a natural setting), it was not possible to precisely determine peak (or best) hearing sensitivity in the species. Maximum sensitivity occurred between 8 and 64 kHz. Reported thresholds were 124 dB at 1.6 kHz, 71.7 dB at 4 kHz, 63.7 dB at 8 kHz, 63.3 dB at 16 kHz, 66.5 dB at 32 kHz, 67.3 dB at 64 kHz, 74.3 dB at 80 kHz, 124.2 dB at 100 kHz, and 122.9 dB at 110 kHz. Tests on a stranded infant dolphin indicated very high-frequency sensitivity where lowest threshold was 49.5 dB re 1µPa at 90 kHz (Nachtigall et al. 2005). Response delays for echolocation were founds to be among the shortest among marine mammals, suggesting this species should be able to follow clicks and echoes during close-range foraging (Mooney, Nachtigall, and Yuen 2006).

Risso's dolphin vocalizations include broadband clicks, barks, buzzes, grunts, chirps, whistles, and simultaneous whistle and burst-pulse sounds (Corkeron and Van Parijs 2001). The combined whistle and burst pulse sound appears to be unique to Risso's dolphin (Corkeron and Van Parijs 2001). Five different whistle types were recorded in one survey ranging in frequency from 4 to 22 kHz (Corkeron and Van Parijs 2001). Broadband clicks had a frequency range of 6 to greater than 22 kHz. Low-frequency narrowband grunt vocalizations had a frequency range of 0.4 to 0.8 kHz. Spectral mean peak values are 22.4, 25.5, 30.5, and 38.8 kHz for clicks, and the spectral notch mean values are 19.6, 27.7, and 35.9 kHz for clicks produced by this species (Soldevilla et al. 2008). A recent study established empirically that Risso's dolphins echolocate; estimated source levels were up to 216 dB re 1 µPa-m (Philips et al. 2003).

Diving. Individuals may remain submerged on dives as long as 30 min and dive as deep as 600 m (DiGiovanni et al. 2005). Dive durations of up to 30 min have been recorded (Wells et al. 2009). Dive data from a rehabilitated Risso's dolphin released in the Gulf of Mexico found dives to be most frequent in the upper 50 m of the water column and maximum dive depth at 400 to 500 m; most dives lasted between 4 and 6 min, with the longest at 10 min (Wells et al. 2009).

5.30.5 Habitat and Distribution

Several studies have documented that Risso's dolphins are found offshore, along the continental slope, and over the outer continental shelf (Baumgartner 1997; Canadas, Sagarminaga, and Garcia-Tiscar 2002; Cetacean and Turtle Assessment Program 1982; Davis et al. 1998; Gannier 2009; Green et al. 1992; Kruse, Caldwell, and Caldwell 1999; Mignucci-Giannoni 1998). Risso's dolphins are also found over submarine canyons (Mussi et al. 2004). Off the coast of Italy, Risso's dolphins were associated with habitats characterized by well-defined depth and slope gradient, on the shelf edge and the upper and lower slope (Azzellino et al. 2008).

Risso's dolphins are distributed worldwide in cool-temperate to tropical waters from roughly 60º N to 60°S, where sea-surface temperatures are generally greater than 10°C (Kruse, Caldwell, and Caldwell 1999). They are relatively abundant in the Mediterranean Sea (Bearzi, Reeves, et al. 2011). Changes in the local distribution and abundance of Risso's dolphins occur occasionally (Kruse, Caldwell, and Caldwell 1999). For instance, water temperature appears to affect Risso's dolphin distributions in the Pacific Ocean, with local distributional shifts occurring off California during El Niño periods when protracted warm-water events occur (Kruse, Caldwell, and Caldwell 1999; Shane 1994).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. In the Pacific, the range of this species is known to include the North Central Pacific Gyre. Occurrence of this species is well known in deep open ocean waters off Hawai'i, and in other locations in the Pacific (Au and Perryman 1985; Carretta et al. 2010; Leatherwood et al. 1980; Miyashita 1993b; Miyashita et al. 1996; Wang, Yang, and Liao 2001) (Figure 5-67).

KUROSHIO CURRENT. The area of expected occurrence for the Risso's dolphin is seaward of the shelf break out to 200 nm (370 km) from shore (Figure 5-68) (Kruse, Caldwell, and Caldwell 1999). There have been possible occurrence documented farther (Miyashita et al. 1996). Occurrence patterns from these studies show similarities year-round. In other parts of the Risso's dolphin's range, including Japan, seasonal shifts in density reflecting onshore/offshore movements are known; however, not enough information has been obtained to depict those seasonal shifts.

EAST CHINA SEA. The Risso's dolphin has a similar life history within Taiwanese and Japanese waters. Similarities in morphology suggest this population is likely part of the northwest Pacific stock (Whiting 2002b).

PHILIPPINE SEA. The primary range of the Risso's dolphin extends to the western boundary of the Philippine Sea, following the curve of the island chain (Figure 5-67 and Figure 5-68).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Risso's dolphin may occur between the shore and the shelf break. They are not expected in enclosed bays (Figure 5-68).

MARIANA ARCHIPELAGO. Risso's dolphins are expected to occur in the Mariana Islands MRA Study Area from the shelf break to seaward of the Mariana Islands MRA Study Area and vicinity (Figure 5-68). Worldwide, most Risso's dolphin sightings have occurred in areas with steep bottom topography; this species is also found in deeper waters. They are less likely to occur from the 50 m isobath to the shelf break, based on their preference for waters with steep bottom topography, although they could occur in areas where deep water is close to shore. Leatherwood, Hubbs, and Fisher (1979) and Shane (1994) reported sightings of Risso's dolphins in shallow waters in the northeastern Pacific, including near oceanic islands. These sites are within areas where the continental shelf is narrow and deep water is closer to the shore (Gannier 2000, 2002; Leatherwood, Hubbs, and Fisher 1979). Occurrence pattern is believed to be the same throughout the year.

Farallon de Medinilla. A small group (three individuals) of Risso's dolphin was sighted in 2010 northeast of the island at 16.968°N and 146.370°E (Oleson and Hill 2010).

CAROLINE ISLANDS. The Caroline Islands are not included in the primary range of this species (Figure 5-67 and Figure 5-68).

5.30.6 Species-specific Threats

Risso's dolphins are occasionally taken directly in dolphin fisheries around the world, and have also been documented as bycatch in various driftnet and purse seine fisheries National Marine Fisheries Service (2012l). In the Republic of (South) Korea "whale meat" markets still can buy and sell meat from stranded or bycaught marine mammals. A DNA surveillance study covering years 2003 to 2005 verified that Risso's dolphin meat was present in food markets (Baker et al. 2006). No significant population impacts seem to be resulting from these takes at the present time. A few Risso's dolphins have also been taken for captive display in the past (Baird et al. 2009; Jefferson, Webber, and Pitman 2008).

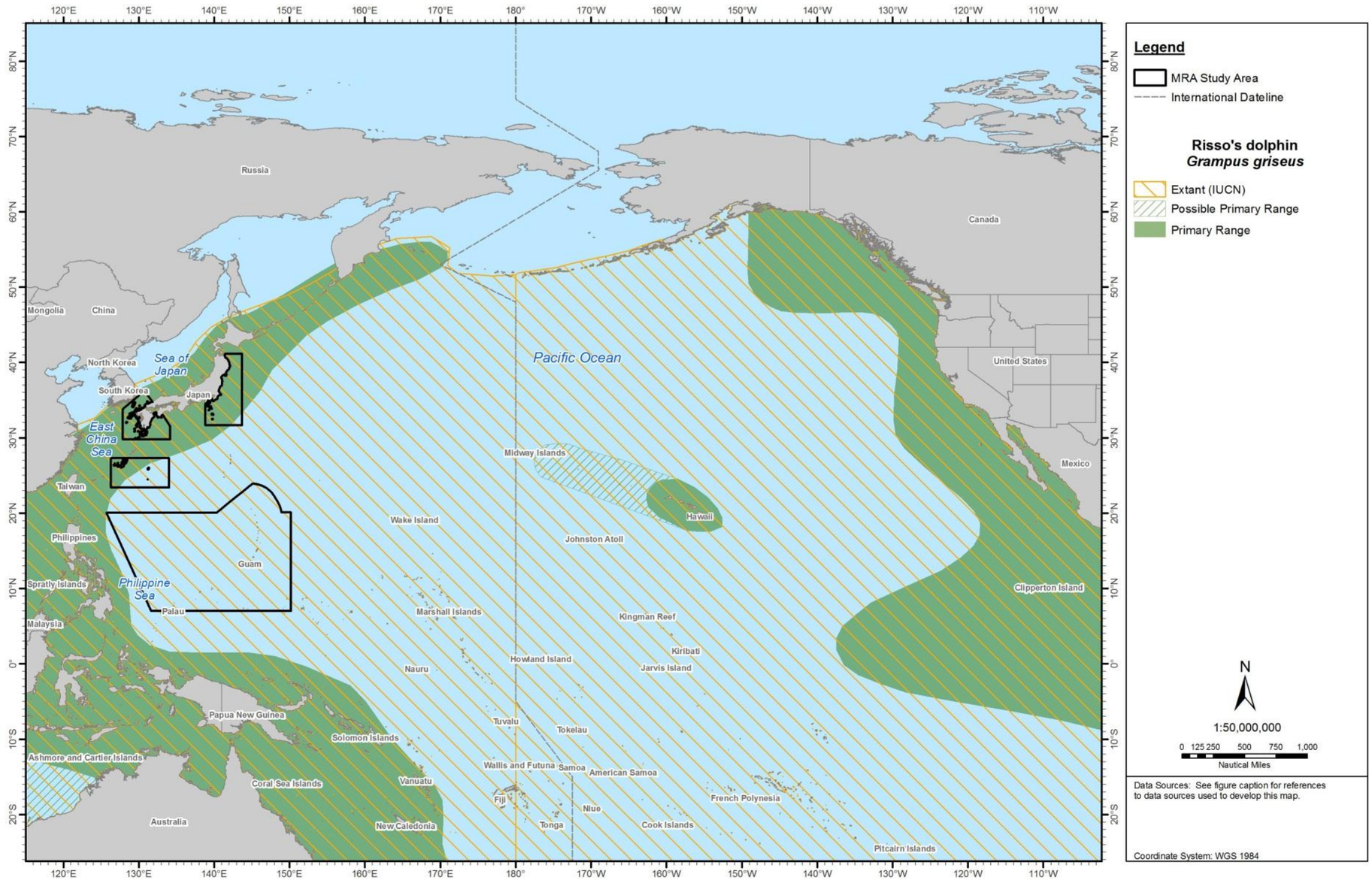

Figure 5-67: Geographic Range of Risso's Dolphin in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

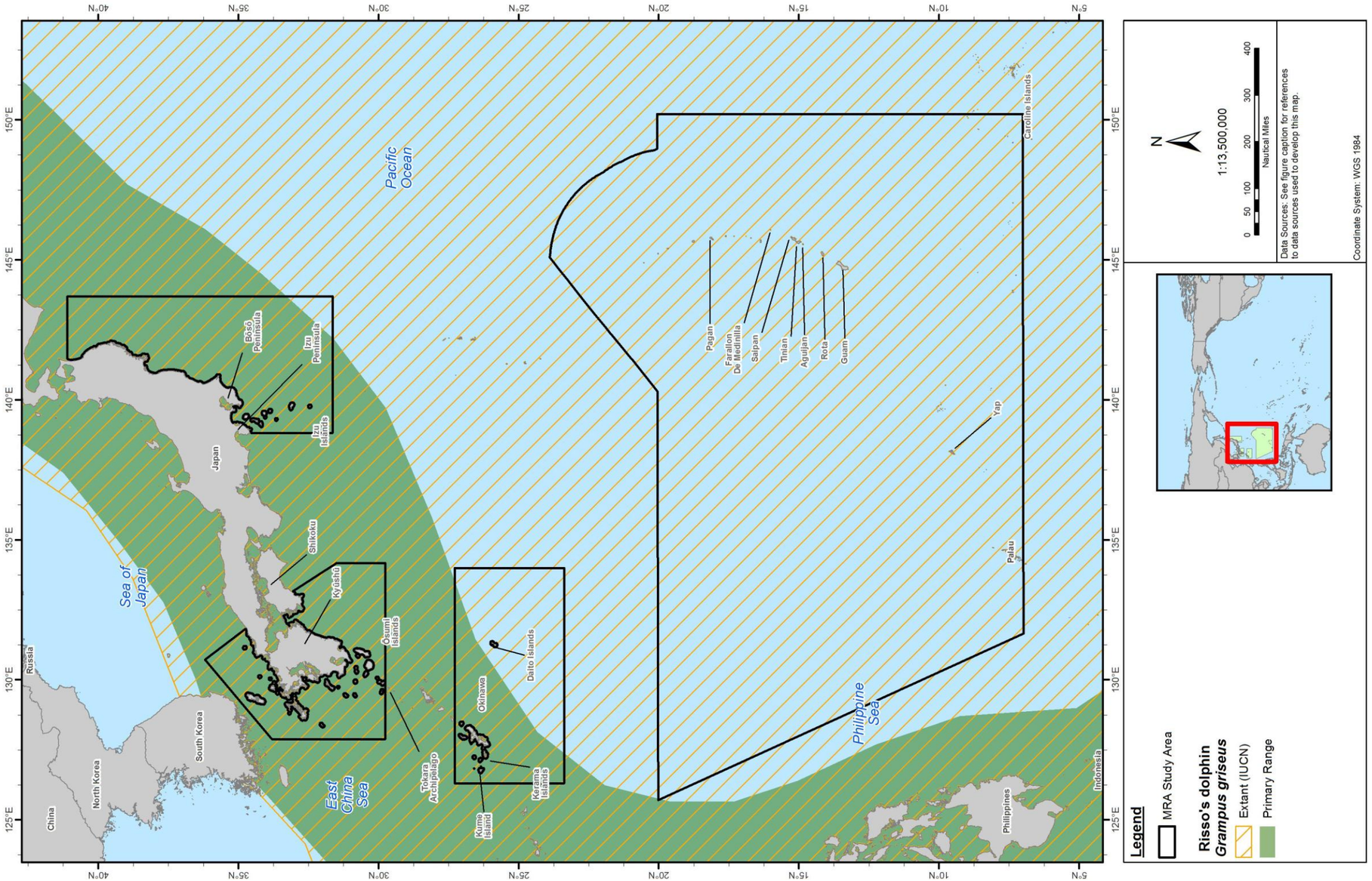

Figure 5-68: Geographic Range of Risso's Dolphin in the MRA Study Area

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.31 PACIFIC WHITE-SIDED DOLPHIN (*LAGENORHYNCHUS OBLIQUIDENS*)

5.31.1 Description

The Pacific white-sided dolphin was first identified in 1865. This species is similar in shape to the dusky dolphin. The Pacific white-sided dolphin is dark gray or black on the back and sides, as well as on the short beak, the leading edge of the tall strongly-recurved dorsal fin, and the pointed flippers. Gray, linear dorsal flank blazes, often called "suspender stripes," project forward from the grayish flank patches along the back and disappear above the eyes (Perrin, Würsig, and Thewissen 2008). Adults in the eastern North Pacific attain lengths of 2.5 m (males) and 2.4 m (females) (Jefferson, Webber, and Pitman 2008). The average weight of an adult Pacific white-sided dolphin is between 300 and 400 lbs. (135 to 180 kg). Two forms are recognized for the eastern North Pacific. The southern form is larger and is thought to range south of 36°N along the coasts of California and Baja California, while the northern form ranges from southern California to Alaska (Carretta and Enriquez 2007; Walker et al. 1986). Genetic data indicate mixing of these two forms off southern California (Lux, Costa, and Dizon 1997). These two forms are not readily distinguishable or recognizable in the field (Jefferson, Webber, and Pitman 2008).

5.31.2 Status and Management

This species is not listed under the ESA but is protected under the MMPA. This species is also listed as least concern by the IUCN and falls under Appendix II CITES regulations. Two geographical forms of Pacific white-sided dolphins have been described for the western North Pacific Ocean (Miyazaki and Shikano 1989). Additional genetic analysis suggests existence of several populations of Pacific white-sided dolphins throughout their range, differentiated geographically between offshore and nearshore areas.

5.31.3 Population and Abundance

A number of abundance estimates for Pacific white-sided dolphins have been based on visual and acoustic surveys in different parts of their range. Some estimates put the global population at about 1,000,000 (Black 2009; Reeves, Stewart, et al. 2002). The estimate for the larger area of the North Pacific Ocean was 931,000 animals (Buckland, Cattanach, and Hobbs 1993). Geographically, the nearest stock assessment was for the California/Oregon/Washington stock (estimated 26,930 [CV=0.28] dolphins). There are an estimated 10.5 deaths or serious injury caused by fisheries in the California/Oregon/Washington stock (Carretta et al. 2012). Abundance of Pacific white-sided dolphins in the area northeast of Japan was estimated at 219,000 animals, based on data from 1987 to 1990 (Miyashita 1993b). No long-term trends for this species are available (Carretta et al. 2010).

5.31.4 Biology, Ecology, and Behavior

Few detailed studies of the behavior of this social dolphin species have been reported. Pacific white-sided dolphins are frequently found in mixed species aggregations, with a large variety of seabirds and other marine mammal species, especially with northern right whale dolphins and Risso's dolphins (Brownell, Walker, and Forney 1999). These dolphins commonly ride bow waves of vessels and are often observed repeatedly performing a number of aerial maneuvers.

Group Size. This is a social species, often observed in large herds ranging from tens to thousands (Black 2009; Leatherwood et al. 1984). Groups are often segregated by age and sex (Black 2009; Jefferson, Webber, and Pitman 2008). Dolphins occur in more dispersed groups while milling, socializing, or

feeding, and in tighter groups while traveling or resting (Black 2009; Jefferson, Webber, and Pitman 2008).

Predator/Prey Interactions. Pacific white-sided dolphins in the eastern North Pacific feed primarily on near-surface and mid-water fishes, such as lanternfish, anchovies, mackerel, and hake, as well as cephalopods (Black 1994; Brownell, Walker, and Forney 1999; Heise 1997; Jefferson, Webber, and Pitman 2008; Morton 2000). White-sided dolphins have been observed feeding in stages: a preparation stage, followed by jaw opening, gular depression, and jaw closing. This species feeding technique is characterized by a ramming motion (used by many odontocetes with long, snapping jaws with many teeth) and some subsequent suction (Kane and Marshall 2009). Feeding appears to be mostly DSL organisms by use of cooperative feeding methods (Black 2009; Jefferson, Webber, and Pitman 2008). Large schools have been observed feeding cooperatively on large shoals of schooling fish (Black 2009; Jefferson, Webber, and Pitman 2008).

Pacific white-sided dolphins have been observed being preyed upon by killer whales, and these dolphins typically flee when they come in contact with the predator (Black 2009). In the eastern Pacific Ocean, Pacific white-sided dolphins are documented prey species of killer whales (Dahlheim and White 2010).

Life History. Males in the central North Pacific reach sexual maturity at about 10 years and length of 1.7 to 1.8 m; and females reach sexual maturity at 8 to 11 years and length of 0.8 to 1.9 m. Calving in some areas apparently occurs during a summer breeding season that extends into fall, peaking June through August (Heise 1997). Testosterone is at its peak in July, and conception occurs between August and November (Robeck et al. 2009). In the central Pacific, pregnancy lasts 11 to 12 months, and calving takes place in late winter to spring (Ferrero and Walker 1996).

Migration. Although Pacific white-sided dolphins do not migrate, seasonal shifts have been documented. Pacific white-sided dolphins are found from the Korean Strait to waters of western Japan in winter, and move east between March and July (Kasuya 1971). Surveys suggest a seasonal north-south movement of Pacific white-sided dolphins in the eastern North Pacific, as water temperatures increase or decrease (Carretta et al. 2005b; Forney 1994; Green et al. 1992).

Hearing/Vocalization. (Tremel et al. 1998) measured the underwater hearing sensitivity of the Pacific white-sided dolphin, and found that this ranged from 75 Hz to 150 kHz. The greatest sensitivities were from 4 to 128 kHz, while the lowest measurable sensitivities were 145 dB at 100 Hz and 131 dB at 140 kHz. Below 8 Hz and above 100 kHz, this dolphin's hearing was similar to that of toothed whales.

Vocalizations produced by Pacific white-sided dolphins include whistles and clicks. Whistles are in the frequency range of 2 to 20 Hz (Thomson and Richardson 1995). Peak frequencies of the pulse trains for echolocation fall between 50 and 80 kHz; the peak amplitude is 170 dB re 1uPa-m (Fahner et al. 2004). Spectral mean peak values are 22.2, 26.2, 33.6, 33.7, and 37.3 kHz for clicks, and the spectral notch mean values are 19.0, 24.5, and 29.7 kHz for clicks produced by this species (Soldevilla et al. 2008). In two known sub-populations of the Pacific white-sided dolphin in the California Bight, clicks could be categorized into types A and B. Sub-populations using click type A slowly traveled with little foraging during the day, whereas the click B sub-population traveled and foraged during this time. These differences possibly illustrate niche partitioning and suggest, for this area at least, that click type can predict behavior (Yamamuro, Aketa, and Uchida 2004). These differences may also indicate the existence of population-specific click types or prey preferences (Soldevilla, Wiggins, and Hildebrand 2010).

Diving. Time/depth recording devices have been attached to only one individual from this species; little detailed information is available on diving capabilities. The Pacific white-sided dolphin is not thought to be a deep diving species. Based on feeding habits, Fitch and Brownell (1968) inferred that Pacific white-sided dolphins dive to at least 120 m. Some data are available from radio-tagged individuals: animals had a mean dive duration of 24 s., and dives of up to 6.2 min were recorded. Dive depth was not recorded for these dolphins, but the mean distance traveled during these dives was 36.2 km (Black 1994). Most foraging dives lasted 15 to 25 s. (Black 1994; Heise 1997).

5.31.5 Habitat and Distribution

The Pacific white-sided dolphin is most common in temperate waters over the outer continental shelf and slope. Sighting records and captures in open sea driftnets indicate that this species also occurs in oceanic waters well beyond the shelf and slope (Ferrero and Walker 1996; Leatherwood et al. 1984)

The Pacific white-sided dolphin is found in cold temperate waters across the northern rim of the Pacific Ocean (Carretta et al. 2010; Ferguson 2005; Jefferson, Webber, and Pitman 2008; Reeves, Stewart, et al. 2002). It is typically found in deep waters along the continental margins and outer shelf and slope waters. It is also known to inhabit inshore regions of southeast Alaska, British Columbia, and Washington, and occurs seasonally off Southern California (Brownell, Walker, and Forney 1999). Salvadeo et al. (2010) concluded that the occurrence of the Pacific white-sided dolphin has decreased by approximately one order of magnitude every decade since the 1980s in the Gulf of California.

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. This species is not known to occur in this area, yet this species' primary range does include waters directly adjacent to the North Central Pacific Gyre (Figure 5-69).

KUROSHIO CURRENT. In the western North Pacific, the Pacific white-sided dolphin ranges northward from the South China Sea to the Kuril and Commander Islands, including the Sea of Japan, Okhotsk Sea, and southern Bering Sea (Brownell, Walker, and Forney 1999; Reeves, Stewart, et al. 2002; Sleptsov 1961). Little information is available about different populations in the western North Pacific. They are found throughout Japanese waters (Brownell, Walker, and Forney 1999). During the summer-fall period, Pacific white-sided dolphins are expected to occur north of 35°N and seaward of the shelf break. They may occur south of 35°N to the southern tip of Kyūshū, including the southern edge of the Sea of Japan (Tsushima Strait) (Figure 5-70).

EAST CHINA SEA. In the western North Pacific, the Pacific white-sided dolphin ranges northward from the South China Sea to the Kuril and Commander Islands, including the Sea of Japan, Okhotsk Sea, and southern Bering Sea (Brownell, Walker, and Forney 1999; Reeves, Stewart, et al. 2002; Sleptsov 1961).

PHILIPPINE SEA. The Philippine Sea is not included in the known primary range of this species (Figure 5-69 and Figure 5-70).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Recent studies suggest possible presence of two distinct populations in Japan: one in coastal waters of Japan and one offshore in the North Pacific (Hayano et al. 2004). They may occur from the shoreline to the shelf break (not including bays) along the east coast of Japan (Figure

5-70). They may also occur from the shoreline to the shelf break along the east coast of Japan north of 35°N.

Kyūshū Island, Ōsumi Islands, and Tokara Archipelago. During the winter-spring period, Pacific white-sided dolphins are expected to occur seaward of the shelf break along the coast of Japan from the East Japan study area northern boundary south to the northwestern tip of Kyūshū, including the southern edge of the Sea of Japan.

MARIANA ARCHIPELAGO. The Mariana Archipelago is not included in the known primary range of this species (Figure 5-69 and Figure 5-70).

CAROLINE ISALNDS. The Caroline Islands are not included in the known primary range of this species (Figure 5-69 and Figure 5-70).

5.31.6 Species-specific Threats

Small numbers of Pacific white-sided dolphins are hunted off the southwest and east central coast of Japan, and at Iki Island off the northern coast of Kyūshū (Mitchell 1975; Miyazaki 1983). In the Republic of (South) Korea, “whale meat” markets still can buy and sell meat from stranded or bycaught marine mammals. A DNA surveillance study from 2003 to 2005 found Pacific white-sided dolphin meat present in area markets (Baker et al. 2006). This species has also been caught for public display off the central Pacific coast of Japan and the southern Sea of Japan (Kasuya, Tobayama, and Matsui 1984). Bycatch of white-sided dolphins from gillnets entanglements can subject the animal to an abnormally rapid ascent, causing many subsequent health problems including accumulation of gas bubbles in tissues (Moore et al. 2009).

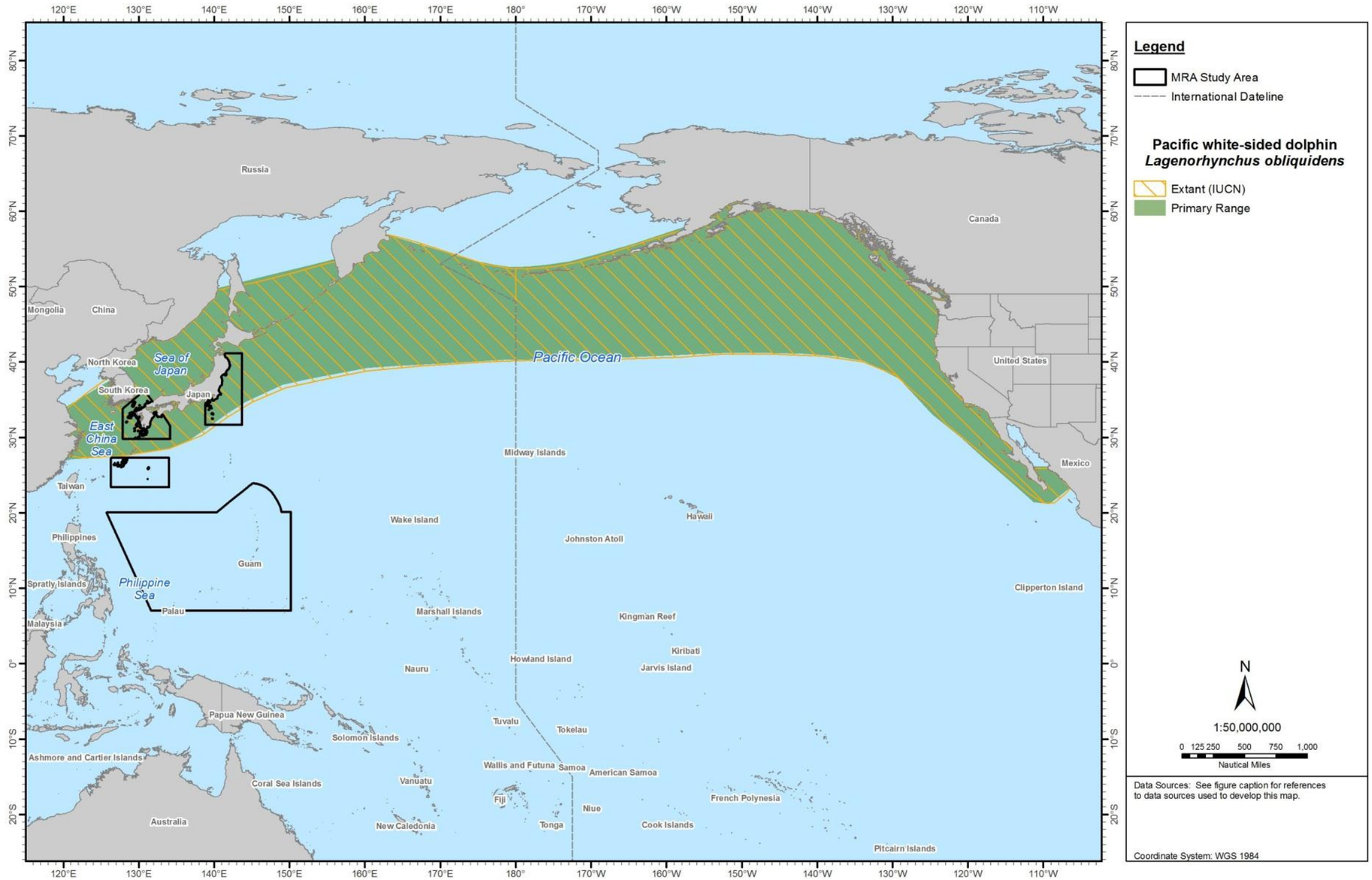

Figure 5-69: Geographic Range of the Pacific White-sided Dolphin in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

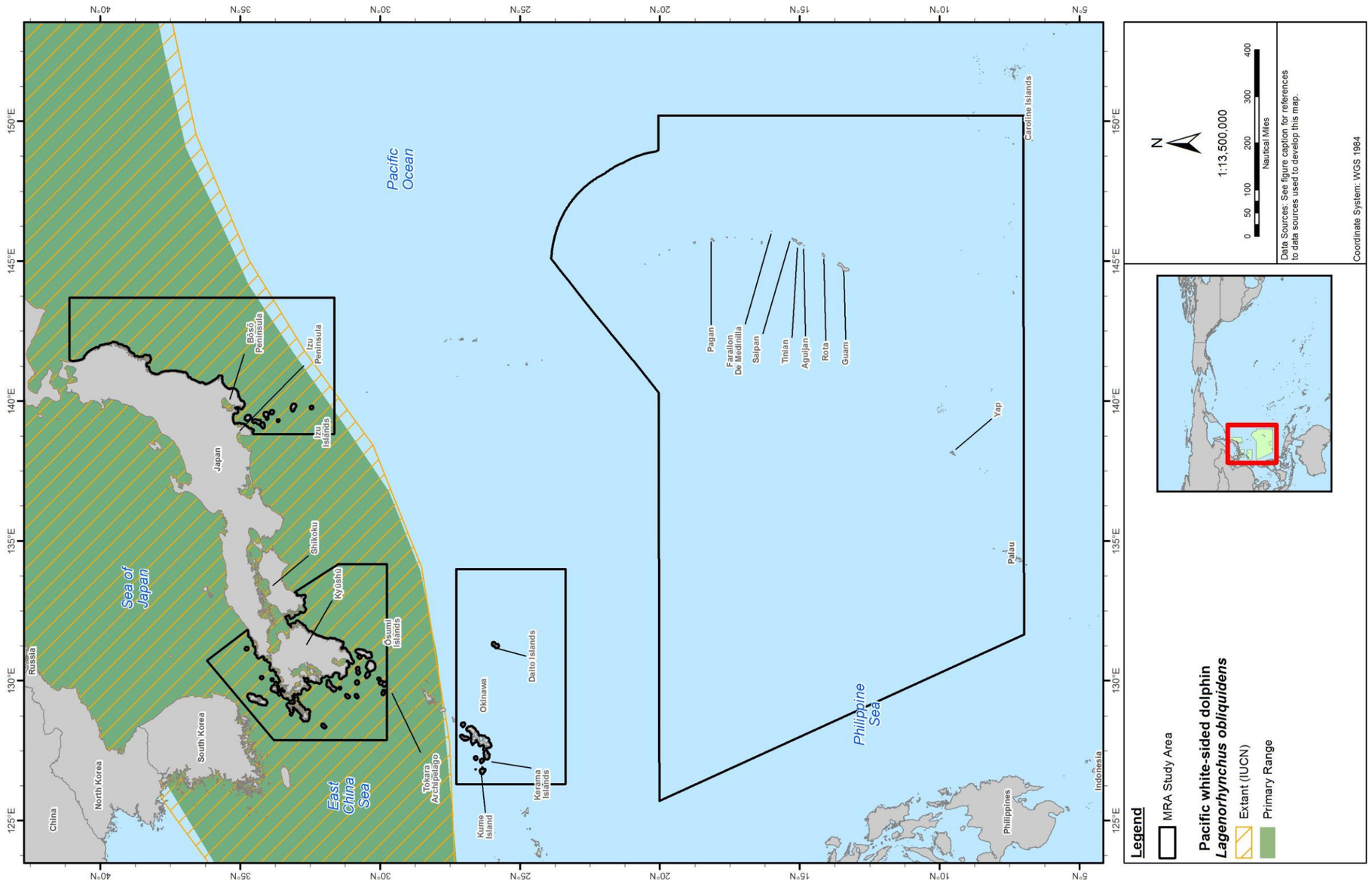

Figure 5-70: Geographic Range of the Pacific White-sided Dolphin in the MRA Study Area

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.32 NORTHERN RIGHT WHALE DOLPHIN (*LISSODELPHIS BOREALIS*)

5.32.1 Description

The northern right whale dolphin, plus its congener, the southern right whale dolphin (*Lissodelphis peronii*), are the only members of the Family Delphinidae without a dorsal fin. The northern species is extremely slender and is mostly black with a small white patch behind the tip of the lower jaw and a wide white patch on the chest that narrows behind the flippers and continues along the belly (Reeves, Stewart, et al. 2002). The flukes are light gray on top and have large white patches on the underside. The beak is short and well-defined with a straight mouthline (Jefferson and Newcomer 1993). The flippers are small and curved. This species reaches lengths of about 3 m; males tend to be a bit larger than females (Leatherwood and Walker 1979). They weigh between 130 and 250 lbs. (60 and 115 kg).

5.32.2 Status and Management

This species it is not listed under the ESA but is protected by the MMPA. This species is also listed as least concern by the IUCN and falls under Appendix II CITES regulations. Dizon et al. (1994) examined a small sample of northern right whale dolphin specimens to determine whether different populations occurred along the west coast of North America and in the open sea waters of the central North Pacific. Although no evidence of separate populations was found, separate stocks are assumed to exist. The management stock in U.S. waters consists of a single California/Oregon/Washington stock (Carretta et al. 2010). There are an estimated 3.6 annual deaths or serious injuries caused by fisheries are in the California/Oregon/Washington stock (Carretta et al. 2012). Although this stock does not have range within the MRA Study Area, northern right whale dolphins are known to have primary range within the Japan portion of theMRA Study Area.

5.32.3 Population and Abundance

The estimate for the larger area of the North Pacific Ocean was 68,000 animals (Buckland, Cattanach, and Hobbs 1993). Geographically, the nearest stock assessment for United States waters was for the California/Oregon/Washington stock (estimated at 8,334 [CV=0.40] dolphins) (Carretta et al. 2012). Abundance of northern right whale dolphins in the area northeast of Japan was estimated as 57,000, based on data from 1987 to 1990 (Miyashita 1993b).

5.32.4 Biology, Ecology, and Behavior

Very little is known about the behavior of this species, and no dedicated effort has focused on studying its behavior. Northern right whale dolphins are known to be very active at the surface. These dolphins are avid bowriders of vessels at sea and often perform low-angle leaps as they move along (Jefferson and Lynn 1994; Jefferson, Webber, and Pitman 2008).

Group Size. Northern right whale dolphins are generally social and are typically found in groups ranging from 100 to 200, but are sometimes seen in large herds numbering in the thousands (Jefferson, Webber, and Pitman 2008; Leatherwood and Walker 1979; Reeves, Stewart, et al. 2002); up to 3,000 have been observed in one group (Jefferson, Webber, and Pitman 2008; Lipsky 2009). Leatherwood and Walker (1979) proposed four distinct group patterns in which this species occurs. Type I groups are tightly packed groups with no identifiable subgroups; Type II groups consist of scattered and distinctly separate subgroups of various sizes; Type III groups swim in V-shaped formations; and Type IV groups arrange themselves in a line and swim abreast of one another, surfacing independently. This species is very often

found with other cetacean species, such as the fin whale, Dall's porpoise, Risso's, and Pacific white-sided dolphins, sometimes in mixed schools (Braham 1983; Leatherwood and Walker 1979; Reeves, Stewart, et al. 2002).

Predator/Prey Interactions. Northern right whale dolphins are known to feed on a wide variety of near-surface and mid-water prey species, including fishes and cephalopods, such as squid. Otolith (ear bone) identification has shown that the northern right whale dolphin preys on many different species (Leatherwood and Walker 1979). Market squid (*Loligo opalescens*) and lanternfish (family Myctophidae) appear to be the main prey species in Southern California waters (Jefferson, Webber, and Pitman 2008). This species may be preyed upon by killer whales and occasionally by sharks (Lipsky 2009).

Life History. Only a single detailed study of life history has been conducted on this species (Ferrero and Walker 1993). Onset of sexual maturity is at approximately 10 years for males and 10 to 10.5 years for females (Ferrero and Walker 1993). Pregnancies last around 12 months, and females typically have a 2-year calving interval. Calving seasonality is not well known in the eastern North Pacific, although small calves are seen in winter or early spring (Jefferson, Webber, and Pitman 2008; Lipsky 2009). In waters of the central North Pacific, a calving peak occurs in July and August (Ferrero and Walker 1993). This species is known to live to at least 42 years (Ferrero and Walker 1993; Jefferson, Webber, and Pitman 2008).

Migration. The species does not migrate, although seasonal shifts do occur. Occasional movements south of 30°N are associated with unusually cold water temperatures (Jefferson and Lynn 1994; Leatherwood and Walker 1979). Surveys suggest that, at least in the eastern North Pacific, seasonal inshore-offshore and north-south movements are related to prey availability, with peak abundance in the Southern California Bight in winter (Forney and Barlow 1998). Periods of peak abundance of northern right whale dolphins in Southern California correspond very closely with known periods of peak abundance of market squid, a major prey species (Jefferson and Lynn 1994; Leatherwood and Walker 1979). Leatherwood and Walker (1979) reported observation of this species off Pyramid Head, San Clemente Island, and Catalina Island, which are important squid fishing grounds in Southern California. Northern right whale dolphins are primarily found off California during the colder water months, with distribution shifting northward into Oregon and Washington as water temperatures increase during late spring and summer (Barlow 1995; Forney and Barlow 1998; Forney, Barlow, and Carretta 1995; Leatherwood and Walker 1979). Northern right whale dolphins can be found farther offshore of Southern California during the summer (Forney and Barlow 1998).

In the western Pacific, northern right whale dolphins range from Cape Nojima, Japan in the south to Paramushir Island, and to Russia in the north (Nishiwaki 1967; Sleptsov 1961). Northern right whale dolphins make seasonal movements; they move south and inshore during the winter and north and offshore during the summer in both the western and eastern Pacific (Kasuya 1971; Leatherwood and Walker 1979).

Hearing/Vocalization. No data have been published on the hearing abilities of this species.

Clicks with high repetition rates and whistles have been recorded from animals at sea (Fish and Turl 1976; Leatherwood and Walker 1979). Maximum source levels were approximately 170 dB 1 µPa-m (Fish and Turl 1976).

Diving. Very little information on diving depths for northern right whale dolphins is available, as dolphins of this species have never been tagged with time depth recorder devices. However, based on behavioral observations, groups are known to dive for up to 6.5 min (Reeves, Stewart, et al. 2002).

5.32.5 Habitat and Distribution

This species occurs in oceanic waters and along the outer continental shelf and slope, normally in waters colder than 20°C (Jefferson and Lynn 1994; Leatherwood and Walker 1979). Northern right whale dolphins generally move nearshore only in areas where the continental shelf is narrow or where productivity on the shelf is especially high (Smith et al. 1986).

The northern right whale dolphin occurs in cool-temperate to subarctic waters of the North Pacific Ocean, from the west coast of North America to Japan and Russia.

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. Although this area is not largely included within the primary range of this species, their range is found adjacent to the northern boundary of the North Central Pacific Gyre (Figure 5-71).

KUROSHIO CURRENT. Northern right whale dolphins are regularly found along the Pacific coast of Japan; no records of this species in the Sea of Japan have been received (Jefferson and Newcomer 1993). Northern right whale dolphins prefer cool waters; their distribution throughout the Japan MRA Study Area varies seasonally. During the winter-spring period, northern right whale dolphins are expected to occur seaward of the shelf break and north of 35°N. During the summer-fall period, occurrence of northern right whale dolphins shifts north of 38°N and includes the area seaward of the shelf break (Figure 5-71).

EAST CHINA SEA. The East China Sea is not included in the known primary range of the northern right whale dolphin (Figure 5-71).

PHILIPPINE SEA. The Philippine Sea is not included in the known primary range of the northern right whale dolphin (Figure 5-71 and Figure 5-72).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. In the Japan Archipelago, they may occur from the shoreline to the shelf break north of 38°N and seaward of the shelf break between 35°N and 38°N (Figure 5-72).

MARIANA ARCHIPELAGO. The waters around the Mariana Archipelago are not included in the known primary range of the northern right whale dolphin (Figure 5-72).

CAROLINE ISLANDS. The waters around the Caroline Islands are not included in the known primary range of the northern right whale dolphin (Figure 5-72).

5.32.6 Species-specific Threats

Northern right whale dolphins have never been hunted extensively in a major fishery, although incidental catches have occurred in purse seines and driftnets (Jefferson, Webber, and Pitman 2008).

The northern right whale dolphin is taken in gillnets and is sometimes killed directly in the Dall's porpoise harpoon drive fishery in Japanese waters (National Marine Fisheries Service). The major threat appears to be bycatch in the California/Oregon thresher shark driftnet fishery, but catches are low—only about five to nine individuals per year (Carretta et al. 2010).

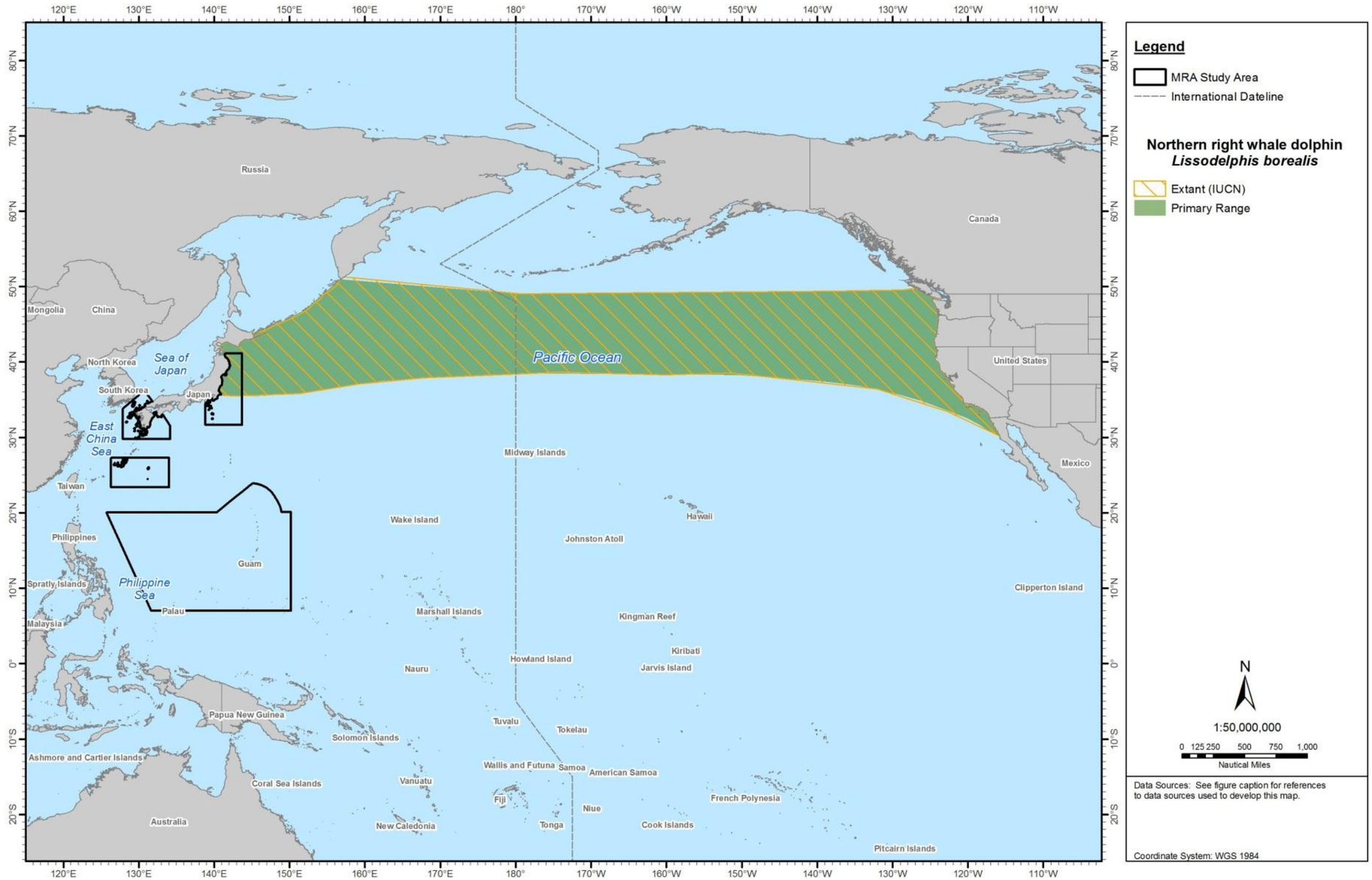

Figure 5-71: Geographic Range of the Northern Right Whale Dolphin in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

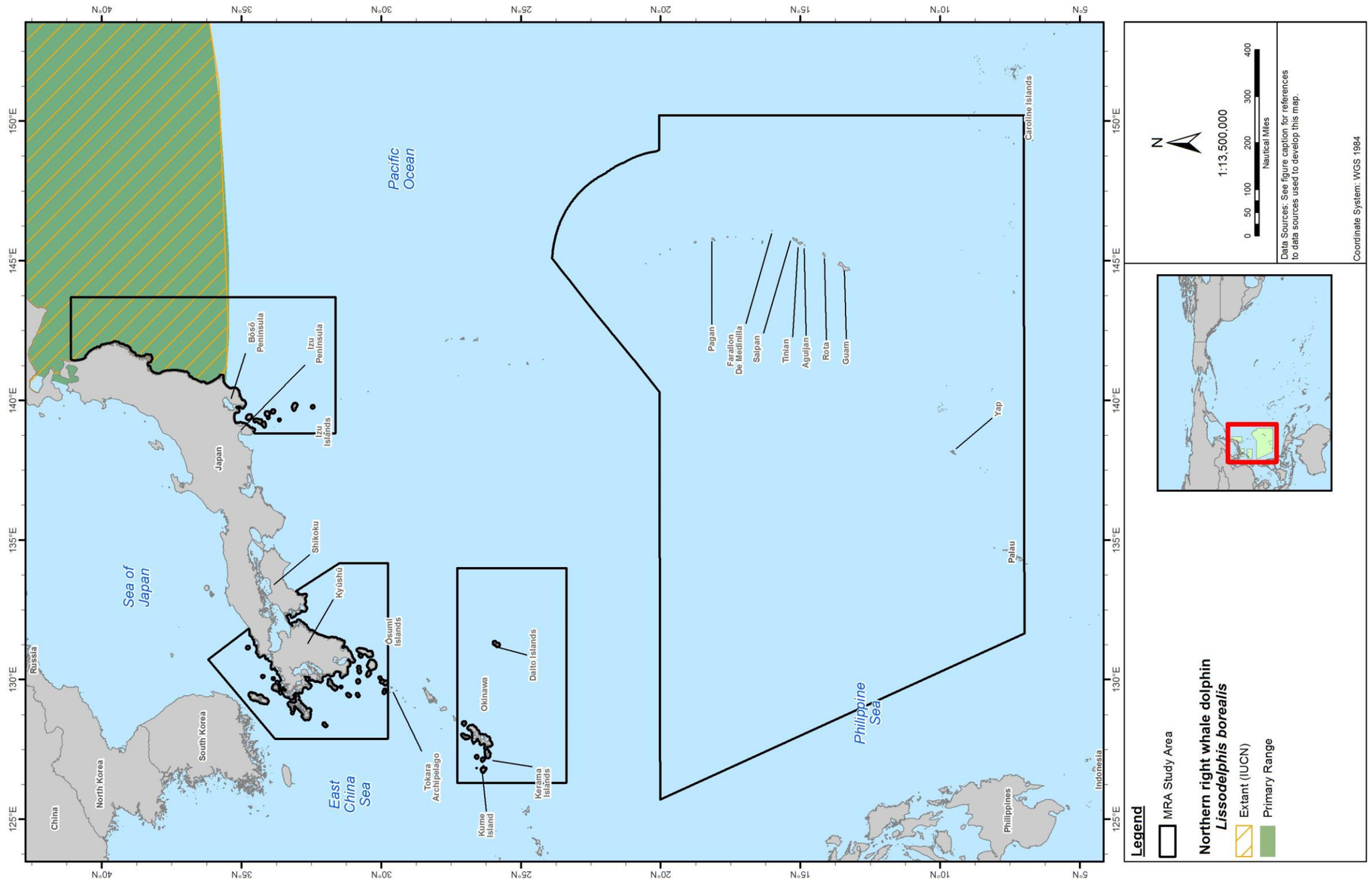

Figure 5-72: Geographic Range of the Northern Right Whale Dolphin in the MRA Study Area
Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.33 MELON-HEADED WHALE (*PEPONOCEPHALA ELECTRA*)

5.33.1 Description

This small tropical dolphin species, the melon-headed whale, is similar in appearance to the pygmy killer whale. Melon-headed whales are moderately robust. The head of adults is bulbous, and the melon may overhang the tip of the lower jaw in adult males. Younger animals have a more sloping forehead, and a short beak generally is present in juveniles and subadults. The melon-headed whale's dorsal fin is tall and slightly falcate, and is located near the middle of the back. The flippers are sickle-shaped, with acutely-pointed tips. Males have more bulbous melons than do females, longer flippers, taller dorsal fins, and tail stocks with exaggerated post-anal humps (the latter are often called ventral keels (Perryman 2008; Perryman et al. 1994).

Although the melon-headed whale actually has a reasonably complex color pattern, it is often described in older literature as simply black with a few white patches. Most of the body is generally dark gray to nearly black (youngsters are lighter gray), with a white urogenital patch that has indistinct margins. On most individuals is also an anchor-shaped patch of light color on the underside of the head, just ahead of the flippers. On larger adults, a black triangular "mask" on the face of melon-headed whales distinguishes them from the somewhat more uniformly colored pygmy killer whale (Jefferson, Webber, and Pitman 2008). A dark stripe runs forward from the eye to the beak tip, and a pale, streaked blowhole stripe widens as it extends toward the tip of the upper jaw. The lips and tip of the lower jaw of larger animals are often light gray or white. The facial color patterning is subtle and can be seen only when the lighting is right. Melon-headed whales also have a rounded cape that dips very low below the dorsal fin (much lower than in the pygmy killer whale). Its margin is often faint, with little contrast between it and the light flanks—the margin may not be visible in sightings at sea unless the lighting is just right (Jefferson, Webber, and Pitman 2008; Perryman et al. 1994).

Melon-headed whales grow to a maximum length of about 2.78 m, with males attaining somewhat greater lengths than females. Length at birth is not well-known, but is thought to be about 1 m or less. Maximum known weight is about 275 kg. Melon-headed whales have 20 to 25 small, slender teeth in each tooth row (Jefferson, Webber, and Pitman 2008).

5.33.2 Status and Management

The melon-headed whale is protected under the MMPA and is not listed under the ESA. This species is also listed as least concern by the IUCN and falls under Appendix II CITES regulations. The MMPA stock assessment reports include a single Pacific management stock with only animals found within the U.S. EEZ of the Hawaiian Islands (Carretta et al. 2010). There are no annual deaths or serious injuries caused by fisheries are in the Hawaiian stock (Carretta et al. 2012). Although this stock does not have range within the MRA Study Area, melon-headed whales are known to have primary and secondary range within the MRA Study Area.

5.33.3 Population and Abundance

No current global population estimates are available. The geographically closest stock assessment for this species was for the Hawaiian stock (estimated 2,950 [CV=1.17] whales). No data regarding current population trends are available (Carretta et al. 2011k). A 2007 cetacean survey (Fulling, Thorson, and Rivers 2011) estimated the numbers of this species in Guam and the CNMI at 2,455 individuals. No other population estimates or population trend data are available for the MRA Study Area.

5.33.4 Biology, Ecology, and Behavior

These animals often float at the water's surface in large schools composed of noticeable subgroups. Melon-headed whales can also be observed moving at high speeds through the water while leaping and, in many areas, ride the bow waves of vessels (Cascadia Research 2008). They are frequently found in mixed-species aggregations, most commonly with Fraser's dolphins (Jefferson and Barros 1997; Perryman et al. 1994), as well as on occasion with spinner, bottlenose, and rough-toothed dolphins (Perryman 2008).

Group Size. Melon-headed whales are typically found in large groups, ranging between 150 and 1,500, with a maximum of 2,000 (Gannier 2002; Jefferson, Webber, and Pitman 2008; Perryman 2008; Perryman et al. 1994). Watkins et al. (1997) described smaller groupings of 10 to 14. A recent study in Hawaiian waters found groups ranging between 1 and 800, with a mean of 275 animals (Aschettino 2010). The mean group size in the ETP is estimated as 258 individuals (Ferguson, Barlow, Feidler, et al. 2006).

Predator/Prey Interactions. Melon-headed whales prey on squid, pelagic fishes, and occasionally crustaceans. Most of the fish and squid families eaten by this species consist of mid-water forms found in waters up to 1,500 m deep, suggesting that feeding takes place deep in the water column (Jefferson and Barros 1997). In the northeastern Atlantic, cephalopod and fish remains were found in the stomach contents of melon-headed whales, with dominant species being cuttlefish and a neritic squid (Spitz et al. 2011).

Life History. Very little information is available on the life history of this species. Females reach sexual maturity at about 11.5 years and males at 16.5 years (Jefferson and Barros 1997). Whether calving is significantly seasonal is unclear, but some evidence suggests a peak in July and August (Jefferson and Barros 1997). These life history parameters are estimated from a study of a single school of melon-headed whales that mass stranded at Aoshima, southern Japan (Miyazaki, Fujise, and Iwata 1998), and therefore must be regarded as preliminary.

Migration. The melon-headed whale is not known to migrate. Although these whales are found worldwide in tropical and subtropical waters, they have seldom been seen at higher latitudes. These higher latitude movements are considered beyond normal range, because records specify these movements occurred during spreads of warm water fluxes (Perryman et al. 1994).

Hearing/Vocalization. No data on hearing ability for this species are available.

Sounds produced by melon-headed whales include whistles, echolocation clicks, and burst-pulse sequences. Whistles had dominant frequencies around 8 to 12 kHz (Watkins et al. 1997), ranging from 890 Hz to 23.5 kHz, with a duration of 586 ms (Frankel and Yin 2010). Higher-level whistles were estimated at no more than 155 dB re 1 µPa-m (Watkins et al. 1997). Clicks had dominant frequencies of 20 to 40 kHz (Watkins et al. 1997), beginning at 13 kHz (Frankel and Yin 2010), and with median peak frequencies from 24.4 to 29.7 kHz (Baumann-Pickering et al. 2010). Higher-level click bursts were judged as approximately 165 dB re 1 µPa-m (Watkins et al. 1997). Burst-pulse vocalizations had a 586-millisecond mean duration, occurring every 2.47 ms, for an average of 46.7 pulses (Frankel and Yin 2010).

Diving. Typically found in deep oceanic waters, this species is assumed to be a deep diver (Jefferson and Barros 1997). In the Gulf of Mexico, melon-headed whales have been found in waters ranging from 835

to 3,200 m and are typically found in deeper offshore waters of Hawai'i (Brownell Jr. et al. 2009). Melon-headed whales prey on pelagic fishes and squids, typically deep in the water column at depths of 1,500 m (Jefferson and Barros 1997; Perryman et al. 1994). Lanternfish, an important prey source for this species, are known to migrate daily over hundreds of m vertically from 200 m during the night to around 700 to 3,000 m during the day (Brownell Jr. et al. 2009). Melon-headed whales likely follow this movement to feed on this species.

5.33.5 Habitat and Distribution

Melon-headed whales are most often found in offshore deep waters but sometimes move close to shore over the continental shelf. Brownell et al. (2009) found that melon-headed whales near oceanic islands rest near shore during the day, and feed in deeper waters at night. Nearshore sightings are generally from areas where deep, oceanic waters are found near the coast (Perryman 2008).

Melon-headed whales are found worldwide in tropical and subtropical waters. They have occasionally been reported at higher latitudes, but these movements are considered beyond their normal range, because the records indicate these movements occurred during incursions of warm water currents (Perryman et al. 1994). During ship-based bird surveys in the ETP, this species was observed from the U.S.-Mexico border south to Peru, typically associated with pelagic sea birds while foraging (Pitman and Ballance 1992).

Sightings in the Gulf of Mexico have been in deep waters, well beyond the edge of the continental shelf and in waters over the abyssal plain (Davis and Fargion 1996; Mullin et al. 1994; Waring et al. 2009b). Melon-headed whales are found close to shore (within a few km) around the Society and Marquesas Islands of French Polynesia (Gannier 2002), and Lembata Island of the Indonesian archipelago (Rudolph, Smeenk, and Leatherwood 1997), as well as in some waters of the Philippines (Leatherwood et al. 1992). In the ETP, this species is primarily found in upwelling-modified and equatorial waters (Au and Perryman 1985; Perryman et al. 1994). High-latitude records, such as the stranding in South Africa, are probably extralimital (Best 2007; Jefferson, Webber, and Pitman 2008).

Open Ocean of the MRA Study Area

The melon-headed whale is a deepwater species found in warm-temperate to tropical waters (Jefferson, Webber, and Pitman 2008). During an abundance survey comparing the Marquesas and the Society Islands, many species of cetaceans, including the melon-headed whale, were more abundant near the Marquesas, possibly due to increased primary productivity associated with the presence of a narrow shelf (Gannier 2009).

NORTH CENTRAL PACIFIC GYRE. The range of this species is known to include waters of the North Central Pacific Gyre (Jefferson, Webber, and Pitman 2008; Perryman 2008) (Figure 5-73). The occurrence of this species is well known in deep waters in this province (Au and Perryman 1985; Carretta et al. 2010; Ferguson 2005; Perrin 1976; Wang, Yang, and Liao 2001). It has been suggested that presence of melon-headed whales in the waters of Guam, Republic of Palau (Palau), and Japan suggests a possible link between equatorial Pacific and northern Pacific populations of this species, via the Mariana Islands (Donaldson 1983).

KUROSHIO CURRENT. Expected occurrence for the melon-headed whale in the Japan MRA Study Area is south of 32°N, seaward of the shelf break (Figure 5-73). They may occur from about 35°N in an area that angles southward, representing the extension of the northern range of the warm Kuroshio Current. This

species is more likely to be present in the northern area of the MRA Study Area when water temperatures are higher. The occurrence pattern is believed similar year-round. The first record from Japan was of an individual killed by fishermen in the shallows of Hiratsuka Beach, Sugami Bay (Sagami Bay) during August 1963 (Nakajima and Nishiwaki 1965).

EAST CHINA SEA. The East China Sea is included in the known secondary range of the melon-headed whale (Figure 5-73). They may also occur in the Tsushima Strait and around the Ogasawara and Izu Islands.

PHILIPPINE SEA. The Philippine Sea is a part of the primary range of the melon-headed whale (Figure 5-73 and Figure 5-74).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. The Japan Archipelago is the known primary and secondary range of this species (Figure 5-74). Additional records for this MRA Study Area include about 104 whales captured at Okinawa (Miyazaki, Fujise, and Iwata 1998), some mass strandings (Miyazaki 1983; Miyazaki, Fujise, and Iwata 1998), and a mixed school of 500 Fraser's dolphins and melon-headed whales driven into a cove in January 1991 (Amano, Miyazaki, and Yanagisawa 1996).

Bōsō Peninsula, Izu Peninsula, and Izu Islands. 500 individuals were sighted in Suruga Bay (Nishiwaki and Norris 1966). A mass stranding of melon-headed whales occurred on the coast of Bōsō Peninsula on February 26, 2006, when 70 dead whales were counted. Tissue samples were collected and analyzed for bioaccumulated contaminants (Endo et al. 2008). North of the Bōsō Peninsula, in February 2002, a stranding occurred at Hasaki, Ibaraki Prefecture, where samples were collected from two sets of animals: in one study, 15 individual samples (Hart et al. 2008) were collected, and in the other study, 20 samples were collected (Kajiwara et al. 2008). Another stranding in this area of seven individuals was documented, and these were biopsied (Kajiwara et al. 2008). In the Chiba Prefecture, strandings were recorded in January 2006, when two males stranded at Asahi, and in February 2006, when three males beached near Ichinomiya. Tissue samples from the five stranded individuals were analyzed (Hart et al. 2008).

Kyūshū Island, Ōsumi Islands, and Tokara Archipelago. A stranding was recorded in January 1982 at Aoshima, Miyazaki Prefecture, where tissue samples were collected from 10 whales for analysis. Lanegashima, Kagoshima Prefecture had a mass stranding in 2001, when five whales were sampled (Kajiwara et al. 2008).

MARIANA ARCHIPELAGO. The melon-headed whale is an oceanic species. Records of its occurrence within the Mariana Islands MRA Study Area and vicinity have been received. Melon-headed whales are expected to occur from the shelf break (200 m isobath) to seaward of the Mariana Islands MRA Study Area and vicinity (Figure 5-75). They may occur from the coastline to the shelf break because deep water is very close to shore at these islands. Occurrence pattern is believed the same throughout the year.

Rota. Sightings off the coast of Rota have occurred (Fulling, Thorson, and Rivers 2011). In July 2004, a sighting of 500 to 700 melon-headed whales was documented at Sasanhayan Bay (Rota) in waters with a bottom depth of 76 m (Jefferson et al. 2006).

Guam. A live stranding occurred on the beach at Inarajan Bay, Guam in April 1980 (Donaldson 1983; Kami and Hosmer 1982). In 2007, there was a report of a melon-headed whale off the southwestern

coast of Guam and another about 200 nm offshore in the same direction (Fulling, Thorson, and Rivers 2011). Norris et al. (2011) and U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific (2007) identified, through acoustic recordings and visual sightings, two melon-headed whales southwest of Guam. In a 2012 survey, a melon-headed whale was sighted off the west coast of the island, where water depth was between 2000 and 2500 m (HDR 2012) (Figure 5-75).

CAROLINE ISLANDS. The Caroline Islands are a part of the primary range of the melon-headed whale (Figure 5-73 and Figure 5-74).

5.33.6 Species-specific Threats

Melon-headed whales are occasionally taken both incidentally in various fisheries (e.g., tuna purse seines in the ETP, and driftnets in other tropical waters) and directly in small cetacean fisheries in Japan, the Caribbean, Sri Lanka, the Philippines, and Indonesia (National Marine Fisheries Service). A near mass-stranding of this species in Hawaiian waters was recorded in 2004, and this has been linked to naval sonar testing that was occurring in the area at the time (Brownell et al. 2009; Southall et al. 2006). This observation suggests that this species may be vulnerable to acoustic impacts from military operations (Brownell et al. 2009; Jefferson, Webber, and Pitman 2008).

Strandings off the coast of Brazil showed susceptibility of melon-headed whales to parasites (Carvalho et al. 2010)Carvalho et al. 2010). For more detailed information on specific host-parasite species identified through this study, refer to Carvalho et al. (2010). Concentrations of total mercury, methyl mercury, cadmium, selenium, zinc, and copper were measured following a mass stranding in Japanese waters. This study found concentrations of mercury-selenium compounds were highest in the liver, and that cadmium accumulated in this species' kidneys (Endo et al. 2008). Other compounds such as PFCs, some formerly produced as a surface protector, have been found in the livers of melon-headed whales off the coast of Japan (Hart et al. 2008). Blubber samples collected from 55 stranded whales during four individual stranding events from 1982 to 2006 were analyzed for PBDEs and organochlorine compounds; results showed a correlation of concentrations of these compounds with peak historical usage of the compounds (Kajiwara et al. 2008).

This Page Intentionally Left Blank

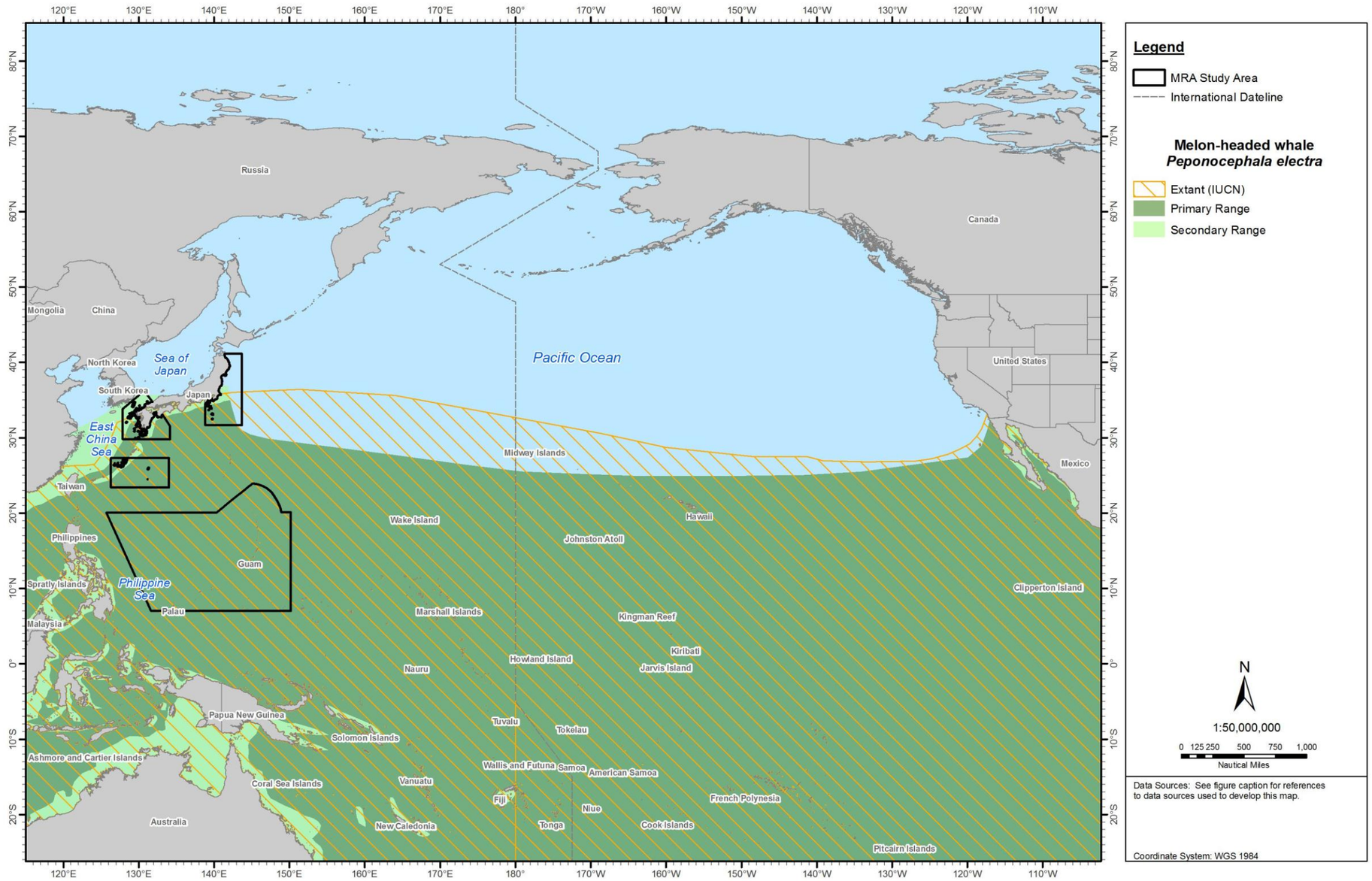

Figure 5-73: Geographic Range of the Melon-headed Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

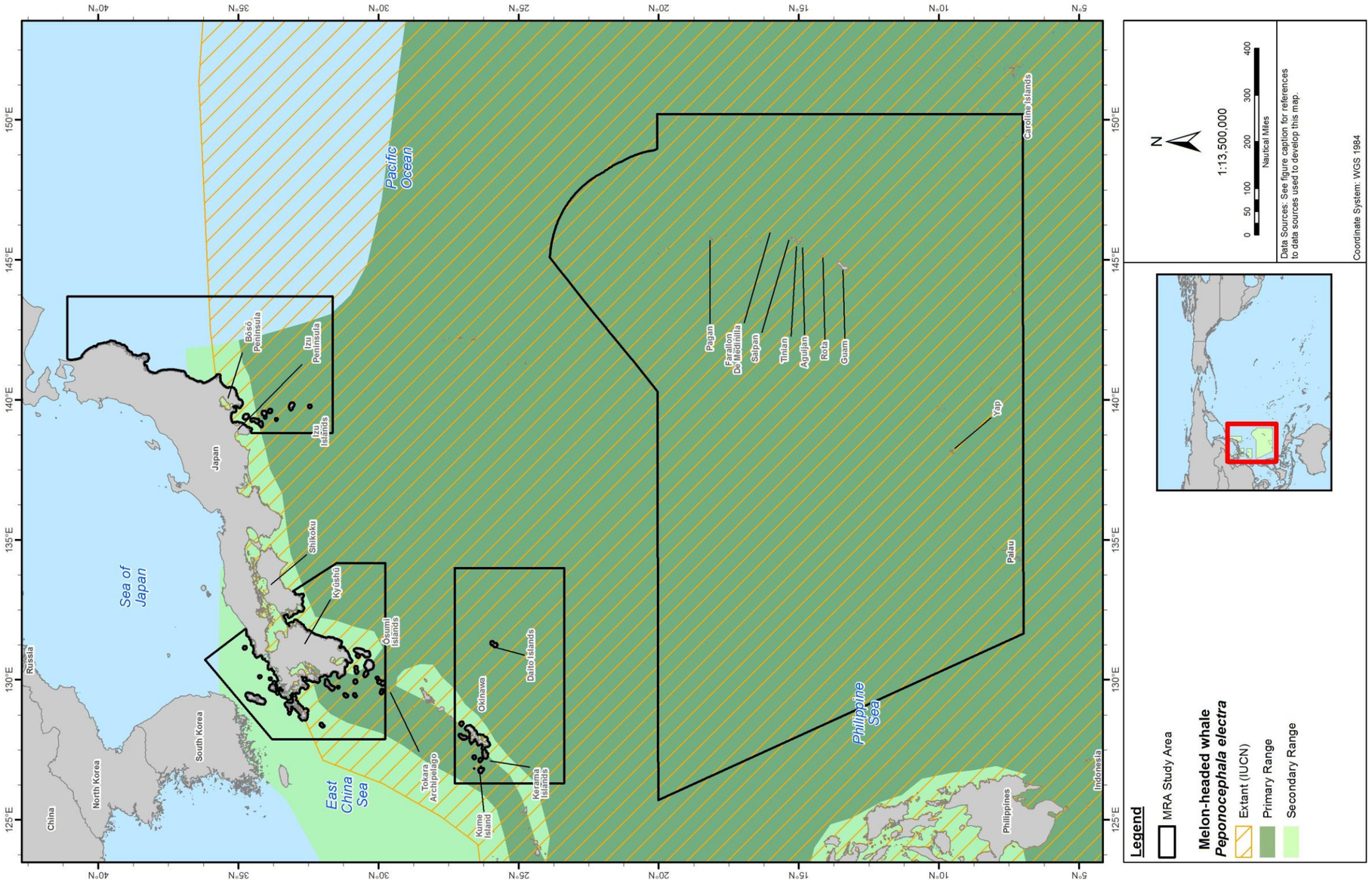

Figure 5-74: Geographic Range of the Melon-headed Whale in the MRA Study Area
Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

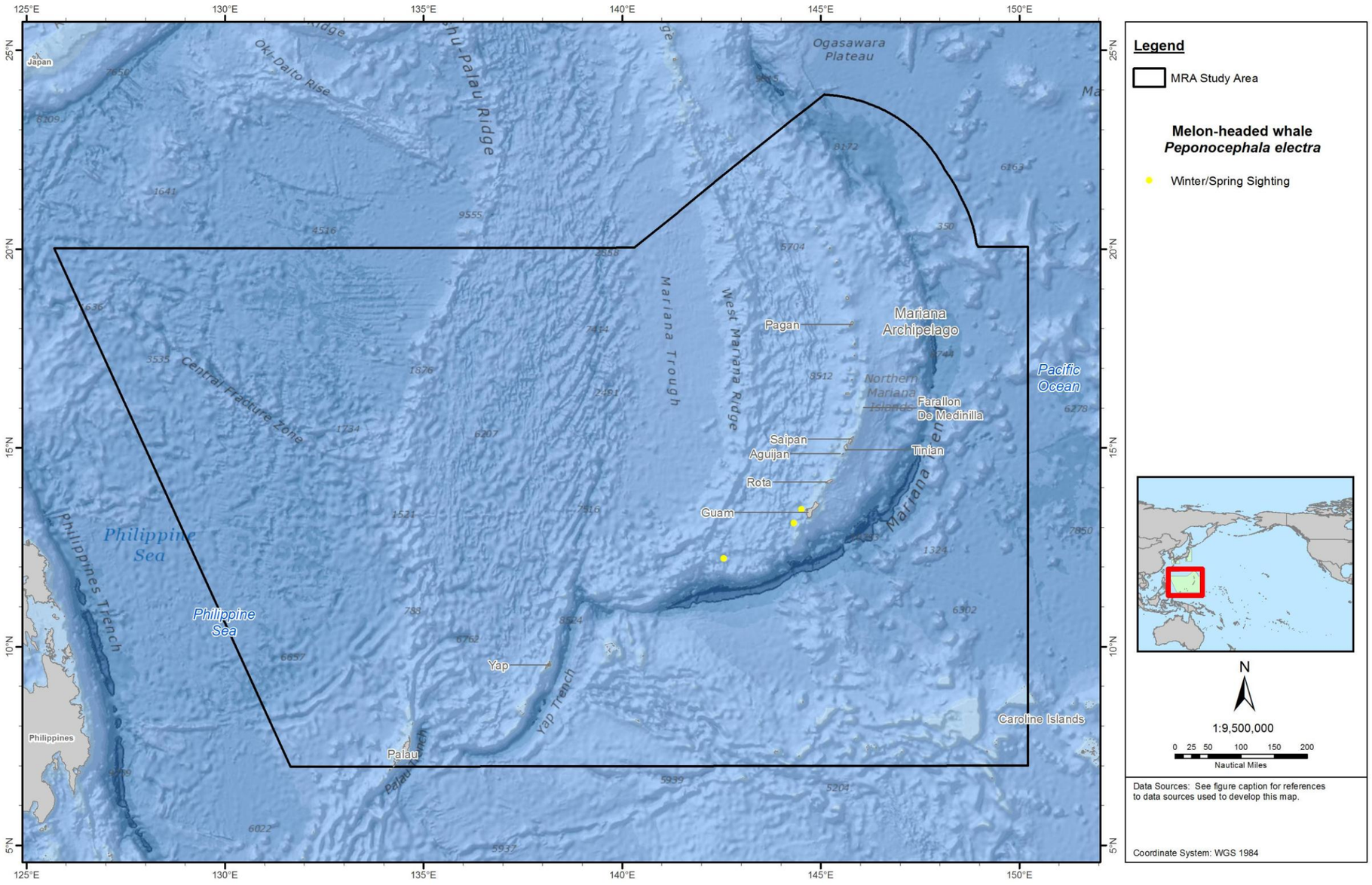

Figure 5-75: Sightings of the Melon-headed Whale in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented.
Sources: Fulling, Thorson, and Rivers (2011); HDR (2012); U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific (2007).

This Page Intentionally Left Blank

5.34 PYGMY KILLER WHALE (*FERESA ATTENUATA*)

5.34.1 Description

The pygmy killer whale is often confused with the false killer whale and melon-headed whale, which are similar in overall appearance to this species. Pygmy killer whales are slender to moderately robust; the body narrows significantly behind the dorsal fin. The head is rounded or even bulbous in profile, and no beak is present (except in some young animals). The head also appears rounded from above (as distinct from triangular in melon-headed whales). The pygmy killer whale's dorsal fin is tall and slightly falcate, often rising at a relatively-shallow angle from the back. The flippers have a convex leading edge and concave trailing edge, with broadly-rounded tips (Jefferson, Webber, and Pitman 2008; Ross and Leatherwood 1994).

The pygmy killer whale's basic coloration is dark gray to black, with a fairly-prominent narrow cape that dips slightly below the dorsal fin. A white to light gray ventral band widens around the genitals. The lips and snout tip are generally white (except perhaps in juveniles). In some individuals, this white color may extend to the snout and forehead (apparently in older animals). Light cookie-cutter shark scars are common on the bodies of many adult pygmy killer whales (Jefferson, Webber, and Pitman 2008).

Adults reach up to 2.6 m, with males growing slightly larger than females. Maximum known weight is 225 kg, based on only a few weighed specimens. Length of newborn pygmy killer whales is not well known, but thought to be about 80 cm. The upper jaw contains 8 to 11 pairs of quite large and heavy teeth, and the lower jaw contains 11 to 13 pairs (Jefferson, Webber, and Pitman 2008).

5.34.2 Status and Management

The pygmy killer whale is protected under the MMPA and is not listed under the ESA. This species is also listed as data deficient by the IUCN and falls under Appendix II CITES regulations. The MMPA stock assessment reports include a single Pacific management stock with only animals found within the U.S. EEZ of the Hawaiian Islands (Carretta et al. 2010). There are no annual deaths or serious injuries caused by fisheries are in the Hawaiian stock (Carretta et al. 2012). Although this stock does not have range within the MRA Study Area, pygmy killer whales are known to have primary and secondary range within the MRA Study Area.

5.34.3 Population and Abundance

Although the pygmy killer whale has an extensive global distribution, it is not known to occur at high densities in any region and thus is probably one of the least abundant of the pantropical delphinids. The current best available abundance estimate for the pygmy killer whale derives from a 2002 shipboard survey of the Hawaiian Islands U.S. Pacific EEZ (estimated 817 animals [CV= 1.12]) (Carretta et al. 2010). An additional stock assessment of the Hawaiian stock reported an estimate of 956 whales. No trend data are available for the Hawaiian stock (Carretta et al. 2011n). A 2007 cetacean survey Fulling, Thorson, and Rivers (2011) estimated the number of this species in Guam and the CNMI at 78 individuals.

5.34.4 Biology, Ecology, and Behavior

Almost nothing is known about the behavior or social organization of this species. Movements are typically slow and sluggish, with only occasional aerial activity (leaps and spyhops) at the sea surface;

pygmy killer whales ride bow waves of vessels only on rare occasions (Donahue and Perryman 2008; Jefferson, Webber, and Pitman 2008).

Group Size. Pygmy killer whales usually form relatively small groups, generally of fewer than 60 individuals (Ross and Leatherwood 1994).

Predator/Prey Interactions. Pygmy killer whales feed predominantly on fish and squid. They have been known to attack other dolphin species, apparently as prey, although this is not common (Jefferson, Webber, and Pitman 2008; Perryman and Foster 1980; Ross and Leatherwood 1994).

The pygmy killer whale has no documented predators (Weller 2008). It may be subject to predation by killer whales. Cookie-cutter shark scars have been documented on this species (Jefferson, Webber, and Pitman 2008).

Life History. Reproductive and life history information is almost completely lacking for this species. Because this is a tropical species, calving probably occurs throughout the year. Newborns measure 80 cm in length (Jefferson, Webber, and Pitman 2008).

Migration. Migrations or seasonal movements are not known for this species.

Hearing/Vocalization. Based on study of a pair of live stranded whales in Florida, pygmy killer whales are most sensitive to frequencies from 20 to 60 kHz, and can hear frequencies as high as 120 kHz. Although the physical hearing attributes of these two whales were consistent with those of other whales (hollow mandibles, void of a bony lamina to the pan bone and enclosed fat bodies stretching caudally and abutting the tympanoperiotic complex), the hearing data for this species indicate a hearing ability inferior to that of other toothed whales (Taniguchi 1999).

The pygmy killer whale emits short-duration, broadband signals similar to a large number of other delphinid species (Madsen, Kerr, and Payne 2004). Clicks produced by pygmy killer whales have centroid frequencies between 70 and 85 kHz; bimodal peak frequencies are between 45 and 117 kHz; the estimated source levels are between 197 and 223 dB re 1 µPa-m (Madsen, Kerr, and Payne 2004). These clicks have characteristics of echolocation clicks (Madsen, Kerr, and Payne 2004).

Diving. Because no tagging studies of this species or studies using depth recording devices have occurred, little information is available on diving behavior (Donahue and Perryman 2008). The species likely is capable of deep dives based on stomach content analyses of stranded pygmy killer whales revealing that this species feeds over the outer continental shelf on fish and squid that occur at depths between 300 and 3,000 m (Mignucci-Giannoni et al. 1999; Zerbini and de Oliveira Santos 1997).

5.34.5 Habitat and Distribution

The pygmy killer whale is generally an open ocean deepwater species (Davis, Evans, and Wursig 2000; Wursig, Jefferson, and Schmidly 2000).

This species has a worldwide distribution in deep tropical and subtropical oceans. Pygmy killer whales generally do not range north of 40°N or south of 35°S (Jefferson, Webber, and Pitman 2008). Reported sightings suggest that this species primarily occurs in equatorial waters, at least in the ETP (Donahue and Perryman 2008; Ross and Leatherwood 1994). Most of the records outside the tropics are associated

with strong, warm western boundary currents that effectively extend tropical conditions into higher latitudes (Ross and Leatherwood 1994).

In the northern Gulf of Mexico, this species is found primarily in deeper waters off the continental shelf and waters out over the abyssal plain (Davis, Evans, and Wursig 2000; Wursig, Jefferson, and Schmidly 2000). In some areas, pygmy killer whales are found within a few km of shore over the shelf, such as around the Marquesas Islands of French Polynesia (Gannier 2002; Gannier 2009), off Lembata Island of the Indonesian archipelago (Rudolph, Smeenk, and Leatherwood 1997), as well as in some waters off the Philippines (Leatherwood et al. 1992).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. This species' range in the open ocean generally extends to the southern regions of the North Pacific Central Pacific Gyre and the southern portion of the North Pacific Transitional provinces (Figure 5-76). Many sightings have been documented during cetacean surveys in the ETP (Au and Perryman 1985; Ferguson, Barlow, Feidler, et al. 2006; Wade and Gerrodette 1993). This species is also known to be present in the western Pacific (Wang and Yang 2006). Its range is generally considered to be south of 40°N and continuous across the Pacific (Donahue and Perryman 2008; Jefferson, Webber, and Pitman 2008).

KUROSHIO CURRENT. Occurrence pattern is believed similar to those of the melon-headed whale, a species for which the pygmy killer whale is often mistaken. The pygmy killer whale is a deepwater species found in warm-temperate to tropical waters. They may occur in an area from about 35°N and then extending southward, representing the extension of the northern range of the warm Kuroshio Current (Figure 5-77). The occurrence pattern is believed similar year-round.

EAST CHINA SEA. The East China Sea is included in the known secondary range of the pygmy killer whale (Figure 5-76).

PHILIPPINE SEA. The Philippine Sea is included in the known primary range of the pygmy killer whale (Figure 5-76 and Figure 5-77).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Only a dozen or so stranding records for this species in Japan are available (Terasawa et al. 1997). Expected occurrence for the pygmy killer whale in the Japan and Okinawa MRA Study Area is south of 32°N, seaward of the shelf break.

Bōsō Peninsula, Izu Peninsula, and Izu Islands. A female pygmy killer whale was found stranded in Sagami Bay (Terasawa et al. 1997).

MARIANA ARCHIPELAGO. Pygmy killer whales are easily confused with false killer whales and melon-headed whales, two species also believed to occur in the Mariana Islands MRA Study Area. The pygmy killer whale is expected to occur from the shelf break (200 m isobath) to seaward of the Mariana Islands MRA Study Area and vicinity (Figure 5-787). They may occur from the 100 m isobath to the shelf break, as deep water is very close to shore at these islands; this species may been seen nearer to shore here than in other areas. A 2007 survey recorded one individual within the waters of the Mariana Islands (Figure 5-78) (U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007). Occurrence pattern is believed the same throughout the year.

Saipan. A sighting of the pygmy killer whale has been recorded southwest of Marpi Reef (HDR 2011).

Guam. Fulling, Thorson, and Rivers (2011) reported a pygmy killer whale sighting off the south coast of Saipan where oceanic depth is 5,000 m.

CAROLINE ISLANDS. The primary range is known to extend into waters around the Caroline Islands, and this species may also be found near the coastal environment, as deep water is adjacent to the shoreline here (Figure 5-76 and Figure 5-77).

5.34.6 Species-specific Threats

Pygmy killer whales have been taken directly in small numbers in harpoon and driftnet fisheries in the Caribbean, Sri Lanka, Japan, and Indonesia. They have also been taken as incidental catches in various tropical fisheries, but always in small numbers (Jefferson, Webber, and Pitman 2008). Pygmy killer whales may be susceptible to underwater noises, such as active sonar and seismic processes (Southall et al. 2007), as indicated by two 2005 mass stranding occasions, one of which was a pygmy killer whale stranding in Taiwan (Wang and Yang 2006).

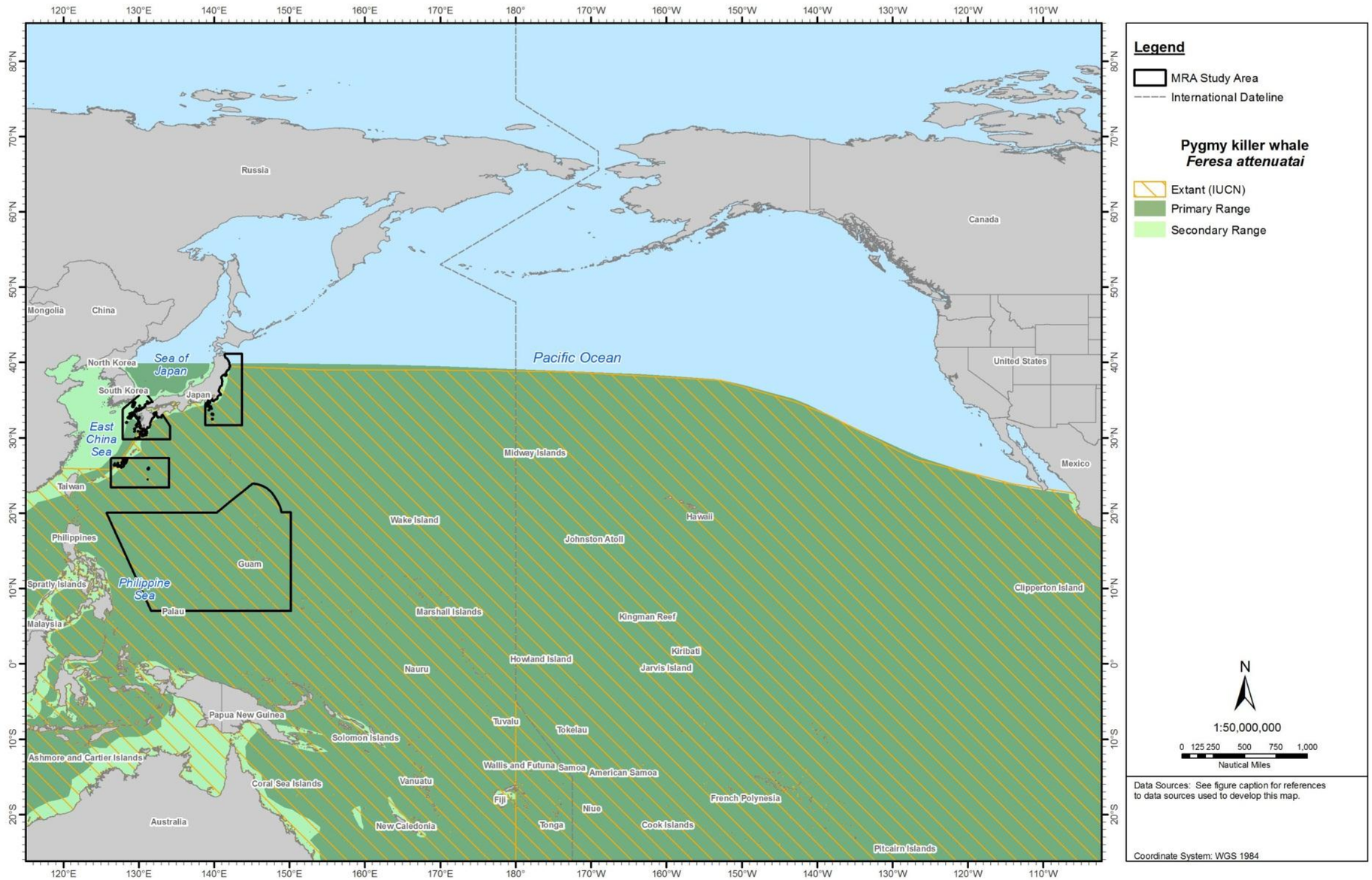

Figure 5-76: Geographic Range of the Pygmy Killer Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

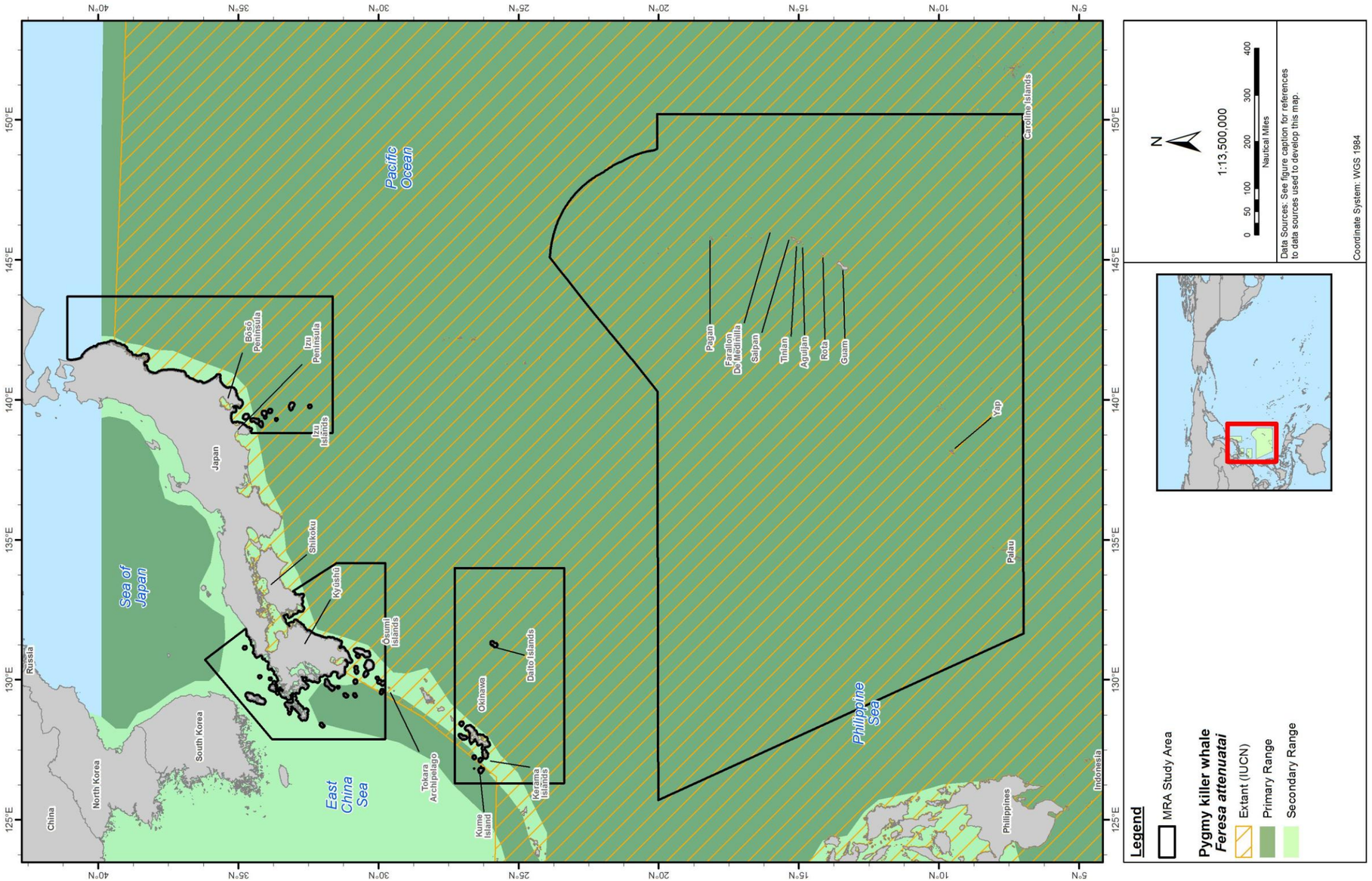

Figure 5-77: Geographic Range of the Pygmy Killer Whale in the MRA Study Area

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

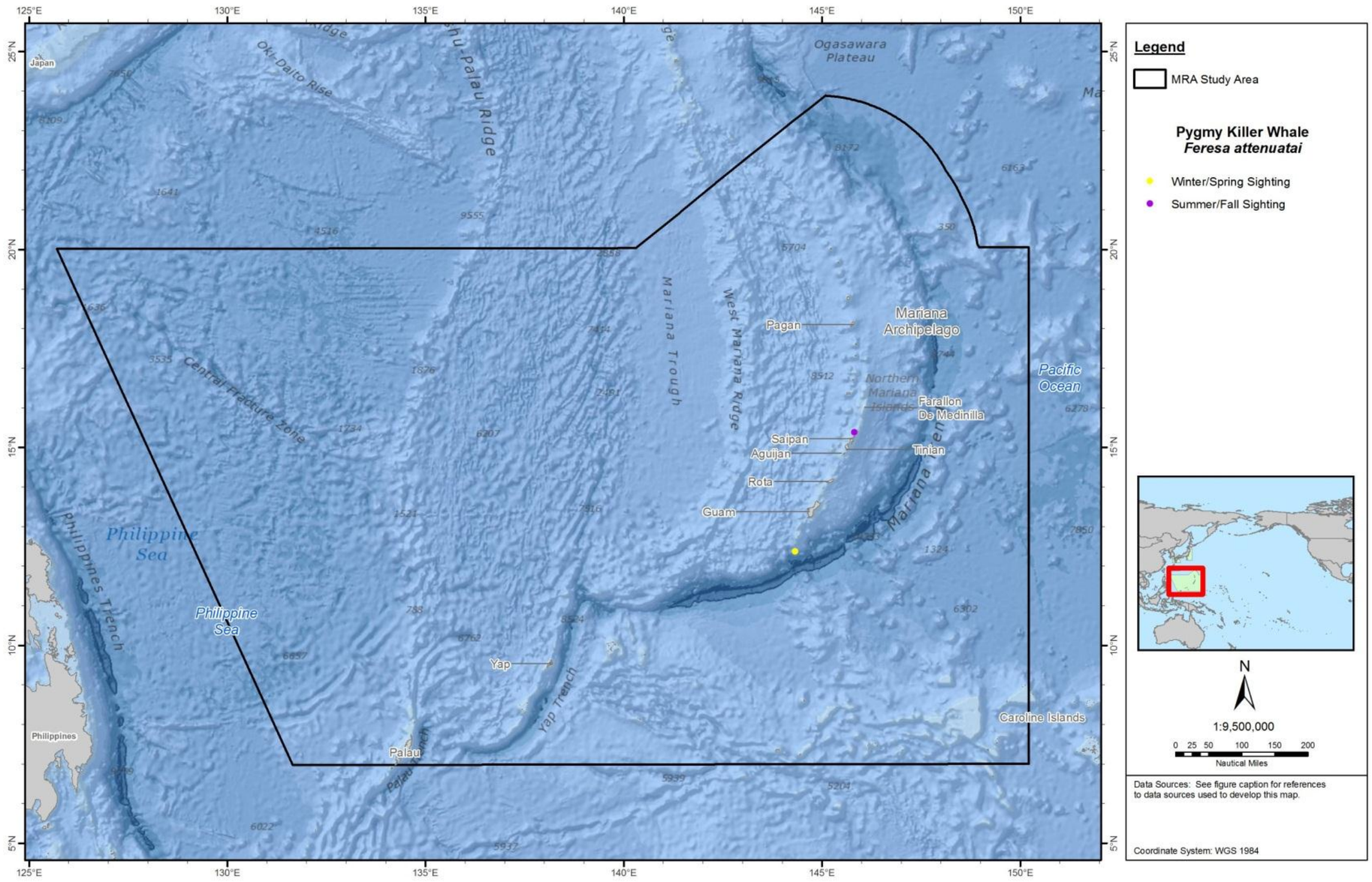

Figure 5-78: Sightings of the Pygmy Killer Whale in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented.
Sources: Fulling, Thorson, and Rivers (2011); Hill et al. (2011); U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific (2007).

This Page Intentionally Left Blank

5.35 FALSE KILLER WHALE (*PSEUDORCA CRASSIDENS*)

5.35.1 Description

The false killer whale has a long slender body. It has a rounded overhanging melon (more protruding in males than in females), with no discernible beak. The melon is relatively narrow seen from above. The dorsal fin, although variable in shape, tends to be falcate and narrow, and is generally somewhat rounded at the tip (however, intraspecific variation is significant). The dorsal fin is located near the midpoint of the back. The flippers of false killer whales have rounded tips and a characteristic hump on the leading edge. The latter is probably the species' most distinctive characteristic, and it gives the flippers the appearance of an S-shape. The flukes are unremarkable (Baird 2009a; Jefferson, Webber, and Pitman 2008).

The false killer whale's color pattern is relatively simple. The animals have a dark gray to black body, with a faint light gray patch on the chest, and sometimes faint light gray areas on the head as well. Any indication of a cape is generally absent, and if present, is very faint and indistinct. Scars on the body may appear white, but over time they appear to repigment, which is not the case in some other species of small cetaceans (Baird 2009a; Jefferson, Webber, and Pitman 2008).

False killer whale adults can be up to 6 m (males) or 5 m (females) long. Large male specimens may weigh up to 2,000 kg. Calves are 1.5 to 2.1 m at birth. Each tooth row contains 7 to 12 stout, conical teeth, which are round in cross-section.

5.35.2 Status and Management

The false killer whale is protected under the MMPA and is not listed under the ESA. This species is also listed as data deficient by the IUCN and falls under Appendix II CITES regulations. While the species is not considered rare, few areas of high density are known. Four Pacific Islands Region management stocks of false killer whales are recognized: (1) the Hawai'i insular stock, including the animals that occur in waters within 100 miles (140 km) of the main Hawaiian Islands; (2) the Hawai'i pelagic stock, including animals that inhabit waters farther than 25 miles (40 km) from the main Hawaiian Islands; (3) the Palmyra Atoll stock, including whales found within the U.S. EEZ of Palmyra Atoll; and (4) the American Samoa stock, including false killer whales found within the U.S. EEZ of American Samoa. There are an estimated 0.6, 10.3, and 0.3 annual deaths or serious injuries caused by fisheries are in the Hawaiian Insural, Hawaiian Pelagic, and Palmyra Atoll stocks, respectively (Carretta et al. 2012). Based on recent evidence of a serious decline in this population (Reeves, Leatherwood, and Baird 2009), a Take Reduction Team (a team of experts to study the specific topic, also referred to as a Biological Reduction Team) was formed by NOAA on January 19, 2010, as required by the MMPA. The Take Reduction Team conducted a status review published in August 2010 (Oleson et al. 2010), and will draft a Take Reduction Plan (also required under MMPA) for assessing ways to reduce mortality and serious injury to this population.

5.35.3 Population and Abundance

False killer whale stock assessments are available for the Hawai'i Pelagic Stock, the Palmyra Stock, and the American Samoa Stock (estimated 484 [CV=0.93], 1,329 [CV=0.65], and an unknown number of whales, respectively) (Carretta et al. 2011f). An estimated 6,000 false killer whales are within the area surrounding (mostly north of) the Mariana Islands (Miyashita 1993b). False killer whales are not considered a rare species, but few areas of high density are known (Baird 2009b; Jefferson, Webber, and

Pitman 2008). A 2007 cetacean survey (Fulling, Thorson, and Rivers 2011) estimated the number of this species in Guam and the CNMI at 637 individuals.

5.35.4 Biology, Ecology, and Behavior

The false killer whale is an active, fast-moving dolphin. This species occasionally rides bow waves of vessels (Baird 2009a). False killer whales have been observed in association with other species, particularly bottlenose dolphins (Leatherwood et al. 1988).

Group Size. False killer whale social ecology is not as well-known as is that for most other tropical oceanic delphinids. False killer whales may occur in large groups (group sizes as large as 300 have been reported) (Baird 2009b; Brown, Caldwell, and Caldwell 1966), and are considered extremely social with high group fidelity (Baird, Gorgone, et al. 2008). Group sizes of 10 to 60 are most commonly observed. Some groups move in a tight-knit herd, but others are sometimes distributed over an ocean region of more than 1 km. Mass strandings of false killer whales occur as frequently or more frequently than those of other cetacean species, sometimes in large numbers (reported ranges in various geographic regions vary from 50 to a high of 835 animals; mean = 180) (Oleson et al. 2010).

Predator/Prey Interactions. False killer whales feed primarily on deep-sea cephalopods and fish (Odell and McClune 1999). They may prefer large fish species, such as mahi mahi and tunas. Twenty-five false killer whales that stranded off the coast of the Strait of Magellan were examined and found to have fed primarily on cephalopods and fish. Squid beaks were found in nearly half of the stranded animals. The most important prey species were found to be the squid species *Martialiabyadesi* and *Illex argentinus,* followed by the coastal fish, *Macruronus magellanicus* (Alonso et al. 1999). False killer whales have been observed to attack other cetaceans, including dolphins, and large whales, such as humpback and sperm whales (Baird 2009a). They are known to behave aggressively toward small cetaceans in tuna purse seine nets. Unlike other whales or dolphins, false killer whales frequently pass prey back and forth among individuals before they start to eat the fish, in what appears to be a way of affirming social bonds (Baird et al. 2010b).

This species is preyed upon by large sharks and by killer whales (Baird 2009a) (Visser et al. 2010). Like many marine mammals, false killer whales accumulate high levels of toxins in their blubber over the course of their long lives. Because they feed on large prey at the top of the food chain (e.g., squid, tunas) they may be impacted by competition with fisheries (Cascadia Research 2010).

Life History. Despite the prevalence of mass strandings of this species, life history parameters have not been well documented. No pronounced seasonality in breeding is known for the false killer whale, although the Hawaiian population has a breeding season that lasts for several months (National Marine Fisheries Service). Based on the little available information, both males and females are believed to attain sexual maturity between 8 and 14 years. False killer whales are slow to reproduce, having one calf only every 6 to 7 years (Cascadia Research 2010). Measured lengths of newborns are documented between 1.5 and 2.1 m (Jefferson, Webber, and Pitman 2008). False killer whales are long-lived animals, with known life spans of up to 57 years for males and 62 years for females (Baird 2009a).

Migration. False killer whales are not considered a migratory species, although seasonal shifts in density likely occur. Seasonal movements in the western North Pacific may be related to prey distribution (Odell and McClune 1999). Satellite tracking of individuals around the Hawaiian islands indicated that false killer whales can move extensively among different islands and also sometimes move from an island coast to as far as 60 miles (96 km) offshore (Baird 2009a).

Hearing/Vocalization. The best hearing sensitivity measured for a false killer whale was around 16 to 64 kHz (Thomas et al. 1988; Thomas, Pawloski, and Au 1990), with peak sensitivity around 30 kHz (Yuen et al. 2005). Hearing through echolocation may be a dynamic practice whereby alteration of the beam shape and focus may help the animal conserve energy while increasing the accuracy of the transmitted information (Kloepper et al. 2012). False killer whales hear outgoing and returning clicks at similar levels, by actively dampening the intensity of outgoing vocalization. They are able to hear returning signals at comparable levels even when distant or smaller objects are located using the same outgoing call levels (Nachtigall and Supin 2008). Hearing of its own echolocation was 30 to 45 dB lower than hearing in a free acoustic field (Supin, Nachtigall, and Breese 2006). False killer whales can not only distinguish varying frequencies during echolocation but also harmonic content (Yuen et al. 2007).

The dominant frequencies of false killer whale whistles are 4 to 9.5 kHz; those of their clicks are 25 to 30 kHz and 95 to 130 kHz (Thomas, Pawloski, and Au 1990; Thomson and Richardson 1995). The source level is 220 to 228 dB re 1 µPa-m (Ketten 1998).

Diving. The maximum known dive depth of false killer whales is about 500 m (Odell and McClune 1999), but based on feeding habits, this species probably dives to depths exceeding that (Ligon and Baird 2001; Odell and McClune 1999). A recent tagging study in Hawaiian waters found false killer whales diving to depths exceeding 235 m, but this was the maximum depth that the time depth recorder was capable of recording. Based on recorded duration, and ascent and descent rates, dive depths of foraging whales were estimated to be deeper than the maximum instrument-recorded depth, and could have been as deep as 700 m (Baird 2009a). The most frequent prey fish found were at depths of 100 to 200 m, while squid were most abundant at depths of 200 to 500 m (Alonso et al. 1999). In subtropical and temperate waters of southern Brazil, false killer whales were found feeding at depths ranging from 50 to 800 m (Andrade, Pinedo, and Barreto 2001).

5.35.5 Habitat and Distribution

The false killer whale has an extensive range throughout the tropics and some warm temperate zones of the Atlantic, Pacific, and Indian oceans. They are found in warmer and temperate waters of the World, generally between 50°S and 50°N latitude with a few records north of 50°N in the Pacific and the Atlantic oceans. False killer whales have been detected in acoustic surveys and are commonly observed in the ETP from the U.S./Mexico border to Peru (Oswald, Barlow, and Norris 2003; Wade and Gerrodette 1993).

They occur in offshore waters and around oceanic islands, and only rarely come into shallow coastal waters (Baird 2009a; Odell and McClune 1999). However, false killer whales have sometimes been known to approach very close to shore in such areas as the inshore waters of Washington and British Columbia (Baird, Langelier, and Stacey 1989), the coast and estuaries of China (Zhou, Qian Weijuan, and Li Yuemin 1982), the Marquesas Islands of French Polynesia (Gannier 2002), and Lembata Island of the Indonesian archipelago (Rudolph, Smeenk, and Leatherwood 1997). Inshore movements are occasionally associated with movements of prey and shoreward flooding of warm ocean currents (Stacey, Leatherwood, and Baird 1994).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. In the North Pacific, this species is known to occur in deep oceanic waters off Hawai‘i, and elsewhere in the Pacific (Figure 5-79) (Carretta et al. 2010; Miyashita et al. 1996; Wang, Yang, and Liao 2001).

KURISHIO CURRENT. The area of expected occurrence for the false killer whale is from the shelf break to 200 nm (370 km) offshore (Figure 5-79).

EAST CHINA SEA. The East China Sea is included in the primary range of the false killer whale (Figure 5-79).

PHILIPPINE SEA. The Philippine Sea is included in the primary and secondary range of the false killer whale (Figure 5-79).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Expected occurrence extends into the Tsushima Strait in waters up to the shoreline, as deep water occurs close to shore here. False killer whales may occur between the shore and the shelf break (they are not expected in shallow bays) or elsewhere in the MRA Study Area. Occurrence pattern is believed similar throughout the year.

MARIANA ARCHIPELAGO. The false killer whale is an oceanic species, occurring in deep waters, and is known to occur close to shore near oceanic islands (Perrin, Würsig, and Thewissen 2008). The false killer whale in the Mariana Islands MRA Study Area and vicinity is expected to occur seaward of the 50 m isobath (Figure 5-81). Ten false killer whales were sighted during a 2007 survey conducted in Mariana Islands waters in waters with bottom depths between 3,059 and 8,058 m (U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007), and additional individuals were detected in the area acoustically (Norris et al. 2011). These whales were found over 200 nm off the west and east coasts of the archipelago (Fulling, Thorson, and Rivers 2011). They may occur from the coastline to the 50 m isobaths, as deep water is very close to shore at these islands. Occurrence pattern is believed the same throughout the year.

Guam. In 2007, there was a false killer whale sighting off the west coast of Guam where water depth is approximately 2,500 m (Fulling, Thorson, and Rivers 2011). Through acoustic recordings and visual sightings, false killer whales were identified off the west coast of Guam and about 200 miles southeast of the island (Norris et al. 2011).

CAROLINE ISLANDS. The Caroline Islands are included in the known range of the false killer whale, and has been documented in coastal waters (Figure 5-79 and Figure 5-80).

5.35.6 Species-specific Threats

Although only rarely taken as a bycatch in fisheries (e.g., driftnets and purse seines), false killer whales often steal fish from longlines and do sometimes get caught on the hooks. These activities may lead to death. They are also shot and otherwise persecuted by fishermen because of this habit. They have been killed in direct fisheries in Japan (where they are driven into shallow bays and speared). In the Republic of (South) Korea “whale meat” markets still can buy and sell meat from stranded or bycaught marine mammals, implying that direct hunting may still occur. A DNA surveillance study from 2003 to 2005 found false killer whale meat present in area markets (Baker et al. 2006). False killer whales have also been live-captured for public display.

Effects of environmental contaminants are another concern. False killer whales examined in Hawaiian waters contained significant levels of anthropogenic contaminants, including PCBs, DDTs, hexachlorocyclohexane, hexachlorobenzene, PBDEs, and other insecticides (mirex and dieldrin) (Ylitalo

et al. 2009). Concentrations of butylin and phenyltin were found in the organs and tissue of false killer whales off the coast of Thailand (Harino et al. 2007a).

This Page Intentionally Left Blank

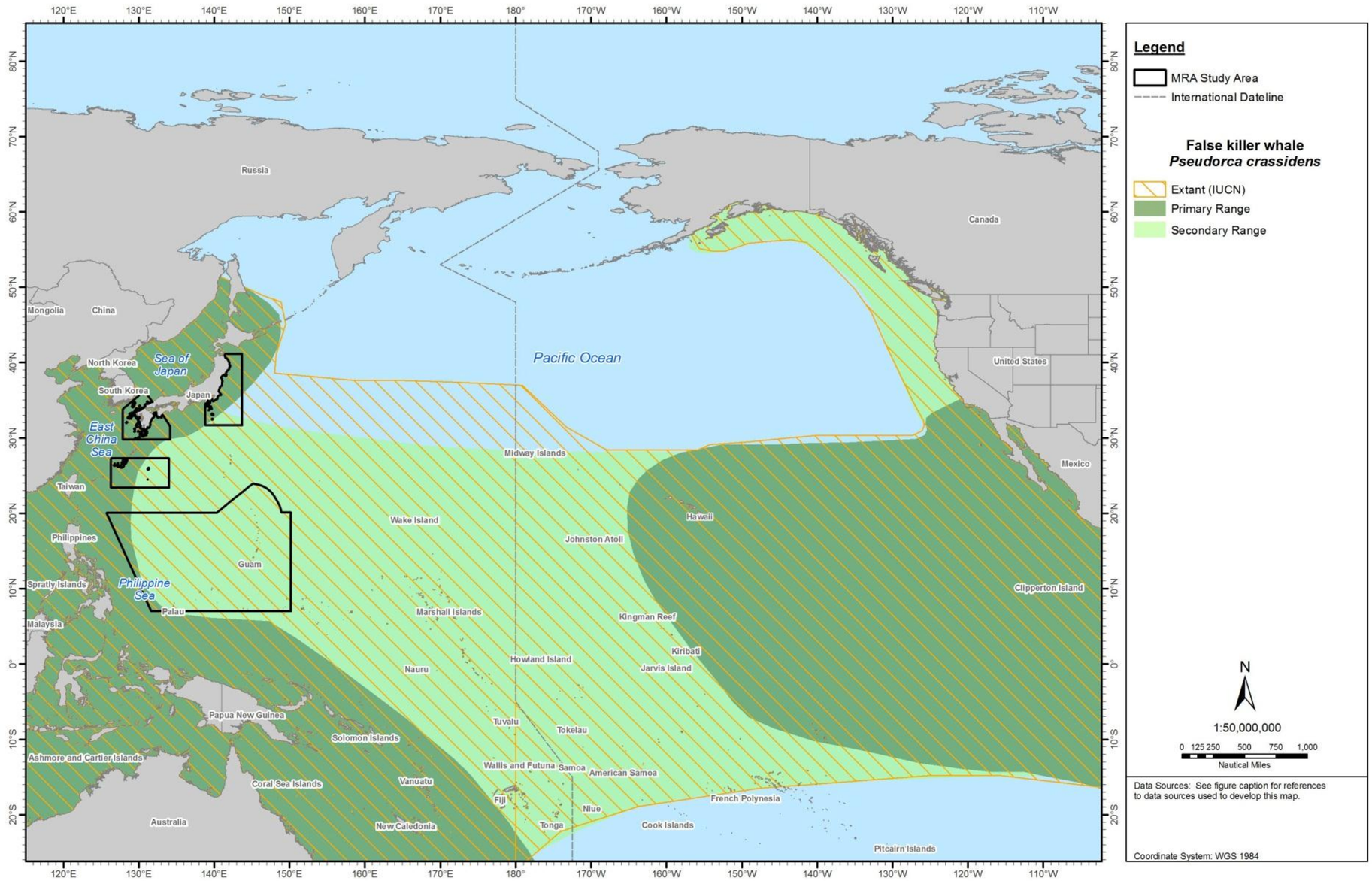

Figure 5-79: Geographic Range of the False Killer Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

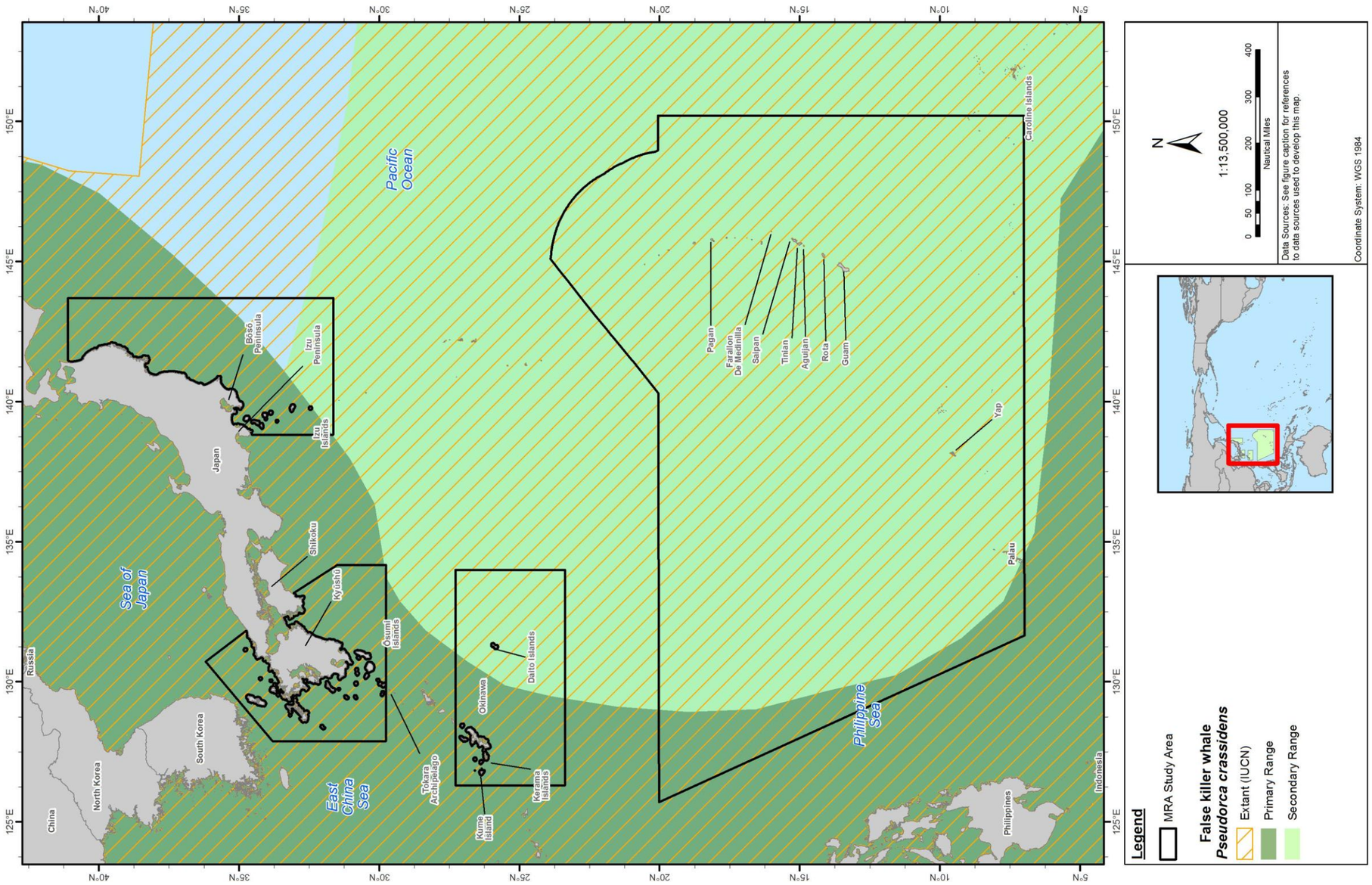

Figure 5-80: Geographic Range of the False Killer Whale in the MRA Study Area

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

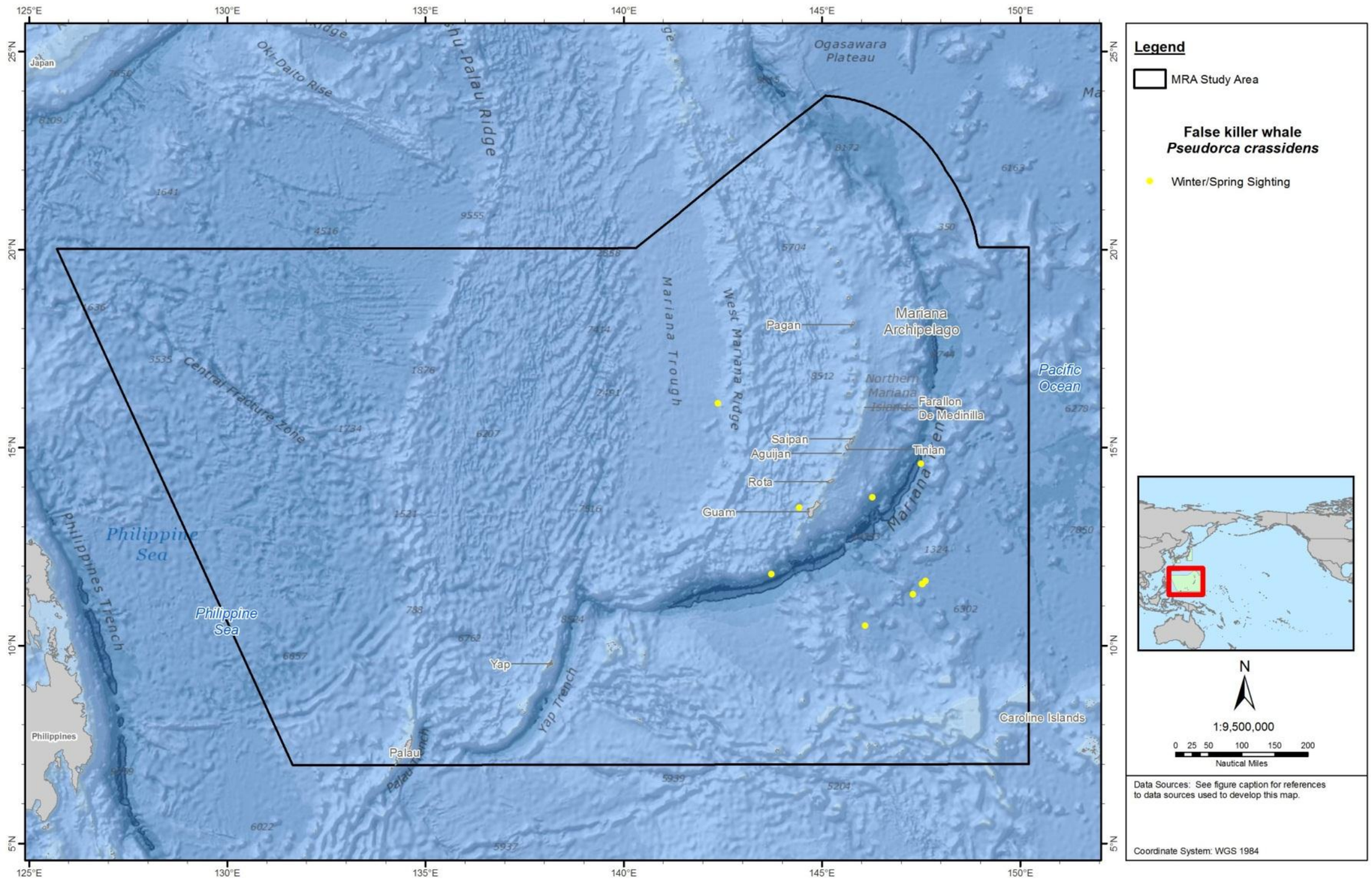

Figure 5-81: Sightings of the False Killer Whale in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented.
Sources: Fulling, Thorson, and Rivers (2011); U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific (2007).

This Page Intentionally Left Blank.

5.36 KILLER WHALE (*ORCINUS ORCA*)

5.36.1 Description

A single species of killer whale is currently recognized, but strong and increasing evidence indicates the possibility of several different species of killer whales worldwide, many of which are called “ecotypes” (Ford 2008). The different geographic forms of killer whale are distinguished by distinct social and foraging behaviors and other ecological traits, as well as differences in size, morphology, and color. In the North Pacific, these recognizable geographic forms are variously known as ‘‘residents’’ and ‘‘transients” and “offshore” ecotypes (Hoelzel et al. 2007). The triansient and the resident population off Kamchatka in Russia are the populations most likely found in the MRA Study Area. A newly identified type in Antarctic waters is broken into three types, called Types A, B, and C. Of these, the most is known about Type C.

Killer whales generally have a robust body that is somewhat spindle-shaped. They have blunt snouts, with only very short and poorly-defined beaks. The mouthline has a slight downward curve toward the gape. The tall, erect dorsal fin is unmistakable, although variations occur among the different ecotypes; the dorsal fin may reach 0.9 m high in females and 1.8 m in males. The dorsal fins of females and young whales are falcate, and are generally pointed or slightly rounded at the tip. In adult males, the dorsal fins tend to be triangular or may even cant forward to a certain degree. The flippers can be extremely large (especially in adult males) and are oval, with blunt tips. Killer whales grow to lengths of up to 2 m (about 11% to 17% of total length of adult females, and 18% to 22% of total length of adult males). Dorsal fins of transients tend to be straighter at the tip than those of residents. Offshore killer whales appear physically smaller than residents or transients, and their fins appear more rounded at the tip with multiple nicks on the trailing edge. Type C or "Ross Sea killer whales" are a dwarf species, and the smallest of the three known types. They have very small eye spots that are more like broad lines instead of ovals. The three Antarctic types are visually distinct (Pitman and Ensor 2003).

Very limited information suggests that females in tropical climes may have larger flippers. The flukes are broad, and they have a straight or even slightly-convex trailing edge. The fluke tips may curl down in large adults (especially bulls) (Dahlheim and Heyning 1999).

Killer whales are black and white, and unmistakable when sighted given their unique morphology and coloration. The lower jaw, undersides of the flukes, and ventral surface from the tip of the lower jaw to the urogenital area are white. White lobes extend up the sides behind the dorsal fin, and a white oval patch of varying shape is above and behind each eye. The remainder of the body is black, except for a light-gray "saddle patch" behind the dorsal fin (not present in all populations). In some areas, a distinct dorsal cape may extend forward from the lower point of the saddle. The boundaries between black and white are usually very distinct and sharp (Dahlheim and Heyning 1999; Jefferson, Webber, and Pitman 2008). On August 7, 2000, a rare sighting of an albino adult resident killer whale occurred in the Aleutian Islands; this animal had an almost all-white coloration (Renner and Bell 2008).

Adult female killer whales are up to 8.5 m long and can weight 7,500 kg; adult males can be up to 9.8 m long and weigh nearly 10,000 kg. Geographic variation among different populations is extensive. Newborns are 2.1 to 2.6 m long and weigh approximately 160-180 kg. Killer whales have 10 to 14 large, slightly recurved teeth in each tooth row; these are pointed and oval in cross section.

5.36.2 Status and Management

The killer whale is protected under the MMPA, and the overall species is not listed on the ESA. The Southern Resident population is listed as endangered under the ESA and is depleted under the MMPA. The North Pacific transient stock is also depleted under the MMPA. This species is also listed as data deficient by the IUCN and falls under Appendix II CITES regulations. Five killer whale stocks are recognized within the Pacific U.S. EEZ: Hawaiian, southern residents, northern residents, southern Alaska residents, and western Alaska North Pacific resident. There are no annual deaths or serious injuries caused by fisheries in the Hawaiian stock (Carretta et al. 2012). Killer whales are not actively managed by most countries in their range, although the IWC has dealt with catches and quotas on an ad hoc basis over the years. The most current recovery plan for the killer whale, completed in 2008, focuses on the Southern Resident Stock off the northwestern coast of the United States. The recovery plan addresses issues such as prey availability, pollution, vessel and acoustic disturbances, and oil spills, and recommends improvements for this species from better response practices, better coordination and monitoring efforts, and education for the public through improved outreach (National Marine Fisheries Service 2008).

5.36.3 Population and Abundance

Global estimates for the killer whale are about 50,000 individuals (Forney and Wade 2006). A survey documented 53 individuals within eastern Canadian Arctic waters (Young, Higdon, and Ferguson 2011), thought to be a minimum abundance estimate for the area (Aznar et al. 2006). Approximately 8,500 individuals are believed to inhabit the ETP (Wade et al. 2003). The closest stock assessment for this species was for the Hawaiian stock (estimated 349 [CV=0.98] whales). No data are available regarding population trends in this area (Carretta et al. 2011i).

5.36.4 Biology, Ecology, and Behavior

Killer whales, like sperm whales, have among the most stable social systems known of all cetaceans. They are one of the most well studied of all cetaceans and are considered extremely complex animals.

Long-term associations among individuals are evident in the resident ecotype of the killer whale, with only limited dispersal from maternal groups known as pods (Baird 2000). Typically, resident pods are known to be stable societies, and individuals may remain in the pod of their birth for life. Pods are known to be matrilines, meaning that they are all related through their mothers' genetic line (Jefferson, Webber, and Pitman 2008; Olesiuk, Ellis, and Ford 2005). In a multi-year social analysis of the J, K, and L pod in the northwest of the U.S., the largest pod (L) had the lowest overall intrapod association. A decline in population size correlated with an increase in fluidity within social units, possibly a common response to outside stressors (Parsons et al. 2009).

In addition to the resident killer whale ecotype, three other ecotypes are currently recognized—including the newest, the Antarctics, of which the best known is the Type C. In addition to residents are transients, offshores, and Type Cs. These four ecotypes have low genetic diversity and differing behaviors that have undergone arguable speciation (Morin et al. 2010; Pilot, Dahlheim, and Hoelzel 2010). Life expectancy of adult male transients seems lower than that of the resident males in Alaska (Herman et al. 2008). Resident Killer whales cover a much larger geographic range and move predictably (Andrews, Pitman, and Ballance 2008), in contrast to the offshores, who roam the Pacific coast from its northern to southern regions, or the type C killer whales, who tend to have a more confined distribution and live in dense pack ice areas (Pitman et al. 2007).

Killer whales are very active at the surface, with aerial behavior often performed in bouts (Ford 2008). Optimal swimming speed for energy expenditure is between 2.6 to 3 m/s., yet whales in western Canadian waters were observed to average 1.6 m/s. (Williams and Noren 2009).

Group Size. As an overall generalization for all killer whales, pod size generally ranges from 1 to 55, with resident pods typically larger than transient (or Type C) pods, which usually number fewer than 10 (Jefferson, Webber, and Pitman 2008; Olesiuk, Ellis, and Ford 2005). Pods often break into subunits and travel apart from each other for periods of time.

Predator/Prey Interactions. Killer whales feed on a variety of prey, including bony fishes, elasmobranchs (a class of fish composed of sharks, skates, and rays), cephalopods, seabirds (including penguins), and even sea turtles (including leatherbacks) (Elwen and Leeney 2011). Residents eat primarily salmon and sometimes squid; the transient ecotype eats other marine mammals including whales (one confirmed record on false killer whales (Visser et al. 2010), porpoises, walruses, seals, and sea lions (Fertl, Acevedo-Gutiérrez, and Darby 1996; Jefferson, Webber, and Pitman 2008; Laidre, Heide-Jorgensen, and Orr 2006; Vos, Quakenbush, and Mahoney 2006). Offshores eat schooling fish and perhaps sharks. Although killer whales do prey on sea otters, otters alone likely could not sustain this large animal; thus these killer whales depend on the abundance of great whale species for their survival (Estes et al. 2009). Increasingly, large whale species have been hunted by transient killer whales, particularly gray whales, whose migratory routes to and from the northern Pacific feeding grounds can be impeded due to this predation (Morell 2011). In a survey of transient killer whales in the northeast Pacific, a calculated kill rate of 0.62 prey items/24 hours was documented, and prey handling techniques changed with differing target species (Dahlheim and White 2010). Some populations are known to specialize in specific types of prey (Jefferson, Webber, and Pitman 2008; Krahn et al. 2004; Wade, Ver Hoef, and DeMaster 2009), which may change due to seasonal movements (Durban et al. 2010). Killer whales have been observed making “false attacks” on sea lions, possibly in order to exhaust prey (Wolf and Mangel 2007).

Although the killer whale has no known natural predators and is considered the top predator of the oceans (Ford 2008), one reported combat between a killer whale and a great white ended with the killer whale killing the great white (Turner 2004). Bite marks attributed to the Cookie Cutter Shark (*Isistius spp*.) have been documented on killer whales in tropical and cold waters of the Pacific (Boisseau 2005), and calculated population limitations have correlated with availability of the northeastern Pacific populations of Chinook salmon, their principal prey species in the area (Ford et al. 2010).

Life History. Female and male killer whales typically reach sexual maturity at about 8 to 15 years (Ford and Ellis 1999), and peak reproduction occurs between 20 and 22 years (Ward, Holmes, and Balcomb 2009). Based on studies conducted in captivity, sexually mature males are 13 years and older (Robeck and Monfort 2006). Reproductive success increases as male size and age increases (Blois-Heulin et al. 2012). Fecundity in two threatened populations off the western Canada coast strongly correlates with abundance of Chinook salmon (Ward, Holmes, and Balcomb 2009). Among resident killer whales in the northeastern Pacific Ocean, females typically give birth for the first time at 11 to 15 years (Ford and Ellis 1999). Pregnancy lasts 15 to 18 months in this species. Calving takes place year round in waters of the Pacific Northwest, but with a peak from October to March (Ford and Ellis 1999). After their peak reproductive stage, female whales decline in fecundity over the next 25 years, reaching a menopausal period later in life (Ward, Holmes, and Balcomb 2009). Killer whales are one of the toothed whales with a distinct menopausal, or post-reproductive, period later in life characterized by aiding younger females in reproduction (Johnstone and Cant 2010). Evidence of breeding between related individuals has been documented, for mates primarily come from within a long-term social group (Blois-Heulin et al. 2012).

Migration. In most areas of their range, killer whales do not show a movement pattern that would be classified as traditional migrations. However, seasonal shifts in density occur frequently—both onshore/offshore and north/south. A tracked killer whale off the coast of Eastern Canada remained in the area while prey aggregates overlapped, then prey availability shifted as ice cover increased. The whale traveled along the east coast of Baffin Island (potentially following the shifts in prey) and into the northern Atlantic. Although this account does not necessarily signify a migration, the 5,400 km covered in one month (average 159.4 ± 44.8 km/day) by this whale indicates the killer whale's ability to undertake long-distance travel (Bearzi, Reeves, et al. 2011).

Hearing/Vocalization. The killer whale has the lowest frequency of maximum sensitivity and one of the lowest high-frequency hearing limits known among toothed whales (Szymanski et al. 1999). The upper limit of hearing is 100 kHz for this species. The most sensitive frequency, in both behavioral and in auditory brainstem response audiograms, has been determined as 20 kHz (Szymanski et al. 1999). Killer whales can distinguish among various salmon species by recognizing differences in the structure of echoes during foraging vocalizations (Au, Horne, and Jones 2010).

The killer whale produces a wide variety of clicks, discrete calls, and whistles, but most of its sounds are pulsed and at 1 to 6 kHz (Thomson and Richardson 1995).Yet Samarra et al. (2010) highlights the importance of sampling techniques and intraspecific variation in recordings of whistles up to 75 kHz. Source levels of echolocation signals range between 195 and 224 dB re 1 µPa-m (Au et al. 2004). High-frequency modulated signals have been recorded in the North Pacific with a peak frequency from 19.6 to 36.1 kHz where the median duration is from 50 to 163 ms with a source level 185 to 193 re:1 µPa at 1 m. These calls may be used in echolocation (Simonis et al. 2012). Killer whales in the offshore ecotype call with a higher minimum frequency than other ecotypes, possibly to avoid masking of their signals and calls by the increased noise within their habitat (Foote and Nystuen 2008). Calls associated with aggression in captive individuals are characterized by pulses modulated in amplitude and frequency lasting 190 ms, and may aid our understanding of calls by wild killer whales (Graham and Noonan 2010). Acoustic studies of resident killer whales in British Columbia have revealed dialects. These killer whales have highly stereotyped, repetitive, discrete calls that are group-specific and shared by all group members (Perrin, Würsig, and Thewissen 2008). These dialects likely are used to maintain group identity and cohesion, and may serve as indicators of relatedness that help to avoid inbreeding between closely related whales (Perrin, Würsig, and Thewissen 2008). Dialects also have been documented in killer whales present in northern Norway, and likely occur in other locales as well (Perrin, Würsig, and Thewissen 2008). Although dialects do exist, some universal "expressions" or calls have been recorded, indicating some degree of innate vocalization repertoires (Baumgartner et al. 2011). Shared repertoires have been shown to correlate to matrilines, and reflect relatedness and social affiliation for the purpose of kin recognition that may subsequently shape whale group association behaviors (Deecke et al. 2010). However, these trans-group similarities are rare, and often groups are still distinguishable from each other (Weiss et al. 2011). Individual-specific calls have been recorded and may be a useful tool for tracking individuals over time (Brown, Smaragdis, and Nousek-McGregor 2010). This can proceed not only by interpretion of dialects, but by use of results from cataloging biphonic and monophonic calls that may correlate with population and habitat characteristics. When more than one group was present in an area and inter-pod affiliations increased, calls were mainly biphonic, whereas monophonic calls occurred when only one pod was present (Filatova et al. 2009; Foote, Osborne, and Hoelzel 2008). Some dialects off the coast of Shetland, UK not only differ among groups but vary according to differing prey types (mammal-eating versus fish-eating killer whales). This trait is hypothesized to have evolved in groups preying on acoustically sensitive species (Barlow et al. 2011; Borsa 2006). In a case study of two juveniles during long-term separation from their pod, mimicry of sea lion calls was recorded, and

differing usage of calls indicated the possibility of vocal learning within this species (Foote et al. 2006). When killer whales were exposed to recordings of calls from their pod, they sent response calls and most often changed direction to swim toward the calls; yet when calls from another pod were played, movement toward the origin was less frequent (Filatova et al. 2011). In the presence of vessel noise, killer whales have increased the amplitude of their calls to compensate (Beron-Vera et al. 2007). Calls are reduced during hunting, possibly to decrease detection by prey species; the calls then increase following completion of a successful attack—possibly to alert others of the availability of food, perhaps to indicate a time of general increase in socialization, or possibly as a result of increased energy regained at cession of hunting (Deecke, Ford, and Slater 2005).

Diving. The maximum depth recorded for free-ranging killer whales diving off British Columbia is 264 m (Baird, Hanson, and Dill 2005). Regular dives to or close to the bottom in depths of over 100 m, with a maximum depth of 260 m, have been recorded (Baird, Hanson, et al. 2003). A trained killer whale dove to a maximum of 260 m (Dahlheim and Heyning 1999). Tagged killer whales in Washington were recorded diving to a maximum depth that exceeded 230 m, which was the limit of the time depth recorder; however, most of the dives terminated within the upper 30 m of the water column—on average, for seven tagged individuals, less than 1% of all dives examined exceeded depths of 30 m (Baird, Hanson, et al. 2003). Dive durations of over 10 min have been recorded (Saulitis et al. 2000). The longest duration of a recorded dive from a radio-tagged killer whale was 17 min (Dahlheim and Heyning 1999). Transient and resident killer whales differ markedly in travel patterns, dive intervals, and group sizes. Transients travel along shorelines more frequently, have longer average dive times, and live in smaller groups than residents (Barrett-Lennard, Ford, and Heise 1996). Within-group variations in dives have been documented in southeast Alaska, where day-night comparisons showed deep and shallow longer dives were less frequent at night (Miller, Shapiro, and Deecke 2010). Killer whales have been observed performing a hunting tactic whereby they congregate in large groups, dive to 160 to 180 m below schooling herring, and in coordination push herring more than 150 m up, splitting the large aggregations of fish into small dense schools. During these hunting tactics, the maximum depth recorded was 590 ft. (180 m) (Nøttestad, Fernö, and Axelsen 2002). Group diving and surfacing tend to be closely synchronized, with longer dives of 2 to 5 min separated by three or four short shallow dives (Ford 2008). (Miller, Shapiro, and Deecke 2010) suggest a compromise among individuals during synchronized dives, whereby smaller members dive close to their physiological limits and larger whales never exceed their aerobic dive limit.

5.36.5 Habitat and Geographic Range

Killer whales are found in all marine habitats from the coastal zone (including most bays and inshore channels) to deep oceanic basins, and from equatorial regions to the polar pack ice zones of both hemispheres. Although killer whales are also found in tropical waters and the open ocean, they are most numerous in coastal waters and at higher latitudes (Dahlheim and Heyning 1999).

The killer whale is a truly cosmopolitan species, and its range includes all marine waters of world from the equator to the ice edges—all oceans, seas, bays, and gulfs—and the species even moves into estuarine or fresh waters on occasion (Dahlheim and Heyning 1999). Three geographic forms of killer whales (Antarctic types) are recognized in the Southern Hemisphere: Types A, B, and C (Pitman and Ensor 2003). Type A is the most widely-distributed, extending from tropical waters to the high latitudes. Types B and C appear to have more restricted distributions, both occurring mainly around the Antarctic continent, often among the pack ice. Arctic populations around eastern Canada may pulse and advance in range because of climate change and melting ices (Higdon and Ferguson 2009).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. This species is known to occur in deep oceanic waters in the Pacific (Figure 5-82) (Carretta et al. 2010; Miyashita et al. 1996; Wang, Yang, and Liao 2001). In the ETP, killer whales are known to occur from offshore waters of San Diego to Hawai'i and south to Peru (Ferguson 2005; Ferguson, Barlow, Feidler, et al. 2006). Offshore killer whales are known to inhabit both the western and eastern temperate Pacific, and continuous distribution across the North Pacific is likely (Dahlheim et al. 2008). Observations from Japanese whaling or whale sighting vessels are more credible (Miyashita et al. 1996), and indicate concentrations of killer whales north of the Northern Mariana Islands.

KUROSHIO CURRENT. Japanese tuna longline fishermen and Japanese whaling or whale sighting vessels reported killer whale presence in Pacific equatorial waters (Iwashita, Inque, and Iwasaki 1963), although (Reeves et al. 1999) noted that reliability of many records from fishermen is questionable because of insufficient documentation.

EAST CHINA SEA. The East China Sea falls within the known primary range of the killer whale (Figure 5-82).

PHILIPPINE SEA. The Philippine Sea falls within the known primary and secondary range of the killer whale (Figure 5-82 and Figure 5-83).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Expected occurrence of the killer whale is from the shore out to 370 km. This takes into consideration the map in (Dahlheim and Heyning 1999), which shows the distribution of sightings and catches (based in large part on (Nishiwaki and Handa 1958) within an approximately 370-km swath from the Japanese coastline. This is also supported by events from February 1997, when a group of 10 killer whales (including calves) was sighted about 50 km off the Japanese coast and driven into Hatajiri Bay, near Taiji; five individuals were sold for captivity and the others were released (Perry and Thornton 2000). Additionally, a number of sightings occurred north of the Japan and Okinawa MRA Study Area off northern Hokkaidō around the Rishiri and Rebun islands (Nishiwaki and Handa 1958). Famously, during early February 2005, 12 individuals were found trapped in pack ice in the Nemuro Strait off Hokkaidō's Shiretoko Peninsula (Anonymous 2005). Occurrence pattern is believed similar throughout the year.

Bōsō Peninsula, Izu Peninsula, and Izu Islands. In February 2000, a lone male killer whale made its way from the harbor into the canal that runs through Nagoya (Spong 2000). He also reported two individuals seen at the entrance to the Fuji River in Suruga Bay during May 2000.

MARIANA ARCHIPELAGO. The Mariana Archipelago falls with the secondary range of the killer whale (Figure 5-83).The distinctiveness of this species leads to expectation that its regular occurrence in a certain locale would be reported more than that of any other member of the dolphin family. This species has been sighted sporadically in coastal and open ocean tropical waters (Reeves et al. 1999; Rock 1993; Visser and Bonoccorso 2003).

Farallon de Medinilla. Five orcas were identified during an aerial seabird survey of FDM on May 25, 2010 (Wenninger 2010). This pod was seen about 20 miles south os the island. The killer whales had

previously killed a large whale (species not determined) evident by the hindered view of the large, dark mass below the water surface and the surrounding bloodied water.

Tinian. One sighting of a killer whale occurred 27 km west of Tinian in January 1997, and was reported to the NOAA Fisheries Platforms of Opportunity Program.

Guam. A few sightings of killer whales off Guam (most unconfirmed) have been reported (Eldredge 1991). A badly decomposed killer whale was found stranded on Guam in August 1981 (Kami and Hosmer 1982).

CAROLINE ISLANDS. The waters around the Caroline Islands are included in the killer whale's known secondary range (Figure 5-82 and Figure 5-83).

Yap. No reports of sightings of killer whales in the vicinity of Yap were found.

Palau. Killer whales were sighted around Palau (Rock 1993).

5.36.6 Species-specific Threats

Killer whales have been hunted in many areas of the world, but no major fishery has focused on them as the main target. They are sometimes persecuted in retaliation for real or perceived competition with fisheries in many countries (Williams and Lusseau 2006), where local fisheries may be reducing energy acquisition for this species (Williams and Lusseau 2006). Some have been taken for food in Japan, Greenland, Indonesia, and the Lesser Antilles. In the Republic of (South) Korea "whale meat" markets still can buy and sell meat from stranded or bycaught marine mammals. A DNA surveillance study from 2003 to 2005 found killer whale meat present in area markets (Baker et al. 2006). Some have been historically taken, including in the United States, for display in captivity. This still occurs outside of the United States in some areas.

Reduction of food availability (i.e., prey) in certain areas may have a larger effect than that expected from mere caloric deficiencies. Lack of food prey may also create a shift in social structure in the Southern Resident populations of this species. In times of increased prey availability, killer whale have increased social interactions and spend more time clustered together. This tight aggregation, where less time is spent in solitary, hunting activities, has been shown to increase the whole population's suseptability to disease, and may have lasting ecological and evolutionary ramifications (Foster et al. 2012).

Boat traffic has been shown to affect the behavior of the endangered Southern Resident killer whale population around San Juan Island, Washington (Lusseau et al. 2009). In the presence of boats, whales were significantly less likely to forage and significantly more likely to travel (Lusseau et al. 2009). These changes in behavior were particularly evident when boats were within 100 m of the whales. These short-term disruptions of feeding activity may have important long-term consequences at the population level for this endangered group of whales.

Other threats include entanglement in fishing nets and lines, live-captures for display, chemical pollution/oil spills, acoustic disturbance from shipping, oil and gas exploration and extraction activities, and military exercises (Ford 2008; Weir 2008). It has been demonstrated, some killer whales, such as the population residing off Vancouver Island, may modify behaviors due to increased vessel traffic (Wieland, Jones, and Renn 2010). This study calculated an increased call duration over time, showing adjustments

in vocalization possibly because of competition with anthropogenic background noise, and possibly harming whale navigation and communication (Wieland, Jones, and Renn 2010). Off the coast of Washington, killer whales were recorded increasing the amplitude of their calls 1 dB for every 1dB increase of background noise (Holt et al. 2009). Exhaust from whale-watching vessels imbibed by southern resident killer whales has been shown to negatively affect their health (including potential carcinogenic effects). To reduce negative exposure, boats are recommended to position themselves downwind of whales, and no more than 20 vessels should be within an 800-m radius of the animals at one time (Belliere et al. 2011). Killer whales are believed more vulnerable to vessel disturbance during feeding; therefore, proposals for marine protected areas and other regulations are now urged in consideration of how resident populations use an area (Ashe, Noren, and Williams 2010).

Killer whales may be subject to certain pathogens, as indicated by presence of antibodies of *Neospora caninum* in blood samples collected from whales in Japanese waters (Omata et al. 2006). A novel case of zygomytosis associated with *Cunninghamella bertholletiae,* a bacterial infection that may have followed stomach ulcetations from ingested stones in the gastric compartments (Abdo et al. 2012). Anthropogenic contaminants such as DDTs, PCBs, PBDEs, and natural organohalogens including halogenated dimethylbipyrroles, heptachlorinated methylbipyrrole, two methoxylated tetrabromodiphenyl ethers, and dimethoxylated tetrabromobiphenyl were found in the blubber of killer whales stranded off the northern coast of Japan. These concentrations were higher in calves than in nursing mothers, suggesting passage of a large amount of pollutants through the whale's milk (Haraguchi, Hisamichi, and Endo 2009; Kajiwara et al. 2006) and different accumulation between sexes (Burger 2007). In California, accumulation of PCBs in juvenile whales during rapid growth phases of development may increase their risk of immune and endocrine dysfunction (Krahn et al. 2009). In other areas, including the Indian Ocean, persistent organic pollutants have been documented in this species at concentrations exceeding thresholds for known immune and endocrine system disruption (Noel et al. 2009). These pollutants also have been found in killer whale preferred prey (e.g., Chinook salmon in British Columbia) (Cullon et al. 2009). Other potentially harmful compounds (mercury, methyl mercury, and selenium) have been documented in the tissues of killer whales stranded in Japanese waters. Trace levels of these compounds possibly can be passed from mother to fetus or infant (Endo, Kimura, et al. 2007). In northern Japan, liver, kidney, and muscle biopsies showed concentrations of mercury and cadmium that decreased with age. Iron concentrations increased with age, manganese and copper concentrations were higher in calves, and zinc was also found in the tissues of the stranded whales (Endo, Kimura, et al. 2007). Vulnerability to disease may correlate with strength of social links (Guimaraes et al. 2007).

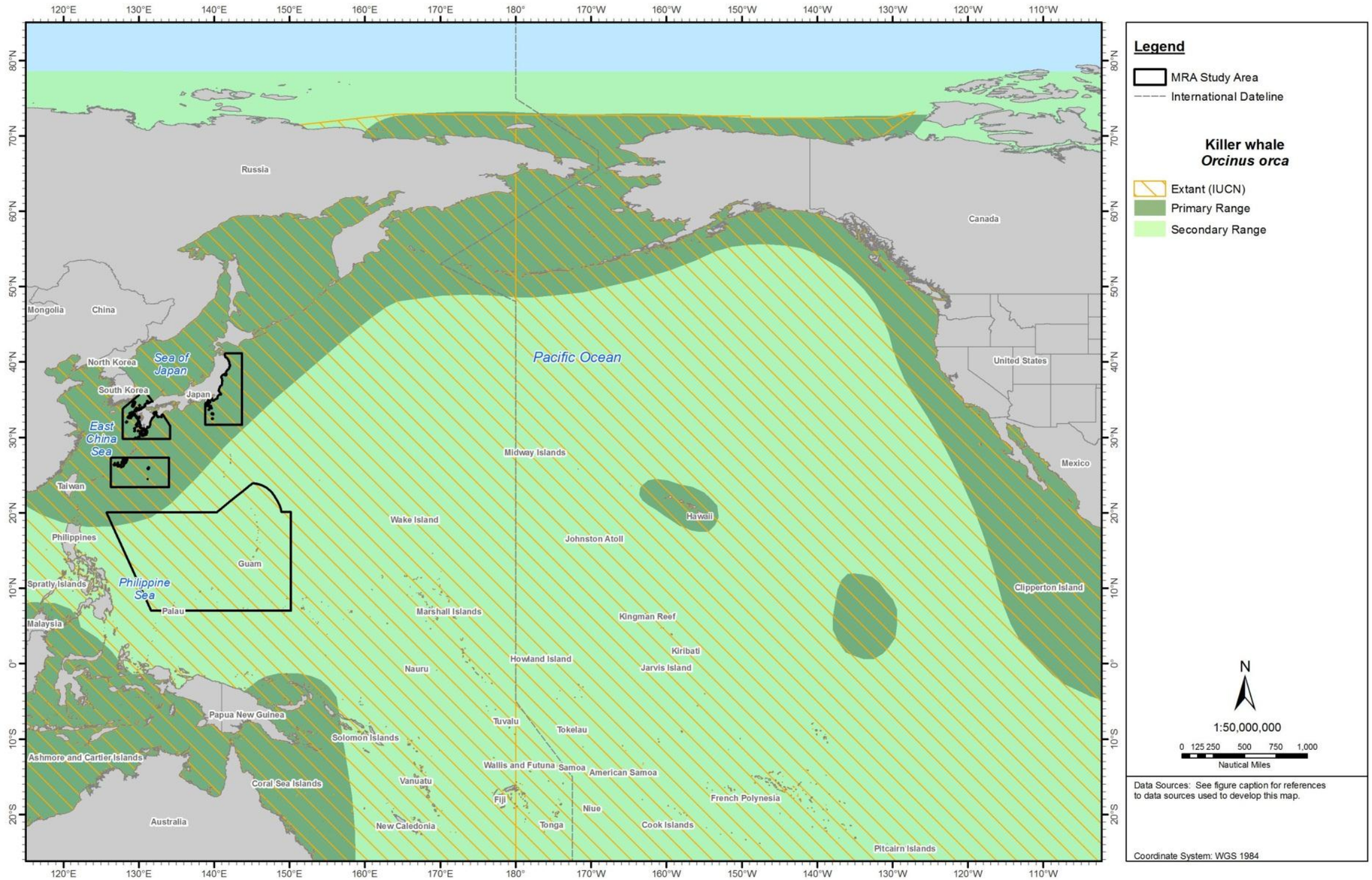

Figure 5-82: Geographic Range of the Killer Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

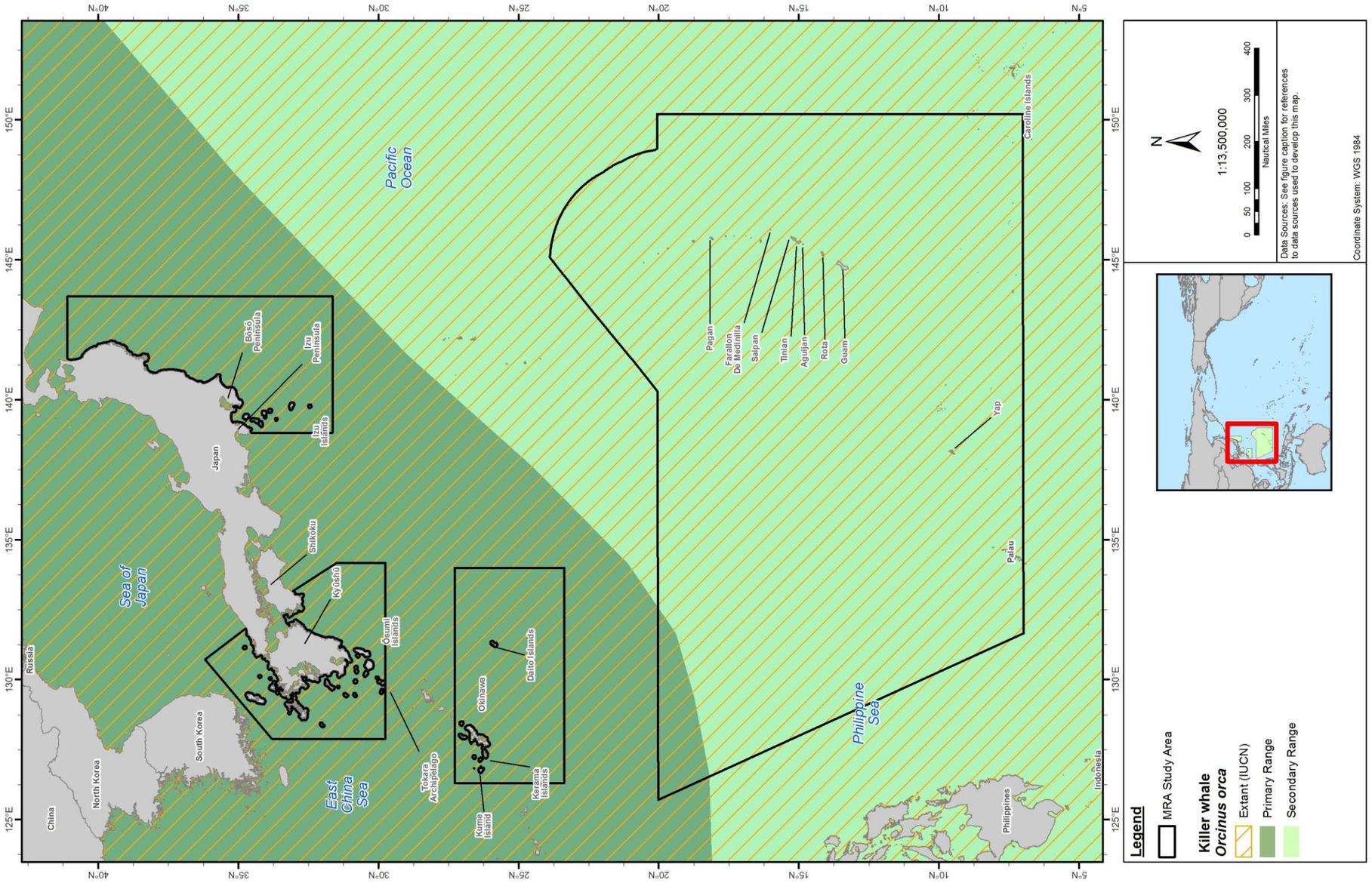

Figure 5-83. Geographic Range of the Killer Whale in the MRA Study Area

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.37 SHORT-FINNED PILOT WHALE (*GLOBICEPHALA MACRORHYNCHUS*)

5.37.1 Description

Even marine mammal experts have difficulty distinguishing between the two species of pilot whales at sea (short-finned, *Globicephala macrorhynchus*, and long-finned, *Globicephala melas*); therefore, many at-sea records identifying these at the species level are questionable. This has resulted in confusion and a lack of clarity in specifying ranges where the two species overlap.

Short-finned pilot whales are large dolphins. They possess bulbous heads, upsloping mouthlines, and short or nonexistent beaks. The shape of the head varies significantly with age and sex, becoming more globose in adult males. In some geographical forms, the head of adult males may appear squarish, especially when viewed from above or below. The dorsal fin is situated only about a third of the way back from the head; it is low and falcate, with a very wide base that varies with age and sex. The flippers of short-finned pilot whales are long and sickle shaped, reaching 14 to 19% of the body length. The shape of the flippers is more continuously curved in this species than in the long-finned species. Adult males are significantly larger than females, with bulging squarish foreheads that may overhang the lower jaw, strongly hooked dorsal fins that have a thickened leading edge, and deepened tail stocks that possess a protruding post-anal “keel” (Jefferson, Webber, and Pitman 2008; Olson 2009).

Short-finned pilot whales are black to dark brownish-gray, except for a light gray, anchor-shaped patch on the chest, a gray post-dorsal fin saddle, and a pair of roughly parallel bands high on the back that sometimes end as a light streak or teardrop above each eye. This is the reason for one of their other common names, blackfish (the term blackfish is variously used, usually by fishermen, to refer to killer, false killer, pygmy killer, pilot, and melon-headed whales). Calves in this species are somewhat paler than adults (Jefferson, Webber, and Pitman 2008).

Adults reach 5.5 m (females) and 7.2 m (males). Adults can weigh between 1,000 and 3,000 kg (National Marine Fisheries Service). Short-finned pilot whales are about 1.4 to 1.9 m long at birth. Usually seven to nine short, sharply pointed teeth are in each tooth row; teeth rows occur only at the anterior portion of the rostrum.

5.37.2 Status and Management

The species is protected under the MMPA and is not listed under the ESA. This species is also listed as data deficient by the IUCN and falls under Appendix II CITES regulations. MMPA stock assessment reports include short-finned pilot whales within the Pacific U.S. EEZ that are divided into two discrete, non-contiguous areas: (1) waters off California, Oregon, and Washington; and (2) Hawaiian waters (Carretta et al. 2010). Although these two stocks do not have range within the MRA Study Area, short-finned pilot whales are known to have primary range within the MRA Study Area. There are an estimated 0.7 annual deaths or serious injuries caused by fisheries are in the Hawaiian stock (Carretta et al. 2012). The short-finned pilot whale is widely distributed throughout most tropical and warm temperate waters of the world. Stock structure of short-finned pilot whales has not been adequately studied in the North Pacific, except in Japanese waters, where two forms have been identified based on pigmentation patterns and head shape differences of adult males (Kasuya, Miyashita, and Kasamatsu 1988; Miyazaki and Amano 1994). These forms are also segregated geographically and genetically (Kasuya and Tai 1993; Wada 1988).

5.37.3 Population and Abundance

No global abundance estimates for this species are known, but some estimates within specific regions are available. The geographically nearest stock assessments were for the Hawaiʻi stock (estimated 8,846 [CV=0.49] whales) (Carretta et al. 2012).The southern form of the short-finned pilot whale off the Pacific coast of Japan was estimated at 53,608 individuals (Miyashita 1993a). The approximate abundance estimates within the waters of northern Japan from the 1980s to 2006 allude to a declining population (Antunes et al. 2011). The southern stock of short-finned pilot whales (Kasuya, Miyashita, and Kasamatsu 1988), which is probably the one associated with the Marianas Islands area, has been estimated to number about 18,700 whales in the area south of 30°N latitude (Miyashita 1993a). A 2007 cetacean survey (Fulling, Thorson, and Rivers 2011) estimated the number of this species in Guam and the CNMI at 909 individuals.

5.37.4 Biology, Ecology, and Behavior

Pilot whales are often sighted with other cetaceans, in particular bottlenose dolphins (Bernard and Reilly 1999; Gannier 2000). These are the most frequently reported mass-stranded marine mammals globally (Mazzuca et al. 1999; Nelson and Lien 1996). They very rarely ride bow waves of vessels. Studies suggest that short-finned pilot whales live in relatively stable maternal groups, and that social bonds possibly cause/explain the frequent mass strandings (Heimlich-Boran 1993).

Group Size. Short-finned pilot whales may be seen in groups of several individuals to upwards of several hundred. They are an extremely social species and almost never are sighted alone (Jefferson, Webber, and Pitman 2008).

Predator/Prey Interactions. Pilot whales feed primarily on squid but also take fish (Bernard and Reilly 1999). They are generally well adapted to feeding on squid (Jefferson, Webber, and Pitman 2008; Werth 2006a). Pilot whales are not generally known to prey on other marine mammals, but records from the ETP suggest the short-finned pilot whale does occasionally chase and attack, and may eat, dolphins during fishery operations (Olson 2009; Perryman and Foster 1980); they have also been observed harassing sperm whales in the Gulf of Mexico (Weller et al. 1996).

This species is not known to have any predators (Weller 2008). It may be subject to predation by killer whales.

Life History. Average age at sexual maturity for short-finned pilot whales is 9 years for females and 17 years for males (Bernard and Reilly 1999). The pregnancy period for short-finned pilot whales is 15 to 16 months, with a mean calving interval of 4.6 to 5.7 years (Bernard and Reilly 1999). Calving peaks in spring and fall in the southern ocean; in the Northern Hemisphere, calving varies by stock but often occurs in fall and winter. Calving peaks in the Northern Hemisphere vary by stock (Jefferson, Leatherwood, and Webber 1993b); the Japan southern form has a calving peak during July/August, while the northern form peaks during December/January (Kasuya and Tai 1993). Short-finned pilot whales are one of the toothed whales with a distinct menopausal, or post-reproductive, period later in life that is characterized by aiding younger females in reproduction (Johnstone and Cant 2010).Maximum known age is 63 years (Jefferson, Webber, and Pitman 2008; Kasuya and Marsh 1984).

Migration. Short-finned pilot whales are not considered a migratory species, although seasonal shifts in abundance have been noted in some portions of the species' range. Several studies in diverse regions

indicate that distribution and seasonal inshore/offshore movements of pilot whales correspond with the abundance of squid (Bernard and Reilly 1999; Hui 1985; Payne and Heinemann 1993).

Hearing/Vocalization. Hearing was tested in a healthy captive female that was most sensitive to noise at 40 KHz, with upper limits to hearing between 80 and 200 KHz (Bahoura and Simard 2010).

Short-finned pilot whale whistles and clicks have a dominant frequency range of 2 to 14 kHz and a source level of 180 dB re 1 µPa-m (Ketten 1998). Vocalization patterns of the northern and southern forms of the short-finned pilot whale off Japan compared, and it was found that the calls of the northern form were longer in duration and wider in frequency range than those of the southern form (Nakahara et al. 2003). Researchers believe call duration and patterns are unchanged during deep dives, although compression of air cavities within the animal occurs (Jensen et al. 2011).

Diving. Adult and subadult tagged whales have been found to reach a maximum depth of 1,019 m and achieve a maximum dive duration of 21 min (Aguilar Soto et al. 2008).

5.37.5 Habitat and Distribution

The short-finned pilot whale is found worldwide in tropical to warm temperate seas, generally in deep offshore areas (Jefferson, Webber, and Pitman 2008); thus the species occupies waters over the continental shelf break, in slope waters, and in areas of high topographic relief (Gannier 2009; Olson 2009). While pilot whales are typically distributed along the continental shelf break, movements over the continental shelf are commonly observed in the northeastern U.S. (Payne and Heinemann 1993) and close to shore at oceanic islands, where the shelf is narrow and deeper waters are found nearby (Gannier 2000; Mignucci-Giannoni 1998). A number of studies in different regions suggest that distribution and seasonal inshore/offshore movements of pilot whales coincide closely with abundance of squid, their preferred prey (Bernard and Reilly 1999; Hui 1985; Payne and Heinemann 1993).

The short-finned pilot whale usually does not range north of 50°N or south of 40°S (Jefferson, Webber, and Pitman 2008). Some distributional overlap occurs with their long-finned relatives (*G. melas* is the only other species currently recognized), which appear to prefer cold temperate waters of the North Atlantic, Southern Hemisphere, and previously the western North Pacific. Short-finned pilot whales are thought to inhabit the North Pacific at present. They occur in the Red Sea but not the Mediterranean Sea (Jefferson, Webber, and Pitman 2008).

The northern short-finned form is found in cold coastal waters between 34°N and 43°N, while the southern form is observed in coastal and offshore waters south of the Kuroshio Front (south of 39°N), in the Ryukyu Islands.

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. This species' range generally extends throughout the North Central Pacific Gyre (Figure 5-84). Many sightings have been documented during cetacean surveys of the ETP, where the species is reasonably common (Au and Perryman 1985; Ferguson, Barlow, Feidler, et al. 2006; Wade and Gerrodette 1993).

KUROSHIO CURRENT. The Kuroshio Current is included in the known primary range of this species (Figure 5-84). This species may occur in the area of the Tsushima Strait based on published sighting and whaling records, and on its known preference for steep bottom topography, which is most probably

related to distribution of squid. Seasonal shifts in occurrence of this species are known(Kasuya, Miyashita, and Kasamatsu 1988; Kasuya and Tai 1993), but without plotted data, accurately portraying these shifts is not currently possible.

EAST CHINA SEA. The East China Sea falls within the known primary range of the short-finned pilot whale (Figure 5-84).

PHILIPPINE SEA. The Philippine Sea falls within the known primary range of the killer whale (Figure 5-84 and Figure 5-85)

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. The short-finned pilot whale is expected to occur seaward of the shelf break (Figure 5-85). It may occur between the shoreline and the shelf break, including within the bays, as well as around Okinawa and the Amami and Ogasawara islands.

MARIANA ARCHIPELAGO. A very small number of occurrence records exist for the short-finned pilot whale in the Mariana Islands MRA Study Area and vicinity. February through March 1994, a short-finned pilot whale was reported in the vicinity of the Northern Mariana Islands, but the actual sighting coordinates were not provided (Miyashita et al. 1996). A group of more than 30 individuals was sighted in late April 1977 near Uruno Point, off the northwest coast of Guam (Birkeland 1977). A stranding occurred on Guam in July 1980 (Donaldson 1983; Kami and Hosmer 1982; Schulz 1980). Expected occurrence of the short-finned pilot whale in the Mariana Islands MRA Study Area and vicinity is seaward of the 100 m isobath (Figure 5-86). Three individuals were seen during a cetacean survey in 2007 around the West Mariana Ridge (Fulling, Thorson, and Rivers 2011). Five whales were identified 200 miles northwest of the archipelago (Figure 5-86) (U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific 2007); additional acoustical data may indicate presence of more individuals (Norris et al. 2011).

Farallon de Medinilla. A group of 23 pilot whales was sighted in 2010 northeast of the island at 17.001°N and 146.370°E (Oleson and Hill 2010).

Saipan. One sighting of the short-finned pilot whale occurred on the northwest coast of Saipan during a 2010 survey (HDR 2011).

Tinian. One sighting of the short-finned pilot whale occurred on the west coast of Rota during a 2010 survey (HDR 2011).

Rota. Another sighting of this species occurred on the west coast of Rota (HDR 2011).

Guam. A stranding occurred on Guam in July 1980 (Donaldson 1983; Kami and Hosmer 1982; Schulz 1980). A group of more than 30 individuals was sighted in late April 1977 near Uruno Point, off the northwest coast of Guam (Birkeland 1977). Another was seen about 200 nm south of the island. One group that may have been short-finned pilot whales was sighted about 10 km northwest of Tumon Bay off the coast of west Guam in 2010 (HDR 2011). In a 2012 survey, another whale was seen off the western coast of the island (HDR 2012).

Apra Harbor - Two short-finned pilot whales were reported off the west and east coast of Guam, near the mouth of Apra Harbor, in waters with bottom depths ranging from 3,041 to 14,731 ft (Fulling, Thorson, and Rivers 2011).

Guam National Wildlife Refuge: Ritidian Unit - One sighting of the short-finned pilot whale, off the west coast of Guam, between Tumon Bay and Ritidian Point, was recorded during a 2010 survey.

CAROLINE ISLANDS. The waters around the Caroline Islands are a part of the known primary range of the short-finned pilot whale; it may occur between the shoreline and the shelf break (Figure 5-85).

5.37.6 Species-specific Threats

Short-finned pilot whales have been killed directly in artisanal harpoon fisheries in the Caribbean and Indonesia, as well as in drive fisheries in Japan (National Marine Fisheries Service). Whales of this species are also taken as by-catch in several fisheries in the North Pacific, including driftnet fisheries for swordfish and sharks. In the Republic of (South) Korea, “whale meat” markets still can buy and sell meat from stranded or bycaught marine mammals. A DNA surveillance study from 2003 to 2005 found pilot whale meat present in area markets (Baker et al. 2006). Several short-finned pilot whales have been captured for public display and research in the U.S. and Japan (Jefferson, Webber, and Pitman 2008). Vessel noise has been shown to decrease this species’ communication range in quiet, deep-water habitats by 58% when the source of vessel noise is within 50 m of the animal and the vessel moves at a speed of 5 knots in shallow water (Jensen et al. 2009).

Other species-specific threats include a relatively high occurrence of mandibular fractures and infection. Skeletal remains collected from a mass stranding in 1973 off the eastern coast of the U.S. showed a positive correlation between body length and fractured mandibles, possibly due to conspecific interactions. Other characteristics were examined in relation to fractures, but the small sample size precluded conclusions about other significant correlations (Oremland et al. 2010). The most pathogenic multivirus found in a cetacean was found in the brain of a short-finned pilot whale in the Eastern Atlantic Ocean and a long-finned pilot whale in the Western Atlantic ocean; this multivirus has been proposed as a separate genetic cluster called the pilot whale morbillivirus (Boye, Simon, and Madsen 2010). An analysis of strandings off the coast of Brazil showed susceptibility of short-finned pilot whales to parasites (Carvalho et al. 2010). For more detailed information on specific host-parasite species identified through this study, refer to Carvalho et al. (2010). Concentrations of butylin and phenyltin were found in the organs and tissue of short-finned pilot whales off the coast of Thailand (Harino et al. 2007a).

This Page Intentionally Left Blank

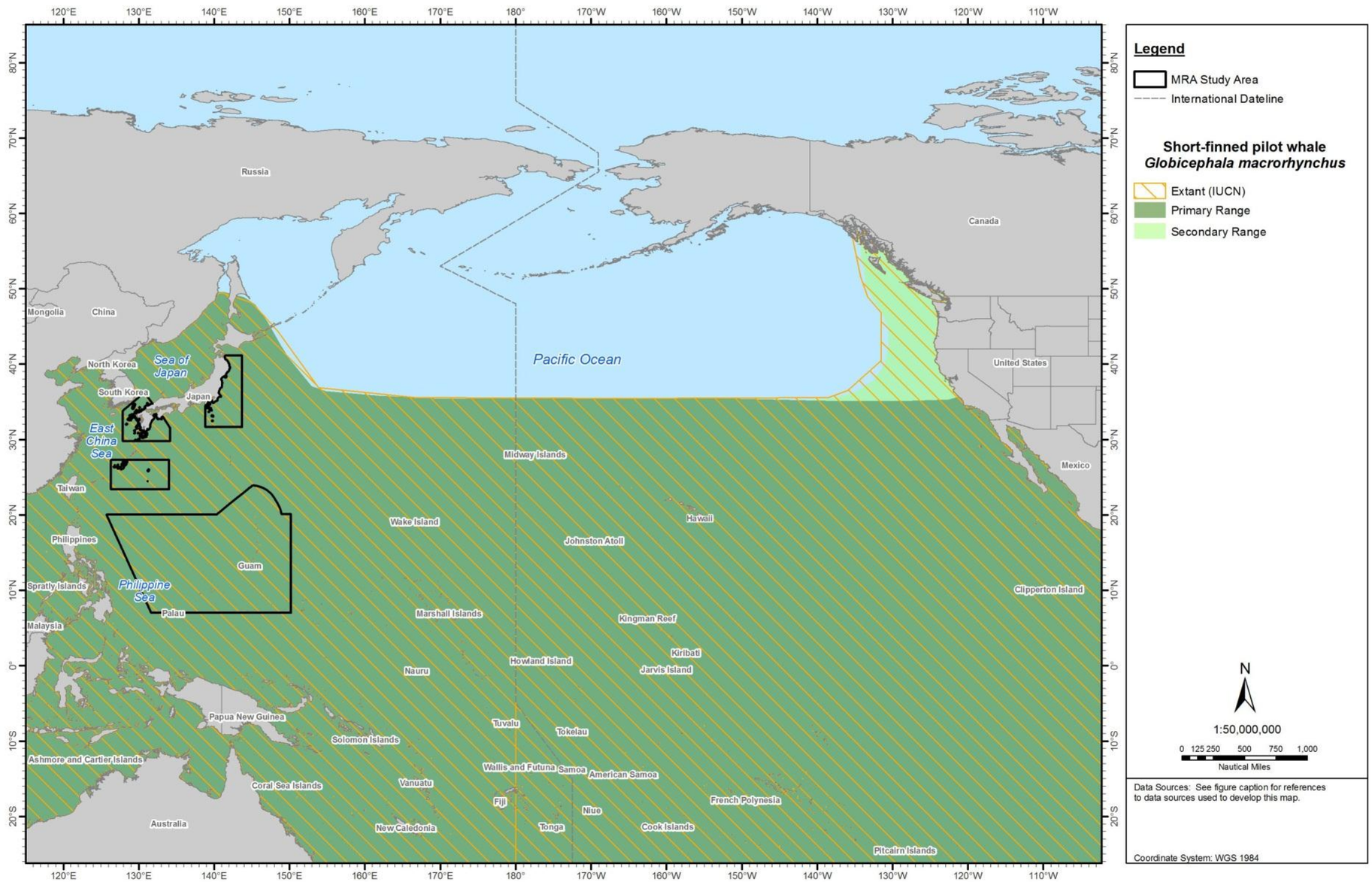

Figure 5-84: Geographic Range of the Short-finned Pilot Whale in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

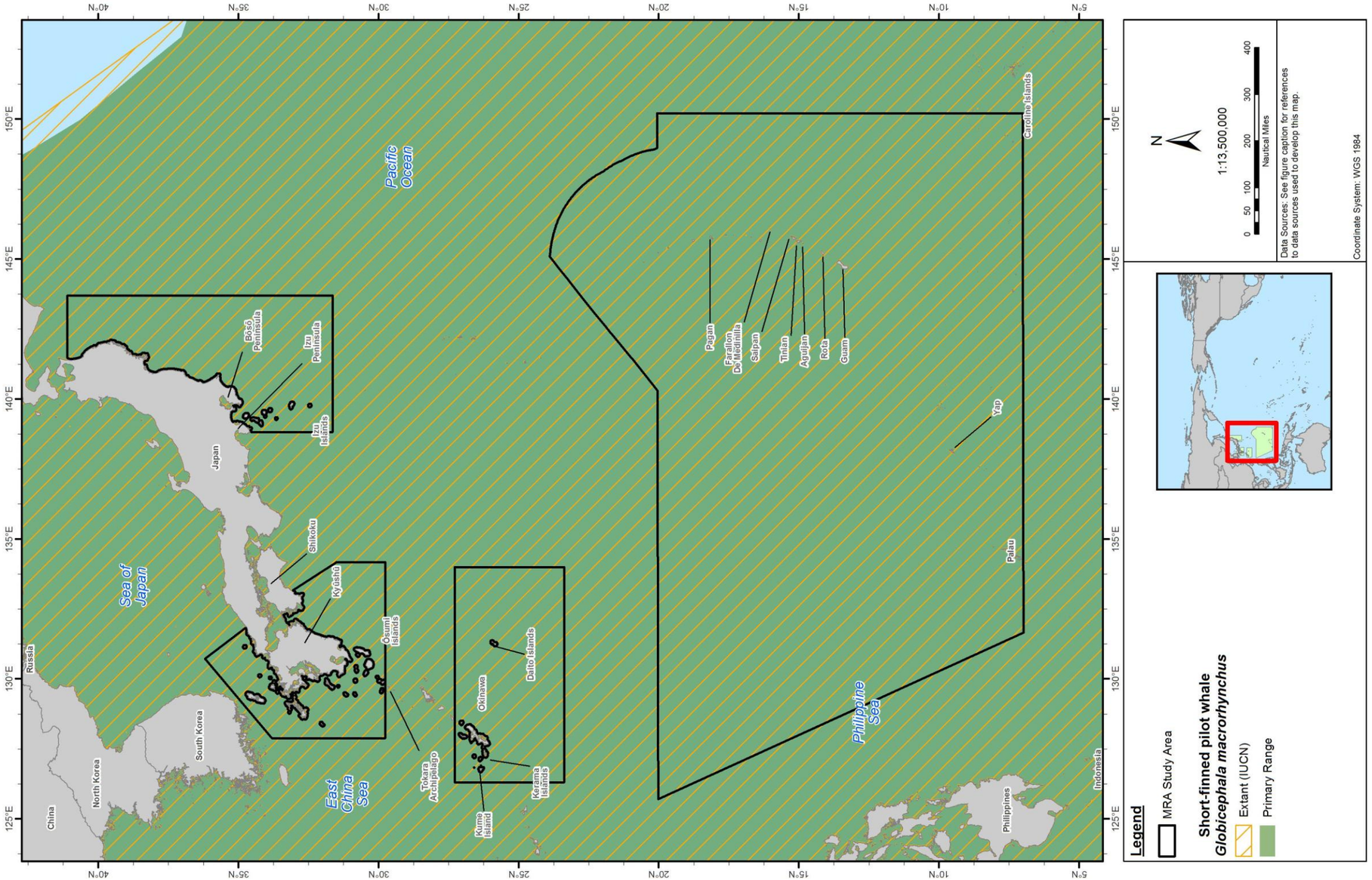

Figure 5-85: Geographic Range of the Short-finned Pilot Whale in the MRA Study Area
Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

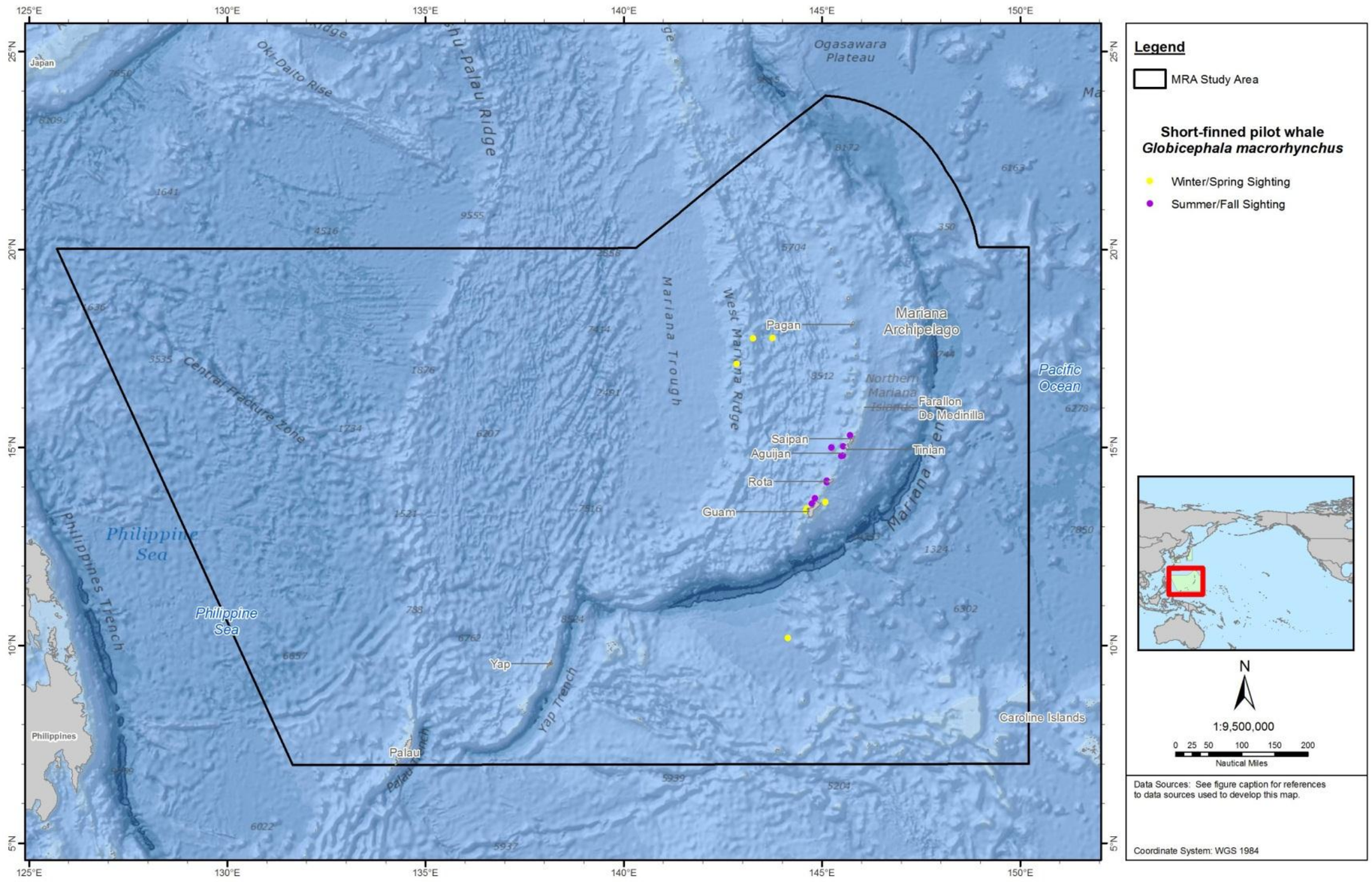

Figure 5-86: Sightings of the Short-finned Pilot Whale in the Mariana Archipelago Portion of the MRA Study Area. Available Sighting and Stranding Records are Represented.
Sources: Fulling, Thorson, and Rivers (2011); HDR (2012); Hill et al. (2013); Hill et al. (2011); U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific (2007).

This Page Intentionally Left Blank.

5.38 INDO-PACIFIC BOTTLENOSE DOLPHIN (*TURSIOPS ADUNCUS*)

5.38.1 Description

The taxonomy of *Tursiops* continues to be in flux; two species are currently recognized (IWC 2004; Rice 1998), with more likely to be recognized upon completion of additional morphometric and genetic analyses (Natoli, Peddemors, and Hoelzel 2004). Indo-Pacific bottlenose dolphins can be distinguished from common bottlenose dolphins using genetic, osteological, and external morphometric data (Hale, Barreto, and Ross 2000; Kemper 2004; Wang, Chou, and White 1999, 2000). Some evidence indicates that this species, as its congener, has a tendency to occur as two morphotypes: a nearshore (coastal) and an offshore form.

Indo-Pacific bottlenose dolphins are moderately sized, relatively slender dolphins that are generally light to moderate gray in color. This species is distinguished from the common bottlenose dolphin by the presence of spotting on the belly of adults, and a light spinal blaze. The Indo-Pacific bottlenose has a longer, more slender beak than its congener, set off from the melon by a deep crease (Wells and Scott 1999). This species appears to vary regionally in body size much less than does the common bottlenose dolphin; this species can weigh up to 230 kg and maximum adult body length is typically around 2.7 m (Jefferson, Webber, and Pitman 2008).

5.38.2 Status and Management

The Indo-Pacific bottlenose dolphin is protected under the MMPA but is not listed under the ESA. This species is also listed as data deficient by the IUCN and falls under Appendix II CITES regulations.

5.38.3 Population and Abundance

One available abundance estimate for the Indo-Pacific bottlenose dolphin in Japanese waters (Shirakihara et al. 2002) appears to be for one population in the coastal waters of Amakusa-Shimoshima Island, western Kyūshū, totaling around 218 individuals. Abundance at Mikura Island has not been estimated, but 169 individuals are specified in the photo-identification catalog (Kogi et al. 2004). Other populations likely are similarly small, consisting of no more than a few hundred individuals—except for the population off the Eastern Cape coast of South Africa, which is estimated at 28,482 individuals (Reisinger and Karczmarski 2010). Estimated abundance of Indo-Pacific bottlenose dolphins within the region adjacent to the MRA Study Area is 31,700 animals north of the Mariana Islands (Miyashita 1993a), which also may possibly coincide with the stock of offshore Indo-Pacific bottlenose dolphins that occurs around the Mariana Islands.

5.38.4 Biology, Ecology, and Behavior

As in their better-known congeners, group composition appears to be a consequence of fission-fusion, and fluidity in associations is common (Chilvers and Corkeron 2002). The social organization of the population in Moreton Bay, Australia, is influenced to a great degree by association with shrimp trawlers (Chilvers, Corkeron, and Puotinen 2003). Site fidelity has been studied using records of photo-identified individuals, and results of the study seem to indicate small-scale residency as the norm for this species (Corkeron, Bryden, and Hedstrom 1990; Shirakihara et al. 2002). Male Indo-Pacific bottlenose dolphins in Shark Bay, western Australia, form alliances and “super-alliances,” and use complex strategies to gain access to mating opportunities with females (Connor, Heithaus, and Barre 2001; Krützen et al. 2003). Societal structure of this population is clearly quite sophisticated, with even cultural transmission of tool

use having been documented (Krützen et al. 2003). Indo-Pacific bottlenose dolphins have been seen "flipper rubbing" off the coast of Tōkyō, Japan, where one individual rubbed the body of its partner, and then partners took turns rubbing each other's anterior flipper edge. Flipper-body rubbing was most common between same sexes and same age group pairs, and was seen most often between mothers and calves (Sakai et al. 2006).

Group Size. Group size tends to be relatively small (compared to other oceanic dolphins)—generally less than a few dozen individuals, but sometimes 100 animals or more (Shirakihara et al. 2002). Group behaviors such as an individual's making bodily contact with one or more other dolphins can correlate significantly with arrival or departure of those one or more dolphins from the group (Paulos, Dudzinski, and Kuczaj 2008).

Predator/Prey Interaction. While only a few studies of feeding habits of this species have been published, Indo-Pacific bottlenose dolphins off South Africa feed on a wide variety of benthic, reef, and sandy-bottom fish, pelagic schooling fish, some deepwater fish, and cephalopods (Cockcroft and Ross 1990). In Tanzania, this species feeds on a large number of prey species, with only a few small- and medium-sized neritic fish and cephalopods contributing substantially to the diet (Amir et al. 2005). In Moreton Bay, Australia, they feed opportunistically mainly on various shallow-water fishes and cephalopods (Corkeron 1990). The stomach contents of a stranding near western Kyūshū, Japan, included one eel, two Chinese herring, five mullet, three filefish, one squid, and another unidentified bony fish (Yamazaki, Oda, and Shirakihara 2008). In Shark Bay, Australia, *Tursiops spp.* are known to scare fishes out of seagrass beds by forming bubbles with their tail slaps over the vegetation (Connor et al. 2000). They have also been documented to "beach" themselves to isolate fish on sand beaches before returning to the water (Wei et al. 2002), and using marine sponges to protect the rostra when foraging (Smolker et al. 1997). More recently, Indo-Pacific Bottlenose Dolphins have been documented "conching", whereby individuals insert their rostrum into to the conch's (*Turbinella spp*.) aperture and lift the animal out of the water. Hypothesized explanations for this behavior include feeding on the live conch, indulging in play behavior, and a socio-sexual display (Amaral et al. 2012).

Sharks are common predators of populations in both South Africa (Cockcroft and Ross 1990) and Australia (Goold and Jefferson 2002). Risk of shark predation is determined by the number of predators in an area, the ability of predators and prey to detect each other, and the probability of capture after detection; predation risk can be influenced by a suite of habitat attributes, such as water clarity and depth (Furuta 1984).

Life History. Sexual maturity is reached at ages of 9 to 14 years and lengths of 220 to 240 cm in both areas (Cheal and Gales 1992; Cockcroft and Ross 1990). Male alliances have been shown to increase reproductive success; alliances of related individuals are the most successful (Ortega-Ortiz et al. 2011). Some study of life history in Japanese waters has involved long-term observations of living individuals at Mikura Island (Kogi et al. 2004). The mean age at weaning was 3.5 years, and the calving interval averaged 3.4 years. The South African and Australian dolphins can live to ages past 40 years (Cockcroft and Ross 1990).

Migration. Climate changes can contribute to range extensions. For example, a 600 km northward range extension to Monterey Bay (for some bottlenose dolphins known from the San Diego, California area) was linked to the 1982/1983 El Niño event (Wells et al. 1999). Some dolphins remain to this day in the northern waters following return to normal water temperatures, suggesting that the dolphins might

have responded more to secondary effects of the warm-water incursion, such as changes in prey distribution, than to the temperature changes themselves (Wells and Scott 1999).

Hearing/Vocalization. Much less study of the acoustics and hearing of this species has occurred than of the common bottlenose dolphin, but it is reasonable to assume that sound production and hearing capabilities of the two species are quite similar.

Sounds emitted by Indo-Pacific bottlenose dolphins have been classified into two broad categories: pulsed sounds (including clicks and burst-pulses) and narrow-band continuous bands (whistles), which usually are FM. One unique type of sound made by Indo-Pacific bottlenose dolphin adult males is the "pop," apparently used in formation of consortships among adult males (Connor and Smolker 1996). Generally, whistles range in frequency from 4 to 20 kHz, although whistles have been described with fundamental frequencies all below 2 kHz (Schultz et al. 1995(Schultz et al. 1995). Indo-Pacific bottlenose dolphins living off Australia's coast had whistle rates and diversity higher in groups without calves. In the same population, whistle types differed with varying behavior (Hawkins and Gartside 2010). Geographic differences in the whistles of three of the Japanese populations have been described (Morisaka et al. 2005b). The social whistles of Indo-Pacific bottlenose dolphin's living in Japanese waters vary, not only among populations, but within the same populations among years (Morisaka et al. 2005b). Additionally, ambient noise may drive the variation in whistles among different populations (Morisaka et al. 2005a).

Diving. No accounts have been published of radio- or satellite-tracking studies of Indo-Pacific bottlenose dolphins, and therefore little is known of their diving capabilities. However, based on the relatively shallow waters they tend to use, most of their dives are presumed relatively shallow (less than 100 m).

5.38.5 Habitat and Distribution

Indo-Pacific bottlenose dolphins are common in shallow water within 1 km of shore, including many bays and other inshore waters; individuals are seen regularly just seaward of the surf zone and in clear water just outside turbid estuarine plumes (Reeves, Stewart, et al. 2002). Occurrence of *Tursiops* in the Indian and western Pacific Oceans has lead to the determination that the Indo-Pacific bottlenose dolphin occurs in estuarine and near-coastal oceanic waters (Hale, Barreto, and Ross 2000). Also in the Indian Ocean, intra-specific habitat partitioning has been documented, even on a fine scale. One group occurred in the lagoon's shallow waters and another group concentrated around a deeper reef bank (Kiszka et al. 2012).This species' use of the Clarence River estuary, Australia, and its special distribution therein depends on the tidal phase and interaction between the tides and seasons (distribution is largest during high and flood tides); but the species' distribution in the Richmond River estuary, Australia, does not apparently depend on these factors (Fury and Harrison 2011). In addition to coastal waters of the continental shelf, the indo-Pacific bottlenose dolphin occurs around some coastal and offshore islands.

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. The Indo-Pacific bottlenose dolphin is reported throughout much of the warm temperate and tropical Indian Ocean and western Pacific Ocean (Figure 5-87). In the western North Pacific, this species occurs from southern Japan southward (including the Taiwan Strait), in the subtropical western South Pacific, in much of the Indonesian archipelago, along the north coast of Australia between New South Wales and Western Australia, and along the entire rim of the Indian Ocean to South Africa, including the Persian Gulf and Red Sea (Reeves, Stewart, et al. 2002). Both the common bottlenose dolphin and the Indo-Pacific bottlenose dolphin occur in the Indo-Pacific region.

KUROSHIO CURRENT. The distribution of the Indo-Pacific bottlenose dolphin in Japanese waters was summarized by (Kasuya et al. 1997). Information on the location of specific populations of the species has been studied by multiple scientists (Kakuda et al. 2002; Shirakihara et al. 2002; Shirakihara, Yoshida, and Shirakihara 2003; Uchida 1982, 1985).

This is a coastal species that inhabits primarily tropical waters, but extends into the warm temperate zone. There are five more or less disjunctive populations are known in Japanese waters:

1. Tachibana Bay (Shirakihara et al. 2002; Shirakihara, Yoshida, and Shirakihara 2003).
2. Amami Islands (Miyazaki and Nakayama 1989).
3. Okinawa (Uchida 1982, 1985).
4. Ogasawara Islands (Shirakihara, Yoshida, and Shirakihara 2003).
5. Mikura Island (Kakuda et al. 2002; Kogi et al. 2004).

In addition, the species is expected elsewhere along the continental shelf (including bays and inland seas) south of Tōkyō Bay (34°N), and this includes the Tsushima Strait. They may occur seaward of each of these areas (out to 50 nm [93 km]), except at the Ogasawara Islands 50 nm [93 km] from the shelf break), and extending across the entire area between the Ryukyu Islands and shallow shelf of the East China Sea (Figure 5-88). Occurrence pattern is believed similar year-round.

EAST CHINA SEA. This species is expected to occur in the East China Sea (Figure 5-87). A DNA study found primarily common bottlenose dolphins in the Yellow Sea and the northern East China Sea, whereas the similar Indo-Pacific bottlenose dolphin was found mostly in southern Chinese Waters (Yang et al. 2005). Range overlap occurs in the Taiwan Strait and possibly in adjacent waters; yet reproductive isolation is likely.

PHILIPPINE SEA. The Indo-Pacific bottlenose dolphin is reported throughout much of the warm temperate and tropical Indian Ocean and western Pacific Ocean.

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. This species is known to occur around the Japan Archipelago (Figure 5-87 and Figure 5-88).

Kyūshū Island, Ōsumi Islands, and Tokara Archipelago. Indo-Pacific bottlenose dolphins live near Amakusa-Shimoshima Island year-round. Dolphin-watching vessels in this area can affect the behavior of some groups. In the presence of one boat, dolphins remained under water for increased durations and increased in speed at the surface. In the presence of 4 to 5 boats, groups swam longer distances underwater before surfacing, and subsequently dove sooner (Robson 2002).

MARIANA ARCHIPELAGO. Because the Indo-Pacific bottlenose dolphin occurs directly west and to the south of the Mariana Islands MRA Study Area (Figure 5-87 and Figure 5-88), extralimital occurrences of this species are possible here.

CAROLINE ISLANDS. The Indo-Pacific bottlenose dolphin is reported throughout much of the warm temperate and tropical Indian Ocean and western Pacific Ocean, and is common in shallow, nearshore waters (Figure 5-88).

5.38.6 Species-specific Threats

Trade of these animals has been documented within the last decade. In 2003, over 94 dolphins were exported from the Solomon Islands to Mexico, and in 2003, 28 individuals were sent to the United Arab Emirates. Despite concern expressed by the IUCN, in 2008, 18 dolphins went to the Philippines (Parsons, Rose, and Telecky 2010).

Human disturbances such as vessel traffic are believed harmful to Indo-Pacific bottlenose dolphins based on group behavioral reactions (Stensland and Berggren 2007). When boats approached a group of dolphins within 50 m, less feeding occurred, reduced resting was seen, and more densely packed groups with movements less neutral were observed. These behaviors were less pronounced when the boats were at a 150-m distance and the approach of the vessel was more controlled (Shirakihara, Yoshida, and Shirakihara 2003). The type of vessel also plays a role in the amount of stress (avoidance behavior) seen: kayaks seem to create less stress to the animals in contrast to the increased stress created by fishing boats, motorized inflatable boats, and powerboats (Shaughnessy and Fay 1977).

The indo-Pacific bottlenose dolphin can be displaced from its habitat near estuaries during and shortly after flooding events. In two Australian estuaries, a combination of low salinity, higher turbidity, lowered pH, and reduced dissolved oxygen discouraged occurrence of the dolphins in the affected area. When the dolphins' returned depended on the severity of the flood, but their return also seemed to coincide with a rise in salinity to above 29%. The delay in return may have been because of requisites of the dolphins' physiology or a parallel delay in return of prey species to the estuary (Fury and Harrison 2011).

Harmful health effects may be caused by pollutants and infections in the Indo-Pacific bottlenose dolphin. Antibodies for *Toxoplasma gondii* (known to cause mortality and morbidity in other warm-blooded hosts) have been documented in serum samples from the Solomon Islands (Omata et al. 2005). In individuals tested off the coast of East Africa, the following contaminants were found: organohalogen compounds such as methoxylated PBDEs and OCPs, and industrial pollutants (such as PCBs, or lindane and DDT residue, which are both used as insecticides). In this species, mother-calf transfer of OCPs was 72% and of methoxylated PBDEs was 85% (Mwevura et al. 2010). Mother-calf transmission in Australian waters of lung nematodes, known to compromise the animal's health, have been documented in carcasses of this species; prevalence of lung nematodes is relative to year, season, age class, and geographic range (Tomo, Kemper, and Lavery 2010).

This Page Intentionally Left Blank.

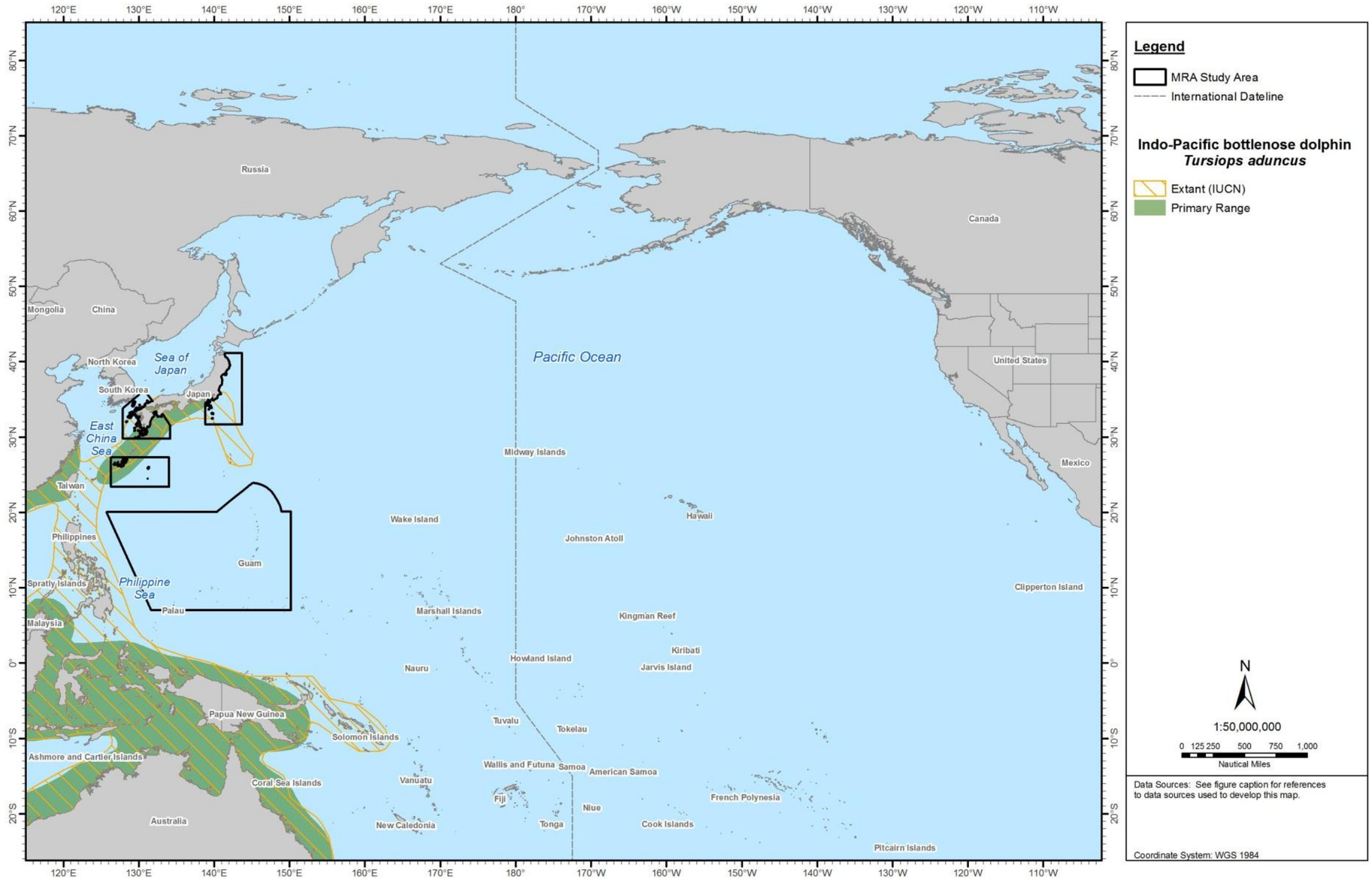

Figure 5-87: Geographic Range of the Indo-Pacific Bottlenose Dolphin in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

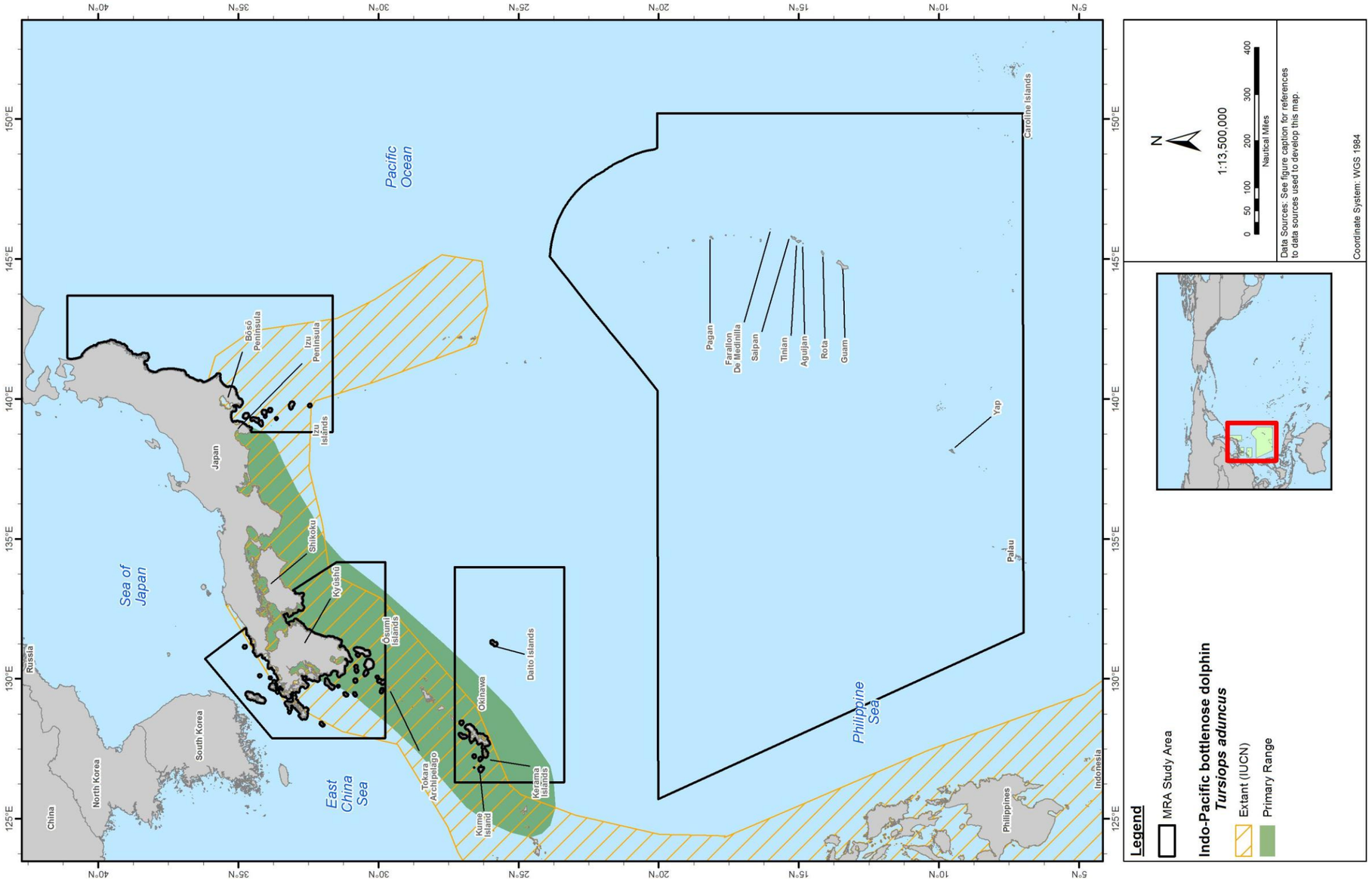

Figure 5-88: Geographic Range of the Indo-Pacific Bottlenose Dolphin in the MRA Study Area
Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.39 FINLESS PORPOISE (*NEOPHOCAENA PHOCAENOIDES*)

5.39.1 Description

Originally the finless porpoise was thought to include three subspecies (Jefferson and Hung 2004; Rice 1998). Recently, DNA sequencing and morphological characteristics have indicated reproductive isolation of finless porpoises in Chinese waters (Wang et al. 2008). Thus, two distinct species of finless porpoise have been accepted (Wang, Yang, et al. 2010). The Society for Marine Mammalogy adopted the two-species classification in 2009, creating the Indo-Pacific finless porpoise (*Neophocaena phocaenoides)* and the narrow ridged finless porpoise (*N. asiaorientalis*) (Perrin et al. 2009; Wang, Yang, et al. 2010).The narrow ridged finless porpoise is not the focus of this species profile; hereafter, the term "finless porpoise" refers to *Neophocaena phocaenoides.*

A comparison of photographs and live specimens from Chinese waters show that *N. phocaenoides* can be distinguished from *N. asiaorientalis* by the angle of the apex of the dorsal ridge (Wang, Yang, et al. 2010). The dorsal ridge apex of *N. phocaenoides* is sharply angled at 75% to 90% of the length of the body, while in *N. asiaorientalis*, the dorsal ridge is tapered evenly from the highest point at 50% to 65% of the body length (Wang, Yang, et al. 2010). Differences in tubercle structure were also observed, with *N. phocaenoides* having a wide patch of tubercles on the dorsal surface and *N. asiaoreintalis* have a narrow band of tubercles along the midline of the back (Wang, Yang, et al. 2010). *N. phocaenoides* tends to be darker, in the region of the Matsu islands *N. asiaorientalis.* The two species may also display different surfacing behaviors, although further study on these behaviors is warranted (Wang, Yang, et al. 2010).

The finless porpoise is one of a few small cetacean species lacking a dorsal fin. A highly variable dorsal ridge is covered with a series of small denticles (or bumps), running along the back at the level of the flippers to the top of the tail stock (Jefferson and Hung 2004). The body is moderately robust, and the head is blunt, without a beak.

Indo-Pacific finless porpoises are generally various shades of gray, with extensive geographic variation in adults (Jefferson and Hung 2004). Individuals in Japanese waters are much lighter than individuals in more tropical parts of the species' range, where they may appear nearly black. Although the maximum known length is 227 cm, most finless porpoises are less than 2 m long (Jefferson and Hung 2004). Their average weight is about 70 kg (Perrin, Würsig, and Thewissen 2008).

5.39.2 Status and Management

The finless porpoise is protected by the MMPA and is not listed under the ESA. This species is also listed as vulnerable by the IUCN and falls under Appendix I CITES regulations. The Yangtze River subspecies is classified as endangered due to a dramatic population decline (Wang, Yang, et al. 2010). Reports suggest the Inland Sea population may also be declining (Kato and Kasuya 2002; Shirakihara 2005; Wang, Yang, et al. 2010). The finless porpoise is protected in Japan through the Act on Protection of Fisheries Resources (Isobe et al. 2011). Five known populations occur in Japanese waters: Sendai Bay to Tōkyō Bay, Ise-Mikawa Bays, Inland Sea-Hibiki Nada, Omura Bay, and Ariake Sound-Tachibana Bay (Yang et al. 2008; Yoshida 2002). An additional three populations occur in Chinese waters (Kasuya and Shirakihara 2005).

5.39.3 Population and Abundance

Estimates for the Japanese populations are as follows: Omura Bay (289), Araike Sound and Tachibana Bay (3,807), and Ise and Mikawa Bays (3,743) (Shirakihara 2005). The Inland Sea population was estimated from aerial surveys in 2000 at 7,572 individuals, with a density of 0.506 individuals/km^2 (Shirakihara, Shirakihara, and Yamamoto 2007). Little is known about the abundance trends of most populations; however, the Inland Sea population is known to have declined dramatically since the 1970s (Kasuya, Yamamoto, and Iwatsuki 2002). The population density at Omura Bay has been placed at 0.6 individuals/km^2 (Yoshida et al. 1997), and is considered the smallest of the five Japanese populations (Akamatsu et al. 2010). The density in Ariake Sound-Tachibana Bay is 1.3 individuals/km^2 (Yoshida et al. 1997). Along the eastern coast of Honshū, Tōkyō Bay, and Sendai Bay, population and density estimates are 3,387 animals and 0.502 individuals/km^2 (Amano et al. 2003).

Three populations of finless porpoise occur in Chinese waters: the Yangtze River population, the Yellow Sea population in the northern East China Sea and Yellow/Bohai Seas, and the South China Sea population in the South China Sea and southern East China Sea (Yang et al. 2008). Freshwater population in China is declining (Yang et al. 2008), estimated at 2,700 individuals (Wei et al. 2002).

5.39.4 Biology, Ecology, and Behavior

Finless porpoises are generally considered shy and cryptic. Aerial behavior tends to be quite rare, compared to other species of small cetaceans. Finless porpoises do not ride bow waves, as do many other small cetacean species. They tend to be most active when feeding or socializing (Jefferson and Hung 2004).

Group Size. Most finless porpoise groups are small, less than about a dozen individuals. Larger groups have been documented in various parts of the range, but these usually appear to be opportunistic aggregations that form to take advantage of good feeding opportunities (Jefferson and Hung 2004).

The average group size detected in the Inland Sea of Japan was 1.56 individuals, and a total of 148 groups were seen in 2000 (Shirakihara, Shirakihara, and Yamamoto 2007). Finless porpoises in groups ranging from one to three individuals have been documented (Akamatsu et al. 2010).

Predator/Prey Interactions. Finless porpoises appear to be opportunistic feeders, taking whatever local prey species are most abundant. They feed mostly on various species of shallow-water pelagic and demersal fishes, cephalopods, and crustaceans (Jefferson and Hung 2004; Shirakihara et al. 2008). The stomach contents of 87 finless porpoises from Ariake Sound-Tachibana Bay and Omura Bay in Kyūshū revealed 3,267 individual prey items covering 20 fish species, 3 cephalopods, and 1 species of crustacean (Shirakihara et al. 2008). Cephalopods occurred in 91.5% of the stomachs examined. Prey type differed by geographic location, perhaps because of differences in prey availability (Shirakihara et al. 2008). Distinction between age class and prey preferences have been shown, with demersal fish and cephalopods the preferred prey for weaned calves, and konoshiro gizzard shad (*Konosirus punctatus)* and cephalopods the preferred food for adults in the Omura Bay and Ariake Sound-Tachibana Bay populations (Shirakihara et al. 2008). Hairo Strait, connecting Omura Bay to the East China Sea, may be a feeding ground for Finless Porpoises (Akamatsu et al. 2010). Land-based observations in Hong Kong and elsewhere have shown that they can be quite active and agile when pursuing fish, and some evidence suggests they may sometimes feed in association with commercial fishing vessels (Barros, Jefferson, and Parsons 2002).

Great white sharks are a documented predator of the finless porpoise in the East China Sea (Kasuya 1999c).

Life History. Life history of this species has been relatively well-studied, mostly from stranded and incidentally captured individuals. Growth curves have been constructed for various populations in Japanese and Chinese waters. Growth is rapid during the first year, and then begins to level off. Some animals in southern China appear to live as long as 33 years (Jefferson, Robertson, and Wang 2002). Sexual maturity is reached at lengths of 130 to 150 cm and ages of 3 to 6 years for different populations, generally with males maturing a few years later than females (Hung et al. 2006; Jefferson, Robertson, and Wang 2002). Gestation is a less than 1 year. Calving is broadly seasonal, with the calving peak varying widely among populations, and likely associated with local periods of highest productivity (Shirakihara et al. 2008). Newborns range from about 70 to 85 cm long. The mean estimated length at weaning is 101 cm, which corresponds to about 6 months of age (Shirakihara et al. 2008).

Hearing/Vocalization. Finless porpoises have been shown to have high-quality hearing within the upper level of their hearing range (Popov et al. 2006). An evoked-potential audiogram for the species has been produced, based on two Yangtze River individuals in a semi-natural reserve (Popov et al. 2005). The range of greatest sensitivity was 45 to 139 kHz, with peak sensitivity at 54 kHz (Popov et al. 2005).

Much of what is known of the acoustic capabilities of finless porpoises comes from studies of captive animals and from those in a semi-natural reserve in the Yangtze River, China. Finless porpoises make clicks, which are presumably used for echolocation (Akamatsu et al. 2005). Click trains occur every 5 s. on average and change in sound intensity and inter-click interval every 20-70 m (Akamatsu et al. 2005). Click sounds are the typical narrow-band, high-frequency (87 to 145 kHz) pulses produced by members of the porpoise family (Akamatsu, Wang, and Wang 2005; Kamminga, Kataoka, and Engelsma 1986; Li et al. 2005). The source sound level of the porpoise was estimated to be less than 167.4 dB (Wang et al. 2005). Pulse durations are 30 to 122 microseconds (Li et al. 2005). The sound pressure level of clicks was measured at 162 dB re 1 µPa-m peak-to-peak (Akamatsu, Wang, and Wang 2005). In Hong Kong waters, both narrow band clicks (peak energy at 142 kHz) and broader-band click sounds have been reported (Goold and Jefferson 2002). The interpulse interval of finless porpoises has been measured at up to 90 ms (Akamatsu et al. 2008).

Migration. The rare occurrence of finless porpoise sightings in the Nansei Islands suggests that finless porpoise movement is limited to areas between Japan and China-Korea (Yoshida et al. 2010). Movements of finless porpoises in semi-enclosed waters of Omura Bay indicate that they only occasionally move out of their habitat (Akamatsu et al. 2010). Data indicate that the porpoises pass through the Kanmon Strait, primarily at night, rather than utilize it as foraging grounds (Akamatsu et al. 2008). Individuals from the Omura Bay population have been detected moving into the Hairo Strait mainly from March-April (73% of detected individuals) and primarily at night (76% of individuals)—likely to forage for prey.

Diving. Most dives appear to be short (less than 30 s.). Yet, dives of up to 4 min in duration have been noted (Jefferson and Hung 2004). Dive depths have been measured directly only in the Yangtze River, where the maximum dive depth is 11.5 m, with an average dive depth of 1.7 m (Akamatsu et al. 2005); because no marine tagging studies have occurred, virtually nothing is known about diving depth in marine waters.

5.39.5 Habitat and Distribution

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. The open ocean waters of the North Central Pacific Gyre are not included in the range of this species (Figure 5-89).

KUROSHIO CURRENT. The finless porpoise occurs in this part of the MRA Study Area; however they are primarily a coastal species (Figure 5-89).

EAST CHINA SEA. The range of the finless porpoise is known to extend for several hundreds of km offshore in the shallow shelf waters of the Yellow and the East China Seas, although sightings have been limited (Figure 5-89) (Jefferson and Hung 2004).

PHILLIPINE SEA. The finless porpoise is not found in this area.

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Japan is considered the northernmost portion of the finless porpoise's range (Figure 5-90). In the Sea of Japan, encounter rates decreased with depth and peaked at depths between 10 and 20 m, with variance across the stratum from west to east (higher in the western stratum) (Shirakihara, Shirakihara, and Yamamoto 2007). Sand dredging in the eastern-central portion of the Inland Sea may account for the lower numbers of porpoises there when compared to the west (Shirakihara, Shirakihara, and Yamamoto 2007). In Japan, data suggest that finless porpoise habitat is characterized by shallow water depth and proximity to shore (Yoshida et al. 2010).

Bōsō Peninsula, Izu Peninsula, and Izu Islands. Aerial sightings from Sendai Bay to Bōsō Peninsula were concentrated from southern Sendai Bay to the middle of Fukushima coast (Amano et al. 2003). The density of these finless porpoises is lower than that within other areas of Japan (Amano et al. 2003). Of the five known populations of finless porpoises in Japan, the Tōkyō Bay to Sendai Bay population occurs within the MRA Study Area on Honshū. The Inland Sea population abuts the islands of Honshū, Kyūshū, and Shikoku, but is not within the MRA Study Area.

Kyūshū Island, Ōsumi Islands, and Tokara Archipelago. Of the five known populations of finless porpoises in Japan, two are located on the Island of Kyūshū: the Omura Bay and Araike Sound-Tachibana Bay populations (Yang et al. 2008). Between 1987 and 1992, 67 by-caught, 5 stranded, and 6 drifting porpoises were collected from Ariake Sound-Tachibana Bay, and 9 were collected as by-catch from Omura Bay (Shirakihara et al. 2008). Hairo Strait, connecting Omura Bay to the East China Sea, may be a feeding ground for finless porpoises (Akamatsu et al. 2010). Of 226 individuals acoustically detected in the strait, 76% occurred in the corridor at night, and 73% of the detections occurred from March through April. Their movements were associated with tidal fluctuations—the porpoise occurred in the strait as the tide was flowing into the ocean (Akamatsu et al. 2010).

Okinawa Island, Kerma Islands, Kume Island, and Daito Island. Finless porpoises were documented in the stomach of a great white shark off of the East China Sea coast of Okinawa, although they may have been ingested elsewhere (Kasuya 1999b). In February 2004, the first recorded live finless porpoise on the Nansei Islands was spotted 500 m east of the Motobu Peninsula on Okinawa Island. It was likely a stray from the Chinese population (Yoshida et al. 2010). Finless porpoise strandings have occurred on both sides of the Kanmon Strait, which separates Kyūshū and Honshū Islands and connects the Seto

Inland Sea and the Sea of Japan (Akamatsu et al. 2008). During 75 days from March 2005 to March 2006, 37 porpoises were detected in the strait, mostly appearing at night, with an inverse relation to ship traffic and a correlation with current direction. Data indicate that the porpoises pass through the strait rather than utilize it as foraging grounds (Akamatsu et al. 2008).

5.39.6 Species-specific Threats

Finless porpoises are predominately a coastal species, rendering them especially vulnerable to human activities (Wang, Shelver, et al. 2010). Direct and incidental catches, especially in nets, and entanglement are major threats to this species (Kasuya 1999b; Wang, Shelver, et al. 2010; Yang et al. 2008). It is suggested that by-catch is actually positively reinforced based on the high price of finless porpoise meat in Korea (Baker et al. 2006). In the Republic of (South) Korea, “whale meat” markets still can buy and sell meat from stranded or bycaught marine mammals. A DNA surveillance study from in 2003 to 2005 found finless porpoise meat present in area markets (Baker et al. 2006). Habitat fragmentation as a result of dredging and other human activities has occurred in the Seto Inland Sea (Shirakihara, Shirakihara, and Yamamoto 2007).

A relationship has been shown between organotins, particularly butylin, and presence or severity of parasitic infections of lung nematodes in finless porpoises in Seto Inland Sea (Nakayama et al. 2009). (Isobe et al. 2011) also detected a correlation between PCBs and parasitic infection in finless porpoises from Seto Inland Sea and Omura Bay populations. Concentrations of butylin and phenyltin were found in the tissue of finless porpoises off the coast of Thailand. The highest concentrations were found in the liver, where concentrations of the contaminants increased with body length (Harino et al. 2007a). Introduction of chemicals into marine ecosystems is a significant global problem, as some can have a toxic effect on animals and can bioaccumulate and persist in the environment (Park et al. 2010; Ramu et al. 2005; Suzuki et al. 2011). A wide range of anthropogenic chemicals have been detected in finless porpoises, including PBDEs and organochlorines (Ramu et al. 2005); dioxin-like compounds were found in specimens near Hong Kong (Suzuki et al. 2011); perfluorinated compounds were found in porpoises from the Ariake Sea (Nakata et al. 2006), as well as PCBs (Kunisue et al. 2007); even synthetic musk fragrance was found in a finless porpoise fetus (Nakata 2005); and organohalogen compounds were found in specimens from the South China Sea (Ramu et al. 2006) and Korean waters (Park et al. 2010). (Park et al. 2010) showed that DDT levels in finless porpoises are approaching the levels associated with immunosuppression in other marine mammals, while other studies have detected contaminants below threshold values for adverse health effects (Park et al. 2010). Other studies have shown generally low levels (Hung et al. 2006). Maternal transfer of contaminants to young has been recorded (Kunisue et al. 2007; Nakata 2005; Park et al. 2010). The Yangtze population decline has been associated with high organic chemical pollution (Zhao et al. 2008). Morbidity and risk of infectious diseases in porpoises might be increased by environmental toxins (Nakayama et al. 2009).

This Page Intentionally Left Blank

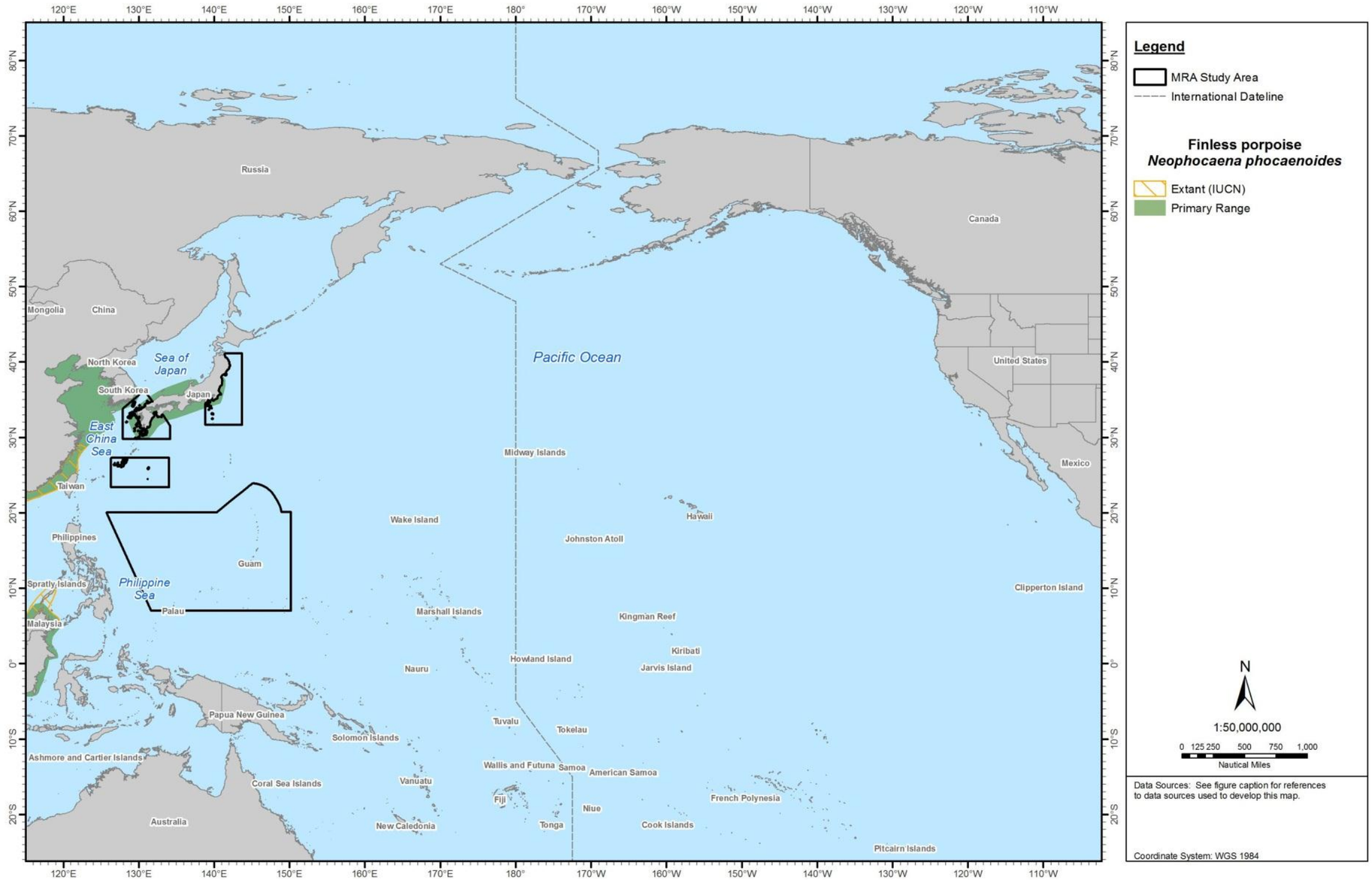

Figure 5-89: Geographic Range of the Indo-Pacific Finless Porpoise in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

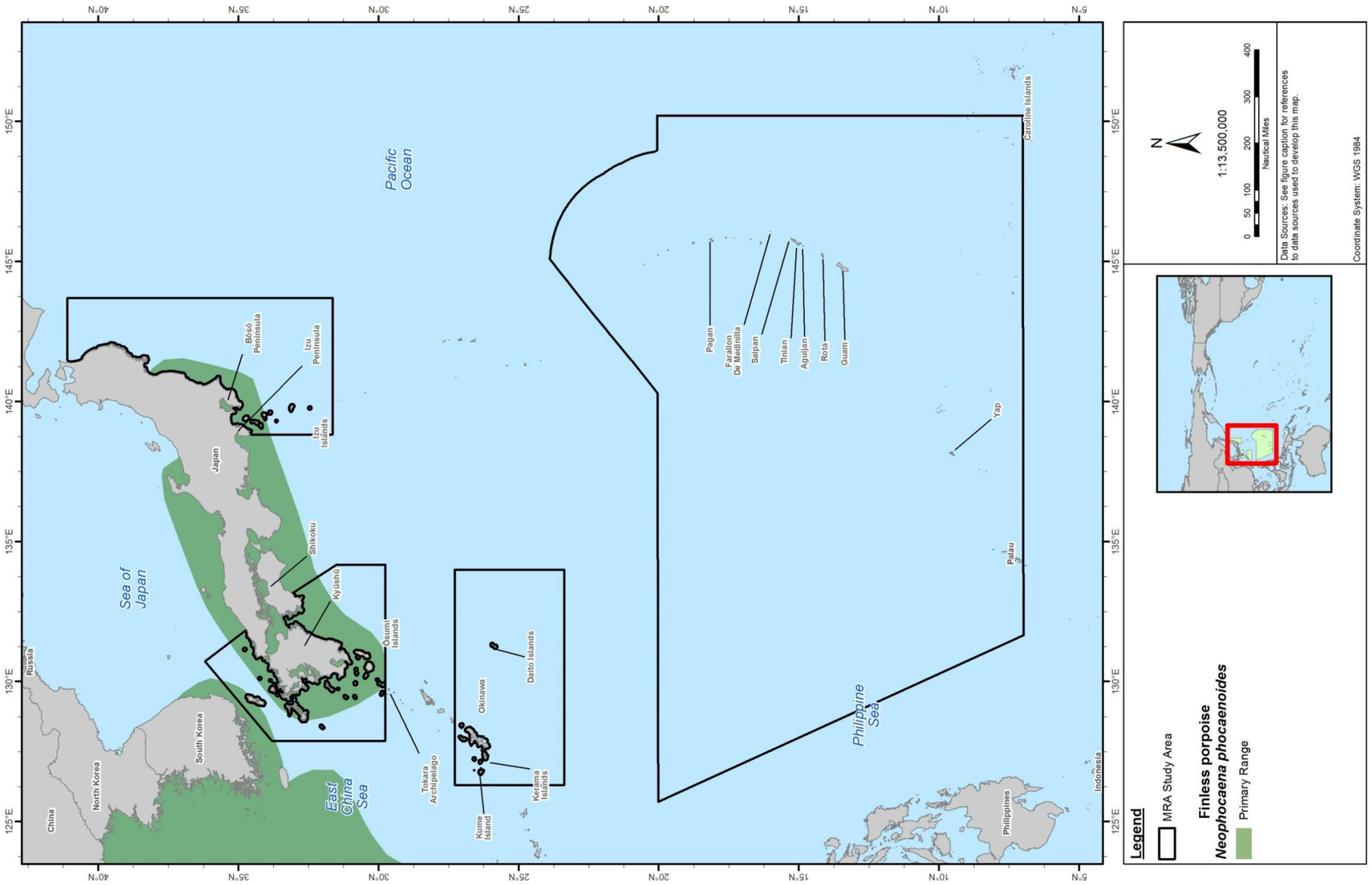

Figure 5-90: Geographic Range of the Indo-Pacific Finless Porpoise in the MRA Study Area
Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.40 DALL'S PORPOISE (*PHOCOENOIDES DALLI*)

5.40.1 Description

Dall's porpoise is the largest member of the porpoise family; this species reaches maximum lengths of approximately 2.2 m (females) and 2.4 m (males) (Jefferson, Webber, and Pitman 2008), and a maximum weight of 200 kg (Jefferson 2002). Dall's porpoise has a stocky body with a wide-based triangular dorsal that is slightly recurved at the tip; in mature males, the fin can become extremely canted (Jefferson 1990). The caudal peduncle is strongly keeled, especially in adult males (Jefferson 1990). The teeth are extremely small, the smallest of any cetacean species (Jefferson, Webber, and Pitman 2008). The individuals of this species found in the western Pacific are larger than those in the eastern Pacific Ocean National Marine Fisheries Service (2012f).

The Dall's porpoise is largely dark gray to black with a large, ventrally continuous white patch that extends up about halfway on each flank (Jefferson, Webber, and Pitman 2008). Frosting variations of the dorsal fin and flukes can be used to discern the general age of the individual (Jefferson 1990). Some other light patches may appear, particularly around the base of the tail stock (Jefferson 1990). Two major color morphs are known for the Dall's porpoise: one with a flank patch that extends forward to about the level of the dorsal fin (*dalli*-type) and the other with a flank patch extending to about the level of the flippers (*truei*-type) (Houck and Jefferson 1999). The *truei*-type is common off the Pacific coast of Japan; all other populations of Dall's porpoise normally have the *dalli*-type color pattern (Amano and Hayano 2007; Kasuya 1978). The *dalli*-type porpoises can be further split into two color-morphs: the North Pacific population, with a large white patch, and the Sea of Japan/Okhotsk population, with a smaller, more posterior white patch than that of the North Pacific population. It was also suggests that these color differences denote separate subspecies (Amano and Hayano 2007).

5.40.2 Status and Management

The Dall's porpoise is protected under the MMPA and is not listed under the ESA. This species is listed by the IUCN as a species of least concern and falls under Appendix II CITES regulations. Dall's porpoise is managed by NMFS in U.S. waters as two stocks: a California/Oregon/Washington stock and an Alaskan stock (Allen and Angliss 2010a; Carretta et al. 2010). There are an estimated ≥0.4 deaths or serious injury caused by fisheries in the California/Oregon/Washington stock (Carretta et al. 2012). Although these stocks do not have range within the MRA Study Area, Dall's porpoises are known to have primary range within the Japan portion of theMRA Study Area. Mortality occurs as bycatch in a number of U.S. fisheries, but annual takes are considered small and not a threat to the affected populations. Concern about the status of the two stocks recognized in U.S. waters does not appear justified (Allen and Angliss 2010a; Carretta et al. 2010).

At least 11 populations of Dall's porpoises are recognized globally (Amano and Hayano 2007). Three separate Dall's porpoise stocks have been identified in Japanese waters (Amano and Miyazaki 1996; Hayano, Amano, and Miyazaki 2003), although the small degree of genetic variation suggests their recent evolution as separate sub-stocks. One *truei*-type population and two *dalli*-type populations occur (although one of the latter inhabits northern offshore waters beyond the scope of the current MRA Study Area). These stocks are known to be exploited directly by a hand-harpoon fishery that operates off northern Japan, as well as through incidental catches in various net fisheries. At the least, the *truei*-type stock has probably been severely depleted by this mortality, but no more recent population assessments are available. Over 10,000 porpoise are taken annually from the Sea of Japan/Okhotsk

population and from the *truei*-type population off of the Pacific coat of Japan. In winter, mainly *truei*-type porpoises are taken from the Sanriku coast (Amano and Hayano 2007).

5.40.3 Population and Abundance

Geographically, the nearest stock assessment for U.S. waters was for the California/Oregon/Washington stock (estimated 42,000 [CV=0.33] porpoises) (Carretta et al. 2012). An estimated 100,000 porpoises occur off the Japanese coast (National Marine Fisheries Service). In the mid-1980s, the *truei*-type stock was estimated to number around 58,000 individuals, and at least an additional 46,000 *dalli*-type individuals were present (Miyashita and Kasuya 1988).

5.40.4 Biology, Ecology, and Behavior

Dall's porpoises can often be found in association with other small cetacean species such as Risso's dolphins, northern right whale dolphins, and Pacific white-sided dolphins (Braham 1983). Dall's porpoises are avid bowriders, especially on vessels traveling at high speed, and they also occasionally "snout ride" on the pressure waves created by the heads of large whales (Jefferson 1991).

Dall's porpoises reach speeds of 32 km/hr and are one of the fastest swimming small cetaceans in the ocean. These speeds are maintained for only short bursts. Some of their characteristic behavior may play a role in their feeding strategies (Jefferson 2009a; Miller 1989).

Group Size. Dall's are typically found in groups of 1 to 20 (Calambokidis et al. 2004; Houck and Jefferson 1999; Jefferson 1991). Large groups have been reported off the coast of California, numbering 1,000, and off the coast of Alaska, numbering up to 3,000 (Houck and Jefferson 1999), but possible species misidentification of these groups is a concern. Smaller groups gather for certain behaviors, such as feeding and playing, and then split again into smaller groups (Jefferson 1991; Miller 1989). Whether age/sex segregation occurs in other geographical areas where this species is present is unknown; however, Monterey Bay subadults have been noted to spend much of their time near the head of the Monterey Submarine Canyon.

Predator/Prey Interactions. Dall's porpoises feed primarily on small fish and squid (Houck and Jefferson 1999; Ohizumi et al. 2000). This species has very small teeth, so most prey are less than 25 cm long. A study in Monterey Bay showed that Pacific hake, juvenile rockfish, and market squid made up approximately 85% of the food items of this porpoise. The most common prey species in the Sea of Okhotsk are the Japanese pilchard and squid. The diet of Dall's porpoises determined from analyses of stomach contents during studies in the North Pacific along the West Coast included 33 species of near-surface and mid-water fishes, as well as squid (Houck and Jefferson 1999). In some areas, they appear to feed preferentially at night on vertically-migrating fish and squid associated with the DSL (Houck and Jefferson 1999). In waters around northern Japan, they appear to prefer epipelagic prey, but also feed on benthopelagic species (Ohizumi et al. 2000).

Known predators of the Dall's porpoise are killer whales and large sharks (Jefferson 2009a; Jefferson, Webber, and Pitman 2008). Attacks from killer whales occur often in Alaskan waters, where they are considered a major predator to the Dall's porpoise (Jefferson 2009a).

Life History. In the central and western North Pacific, females reach sexual maturity from 4 to 7 years, while males are considered sexually mature between 3.5 and 8.0 years, depending on population (Houck and Jefferson 1999). Like other odontocetes, females are spontaneous multi-ovulators (Willis and Dill

2007). Male's exhibit behaviors of mate-guarding, forming associations with individual females during the breeding season, unlike most other species of cetaceans (Willis and Dill 2007). In Japan, breeding grounds are located in the north and south Okhotsk Sea and in the western North Pacific, south of the Kamchatka Peninsula (Amano and Hayano 2007). The South Japan Sea/Okhotsk population (*dalli* type) has a breeding season approximately 1 month earlier than the *truei* type or North Pacific *dalli* type. Data suggest Dall's porpoises exhibit breeding ground fidelity. *Dalli* types that intermingle with the *truei* stocks types may return to their breeding grounds in South Okhotsk in early May to June (Amano and Hayano 2007). Seemingly, a strong summer calving peaks from June through August, and a possibly smaller peak occurs in March (Jefferson 1989). Pregnancy lasts about 10 to 12 months (Jefferson 2009a). In Japanese waters, life history has been well studied (Houck and Jefferson 1999). Calving occurs in August to September off the Pacific coast of Japan, and in May to June in the Sea of Japan/Okhotsk Sea (Houck and Jefferson 1999). Length at birth is about 100 cm (Jefferson, Webber, and Pitman 2008). Female Dall's porpoises give birth yearly, and attend to the movements and suckling of calves during estrus (Willis and Dill 2007). The lactation period is unknown but thought to be very short, perhaps 2 to 4 months (Jefferson 1990).

Migration. North-south movements in California, Oregon, and Washington have been suggested to correlate to changing oceanographic conditions, both on seasonal and inter-annual time scales; Dall's porpoises shift their distribution southward during cooler-water periods (Forney and Barlow 1998). Dall's porpoise have been reported in southern California waters only in the winter, generally when the water temperature was less than 15°C (Norris and Prescott 1961). Inshore/offshore movements off Southern California have been reported, with individuals remaining inshore during fall and moving offshore in the late spring (Houck and Jefferson 1999). Seasonal movements have also been noted off Oregon and Washington, with higher densities of Dall's porpoises sighted offshore during winter and spring, and inshore during summer and fall (Green et al. 1992).

Inshore/offshore and north/south shifts in abundance have also been reported for Japanese waters (Miyashita and Kasuya 1988). The South Japan Sea population (composed of *dalli* types) migrates from the southern Sea of Japan to the southern Okhotsk Sea and the Pacific coast of Hokkaidō to breed (Amano and Kuramochi 1992; Miyashita and Kasuya 1988).The *truei* type population migrates from wintering grounds on the Pacific Coast of northern Japan to breed in the central Okhotsk Sea. Two other breeding grounds of *dalli* types are the northern Okhotsk Sea and South of the Kamchatka Peninsula (Amano and Hayano 2007).

Hearing/Vocalization. No empirical data are available regarding hearing ability of this species; however, based on the morphology of the cochlea, the upper hearing threshold is estimated at approximately 170 to 200 kHz (Awbrey et al. 1979).

Only short-duration, pulsed sounds have been recorded from Dall's porpoise (Houck and Jefferson 1999); this species apparently does not whistle often (Thomson and Richardson 1995). Dall's porpoises produce short-duration (50- to 1,500-microsecond), high-frequency, narrow band clicks, with peak energies between 120 and 160 kHz (Jefferson 1988).

Diving. Dives exceeding 4 or 5 min have not been observed. Hanson and Baird (1998) provided the first data on diving behavior for this species: an individual tagged for 41 min dove to a mean depth of 33.4 m (S.D. ±23.9 m), for a mean duration of 1.29 min (S.D. ± 0.84 min). However, based on physiological characteristics, this species is probably capable of much deeper dives. Dall's porpoises are generally

found in continental slope, offshore, and nearshore deep waters. They are not often observed in waters with depths less than 100 m (Green et al. 1992).

Males engaged in mate-guarding behaviors tend to undertake shorter dives (Willis and Dill 2007). This is thought to be a trade-off of time and depth of dive and guarding, although possibly the shorter dives may be offset by an increased dive rate (Willis and Dill 2007). Male individuals may suffer from decreased foraging efficiencies as a result of the decrease in the ratio of time spent foraging at depth to time spent in ascent and descent phases of dive (Willis and Dill 2007).

5.40.5 Habitat and Distribution

Dall's porpoises occur throughout the North Pacific Ocean. This species is also found in the adjacent Bering Sea, Sea of Japan, and Okhotsk Sea. In the eastern North Pacific, they occur from around the U.S./Mexico border (Baja California) (28° to 32°N) to the Bering Sea (65°N); in the central North Pacific, they occur above 41°N; in the western North Pacific, they occur from central Japan (35°N) to the Okhotsk Sea; in the Bering Sea, they occur in higher abundance near the shelf break (Jefferson, Webber, and Pitman 2008).

Dall's porpoise is one of the most common odontocete species in North Pacific waters (Calambokidis et al. 2004; Ferrero and Walker 1999; Jefferson 1991; Williams and Thomas 2007; Zagzebski et al. 2006). It is found from northern Baja California, Mexico, north to the southern Chukchi Sea, and south to central Japan (Houck and Jefferson 1999; Jefferson, Leatherwood, and Webber 1993a). In the eastern North Pacific, the species is common only between 32°N and 62°N (Houck and Jefferson 1999; Morejohn and Rice 1973). It is typically found in waters at temperatures less than 63°F (17°C) with depths of more than 590 ft. (180 m) (Houck and Jefferson 1999; Reeves, Stewart, et al. 2002). Groups are sometimes found more than 685 miles (1,100 km) offshore. When inshore, they are found most often in deep, open-ended channels with strong currents (Dahlheim, White, and Waite 2009; Miller 1989). Dall's porpoise is a cold-water species (Houck and Jefferson 1999). Although they do occur in waters up to 24°C (Miyashita and Kasuya 1988), the primary habitat of Dall's porpoise is cool (<17°C), deep (>180 m), outer continental shelf, slope, and offshore waters (Carretta et al. 2005b; Ferrero, Hobbs, and VanBlaricom 2002; Jefferson 1988).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. The range of this species includes just barely the northern border of the North Central Pacific Gyre province (Figure 5-91).

KUROSHIO CURRENT. The Kuroshio Current is included in the known range of this species (Figure 5-921).

EAST CHINA SEA. The East China Sea is included in the known range of this species (Figure 5-91).

PHILLIPINE SEA. The Philippine Sea is not included in the known range of the Dall's Porpoise (Figure 5-921).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. This is a cool-temperate to subpolar, deepwater species (Houck and Jefferson 1999). The following assessment is based primarily on information in Miyashita and Kasuya (1988) and

Amano and Kuramochi (1992). During the winter-spring period, an area of expected occurrence is north of 35°N, beyond the shelf break off the Pacific coast of Japan (Figure 5-92). A buffer of limited occurrence extends south to 33°N (which includes additional sightings reported in Miyashita and Kasuya (1988). During the summer-fall period, the overall range is expected to be quite similar to the winter-spring period, but good evidence suggests a northward shift in density in summer months when animals migrate from the Sea of Japan to the Pacific coast (Amano and Kuramochi 1992). Therefore, the expected occurrence extends south only to about 40°N during the summer.

MARIANA ARCHIPELAGO. The waters around the Mariana Archipelago are not included in the known range of the Dall's Porpoise (Figure 5-91 and Figure 5-92).

CAROLINE ISLANDS. The waters around the Caroline Islands are not included in the known range of the Dall's Porpoise (Figure 5-91 and Figure 5-92).

5.40.6 Species-specific Threats

Dall's porpoise has been largely depleted due to direct fisheries off the coast of Japan. Although the Japanese government is attempting to regulate the hunting of this species, the populations are still reduced indirectly through fisheries focused on other species in the area (United Nations Environment Programme n.d.-a).

This Page Intentionally Left Blank

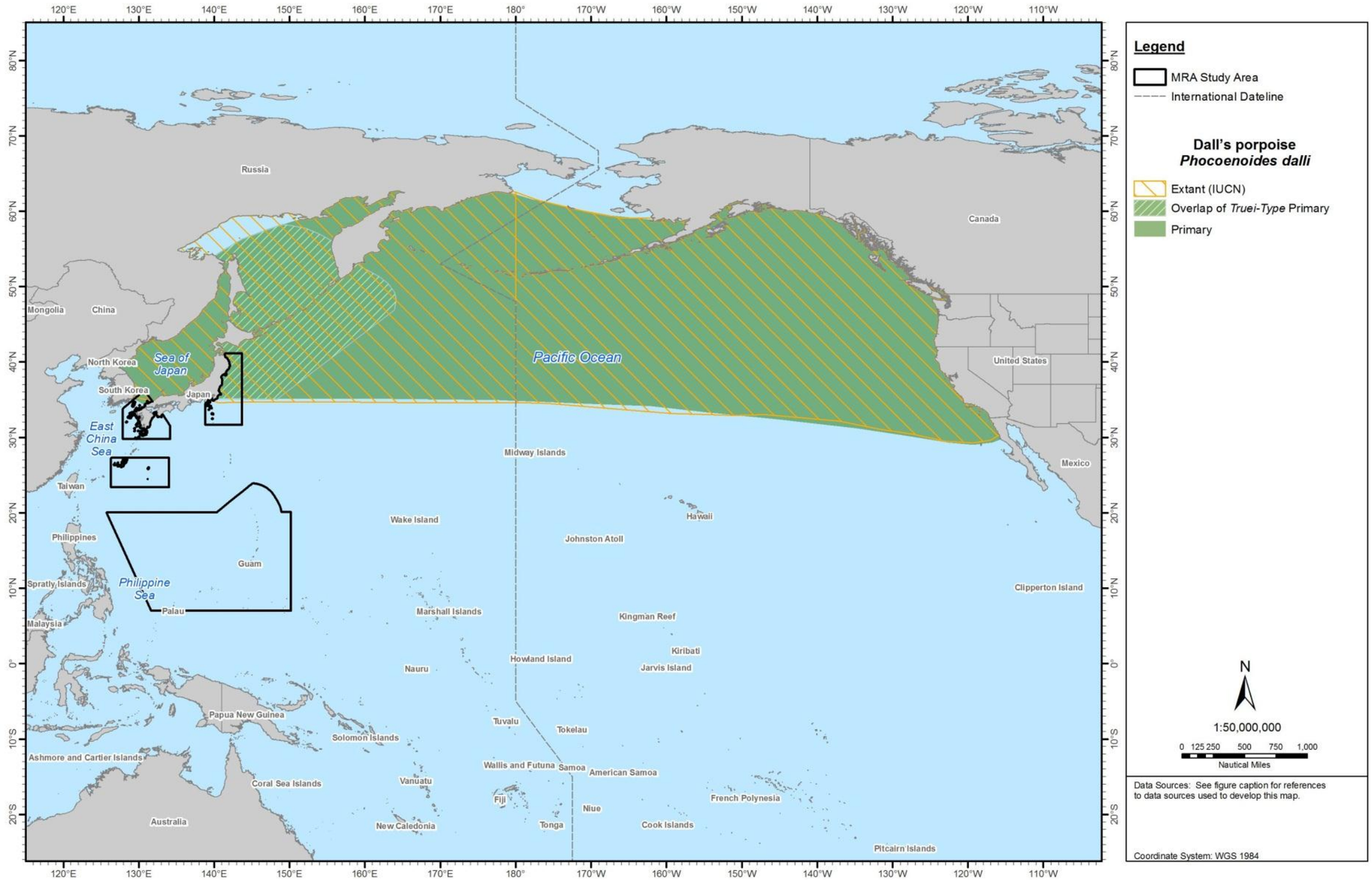

Figure 5-91: Geographic Range for Dall's Porpoise in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

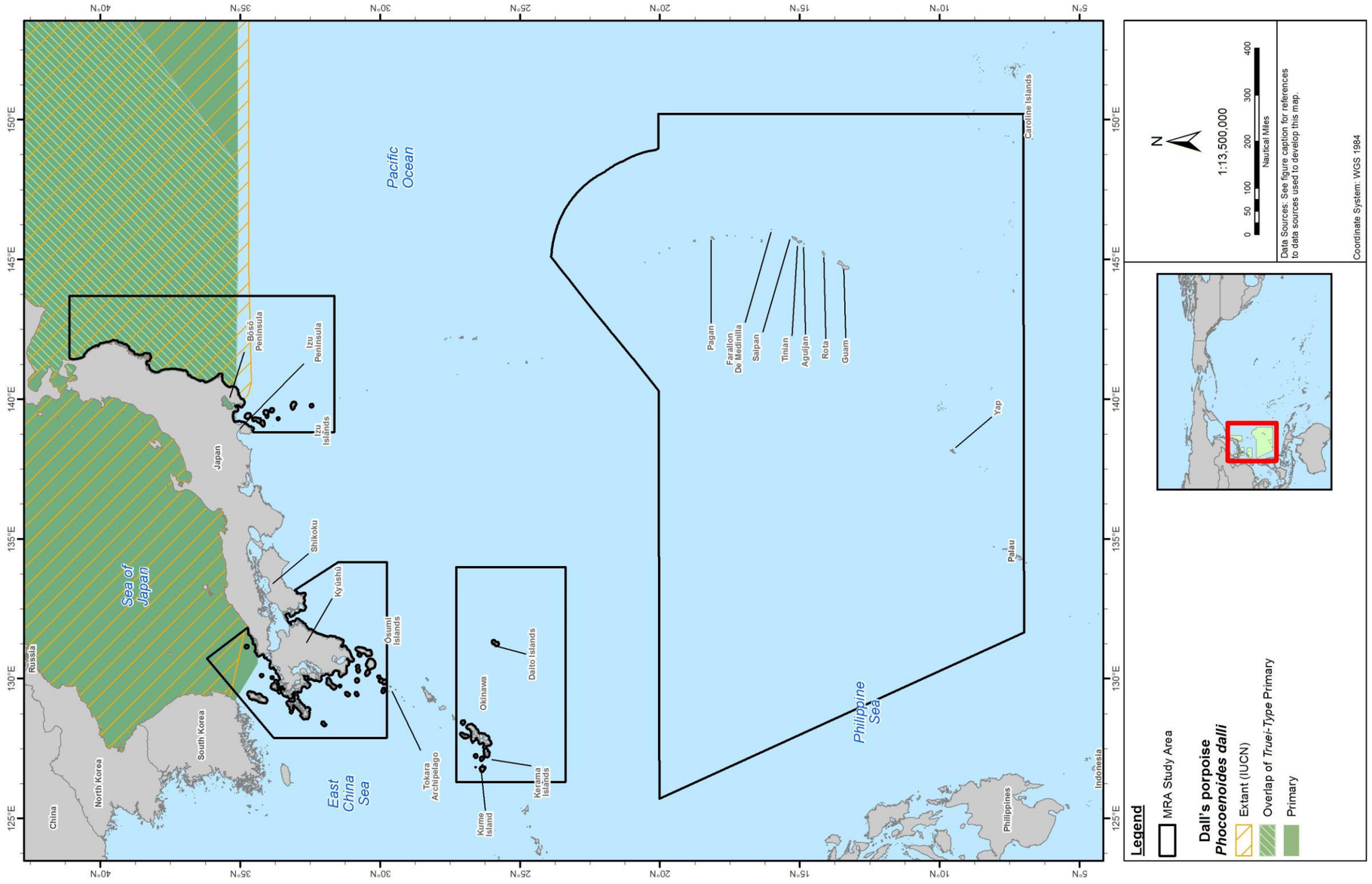

Figure 5-92: Geographic Range for Dall's Porpoise in the MRA Study Area

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.41 NORTHERN FUR SEAL (*CALLORHINUS URSINUS*)

5.41.1 Description

Northern fur seals are extremely sexually dimorphic: males may be more than four times larger than females (Jefferson, Webber, and Pitman 2008). Males can grow up to 2.1 m long and weigh 270 kg, while females can reach 1.5 m and 50 kg or more (Jefferson, Webber, and Pitman 2008). Northern fur seals have thick, cream-colored pelage overlaid by long, coarse guard hairs that make them appear darker. Females and subadults are generally silver to charcoal gray with a lighter underside and some variable light coloration on the face. Adult males may be gray to black or reddish-brown in color (Perrin, Würsig, and Thewissen 2008). Adult males have thicker pelage around their head, neck, chest, and shoulders, and a sagittal crest. Pups are generally black with a light belly (Perrin, Würsig, and Thewissen 2008). Northern fur seals have relatively small heads and short, pointed snouts with long ear flaps (Jefferson, Webber, and Pitman 2008).

5.41.2 Status and Management

Two stocks of northern fur seals (*Callorhinus ursinus*) are recognized in U.S. waters: an eastern Pacific stock and a San Miguel Island stock (Carretta et al. 2010). The eastern Pacific stock is listed as depleted under the MMPA, while the San Miguel Island stock is protected under the MMPA but is not considered depleted (Carretta et al. 2010). There are no annual fisheries caused mortality and serious injury for the San Miguesl stock (Carretta et al. 2012). The northern fur seal is not listed under the ESA. This species is also listed as data deficient by the IUCN and falls under Appendix II CITES regulations. At least five separate stocks of northern fur seals occur, based on geographic separation during the breeding season. Individuals from these stocks are considered one biological species (National Marine Fisheries Service 1993).

5.41.3 Population and Abundance

Demographic parameters imply populations of northern fur seals may undergo a cyclical pattern (Kuzin 2010). The abundance of northern fur seals in the North Pacific Ocean was estimated at 190,000 individuals during 1987 to 1990 (Buckland, Cattanach, and Hobbs 1993). In 2009, an estimated 140,000 northern fur seals were on Tyuleniy Island in the Sea of Okhotsk, with a recorded number of 38,000 live and 42,000 dead pups. This number has been increasing since a minimum population estimate of 50,000 seals (15,000 recorded pups) in 1992 (Kuzin 2010). The San Miguel Island population, off the coast of California, is also increasing. The breeding population is estimated at 8,000 to 10,000, with 2,500 pups produced annually (Melin, Ream, and Zeppelin 2006). Fecundity was estimated in more than 80% of adult females between 7 and 16 years old (Trites and York 1993).

Most of the world's breeding population of northern fur seals is in the Pribilof Islands, Alaska. Females were experimentally harvested from the area until 1968, and pelagic sampling occurred until 1974, which caused a decline in pup production (pup abundance is used to estimate seal populations) (Towell, Ream, and York 2006). It has also been suggested that paleoclimactic shift may have affected population decline (Newsome et al. 2007).The population has failed to recover, and stands at currently half the former population. A new phase of decline may have started in 2000 (Towell, Ream, and York 2006). The total number of pups alive in 2004 included an estimated 118,784 on St. Paul Island, with a pup mortality rate of 3.3, and 16,461 on St. George Island, with a pup mortality rate of 2.5 (Towell, Ream, and York 2006).

5.41.4 Biology, Ecology, and Behavior

Group Size. Northern fur seals are social during the breeding season, but are most often observed alone or in pairs while at sea (Gentry 2009; Jefferson, Webber, and Pitman 2008). This species tends to congregate in food-rich areas, and as many as 100 have been sighted together (Antonelis and Fiscus 1980; Gentry 2009; Kajimura 1984; Sterling and Ream 2004).

Predator/Prey Interactions. Northern fur seals are opportunistic feeders (Kajimura 1984). Their diet consists of northern anchovy, Pacific whiting, market squid, Pacific saury, jack mackerel, rockfishes, sablefish, and the oceanic squids (*Onychoteuthis spp*.) (Antonelis and Perez 1984; Kajimura 1984). Stomach and scat analyses from the Pribilof Islands over a period of 23 years have shown that primary prey types have changed over time, and that pollock, gonatid squid, capelin, bathylagid smelt, sand lance, and Pacific salmon were the most frequently occurring prey species on a decade scale (Sinclair et al. 2008). The principal prey species off Japan are the Pacific squid and pollock (Mori, Kubodera, and Baba 2001). Predation of myctophids occurs at night (Yonezaki et al. 2005). Telemetric tracking data show that foraging grounds in the subarctic and subtropical transition regions of the Pacific are associated with eddies (Ream, Sterling, and Loughlin 2005). Foraging for this species is associated with hydrogeographic features (Kuhn 2011). This species is known to feed along the continental slope and off the shelf; females forage in areas with depths of 100 to 200 m, while males forage in areas with depths exceeding 400 m (Calambokidis et al. 2004; Gentry 2009). Kuhn (2011) reports that satellite data from St. Paul Island, Alaska show that foraging bouts of northern fur seals are also associated with strong thermoclines. These thermoclines may act to congregate prey. Females may make shorter foraging trips at higher velocities than males (Hanks et al. 2011). Lactating adult females were shown to make two to eight consecutive foraging trips from the Pribilof Islands (Call et al. 2008) employing three distinct foraging tactics, and also demonstrated individual-level and rookery-specific foraging behaviors. These behaviors are: foraging site fidelity, low site fidelity, and a change from shelf foraging to outer or off shelf domains late in the season. Each was correlated with an associated pattern of mass change, with high site fidelity resulting in increased body mass in association with trip length. Juvenile fur seals are limited in their foraging capabilities (Shero et al. 2012). Foraging behavior, which occurs primarily at night, indicates that pups may feed on vertically migrating species (Baker 2007). Three-year-old pups feed at similar latitudes but at lower trophic levels than adult males (Newsome et al. 2007).

This species may be preyed upon by killer whales (Newman and Springer 2008), sharks, and Steller sea lions (Gentry 2009; Jefferson, Webber, and Pitman 2008).

Life History. Northern fur seals become sexually mature at 3 to 4 years, and females generally produce one pup per year for their entire lives. Males tend to become physically mature and large enough to compete for a territory later, at around 8 to 9 years. Northern fur seals breed mid-June through August, with a peak during July. Typically, male seals arrive at the rookeries as much as a month before females to establish territories; the northern fur seal has multiple mates. Northern fur seals are gregarious during the breeding season and maintain a complex social structure on the rookeries. Adult males defend the boundaries of their territories (Kiyota, Insley, and Lance 2008) and must fast throughout the breeding season (Perrin, Würsig, and Thewissen 2008). Northern fur seals exhibit strong site fidelity for mating and pupping; the male will defend only one territorial location in its reproductive lifetime, and females bear their young within 8 to 10 m of a particular site in successive years (Perrin, Würsig, and Thewissen 2008). Territorial males have been observed to take females by force from other territories (Kiyota, Insley, and Lance 2008). They establish territories in early to mid-May; females arrive in late May and give birth a few days later (Bonnell et al. 1980). The mean birthrate of northern fur seals in

Honshū is earlier than that in Hokkaidō, indicating that birthing occurs earlier at lower latitudes due to photoperiod influence (Kiyota, Tomita, and Baba 2009). Embryonic delay also is known to occur (Browne et al. 2006). Females give birth a day after arriving at the rookery (Jefferson, Webber, and Pitman 2008; Towell, Ream, and York 2006). Females alternate between nursing on land for about 2 days and feeding at sea for around 4 days (DeLong 1982). Pup abuse is recorded to occur regularly each breeding season on St. Paul Island, with each pup being harassed on average 3.8 times per season by non-territorial males and more frequently during the late breeding season. Adult females intervene in harassment only if they are attending to the pups, and actual infanticides are reportedly rare (Kiyota and Okamura 2005). Pups are weaned at around 4 months (Gentry 1998). Weaned pups have a high tolerance for cold water, but are still susceptible to thermal imbalance while resting. Behavioral strategies may aid with thermal regulations challenges (Liwanag 2010). Jughandle behavior, whereby one front flipper is placed between the two back flippers, is thought to be unique to northern fur seals and may help regulate body temperature in adults and pups. Grooming is also thought to provide thermal stability (Liwanag 2010). In late July, males abandon their territories, allowing subadult males to mate with females during the rest of the summer breeding season (Perrin, Würsig, and Thewissen 2008).

Migration. Most northern fur seals, excluding those of the San Miguel Island stock, migrate along continental margins from low-latitude winter foraging areas to northern breeding islands (Gentry 2009; Ragen, Antonelis, and Kiyota 1995). They leave the breeding islands in November to early December and concentrate around the continental margins of the North Pacific Ocean in January and February, where they have access to vast, predictable food supplies (Gentry 2009). They do not seem to follow coastal or bathymetric features while in transit (Ream, Sterling, and Loughlin 2005). Seals leaving the Pribilof Islands appear to follow the water movements of the Alaska Gyre and North Pacific current. The utilization of such oceanographic features may reduce energy expenditures (Ream, Sterling, and Loughlin 2005). Adult female fur seals equipped with radio transmitters have been recorded conducting roundtrip foraging trips of up to 285 miles (740 km) (National Marine Fisheries Service 2007). Females may migrate farther south than males during the winter (Newsome et al. 2007).

Juveniles have been known to cover long distances and to conduct trips between 8 and 29 days in duration, ranging from 171 to 680 km (Sterling and Ream 2004). They have been recorded traversing an area 2,500 km wide from the Gulf of Alaska to the central Aleutian Islands, and spanning a latitudinal area of 1,000 km from 45°N to 60°N (Baker 2007). Results from a satellite tracking study by (Baker 2007) show that pups did not travel far from their natal grounds prior to migration in December, and most pups that left the Bering Sea remained in offshore pelagic areas, with few pups remaining near shore.

Hearing/Vocalization. The underwater hearing range of the northern fur seal ranges from 0.5 Hz to 40 kHz, although their best underwater hearing occurs between 4 Hz and 17 to 28 kHz (Babushina, Zaslavsky, and Yurkevich 1991; Moore and Schusterman 1987). The hearing threshold has been reported to be alternately 50 to 60 dB re 1 µPa-m or 90 to 100 dB re 1 µPa-m at 1 kHz (Moore and Schusterman 1987). The underwater hearing sensitivity of this species is 15 to 20 dB better than it is in the air (Babushina, Zaslavsky, and Yurkevich 1991). The maximum sensitivity in air is at 3 to 5 kHz (Babushina, Zaslavsky, and Yurkevich 1991), after which an anomalous hearing loss occurs at approximately 4 or 5 kHz (Babushina, Zaslavsky, and Yurkevich 1991; Moore and Schusterman 1987).

Northern fur seals produce underwater clicks, and in-air bleating, barking, coughing, and roaring sounds (Thomson and Richardson 1995). Males vocalize (roar) almost continuously at rookeries (Gentry 1998). In-air and underwater audiograms of the northern fur seal are available. Of all the pinniped species for

which hearing information is available, the northern fur seal is the most sensitive to airborne sound (Moore and Schusterman 1987).

Diving. The average dive time of northern fur seals is 2.6 min, and most dives are shallow, between 4 and 50 m (Gentry 2009; National Marine Fisheries Service 2007). However, dives greater than 250 m have been recorded for this species (National Marine Fisheries Service 2007). Pups are relatively incapable of moving around on their own; they do not enter the water until they are 40 to 50 days old (Baker and Donohue 2000), and then make short shallow dives despite covering possibly large distances after weaning (Baker and Donohue 2000).

5.41.5 Habitat and Distribution

The northern fur seal is an extremely oceanic species spending all but 35 to 45 days per year at sea (Perrin, Würsig, and Thewissen 2008). They are usually sighted 70 to 130 km from land along the continental shelf and slope, seamounts, submarine canyons, and sea valleys, where there are upwellings of nutrient-rich water (Kajimura 1984).

Northern fur seals range throughout the North Pacific along the West Coast from California (32° N) to the Bering Sea, and west to the Okhotsk Sea and Honshū Island, Japan (36° N) (Baird and Hanson 1997; Carretta et al. 2010). They are typically found over the edge of the continental shelf and slope Sterling (Gentry 2009; Sterling and Ream 2004). The largest rookery is on St. Paul and St. George Islands in the Pribilof Islands Archipelago in Alaska. Smaller breeding colonies are located on the Kuril Islands in Japan, the Commander Islands in Russia, Bogoslof Island in the southeastern Bering Sea, and San Miguel Island in the Channel Islands off southern California (Robson 2002). Northern fur seals are found throughout their offshore range throughout the year, although seasonal peaks are known to occur. Females and subadult males are often observed off Canada's west coast during winter (Baird and Hanson 1997).

All northern fur seals except the San Miguel Island stock migrate along continental margins from low-latitude winter foraging areas to northern breeding islands (Gentry 1998). The northward migration begins in March (Antonelis and Fiscus 1980). They leave the breeding islands in November and concentrate around the continental margins of the North Pacific Ocean in January and February. There they have access to vast, predictable food supplies (Gentry 1998).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. The North Central Pacific Gyre is not included in the known primary range of the northern fur sea (Figure 5-93).

KUROSHIO CURRENT. The northern fur seal occurs in the Kuroshio Current (Figure 5-93). An area of expected occurrence is north of 35°N in the MRA Study Area. They are usually sighted offshore (70 to 130 km from land) and along the continental shelf and slope, where they typically forage (Kajimura 1984). They may occur farther south in the East Japan study area and West Japan study area. Occurrence pattern is the same throughout the year.

EAST CHINA SEA. The East China Sea is not included in the known primary range of the northern fur sea (Figure 5-93).

PHILLIPINE SEA. The Philippine Sea is not included in the known primary range of the northern fur sea (Figure 5-93 and Figure 5-94).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Northern fur seals regularly occur in the MRA Study Area between November and July when they migrate off Japan (Figure 5-94). They move southward along the western coast of Hokkaidō and Honshū into the Sea of Japan (Panin and Panina 1968). Most northern fur seals remain north of the transition zone between the Oyashio and Kuroshio currents (about 35°N) (Perrin, Würsig, and Thewissen 2008); however, some seals migrate as far south as the southern Sea of Japan, along the east coast of Korea (Nishiwaki and Nagasaki 1960). Extralimital records refer to presence as far south as Chinese waters (Zhou 1991). In spring or early summer, northern fur seals return to their northern breeding areas in and around the Bering Sea (Nishiwaki and Nagasaki 1960). Northern fur seals are known to breed in the Kuril Islands (Dickerson et al. 2010; Robson 2002).

Bosco Peninsula, Izu Peninsula, and Izu Islands. They are generally more abundant off the Pacific coast of Japan, and have been sighted on the east coast of Honshū off Iwate, Miyagi, Ibaragi, and Choshi (Nishiwaki and Nagasaki 1960; Panin and Panina 1968).

MARIANA ARCHIPELAGO. The coastal waters around the Mariana Archipelago are not included in the known primary range of the northern fur sea (Figure 5-93 and Figure 5-94).

CAROLINE ISLANDS. The coastal waters around the Caroline Islands are not included in the known primary range of the northern fur sea (Figure 5-93 and Figure 5-94).

5.41.6 Species-specific Threats

Subsistence and commercial hunting may have played a role in extirpation of some populations of the northern fur seal (Etnier 2007). Population decline may be partially due to the low survival rates of pups within the first year of life. This low survival rate is potentially caused by the reduced oxygen (O_2) storage potential in pups. This biochemical and physiological trait limits the pup's diving capabilities, and subsequently, their foraging success (Shero et al. 2012).

Infectious disease is not regarded as a cause of population decline based on evidence obtained during postmortem examinations of over 3,000 northern fur seals in the Pribilof Islands (Spraker and Lander 2010). Identified causes of mortality include bite wounds and secondary infections, pulmonary edema, dystocia, blunt trauma, and neoplasia. Hypothermia, blunt trauma, entanglement, and bite wounds are fatal conditions for subadult male northern fur seals (Spraker and Lander 2010). Northern fur seals are impacted by DA in algal blooms along the California coast (Lefebrve et al. 2010). Hookworms are well documented to infect northern fur seals (DeLong et al. 2009; Ionita et al. 2008; Lyons 2005; Lyons et al. 2011). Pup mortality is associated with hookworm infection, which is transmitted to pups from their mother's milk. The relationship between the parasitic hookworm and the fur seal host appears to be in constant flux (Lyons et al. 2011). Invermectin, an anti-parasitic medication, has been shown effective against hookworms in a small number of pups (DeLong et al. 2009). As populations have declined, so has the prevalence of hookworms (Ionita et al. 2008). In captivity, "Otarrid Keratitis," a corneal disease, is known to occur in northern fur seals, as well as in other otarrid species (Colitz et al. 2010). Exposure to chemical contaminants, such as PCBs and OCPs, is suspected as a cause of the population decline of northern fur seals in Alaskan breeding grounds (Wang, Shelver, et al. 2010). Dioxins observed in northern fur seals pose a potential problem, while PCB concentrations were below the safe limit (Wang, Shelver, et al. 2010). PCBs have been found in the blood of seals in Japan at levels lower than or comparable to what has been found in albatross (Kunisue and Tanabe 2009). PCBs are associated with

carcinoma in California sea lions (*Zalophus californianus)* (Ylitalo et al. 2005) and could affect fur seal populations, although the concentrations have been decreasing (Wang, Shelver, et al. 2010).

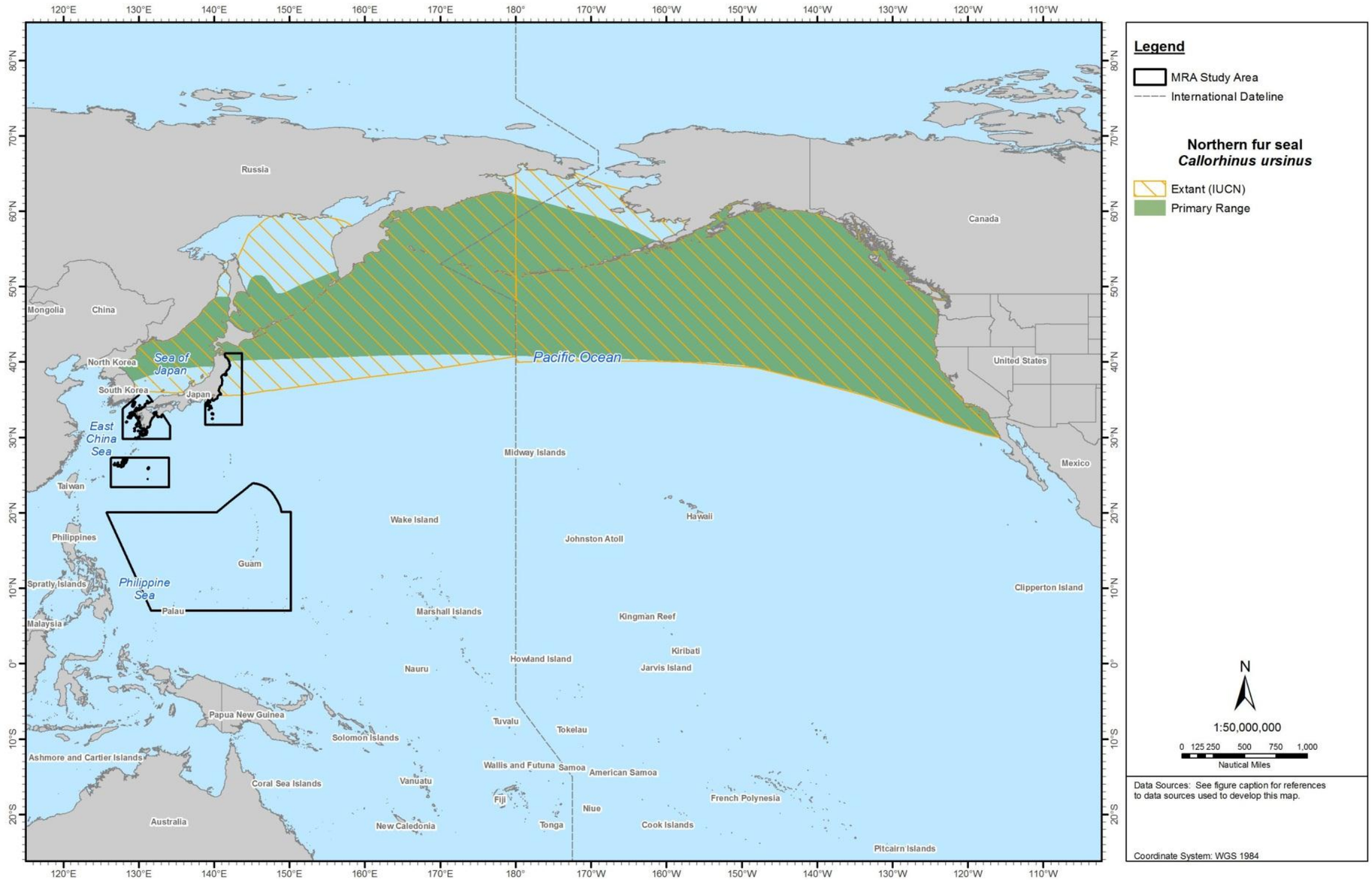

Figure 5-93: Geographic Range of the Northern Fur Seal in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

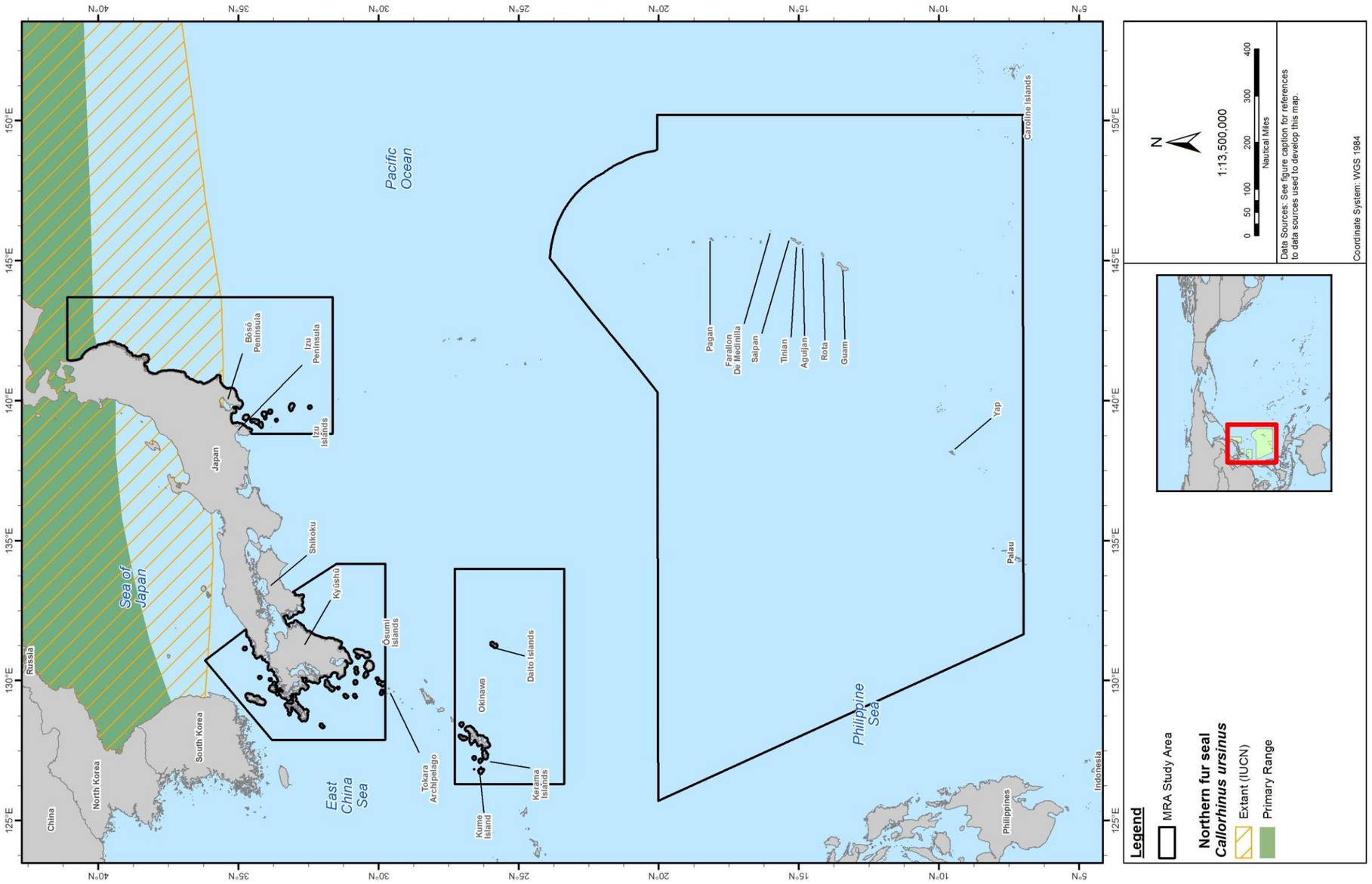

Figure 5-94: Geographic Range of the Northern Fur Seal in the MRA Study Area

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.42 SPOTTED SEAL (*PHOCA LARGHA*)

5.42.1 Description

The spotted seal was originally considered a subspecies of the harbor seal; however, several studies demonstrated ecological, behavioral, and genetic differences warranting species distinction (Bigg 1981; Nakagawa et al. 2010; Shaughnessy and Fay 1977). Spotted seals are often confused with harbor seals (*Phoca vitulina)*, as they are considered sibling species; they are similar in build and proportions, but harbor seals are somewhat smaller (Jefferson, Leatherwood, and Webber 1993b; Nakagawa et al. 2009). Spotted seals are generally pale, silver-grey above and below, and have a darker mantle with dark spots overall (Shaughnessy and Fay 1977). Spotting is fairly evenly distributed (Jefferson, Leatherwood, and Webber 1993b). The spotted seal (or larga seal) is a small- to medium-sized seal. Males reach a maximum length of 1.7 m, while females are slightly smaller at 1.6 m. Adults weigh between 82 and 123 kg (Jefferson, Leatherwood, and Webber 1993b).

5.42.2 Status and Management

The spotted seal is threatened (Southern stock) under the ESA and depleted under the MMPA. This species is also listed as data deficient by the IUCN and does not fall under CITES regulations. The spotted seal is categorized as a Critically Endangered Species in China and South Korea (Han et al. 2010). There are three distict population segments (DPS) of spotted seal in the Pacific: the Southern DPS, the Sea of Okhotsk DPS, and the Bearing Sea DPS (National Marine Fisheries Service 2012p).

5.42.3 Population and Abundance

The abundance of spotted seals in the Okhotsk Sea along the northern coast of Hokkaidō has been estimated at 13,653 individuals during the breeding season (Mizuno 2002). Spotted seal populations around Hokkaidō have no significant genetic differences (Nakagawa et al. 2010). According to the Hokkaidō Government population estimates, 320 spotted seals were observed in the Sea of Japan in March 2003, increasing to roughly 1,000 in February 2006. This indicates an increase in the number of seals migrating to the Sea of Japan (Hokkaido Government 2006). The Liaodong Gulf, China population was estimated at fewer than 1,000 individuals during a 2005 to 2008 study. Data suggest this population is in decline (Nakagawa et al. 2010).

5.42.4 Biology, Ecology, and Behavior

Group Size. Spotted seals are usually solitary while at sea but form large aggregations when they haul out on the early ice that forms near river mouths and estuaries (Burns 2002). They are often seen in groups of three (a female, her mate for the season, and her pup from last season) on the pack ice front during the breeding season (Quakenbush 1988).

Predator/Prey Interactions. Spotted seals feed on a wide variety of prey including fishes, crustaceans, and cephalopods; major seasonal and regional differences in diet are due to the wide ranging distribution of this species (Burns 2002), although fish are the dominant component of their diets (Dehn et al. 2006). Spotted seals off Hokkaidō are known to feed on fishes, cephalopods, euphasiids, decapods, squid, and octopus (Kato 1982). Fish were identified in 100% of 79 spotted seal stomachs in a study off the coast of Alaska and Canada, while mollusks occurred in less than 10% of the stomachs, and invertebrate prey was mainly comprised of crustaceans with amphipods at the largest proportion (Dehn et al. 2006). Pacific herring was the most frequently found fish in the gut of the spotted seal, followed by

gadids (Dehn et al. 2006). In the Sea of Okhotsk, spotted seals consumed mostly walleye pollock (Kato 1982). Spotted seals may feed on higher trophic levels than other pagophilic (preferring ice) seals (Dehn et al. 2006). Spotted seals likely respond to the seasonal availability of fish (Dehn et al. 2006). Feeding most frequently occurs in the morning and evening (Burns 2002).

Pagophilic seals are prey of higher tropic level organisms such as the Artic Fox, polar bear, walrus, and humans (Hammill and Smith 1991).

Life History. Spotted seals are annually monogamous and territorial (Burns 2002). The birth season lasts 1 to 2 months; lactation lasts from 2 to 6 weeks (Bigg 1981). Spotted seal births coincide with the period of maximum snow accumulation, weakest ocean currents, and slowest ice movements (Burns 1970). Pups are born between February and May; the timing of spotted seal pupping varies geographically (Quakenbush 1988). Pups are born earlier in the southern parts of the species' range (Burns 2002). Pups are weaned after 4 weeks (Quakenbush 1988). Along the coast of Hokkaidō, pupping occurs during the middle and end of March, and pups are weaned within 3 weeks (Mizuno 2002; Naito and Nishiwaki 1972). In this area, spotted seals mainly haul out between January and April, with peak numbers during the breeding season (March) (Mizuno, Suzuki, and Ohtaishi 2001). Spotted seal pups have a high mortality rate during the nursing period (Burns 2008).

Migration. Seals have been shown to undertake long-distance migration in the Chukchi Sea (Lowry et al. 1998). The spotted seal is ice-breeding (Burns 2002). During ice-free months, seals spend about 16% of their time at haulout sites (Lowry et al. 1998). The rest of their time is spent at sea, probably feeding; trips at sea may cover over 1,000 km (Lowry et al. 1998). Spotted seals may spend many consecutive days at sea and return to coastal haulout sites for periods of several days between feeding bouts (Lowry et al. 1998). Individual spotted seals may migrate from the coast of Hokkaidō to adjacent waters and spend the summer season on the coast of Sakhalin. Some spotted seals are observed on the east side of Hokkaidō from March through April (Mizuno, Suzuki, and Ohtaishi 2001; Naito 1976). They are known to migrate to the Sea of Japan and Okhotsk coast of Hokkaidō from November through May (Burns 2002).

Hearing/Vocalization. Spotted seal hearing is presumed similar to that of the closely-related harbor seal. The harbor seal hears almost equally well in air and underwater (Kastak and Schusterman 1998). Harbor seals hear best at frequencies from 1 to 180 kHz; the peak hearing sensitivity is at 32 kHz in water and 12 kHz in air (Kastak 1998; Terhune and Turnbull 1995; Wolski et al. 2003). (Kastak and Schusterman 1998) observed a TTS of 8 dB at 100 Hz, with complete recovery approximately 1 week following exposure. (Kastak and Schusterman 1998) determined that underwater noise of moderate intensity (65 to 75 dB source levels) and duration (20 to 22 min) is sufficient to induce TTS in harbor seals.

Spotted seal calls appear to be relatively similar to those of harbor seals (Schevill et al. 1963). Male harbor seals produce communication sounds in the frequency range of 100 to 1,000 Hz (Thomson and Richardson 1995). A captive spotted seal emitted very faint clicks with major components at about 12 kHz (Cummings and Fish 1971). Beier and Wartzok (1979) reported that a captive male spotted seal primarily growled and drummed, while the female most often barked. Vocalizations occur more frequently during the breeding season than at any other time of the year (Beier and Wartzok 1979).

Diving. Spotted seals are capable of diving to depths of 500 m (Burns 2002).

5.42.5 Habitat and Distribution

Spotted seals range from the Beaufort, Chukchi, Bering, and Okhotsk Seas south to the northern Yellow Sea and western Sea of Japan (Shaughnessy and Fay 1977). Breeding is associated with seasonal pack ice and mainly occurs in parts of the Bering Sea, Okhotsk Sea, Tartar Strait, Peter the Great Bay, and Bohai Sea (Shaughnessy and Fay 1977). Spotted seal distribution overlaps with harbor seals in the southern part of the Bering Sea (Quakenbush 1988). Not much is known about their winter distribution and migration routes (Quakenbush 1988). During early spring, spotted seals are distributed along the southern margin of the pack ice; they move to coastal haulout sites when the ice retreats in late spring (Shaughnessy and Fay 1977). In Japan, individuals are mainly distributed around Hokkaidō, particularly on the pack ice in the southern Okhotsk Sea during the pupping and breeding season (Jefferson, Webber, and Pitman 2008; Naito and Konno 1979). Some seals have been recorded in the far south along the east and west coasts of Honshū and off the southeast coast of Shikoku (Naito 1976). Spotted seals are also found around Nemuro on the Cape of Erimo in Hokkaidō (Nishiwaki and Nagasaki 1960) and in the northern Sea of Japan (Naito 1976; Naito and Konno 1979; Naito and Nishiwaki 1972). Haul out sites are located along the northern and central coasts of Hokkaidō (Mizuno, Suzuki, and Ohtaishi 2001).

When pack ice is present, spotted seals inhabit the frontal zone, which is generally made up of regular floes 10 to 20 m in diameter with brash ice or open water between (Burns 1970). Spotted seals give birth and wean pups on sea ice; therefore, the timing of these events depends on favorable sea ice conditions which is used for shelter and protection (Burns 2002). During warmer months when the sea-ice cover diminishes, spotted seals commonly haul out on coastal barrier islands, sandbars, rocks, and reefs (Lowry et al. 1998). They may also be found on river bars and tidal flats (Burns 2002).

Eight breeding colonies of northern fur seals are known. These are Liaodong Gulf; Peter the Great Bay; western coast of Sakhalin Island in the Tatar Strait; the eastern coast of Sakhalin Island extending to northern Hokkaidō; the Shelikova Gulf, northeast from Kronotsky Cape on the eastern side of the Kamchatka Peninsula to Olyutorski Gulf; the Gulf of Anadyr in the Bering Sea; and from Bristol Bay, Alaska to the west of Pribilof (Han et al. 2010).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. Most of the North Central Pacific Gyre is not included in the known range of this species, but adjacent waters to the west are included in their known range (Figure 5-95).

KUROSHIO CURRENT. The spotted seal does occur in the Kuroshio Current (Figure 5-95).

EAST CHINA SEA. This species may occur farther offshore of the southern tip of Kyūshū and west into the East China Sea. The spotted seal occurs in the East China Sea (Figure 5-95).

PHILLIPINE SEA. The Philippine Sea is not included in the known range of the spotted seal (Figure 5-95 and Figure 5-96).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. The spotted seal is a wide-ranging species that inhabits both pack ice and coastal areas (Burns 1970; Lowry et al. 1998). Spotted seals regularly occur in the Japan MRA Study Area

throughout the year (Figure 5-96). The spotted seal is one of the main seal species in Hokkaidō (Nakagawa et al. 2010).

Bōsō Peninsula, Izu Peninsula, and Izu Islands. Spotted seals haul out along the coast of Hokkaidō and have been sighted along the coasts of Honshū and Shikoku (Naito 1976). A juvenile spotted seal won national fame when it first appeared in the Tama River near Tōkyō in August 2002. It has since been seen hauled out on beaches near Kamogawa in the Greater Tōkyō area (Anonymous 2004).

Okinawa Island, Kerma Islands, Kume Island, and Daito Islands. Based on sighting records and the known distribution pattern, spotted seals are expected to occur from the shoreline to about 100 to 150 nm (185 to 278 km) offshore of Japan, excluding Okinawa and enclosed bays (Burns 2002; Zhou 1991).

MARIANA ARCHIPELAGO. The coastal waters around the Mariana Archipelago are not included in the known range of the spotted seal (Figure 5-95 and Figure 5-96).

CAROLINE ISLANDS. The coastal waters around the Caroline Islands are not included in the known range of the spotted seal (Figure 5-95 and Figure 5-96).

5.42.6 Species-specific Threats

Hunting by humans is a threat to the spotted seal (Han et al. 2010). About 30,000 spotted seals were harvested from 1930-1990 (Han et al. 2010). Along the Hokkaidō coast and in Peter the Great Bay, spotted seals reportedly have high levels of anthropogenically induced mortalities (Mizuno 2002; Mizuno, Suzuki, and Ohtaishi 2001)—for example, accidental entanglements in salmon traps off the Nemuro Peninsula in Japan (National Marine Fisheries Service). Habitat destruction is also considered a threat to this species (Han et al. 2010). Because of this high degree of mortality, the Liaodong population has low genetic diversity, which can threaten long-term survival of this sub-population (Han et al. 2010). Studies have indicated that the small geographic range of spotted seals would result in an increased sensitivity to global warming (Laidre et al. 2008). The pathogen *Streptococcus phocae* has been found in a female spotted seal in Alaska. These bacteria can have detrimental effects on small populations (Hueffer et al. 2011).

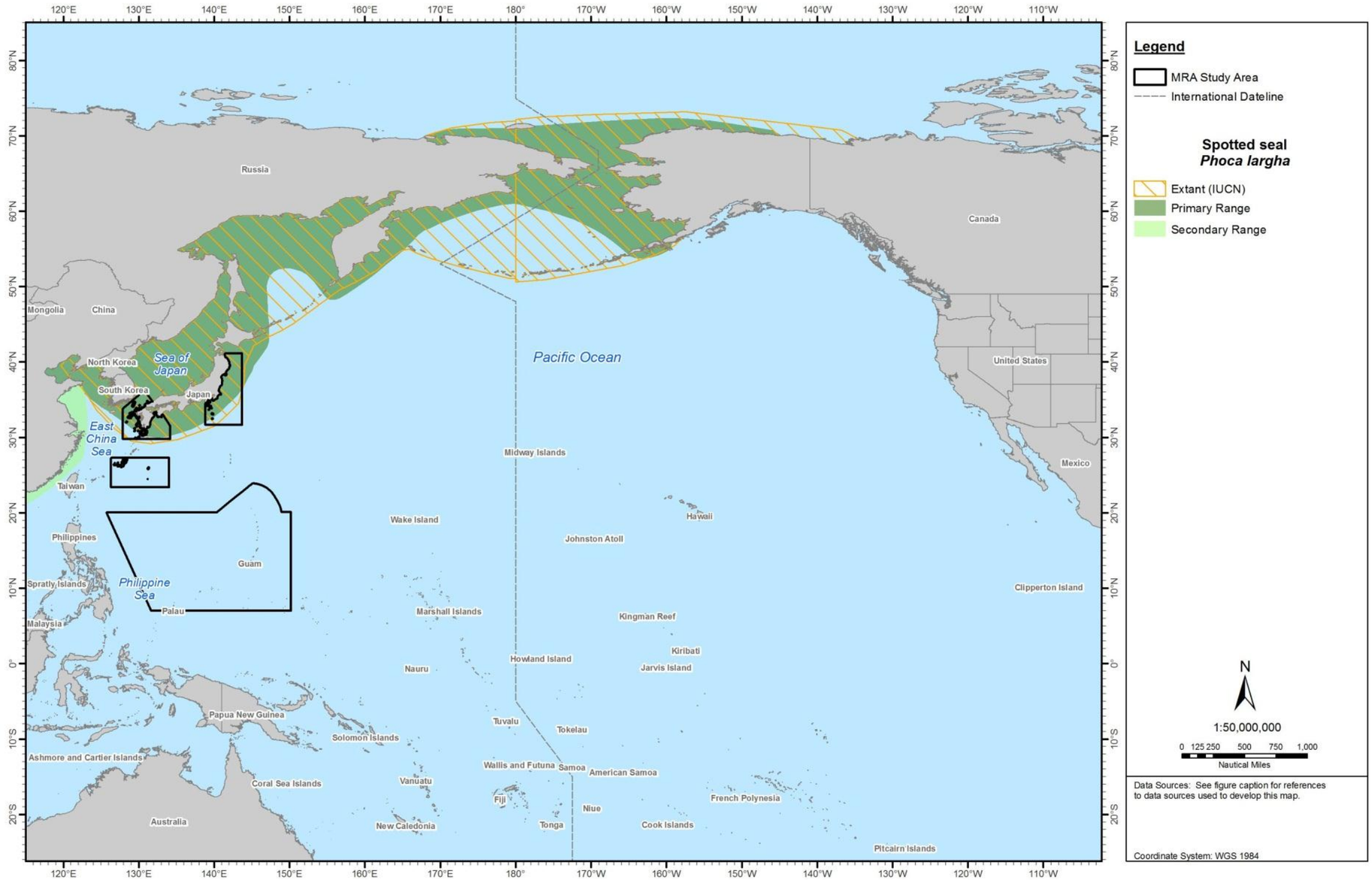

Figure 5-95: Geographic Range of the Spotted Seal in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

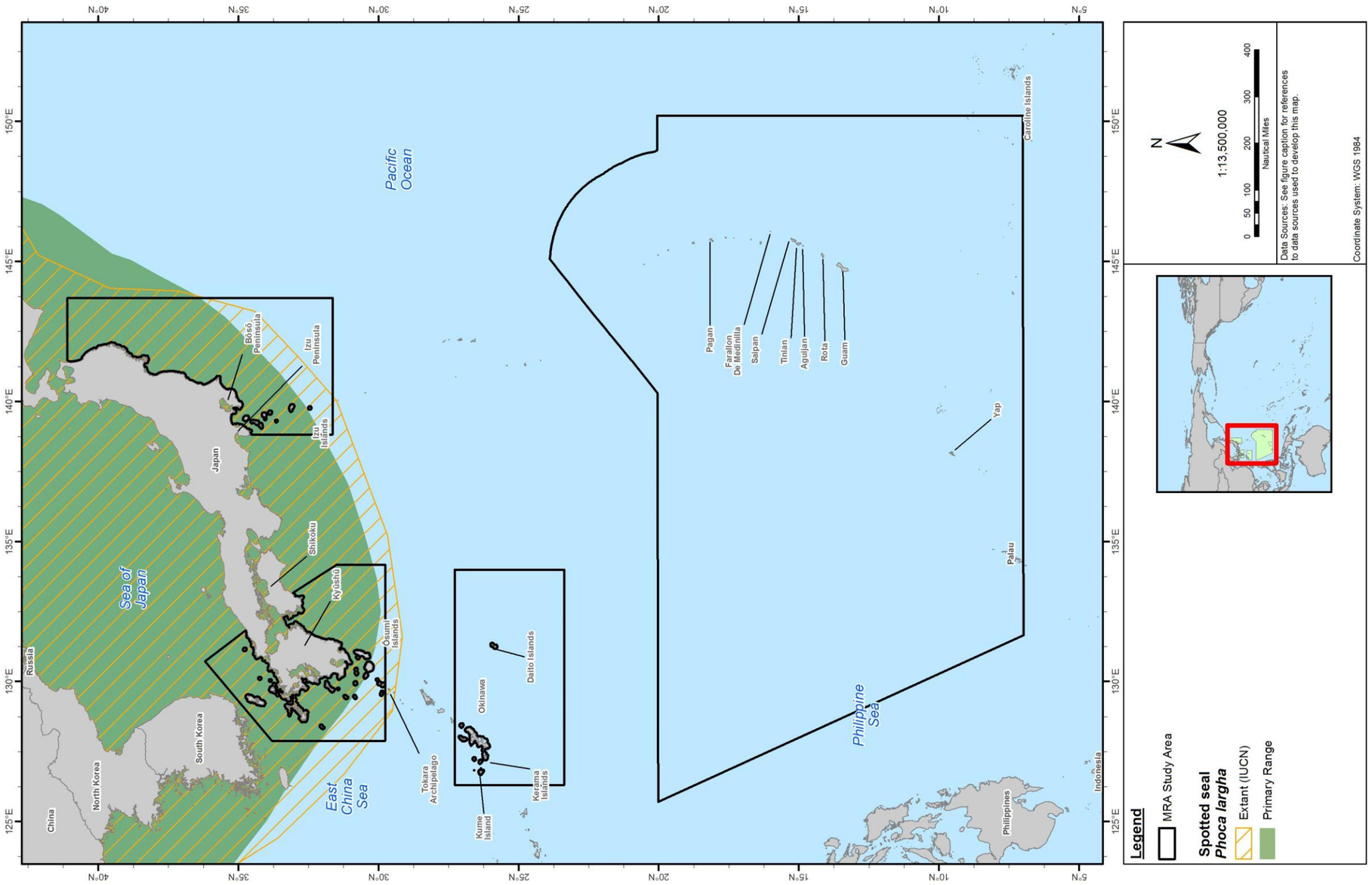

Figure 5-96: Geographic Range of the Spotted Seal in the MRA Study Area

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.43 DUGONG (*DUGONG DUGON*)

5.43.1 Description

Dugongs and manatees (*Trichechus spp.*) are the only extant members of the order sirenia (sea cows) (Jefferson, Webber, and Pitman 2008).

The dugong has a fluked tail (like dolphins and whales) and no dorsal fin (Marsh et al. 2002). The flippers are short and, unlike manatees, lack nails (Marsh et al. 2002). Dugongs are typically more streamlined than manatees (Jefferson, Leatherwood, and Webber 1993a). The head is squarish with very small eyes. The tusks of mature males and some old females erupt from either side of the mouth (Marsh et al. 2002). Once the tusks of male dugongs erupt after puberty, they begin to wear and may be used for sexual selection (Reidenberg 2007) and are not associated with foraging capabilities (Domning and Beatty 2007). The maximum size of this species is 3.3 m long, with a weight of 400 kg (Jefferson, Leatherwood, and Webber 1993a).

5.43.2 Status and Management

The dugong is listed as endangered under the ESA throughout its entire range (U.S. Fish and Wildlife Service 2003), and is designated as endangered by the IUCN Red List (Marsh et al. 2002). This species also falls under Appendix I CITES regulations. They are also protected through the Convention on the Conservation of Migratory Species of Wild Animals/Bonn Convention (Secretariat of the Pacific Regional Environment Programme 2011); they are also protected in New Caledonia (Garrigue, Patenaude, and Marsh 2008). In Japan, dugongs are classified by the Mammalogical Society of Japan as “critically endangered”, officially protected by the Fishery Resource Protection Act in 1993, and covered in the Wildlife Protection and Hunting Law of 2003 (Shirakihara et al. 2007). The dugong at Okinawa is designated as a protected animal under Japanese law and is considered an important component of the culture and history of native Okinawans (Secretariat of the Pacific Regional Environment Programme 2011). In Palau, the protection law covering the dugong addresses kills, restraints, and transportation; these regulations are specified in the Protected Sea Life law (subchapter IV), where fines and punishments are also addressed (Secretariat of the Pacific Regional Environment Programme 2011). To date, no one has been prosecuted to the full extent of the law for takes or harm to the dugong, and poaching continues illegally.

5.43.3 Population and Abundance

Australia’s coastal waters are known to be habitat for the world’s largest dugong population (Marsh et al. 2002). Marsh et al. (2005) places the Australian dugong population at 72,000 in the early 1960s and at 4,220 dugongs in the 1990s. The urban coast of Queensland currently supports 4,000 dugongs (Marsh et al. 2005). Torres Strait, Australia is also a globally important dugong habitat (Marsh 1995; Marsh and Kwan 2008; Marsh et al. 2002). Using aerial surveys, populations for this species in the Torres Strait were estimated at 11,956 (Pollock et al. 2006), which is a decline from the previous 14,106 (Marsh et al. 2005; Marsh 1989). In Moreton Bay, population counts from aerial surveys conducted since 1988 give numbers ranging between 344 (± SE 88) and 1,019 (± SE 166) (Chilvers et al. 2005). In New Caledonia, 323 dugongs were sighted in a 2003 aerial survey, with an estimated minimum population size of 1,814 individuals (Garrigue, Patenaude, and Marsh 2008). In Thailand, important habitats are believed to surround the Muk and Talibong Islands. In a 2003 survey, scientists estimated 9.2% to 16.7% of the animals observed in the Muk and Talibong Islands were calves, and in 2001, a total of 123 individuals were seen around these islands (Adulyanukosol et al. 2007). Jaaman, Lah-Anyi, and Pierce (2009)

recorded fisherman interviews from Malaysia, yielding information (though anecdotal) that the local dugong population has dropped significantly here.

The dugong population off of Okinawa is thought to be a small and present at a single, geographically isolated location. Ten dugongs were sighted during Okinawa aerial surveys (Shirakihara et al. 2007). Although abundance estimates are not available (Kasuya 1999a; Marine Mammal Commission 2002), yet past surveys in the Japan archipelago have sighted fewer than a dozen animals (Marine Mammal Commission 2002). The dugong's status is uncertain, and a recent IUCN review indicates a great likelihood for extinction of the Okinawa population (Marsh et al. 2002). The reduction in available habitat for this species appears to be associated with its decline in abundance, although dugong records have been restricted to Okinawa since the 1970s prior to much of the recent development here (Shirakihara et al. 2007). A total of 27 individuals were counted during a 2003 aerial survey at Palau, the only location in the Micronesia region with a dugong population (Davis 2004).

Dugongs exist as isolated, relict populations throughout most of their range (Marsh et al. 2002). Dugongs have a low rate of population increase (less than or equal to 5%) (Boyd, Lockyer, and Marsh 1999; Marsh, Penrose, and Eros 2003); the overall population is thought to be declining (Marsh et al. 2002).

5.43.4 Biology, Ecology, and Behavior

Acoustic studies based in Japan and satellite tracking studies in Queensland, Australia, show that tidal and diel variations affect dugong behavior and habitat use (Ichikawa et al. 2006; Sheppard et al. 2009). Satellite-tracked dugongs tend to remain closer to shore during high tide than low tide and closer to shore at night (Sheppard et al. 2009). In the afternoon, evening, and during incoming tides, nearshore movement is more prevalent. Offshore movement is more prevalent during outgoing tides and from midnight to midday. This behavior may allow dugongs to exploit intertidal seagrass beds and also may allow them to avoid anthropogenic disturbances (Sheppard et al. 2009).

Group Size. Most dugongs are sighted alone or in groups of two animals (Adulyanukosol et al. 2007; Davis 2004; Marsh et al. 2002; Shirakihara et al. 2007). Large aggregations of up to several hundred animals are regularly seen however at some locations, near Brisbane, Australia (largest group was recorded at 857 individuals) and Bundsberg, Australia (largest recorded group was 459 individuals) where they feed on seagrass meadows (Chilvers et al. 2005; Lanyon 2003; Marsh et al. 2002). In the Muk and Talibong Islands off Thailand, dugongs have been observed in groups of 1–79 animals. Calf-cow pairs were observed in groups of 3 to 10 individuals (Adulyanukosol et al. 2007).

Predator/Prey Interactions. Sirenians are the only herbivorous marine mammals (Marsh et al. 2002; Preen 1995a), and are known to forage on seagrass beds (Aragones et al. 2006; Preen 1995a; Sheppard, Lawler, and Marsh 2007; Sheppard et al. 2006). This behavior begins soon after birth (Marsh et al. 2002). Depending on the species of seagrass consumed, dugongs target either the leaves alone or uproot the entire plant and consume the leaves, roots, and rhizomes, leaving behind distinct feeding scars (Marshall et al. 2003; Preen 1995b). Seagrasses of the genera *Halophila* and *Halodule* are preferred (Aketa 2002; Marsh et al. 2002; Sheppard, Lawler, and Marsh 2007). Marine algae are also eaten (Marsh et al. 2002; Yamamuro, Aketa, and Uchida 2004), yet it is not known whether algae are a minor part of their diet or if dugongs only feed on algae when seagrasses are scarce (Whiting 2002a). Dugongs are known to occasionally supplement their herbivorous diet with macro-invertebrates (Aketa 2002; Preen 1995b). The highly specialized dietary requirements of the dugong suggest that only certain seagrass

meadows may be suitable as dugong habitat (Preen 1995b). Dugong grazing possibly optimizes seagrass growth (Aragones et al. 2006).

Dugongs feed primarily at night (Ichikawa et al. 2006; Shirakihara et al. 2007; Tsutsumi et al. 2006). Acoustical data suggest two or more dugongs at a time feed in the same area, and that they can feed in beds as shallow as twice their body height (Tsutsumi et al. 2006). Tusks are not thought to play a significant role in the feeding habits of the modern dugong (Domning and Beatty 2007). Dugongs are hindgut fermenters, relying on symbiotic organisms to aid in digestion of fibrous plant matter and have cheek-teeth small in comparison with those of other herbivorous mammalian hind gut fermenters (Lanyon and Sanson 2006). Oral horny pads may have assumed a major role in food consumption of dugongs (Lanyon and Sanson 2006).

Sharks are an active (Wirsing, Heithaus, and Dill 2007c) and perhaps the primary predator of dugongs (Heithaus and Dill 2002). Deep diving is thought to be an anti-predator strategy of the dugong, in an effort to remove the ability of sharks to see its silhouette (Sheppard et al. 2006). Dugongs in Shark Bay, Australia have been observed to tradeoff between predator risk and food availability by altering foraging patterns from the profitable excavation foraging technique to less profitable cropping technique. This tradeoff allows for regular visual scans in the presence of predators (Wirsing, Heithaus, and Dill 2007d). Dugongs have been shown to move to safer but relatively impoverished patches in deeper water in the presence of tiger sharks (Wirsing, Heithaus, and Dill 2007a, b, c, d). Killer whales have also been observed attacking dugongs (Anderson and Prince 1985).

Life History. Dugongs are slow growing mammals, with females reaching sexual maturity only after 6 to 17 years and producing a single calf every 2.5 to 5 years (Marsh et al. 2002). Dugongs have limited reproductive growth potential (Boyd, Lockyer, and Marsh 1999; Laist and Reynolds 2005). Mating behavior appears to differ from region to region, based on the few studies conducted on this topic (Boyd, Lockyer, and Marsh 1999). They appear to prefer mating in shallow water (Preen 1995b). Adulyanukosol et al. (2007) issued the first report of dugong mating behavior in tropical Asia, offering a generalization of mating behavior with five distinct stages: following, approaching and stimulating (includes muzzling on the ventral side of the body), pairing, mounting, and separating. Competition and fighting has been observed among males by Preen (1995a); presence of fighting and male to male competition may be supported by observations of parallel scars noted in a study by Adulyanukosol et al. (2007). The estimated gestation period is about 12 months; calves are nursed for at least 13 months (Marsh et al. 2002). Calves vary in size from 1 to 1.5 m (Adulyanukosol et al. 2007). Strong social bonds are evident between calf-cow pairs (Adulyanukosol et al. 2007; Marsh 1995). The life history and reproductive rate of dugongs correlate with seagrass dieback and recovery, with dugongs adversely affected by seagrass dieback (Marsh and Kwan 2008).

Migration. Satellite tracking data indicate that dugongs, across all ages and sex classes, can undertake long-distance movements ranging from 100 to 600 km, similar throughout the species (Sheppard et al. 2006). They tend to travel near the coast (Sheppard et al. 2006), although they are able to cross ocean trenches. Whiting (1999) reported dugongs, including calves, at Ashmore Reef on the Sahul Banks at the edge of the Australian continental shelf. Although Ashmore Reef is only 140 km from the Indonesian island of Roti, the Timor Trough, 2,000 m deep, separates these locations (Marsh et al. 2002). The capacity of dugongs to cross deep ocean trenches (depths up to 4 km) is also supported by reports of dugongs at Aldabra Atoll, located 425 km from Madagascar; dugongs had not previously been observed at this atoll (Marsh et al. 2002). These movements are likely habitat-driven, which is further supported by movements of large numbers of dugongs in western Australia following a tropical cyclone that

reduced availability of prey plants in one area (Gales et al. 2004). Large-scale movement also may correlate with ocean temperature, although individuals have been observed undertaking large-scale movement without thermal benefits (Sheppard2006).

Hearing/Vocalization. No hearing data regarding the dugong are available.

Dugongs produce complex sounds such as chirp-squeaks, barks, and trills (Anderson and Barclay 1995). Chirp-squeaks are in the 3- to 18-kHz range, last approximately 60 ms, and are often produced in sequence (Anderson and Barclay 1995; Ichikawa et al. 2006). Trills last as long as 2,200 ms and are within the 3- to 18-kHz frequency band (Anderson and Barclay 1995). Barks are broadband signals of 500 to 2,200 Hz lasting 30 to 120 ms (Anderson and Barclay 1995). Ichikawa et al. (2003) reported the center frequency of dugong calls ranges from 3 to 6 kHz. Chirps may be unique to individuals (Anderson and Barclay 1995)) and are the most frequently detected calls both in captive and in the wild (Ichikawa et al. 2003; Ichikawa et al. 2006). It has been indicated that dugongs in a focal area exchange vocalizations (Ichikawa et al. 2011), and vocal exchange of chirps could aid in cow/calf cohesion (Ichikawa et al. 2011).

Diving. Dugongs have been recorded diving to depths of at least 36.5 m (Sheppard et al. 2006). A positive relationship between dive duration and depth has been reported: maximum dive time at depths exceeding 1.5 m is 12.3 min (Chilvers et al. 2004); typical mean dive duration for depths less than 3 m from the water's surface is 2.7 (+S.D. 0.17) min (Chilvers et al. 2004). Data suggest that dugongs spend more time travelling through the water column than at the surface, and repeated deep dives occur along travel routes (Sheppard et al. 2006). Deep diving is thought to be an anti-predator strategy (Sheppard et al. 2006).

5.43.5 Habitat and Distribution

The dugong generally frequents coastal waters, but unlike manatees, it strictly occurs in marine waters. Over most of its range, the dugong is known only from incidental sightings, accidental drownings, and anecdotal reports of fishermen (Marsh et al. 2002). This species tends to concentrate in wide, shallow, protected bays; wide, shallow, mangrove channels; and in the lees of large inshore islands (Marsh et al. 2002). These areas coincide with sizeable seagrass beds (Marsh et al. 2002). Seagrass nutritional characteristics play a role in dugong habitat preference, based on a study of Burrum Heads, Australia (Sheppard et al. 2006). Shallow waters, such as tidal sandbanks and estuaries, have also been reported sites for calving (U.S. Fish and Wildlife Service 2003). Dugongs may contain a spatial memory for habitat concentration areas (Sheppard 2006). Dugongs in Australia are also regularly observed in deeper water farther offshore in areas where the continental shelf is wide, shallow, and protected (Marsh et al. 2002). This distribution reflects that of deepwater seagrasses, such as *Halophila spinulosa,* which occurs in western Australia waters (Anderson 1994; Marsh, Penrose, and Eros 2003; Sheppard et al. 2006). Dugong feeding trails have been observed at depths of up to 33 m off northeastern Queensland, Australia (Marsh et al. 2002). Dugongs spend 72% of their day in waters less than 3 m deep (De Iongh et al. 2007). Rarely are they seen more than 20 km offshore (Sheppard et al. 2006). The home range size of dugongs varies with resident geographic location (Sheppard et al. 2006). Australian waters have the largest dugong population (Marsh et al. 2002), and the seagrass beds of Torres Straight are known to be important dugong habitat. Mesoscale movements of dugongs in Australia suggest that their range is significantly influenced by water temperature (Sheppard et al. 2006; Wirsing, Heithaus, and Dill 2007a). Tracked dugongs in Australia used coastal areas up to 300 km long (Whiting 2002a).

The dugong has a large range that spans at least 37 countries and territories, and includes tropical and subtropical coastal and inland waters from east Africa to Vanuatu, between about 26° and 27° north and south of the equator (Marsh et al. 2005; Marsh et al. 2002; Nishiwaki et al. 1979). Dugongs have been repeatedly sighted in Myanmar, with the most recent sighting as bycatch in 2005 (Ilangakoon and Tun 2007). New Caledonia and Vanuatu, where sightings have been documented (Borsa 2006; Garrigue, Patenaude, and Marsh 2008), are thought to be the eastern limit of the dugong's range (Marsh et al. 2002).

Open Ocean of the MRA Study Area

NORTH CENTRAL PACIFIC GYRE. The dugong is primarily a coastal animal (Figure 5-97). Dugongs have likely been extirpated from the Hong Kong area (Jefferson and Hung 2004).

KUROSHIO CURRENT. Dugongs are found only in the nearshore waters around Japan in the Kuroshio current, and do not likely occur in open ocean waters.

EAST CHINA SEA. Dugongs are found only in the nearshore waters around Japan in the East China Sea, and do not likely occur in open ocean waters.

PHILIPPINE SEA. Dugongs are found only in the nearshore waters around Palau and Yap in the Philippine Sea, and do not likely occur in open ocean waters (Figure 5-98).

Coastal Waters of the MRA Study Area

JAPAN ARCHIPELAGO. Amami Osima Island, between Okinawa and Kyūshū, is thought to be the northern limit of the dugong's range (Figure 5-97 and Figure 5-98) (Nishiwaki et al. 1979). Sightings from Amami Islands to Sakishima have occurred, although whether these dugongs are migrants from other areas is unknown (Uchida 1997).

Kyūshū Island, Ōsumi Islands, and Tokara Archipelago. In September 2002, an adult dugong was found dead on the Ushibuka coast of Kyūshū (approximately 750 km north of Okinawa) (Yamamuro, Aketa, and Uchida 2004). Yamamuro, Aketa, and Uchida (2004) noted that it appeared the animal had been feeding farther south than the area where it stranded, and Okinawa is well established as the northern range of the species.

Okinawa Island, Kerma Islands, Kume Island, Daito Island. In Japanese waters, the dugong is only known to occur on Okinawa Island (Kasuya 1999a; Kasuya and Brownell 2001). Expected occurrence for the dugong is from the shore to the shelf break around all of Okinawa, based on sighting, stranding, and fishery bycatch records reported by Dugong Network Okinawa (Dugong Network Okinawa 2001). A concentrated occurrence is off the east coast of Okinawa, from the shore out to the shelf break—known from the high density of sightings there (Dugong Network Okinawa 2001; Yoshida and Trono 2004), along with information suggesting that the density is high on the east coast (Shirakihara et al. 2007). In particular, the east coast of the middle and northern parts of the island between Katsuren Peninsula and Ibu Beach (about 100 km apart) are primary locations for this population (Kasuya and Brownell 2001; Shirakihara et al. 2007). The majority of seagrass beds occur in the central and northern parts of the east coast of Okinawa at depths of 0.4 to 6.4 m (Kasuya 1999a). Kasuya (1999a) noted sizeable seagrass beds off Miyako, Ishigaki, and Iriomote islands, although no surveys have been conducted there, and at least one bycatch record exists for that area. A low or unknown occurrence extends out from the shelf break to the east (out to the 4,000-m isobath), to the north (around the nearby Amami Islands), and to the

west (across to and including the adjacent continental shelf). This is based on the known habitat preferences of this species—at least occasional movements over waters with a bottom depth as deep at 4,000 m (Marsh et al. 2002); a suggestion that the range historically extended north to the Amami Islands (Kasuya and Brownell 2001); and the known global distribution of the species (Marsh et al. 2002). Occurrence pattern is believed similar throughout the year. Also speculated is that during daytime, dugongs occur outside the reef, while during nighttime, dugongs come into inshore feeding areas.

In 1998, 10 dugongs were recorded off the east coast of middle and northern Okinawa Island, where previous sightings and mortalities had been concentrated (Kasuya 1999a; Kasuya and Brownell 2001). Most of these sightings occurred in deep waters (<90 m) near the outer edge of the coral reef, but subsequent subsurface surveys confirmed feeding trails in shallow sea grass beds inshore from locations of the dugong sightings. Six individuals were sighted during an opportunistic helicopter survey in 1999 (Marine Mammal Commission 2002). Subsurface feeding trails were confirmed in shallow sea grass beds at about the same time (Marine Mammal Commission 2002). The Ministry of Environment carried out a 3-year survey from 2001 through 2003 for dugongs at Okinawa (Yoshida and Trono 2004).

An aerial and snorkeling study of dugongs from Okinawa Island, Iriomote Islands, and Sakishima Island, showed no dugongs located off the west coast of Okinawa Island, while nine were sighted off the northeast coast of Okinawa island and one off of the mid-east coast (Shirakihara et al. 2007). According to (Shirakihara et al. 2007), Japanese government studies spotted 19 dugongs off the west coast in 2000 to 2003, within the 90-m isobath of Okinawa Island. The movement pattern of dugongs off Okinawa island includes traveling in deeper waters outside of coastal reefs and sedentary movement in one area outside of the reefs (Shirakihara et al. 2007). At Okinawa, no depth preference in feeding has been identified (Kasuya 1999a; Shirakihara et al. 2007), and feeding is thought to occur at night (Shirakihara et al. 2007). Stomach content analyses of dugongs from Okinawa revealed seven species of seagrasses, as well as annelids, ascidians, and algae (Aketa 2002; Shirakihara et al. 2007; Yamamuro, Aketa, and Uchida 2004).

MARIANA ARCHIPELAGO. The dugong is not expected to occur in the Mariana Islands MRA Study Area during any time of the year. Nishiwaki et al. (1979) reviewed dugong distribution worldwide and concluded that this species likely never occurred in the Mariana Islands (Figure 5-97). The highly endangered status of this species, however, necessitates mentioning any extralimital occurrences in the Mariana Islands MRA Study Area. Extralimital sightings have been recorded in this area, including a sighting in Cocos Lagoon at the southern end of Guam in 1974 (Anonymous 1974; Randall et al. 1975), erroneously noted as 1975 in other records (Eldredge 1991, 2003). Several sightings occurred in 1985 (date unspecified) of a dugong along the southeastern coast of Guam (Eldredge 1991, 2003).

THE CAROLINE ISLANDS. Dugongs are known to occur in coastal waters around Palau and Yap (Figure 5-97 and Figure 5-98).

Palau. Palau is the closest location to the Mariana Islands (1,076 km) where dugongs regularly occur. The dugong population at Palau is one of the few still known to persist in an isolated archipelago (Brownell et al. 1981). In the Micronesia area, dugongs occur only in Palau (part of the western Caroline Islands), except for occasional sightings around Yap and Guam (Buden and Haglelgam 2010; Davis 2004; U.S. Fish and Wildlife Service 2003). They have a high level of historical/cultural importance on this island, where some bones (vertebrae and ribs) are still used for traditional jewelry. Direct kills, although illegal, may still occasionally take place (Secretariat of the Pacific Regional Environment Programme

2011). Near daily sightings of large groups (including adults and calves) occur around Malakal, Koror, where the dugongs forage for short periods (a few hours) (Secretariat of the Pacific Regional Environment Programme 2011).

Yap. Dugongs have been spotted twice in Yap, and once on Eauripuk Atoll and in Kosrae within the FSM (Buden and Haglelgam 2010). The two dugongs spotted in Yap are thought to have been wanderers from the Palau population (Adulyanukosol et al. 2007).

5.43.6 Species-specific Threats

The sensitivity of this species to multiple pressures is one factor that limits reproductive growth and survival (Read 2008). Furthermore, the fact that many individuals live in small, fragmented populations and subsist on an extremely limited diet exacerbates the threats to this species' growth and survival (Laist and Reynolds 2005), although less so in Myanmar (Ilangakoon and Tun 2007). Historical direct hunting of Dugongs has occurred in places within the MRA Study Area. Hunting them in Palauhas been historically and culturally important, and their meat has been considered valuable; some bones (vertebrae and ribs) are still used for traditional jewelry. Direct kills, although now illegal, may still occasionally take place (estimated number of dugongs killed illegally in 2010 to 2011 was between 5 and 15) (Secretariat of the Pacific Regional Environment Programme 2011).

Dugongs are a coastal species in proximity to anthropogenic stressors and utilize almost exclusively seagrass habitat; therefore, habitat degradation is a main threat to the dugong (Marsh and Kwan 2008; Yoshida and Trono 2004). Dugongs feed primarily in shallow, protected coastal environments where seagrasses are found. This puts them in proximity to humans much of the time. These feeding characteristics make the species susceptible to disturbance or injury, especially by boating. Boat presence was shown to reduce feeding by 0.8% in Mortenson Bay, Australia (Hodgson and Marsh 2007). In a stranding survey covering years 1877 to 2005 in New Caledonia, the Loyalty Islands, and Vanuatu, boat collisions accounted for a large number of dugong deaths. In this same survey, one Dugong was seen injured by a shark (Borsa 2006), although predation is currently not a major threat. Given that boating traffic and associated disturbance to feeding and resting, along with ship strikes, are expected to increase in the Queensland area, dugongs here are likely to face increasing pressure (Hodgson and Marsh 2007).

Dugongs are also threated indirectly by fisheries, and may be more impacted than some other cetaceans because of their affinity for coastal areas (Jaaman, Lah-Anyi, and Pierce 2009; Read 2008). In East Malaysia, dugongs are thought particularly susceptible to getting caught in gillnets (Jaaman, Lah-Anyi, and Pierce 2009). They are reported as bycatch, and are not significantly hunted, but they may be eaten if inadvertently caught (Rajamani, Cahanban, and Abdul Rahman 2006). They are directly hunted in some areas such as Melanesia, where traditional hunting is legal (Garrigue, Patenaude, and Marsh 2008; Ilangakoon and Tun 2007). Dugongs are important cultural and dietary animals of the Torres Strait Islanders (Marsh and Kwan 2008). Current harvest rates of dugongs in Torres Strait are not sustainable, and government funding has been allocated for community-based management and catch monitoring (Kwan, Marsh, and Delean 2006). Dugong hunting has historically occurred off Okinawa Island (Shirakihara et al. 2007), although intentional capture of dugongs is currently illegal in Japan. Numbers of stranded, bycaught, and captured dugongs have been decreasing over time, possibly in conjunction with population decline (Shirakihara et al. 2007).

In Okinawa, dugongs are threatened by planned construction of a military and airbase and public airport, which will affect important feeding and resting sites (Yoshida and Trono 2004).

Studies show anthropogenic contaminants accumulate in higher trophic level species (Harino et al. 2007b). Dugongs in waters of Thailand have been exposed to organotoxin compounds such as dibutylin, which have genotoxic and biochemically toxic qualities. Tri-phenyltin has been identified in the organs and tissues of dugongs (Harino et al. 2007b). Bioaccumulation of metals and organochlorine compounds (other than dioxins) does not pose a significant risk to Great Barrier Reef dugong populations, especially in comparison with the other pressures associated with anthropogenic activities (Haynes et al. 2005).

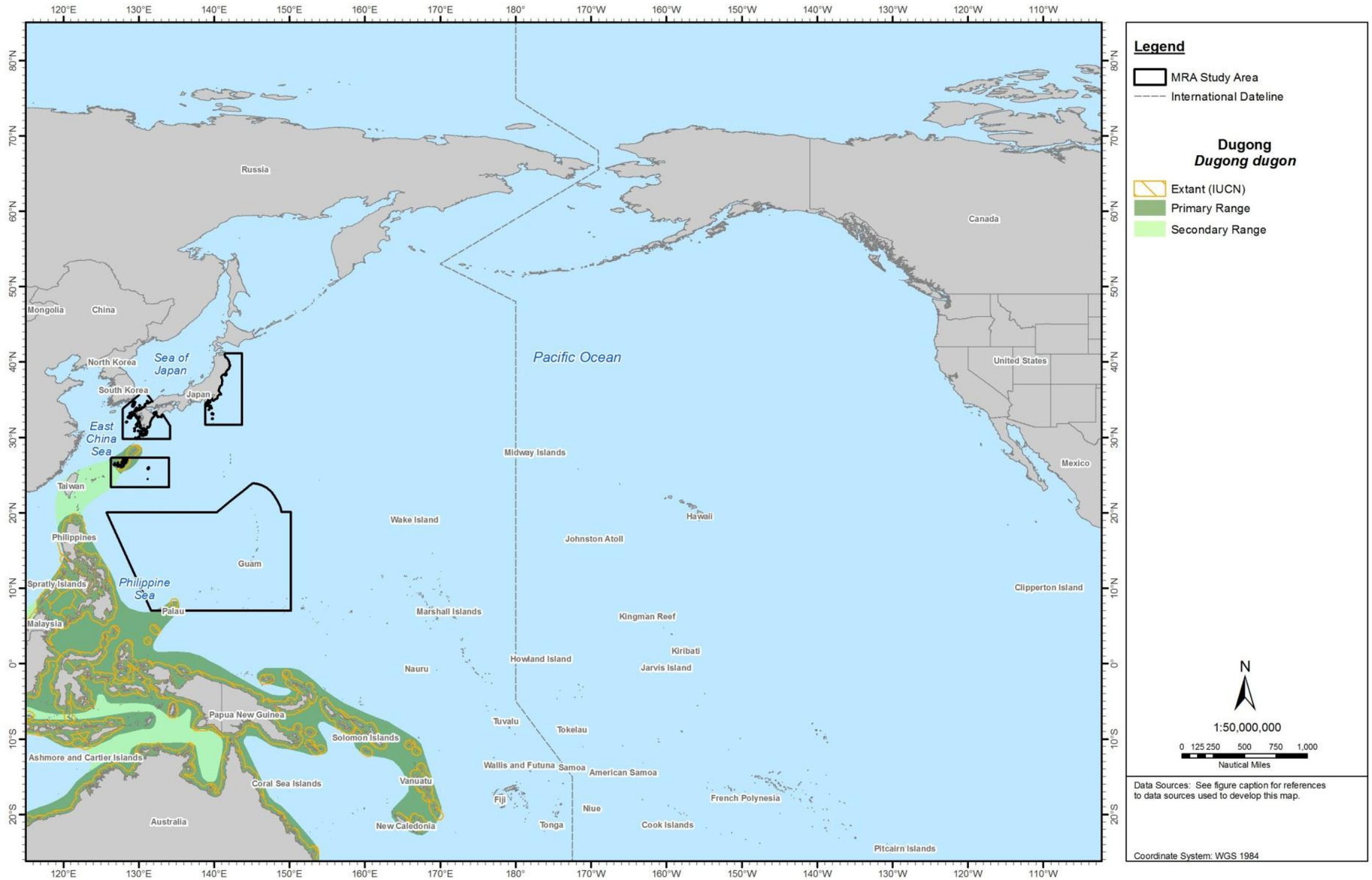

Figure 5-97: Geographic Range for the Dugong in the North Pacific Ocean

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

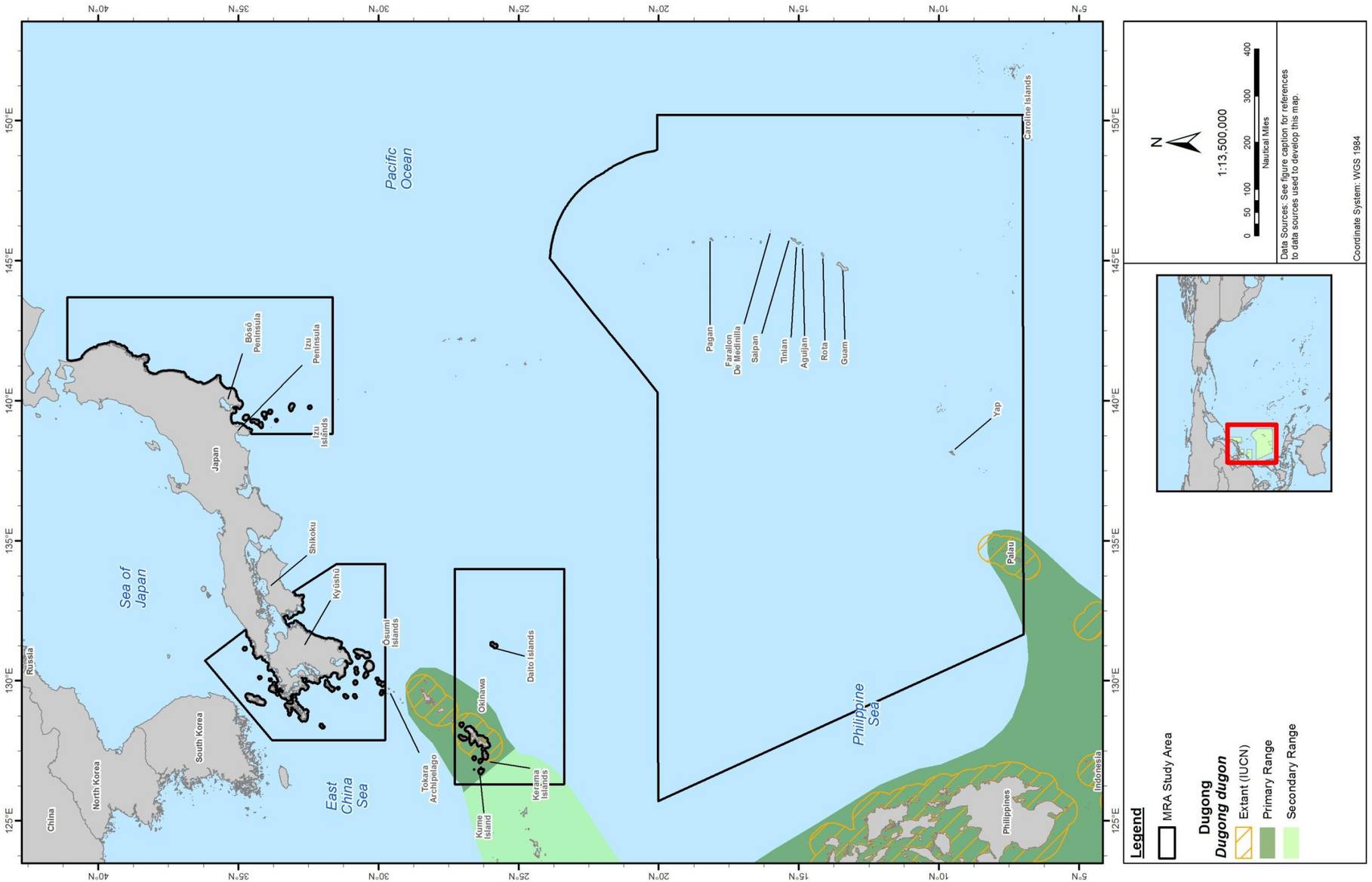

Figure 5-98: Geographic Range for the Dugong in the MRA Study Area

Sources: Jefferson, Webber, and Pitman (2008) [digitized by Tetra Tech with permission]; International Union for Conservation of Nature and Natural Resources (2012a).

5.44 REFERENCES

Abbot, T. A., Premus, V. E. and Abbot, P. A. (2010). A real-time method for autonomous passive acoustic detection-classification of humpback whales. *Journal of the Acoustical Society of America, 127*(5), 2894-2903. doi:10.1121/1.3365255

Abdo, W., Ryono, M., Dover, S. R., Fukushi, H., Okuda, H., Kano, R., et al. (2012). Pulmonary Zygomycosis with *Cunninghamella bertholletiae* in a killer whale (*Orcinus orca*). *Journal of Comparative Pathology, 147*, 94-99. doi:10.1016/i.jcpa.2011.08.012

Aburto, A., D.J. Rountry, and J.L. Danzer. (1997). Behavioral response of blue whales to active signals [Technical Report]. (1746). San Diego, California: Naval Command, Control and Ocean Surveillance Center, RDT&E Division.

Acebes, J. M. V. (2009). *Historical Whaling in the Philippines: Origins of 'Indigenous Subsistence Whaling', Mapping Whaling Grounds and Comparison with Current known Distribution: A HMAP Asia Project Paper*. (Working Paper No. 161, pp. 37) Asia Reserach Centre and History of Marine Animal Populations.

Acevedo-Gutiérrez, A., Croll, D. A. and Tershy, B. R. (2002). High feeding costs limit dive time in the largest whales. *Journal of Experimental Biology, 205*, 1747-1753.

Acevedo-Whitehouse, K., Rocha-Gosselin, A. and Gendron, D. (2010). A novel non-invasive tool for disease surveillance of freeranging whales and its relevance to conservation programs. *Animal Conservation 13*, 217–225. doi:10.1111/j.1469-1795.2009.00326.x

Adulyanukosol, K., Thongsukdee, S., Hara, T., Arai, N. and Tsuchiya, M. (2007). Observations of dugong reproductive behavior in Trang Province,Thailand: further evidence of intraspecific variation in dugong behavior. *Marine Biology, 151*(5), 1887-1891. doi:10.1007/s00227-007-0619-y

Afsal, V. V., Manojkumar, P. P., Yousuf, K. S. S. M., Anoop, B. and Vivekanandan, E. (2009). The first sighting of Longman's beaked whale, *Indopacetus pacificus* in the southern Bay of Bengal. [online]. *Marine Biodiversity Records, 2*, 1-3. doi:10.1017/S1755267209990510

Aguayo, L. A. and Sanchez, T. R. (1987). Sighting records of Fraser's dolphin in the Mexican Pacific waters. *Scientific Reports of the Whales Research Institute, 38*, 187-188.

Aguilar, A. (2008). Fin whale *Balaenoptera physalus*. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 433-437). Amsterdam: Academic Press.

Aguilar Soto, N., Johnson, M., Madsen, P. T., Tyack, P. L., Bocconcelli, A. and Borsani, J. F. (2006). Does intense ship noise disrupt foraging in deep-diving Cuvier's beaked whales (*Ziphius cavirostris*)? *Marine Mammal Science, 22*(3), 690-789. doi:10.1111/j.1748-7692.2006.00044.x

Aguilar Soto, N., Johnson, M. P., Madsen, P. T., Díaz, F., Domínguez, I., Brito, A., et al. (2008). Cheetahs of the deep sea: Deep foraging sprints in short-finned pilot whales off Tenerife (Canary Islands). *Journal of Animal Ecology, 77*(5), 936-947. doi:10.1111/j.1365-2656.2008.01393.x

Agusa, T., Nomura, K., Kunito, T., Anan, Y., Iwata, H., Miyazaki, N., et al. (2008). Interelement relationships and age-related variation of trace element concentrations in liver of striped dolphins (*Stenella coeruleoalba*) from Japanese coastal waters. *Marine Pollution Bulletin, 57*, 807-815. doi:10.1016/j.marpolbu1.2008.01.039

Aissi, M., Celona, A., Comparetto, G., Mangano, R., Wurtz, M. and Moulins, A. (2008). Large-scale seasonal distribution of fin whales (Balaenoptera physalus) in the central Mediterranean Sea.

Journal of the Marine Biological Association of the United Kingdom, 88, 1253-1261. doi:10.1017/S0025315408000891

Akamatsu, T., Nakamura, K., Kawabe, R., Furukawa, S., Murata, H., Kawakubo, A., et al. (2010). Seasonal and diurnal presence of finless porpoises at a corridor to the ocean from their habitat. *Marine Biology, 157*(8), 1879-1887. doi:10.1007/s00227-010-1459-8

Akamatsu, T., Nakazawa, I., Tsuchiyama, T. and Kimura, N. (2008). Evidence of nighttime movement of finless porpoises through Kanmon Strait monitored using a stationary acoustic recording device. *Fisheries Science, 74*(5), 970-975. doi:10.1111/j.1444-2906.2008.01614.x

Akamatsu, T., Wang, D. and Wang, K. (2005). Off-axis sonar beam pattern of free-ranging finless porpoises measured by a stereo pulse event data logger. *Journal of the Acoustical Society of America, 117*(5), 3325-3330.

Akamatsu, T., Wang, D., Wang, K. and Naito, Y. (2005). Biosonar behaviour of free-ranging porpoises. *Proceedings of the Royal Society of London, Part B, 272*, 797-801.

Aketa, K. (2002). Stomach contents of dugongs from Okinawa, southern Japan, from 1992 to 2000. *SIRENEWS, 37*, 8.

Akiyama, J. and Ohta, M. (2007). Increased number of whistles of bottlenose dolphins, *Tursiops truncatus*, arising from interaction with people. *Journal of Veterinary Medical Science, 69*(2), 165-170. doi:10.1292/jvms.69.165

Allen, B. M. and Angliss, R. P. (2010a). *Alaska Marine Mammal Stock Assessments 2009*. (NOAA Technical Memorandum NMFS-AFSC-206, pp. 276). Seattle, WA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center.

Allen, B. M. and Angliss, R. P. (2010b). Baird's Beaked Whale (*Berardius bairdii*): Alaska Stock. In *Alaska Marine Mammal Stock Assessments, 2010*. (NOAA-Technical Memorandum-AFSC-223, pp. 159-161). Seattle, WA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/ak2010whba.pdf

Allen, B. M. and Angliss, R. P. (2010c). Gray Whale (*Eschrichtius robustus*): Eastern North Pacific Stock. In *Alaska Marine Mammal Stock Assessments, 2010*. (NOAA-Technical Memorandum-AFSC-223, pp. 166-178). Seattle, WA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/ak2010whgr-en.pdf

Allen, B. M. and Angliss, R. P. (2010d). Humpback Whale (*Megaptera novaeangliae*): Western North Pacific Stock. In *Alaska Marine Mammal Stock Assessments, 2010*. (NOAA-Technical Memorandum-AFSC-223, pp. 179-187). Seattle, WA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/ak2010whhb-pwn.pdf

Allen, B. M., Mead, J. and Brownell, R. L. (2009). Species review of Blainville's beaked whale, *Mesoplodon densirostris.* (SC/63/SM16, pp. 1-18). Available from http://iwcoffice.org/cache/downloads/34vnlzhwmh440wo0s0c8c48g8/SC-63-SM16.pdf

Allen, S. J., Bejder, L. and Krutzen, M. (2011). Why do Indo-Pacific bottlenose dolphins (*Tursiops* sp.) carry conch shells (*Turbinella* sp.) in Shark Bay, Western Australia? *Marine Mammal Science, 27*(2), 449-454. doi:10.1111/j.1748-7692.2010.00409.x

Alonso, M. K., Pedraza, S. N., Schiavini, A. C. M., Goodall, R. N. P. and Crespo, E. A. (1999). Stomach contents of false killer whales (*Pseudorca crassidens*) stranded on the coasts of the Strait of Magellan, Tierra del Fuego. *Marine Mammal Science, 15*(3), 712-724. doi:10.1111/j.1748-7692.1999.tb00838.x

Alter, S. E., Simmonds, M. P. and Brandon, J. R. (2010). Forecasting the consequences of climate-driven shifts in human behavior on cetaceans. *Marine Policy, 34*(5), 943-954. doi:10.1016/j.marpol.2010.01.026

Alves, F., Dinis, A., Cascao, I. and Freitas, L. (2010). Bryde's whale (Balaenoptera brydei) stable associations and dive profiles: New insights from foraging behavior. *Marine Mammal Science, 26*(1), 202-212. doi:10.1111/j.1748-7692.2009.00333.x

Alves, L. C. P., Moreira, S., Simoes-Lopes, P. C. and Andriolo, A. (2010). Behavioral responses of humpback whales, *Megaptera novaeangliae* (Cetacea: Balaenopteridae), to satellite transmitter deployment procedures. *Zoologia, 27*(1), 1-6. doi:10.1590/S1984-46702010000100001

Amaha, A. (1994). *Geographic variation of the common dolphin, Delphinus delphis (Odontoceti: Delphinidae).* (Ph.D. dissertation). Tokyo University of Fisheries.

Amano, M. and Hayano, A. (2007). Intermingling of *dalli*-type Dall's porpoise into a wintering *trui*-type population off Japan: Implications from color patterns. *Marine Mammal Science, 23*(1), 1-14. doi:10.1111/j.1748-7692.2006.00077.x

Amano, M. and Kuramochi, T. (1992). Segregative migration of Dall's porpoise (*Phocoenoides dalli*) in the Sea of Japan and Sea of Okhotsk. *Marine Mammal Science, 8*(2), 143-151.

Amano, M. and Miyazaki, N. (1996). Geographic variation in external morphology of Dall's porpoise, *Phocoenoides dalli*. *Aquatic Mammals, 22*(3), 167-174.

Amano, M., Miyazaki, N. and Yanagisawa, F. (1996). Life history of Fraser's dolphin, *Lagenodelphis hosei*, based on a school captured off the Pacific coast of Japan. *Marine Mammal Science, 12*(2), 199-214.

Amano, M., Nakahara, F., Hayano, A. and Shirakihara, K. (2003). Abundance estimate of finless porpoises off the Pacific coast of eastern Japan based on aerial surveys. *Mammal Study, 28*, 103-110.

Amano, M. and Yoshioka, M. (2003). Sperm whale diving behavior monitored using a suction-cup-attached TDR tag. *Marine Ecology Progress Series, 258*, 291-295.

Amaral, A. R., Beheregaray, L. B., Bilgmann, K., Boutov, D., Freitas, L., Robertson, K. M., et al. (2012). Seascape genetics of a globally distributed, highly mobile marine mammal: the short-beaked common dolphin (*Genus delphinus*). *Plos One, 7*(2), e31482. doi:10.1371/journal.pone.0031482

Amesbury, S., Bonito, R., Chang, R., Kirkendale, L., Meyer, C., Paulay, G., et al. (2001). *Marine Biodiversity Resource Survey and Baseline Reef Monitoring Survey of the Haputo Ecological Reserve Area, COMNAVMARIANAS*. Mangilao, Guam: Marine Laboratory, University of Guam.

Amir, O. A., Berggren, P., Ndaro, S. G. M. and Jiddawi, N. S. (2005). Feeding ecology of the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) incidentally caught in the gillnet fisheries off Zanzibar, Tanzania. *Estuarine, Coastal and Shelf Science, 63*, 429-437.

Anderson, P. K. (1994). Dugong distribution, the seagrass Halophila spinulosa, and thermal environment in winter in deeper waters of eastern Shark Bay, western Australia. *Wildlife Research, 21*, 381-388.

Anderson, P. K. and Barclay, R. M. R. (1995). Acoustic signals of solitary dugongs: physical characteristics and behavioral correlates. *Journal of Mammalogy, 76*, 1226-1237.

Anderson, P. K. and Prince, R. I. T. (1985). Predation on Dugongs: Attacks by Killer Whales. *Journal of Mammalogy, 66*(3), 554-556. Retrieved from http://www.jstor.org/stable/1380933

Anderson, R. C., Clark, R., Madsen, P. T., Johnson, C., Kiszka, J. and Breysse, O. (2006). Observations of Longman's beaked whale (*Indopacetus pacificus*) in the Western Indian Ocean. *Aquatic Mammals, 32*(2), 223-231. doi:10.1578/AM.32.2.2006.223

Andrade, A. L. V., Pinedo, M. C. and Barreto, A. S. (2001). Gastrointestinal parasites and prey items from a mass stranding of false killer whales, *Pseudorca crassidens*, in Rio Grande do Sul, southern Brazil. *Revista Brasileira de Biologia, 6*(1), 55-61.

Andre, M. (2009). The sperm whale sonar: Monitoring and use in mitigation of anthropogenic noise effects in the marine environment. *Nuclear Instruments & Methods in Physics Research Section a-Accelerators Spectrometers Detectors and Associated Equipment, 602*(1), 262-267. doi:10.1016/j.nima.2008.12.223

Andrews, K. R., Karczmarski, L., Au, W. W. L., Rickards, S. H., Vanderlip, C. A., Bowen, B. W., et al. (2010). Rolling stones and stable homes: social structure, habitat diversity and population genetics of the Hawaiian spinner dolphin (*Stenella longirostris*). *Molecular Ecology, 19*(4), 732-748. doi:10.1111/j.1365-294X.2010.04521.x

Andrews, R. D., Pitman, R. L. and Ballance, L. T. (2008). Satellite tracking reveals distinct movement patterns for Type B and Type C killer whales in the southern Ross Sea, Antarctica. *Polar Biology, 31*, 1461-1468.

Anonymous (1974, February 20). Dugong seen in Cocos Lagoon. *Pacific Daily News*, 11.

Anonymous (2004, 04/20/2004). Tama-chan battles flab, sassy new rival.

Anonymous (2005, 02/09/2005). Killer whale escapes Hokkaido ice floes.

Antonelis, G. A. and Fiscus, C. H. (1980). *The pinnipeds of the California Current. CalCOFI Reports*. (Vol. 21, pp. 68-78).

Antonelis, G. A., Jr. and Perez, M. A. (1984). Estimated annual food consumption by northern fur seals in the California Current. *California Cooperative Oceanic Fisheries Investigations, 25*, 135-145.

Antunes, R., Rendell, L. and Gordon, J. (2010). Measuring inter-pulse intervals in sperm whale clicks: Consistency of automatic estimation methods. *Journal of the Acoustical Society of America, 127*(5), 3239-3247. doi:10.1121/1.3327509

Antunes, R., Schulz, T., Gero, S., Whitehead, H., Gordon, J. and Rendell, L. (2011). Individually distinctive acoustic features in sperm whale codas. *Animal Behaviour, 81*(4), 723-730. doi:10.1016/j.anbehav.2010.12.019

Aoki, K., Amano, M., Mori, K., Kourogi, A., Kubodera, T. and Miyazaki, N. (2012). Active hunting by deep-diving sperm whales: 3D dive profiles and maneuvers during bursts of speed. *Marine Ecology-Progress Series, 444*, 289-301. doi:10.3354/meps09371

Aoki, K., Amano, M., Yoshioka, M., Mori, K., Tokuda, D. and Miyazaki, N. (2007). Diel diving behavior of sperm whales off Japan. *Marine Ecology Progress Series, 349*, 277-287.

Aragones, L. V., Lawler, I. R., Foley, W. J. and Marsh, H. (2006). Dugong grazing and turtle cropping: grazing optimization in tropical seagrass systems? *Oecologia, 149*, 635-647. doi:10.1007/s00442-006-0477-1

Aragones, L. V., Roque, M. A. A., Flores, M. B., Encomienda, R. P., Laule, G. E., Espinos, B. G., et al. (2010). The Philippine marine mammal strandings from 1998 to 2009: Animals in the Philippines in peril? *Aquatic Mammals, 36*(3), 219-233. doi:10.1578/am.36.3.2010.219

Arai, K., Yamada, T. and Takano, Y. (2004). Age estimation of male Stejneger's beaked whales (*Mesoplodon stejnegeri*) based on counting of growth layers in tooth cementum. *Mammal Study, 29*, 125-136.

Archer, F. I. (2009). Striped dolphin *Stenella coeruleoalba*. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals (Second Edition)* (pp. 1127-1129). Academic Press.

Archer, F. I. and Perrin, W. F. (1999). Stenella coeruleoalba. *Mammalian Species, 603*, 1-9.

Arranz, P., de Soto, N. A., Madsen, P. T., Brito, A., Bordes, F. and Johnson, M. P. (2011). Following a foraging fish-finder: Diel habitat use of Blainville's beaked whales revealed by echolocation. *Plos One, 6*(12), e28353. doi:10.1371/journal.pone.0028353

Arrigoni, M., Manfredi, P., Panigada, S., Bramanti, L. and Santangelo, G. (2011). Life-history tables of the Mediterranean fin whale from stranding data. *Marine Ecology-an Evolutionary Perspective, 32*, 1-9. doi:10.1111/j.1439-0485.2011.00437.x

Aruga, Y., Yokohama, Y. and Nakanishi, M. (1968). Primary productivity studies in February-March in the northwestern Pacific off Japan. *Journal of the Oceanographical Society of Japan, 24*(6), 275-280.

Aschettino, J. M. (2010). *Population size and structure of melon-headed whales (Peponocephala electra) around the main Hawaiian Islands: Evidence of multiple populations based on photographic data.* (Master's thesis). Hawaii Pacific University.

Ashe, E., Noren, D. P. and Williams, R. (2010). Animal behaviour and marine protected areas: incorporating behavioural data into the selection of marine protected areas for an endangered killer whale population. *Animal Conservation 13*, 196–203. doi:10.1111/j.1469-1795.2009.00321.x

Au, D. W. K. and Perryman, W. L. (1985). Dolphin habitats in the eastern tropical Pacific. *Fishery Bulletin, 83*, 623-643.

Au, W., Darling, J. and Andrews, K. (2001). High-frequency harmonics and source level of humpback whale songs. *The Journal of the Acoustical Society of America, 110*(5), 2770. Retrieved from http://link.aip.org/link/?JAS/110/2770/3

Au, W. W. L. (1993). *The Sonar of Dolphins* (pp. 277). New York, NY: Springer-Verlag.

Au, W. W. L. and Benoit-Bird, K. J. (2008). Broadband backscatter from individual Hawaiian mesopelagic boundary community animals with implications for spinner dolphin foraging. *Journal of the Acoustical Society of America, 123*(5), 2884-2894. doi:10.1121/1.2902187

Au, W. W. L., Ford, J. K. B., Home, J. K. and Newman Allman, K. A. (2004). Echolocation signals of free-ranging killer whales (Orcinus orca) and modeling of foraging for chinook salmon (Oncorhynchus tshawytscha). *Journal of the Acoustical Society of America, 115*, 901-909.

Au, W. W. L., Horne, J. K. and Jones, C. (2010). Basis of acoustic discrimination of chinook salmon from other salmons by echolocating *Orcinus orca*. *Journal of the Acoustical Society of America, 128*(4), 2225-2232. doi:10.1121/1.3473697

Au, W. W. L., Mobley, J., Burgess, W. C., Lammers, M. O. and Nachtigall, P. E. (2000). Seasonal and diurnal trends of chorusing humpback whales wintering in waters off western Maui. *Marine Mammal Science, 16*(3), 530-544. doi:10.1111/j.1748-7692.2000.tb00949.x

Au, W. W. L., Popper, A. N. and Fay, R. R. (2000). Hearing by whales and dolphins. In R. R. Fay and A. N. Popper (Eds.), *Springer Handbook of Auditory Research*. New York, NY: Springer-Verlag.

Awbrey, F. T., Norris, J. C., Hubbard, A. B. and Evans, W. E. (1979). The bioacoustics of the Dall porpoise-salmon drift net interaction. *Hubbs/Sea World Research Institute Technical Report, 79-120*, 41 pp.

Aznar, F. J., Fognani, P., Balbuena, J. A., Pietrobelli, M. and Raga, J. A. (2006). Distribution of *Pholeter gastrophilus* (Digenea) within the stomach of four odontocete species: the role of the diet and digestive physiology of hosts. *Parasitology, 133*, 369-380. doi:10.1017/s0031182006000321

Azzellino, A., Gaspari, S., Airoldi, S. and Nani, B. (2008). Habitat use and preferences of cetaceans along the continental slope and the adjacent pelagic waters in the western Ligurian Sea. *Deep Sea Research I, 55*, 296–323.

Babushina, E. S., Zaslavsky, G. L. and Yurkevich, L. I. (1991). Air and underwater hearing of the northern fur seal: Audiograms and auditory frequency discrimination. *Biofizika, 36*(5), 904-907.

Bahoura, M. and Simard, Y. (2010). Blue whale calls classification using short-time Fourier and wavelet packet transforms and artificial neural network. *Digital Signal Processing, 20*(4), 1256-1263. doi:10.1016/j.dsp.2009.10.024

Bailey, H. and Thompson, P. (2010). Effect of oceanographic features on fine-scale foraging movements of bottlenose dolphins. *Marine Ecology Progress Series, 418*, 223-233. doi:10.3354/meps08789

Baird, R. W. (2000). The killer whale: Foraging specializations and group hunting. In J. Mann, R. C. Connor, P. L. Tyack and H. Whitehead (Eds.), *Cetacean societies: field studies of dolphins and whales* (pp. 127-153). University of Chicago Press.

Baird, R. W. (2005). Sightings of dwarf (*Kogia sima*) and pygmy (*K. breviceps*) sperm whales from the main Hawaiian Islands. *Pacific Science, 59*, 461-466.

Baird, R. W. (2008). Risso's dolphin *Grampus griseus*. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 975-976). San Diego, CA: Academic Press.

Baird, R. W. (2009a). False killer whale *Pseudorca crassidens*. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals (Second Edition)* (pp. 405-406). Academic Press.

Baird, R. W. (2009b). *A review of false killer whales in Hawaiian waters: Biology, status, and risk factors* [Unpublished report to the MMC]. (Order No. E40475499, pp. 41). Olympia, WA: Cascadia Research Collective. Prepared for U.S. Marine Mammal Commission.

Baird, R. W., Gorgone, A. M., McSweeney, D. J., Webster, D. B., Salden, D. R., Deakos, M. H., et al. (2008). False killer whales (*Psuedorca crassidens*) around the main Hawaiian Islands: Long-term site fidelity, inter-island movements, and association patterns. *Marine Mammal Science, 24*(3), 591-612. doi: 10.1111/j.1748.7692.2008.00200.x

Baird, R. W., Gorgone, A. M. and Webster, D. L. (2002). *An Examination of Movements of Bottlenose Dolphins Between Islands in the Hawaiian Island Chain*. (pp. 10). Prepared for National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, California.

Baird, R. W. and Hanson, B. (1997). Status of the northern fur seal, *Callorhinus ursinus*, in Canada. *Canadian Field-Naturalist, 111*, 263-269.

Baird, R. W., Hanson, M. B., Ashe, E. E., Heithaus, M. R. and Marshall, G. J. (2003). *Studies of Foraging in "Southern Resident" Killer Whales during July 2002: Dive Depths, Bursts in Speed, and the Use of a "Crittercam" System for Examining Sub-surface Behavior*. (Order Number AB133F-02-SE-1744 pp. 18). Seattle, WA: U.S. Department of Commerce, National Marine Fisheries Service, National Marine Mammal Laboratory.

Baird, R. W., Hanson, M. B. and Dill, L. M. (2005). Factors influencing the diving behaviour of fish-eating killer whales: Sex differences and diel and interannual variation in diving rates. *Canadian Journal of Zoology, 83*, 257-267.

Baird, R. W., Langelier, K. M. and Stacey, P. J. (1989). First records of false killer whales, Pseudorca crassidens, in Canada. *Canadian Field-Naturalist, 103*, 368-371.

Baird, R. W., Ligon, A. D. and Hooker, S. K. (2000). *Sub-surface and night-time behavior of humpback whales off Maui, Hawaii: A preliminary report*. (Contract # 40ABNC050729, pp. 18).

Baird, R. W., Ligon, A. D., Hooker, S. K. and Gorgone, A. M. (2001). Subsurface and nighttime behaviour of pantropical spotted dolphins in Hawai'i. *Canadian Journal of Zoology, 79*(6), 988-996.

Baird, R. W., McSweeney, D. J., Bane, C., Barlow, J., S., D. R., Antoine, L. K., et al. (2006). Killer whales in Hawaiian waters: Information on population identity and feeding habits. *Pacific Science, 60*(4), 523–530.

Baird, R. W., McSweeney, D. J., Ligon, A. D. and Webster, D. L. (2004). Tagging feasability and diving of Cuvier's beaked whales (*Ziphius cavirostris*) and Blainville's beaked whales (*Mesoplodon densirostris*) in Hawai'i. La Jolla, CA. Prepared for National Marine Fisheries Service, Southwest Fisheries Science Center.

Baird, R. W., McSweeney, D. J., Schorr, G. S., Mahaffy, S. D., Webster, D. L., Barlow, J., et al. (2009). Studies of beaked whales in Hawai'i: Population size, movements, trophic ecology, social organization, and behaviour. In S. J. Dolman, C. D. MacLeod and P. G. H. Evans (Eds.), *Beaked Whale Research* (pp. 23-25). European Cetacean Society.

Baird, R. W., McSweeney, D. J., Webster, D. L., Gorgone, A. M. and Ligon, A. D. (2003). Studies of odontocete population structure in Hawaiian waters: Results of a survey through the main Hawaiian Islands in May and June 2003 [Contract report]. (pp. 25). Seattle, WA: NOAA.

Baird, R. W., Schorr, G., Webster, D. L., McSweeney, D. J., Hanson, B. and Andrews, R. D. (2010a). Movements and habitat use of Cuvier's and Blainville's beaked whales in Hawaii: results from satellite tagging in 2009/2010 C. Research (Ed.). La Jolla, CA.

Baird, R. W., Schorr, G. S., Webster, D. L., McSweeney, D. J., Hanson, M. B. and Andrews, R. D. (2010b). Movements and habitat use of satellite-tagged false killer whales around the main Hawaiian Islands. *Endangered Species Research, 10*, 107-121.

Baird, R. W., Schorr, G. S., Webster, D. L., McSweeney, D. J. and Mahaffy, S. D. (2006). Studies of beaked whale diving behavior and odontocete stock structure in Hawai'i in March/April 2006 [Unpublished report]. (pp. 31).

Baird, R. W., Webster, D. L., Mahaffy, S. D., McSweeney, D. J., Schorr, G. S. and Ligon, A. D. (2008). Site fidelity and association patterns in a deep-water dolphin: Rough-toothed dolphins (*Steno bredanensis*) in the Hawaiian Archipelago. *Marine Mammal Science, 24*(3), 535-553.

Baird, R. W., Webster, D. L., McSweeney, D. J., Ligon, A. D. and Schorr, G. S. (2005). Diving behavior and ecology of Cuvier's (*Ziphius cavirostris*) and Blainville's beaked whales (*Mesoplodon densirostris*) in Hawai'i. La Jolla, CA Prepared by C. R. Collective. Prepared for Southwest Fisheries Science Center.

Baird, R. W., Webster, D. L., McSweeney, D. J., Ligon, A. D., Schorr, G. S. and Barlow, J. (2006). Diving behaviour of Cuvier's (*Ziphius cavirostris*) and Blainville's (*Mesoplodon densirostris*) beaked whales in Hawai'i. *Canadian Journal of Zoology, 84*(8), 1120-1128. doi:10.1139/Z06-095

Baird, R. W., Webster, D. L., Schorr, G. S., McSweeney, D. J. and Barlow, J. (2008). Diel variation in beaked whale diving behavior. *Marine Mammal Science, 24*(3), 630-642. doi: 10.1111/j.1748-7692.2008.00211.x

Baird, R. W. and Whitehead, H. (2000). Social organization of mammal-eating killer whales: Group stability and dispersal patterns. *Canadian Journal of Zoology, 78*(12), 2096-2105.

Baker, A. N. and Madon, B. (2007). Bryde's whales (Balaenoptera cf. brydei Olsen 1913) in the Hauraki Gulf and northeastern New Zealand waters. *Science for Conservation, 272*, 4-14.

Baker, C. S. and Herman, L. M. (1984). Aggressive behavior between humpback whales (*Megaptera novaeangliae*) wintering in Hawaiian waters. *Canadian Journal of Zoology, 62*, 1922-1937.

Baker, C. S., Lukoschek, V., Lavery, S., Dalebout, M. L., Yong-Un, M., Endo, T., et al. (2006). Incomplete reporting of whale, dolphin and porpoise 'bycatch' revealed by molecular monitoring of Korean markets. *Animal Conservation, 9*(4), 474-482. doi:10.1111/j.1469-1795.2006.00062.x

Baker, C. S., Steel, D., Choi, Y., Lee, H., Kim, K. S., Choi, S. K., et al. (2010). Genetic evidence of illegal trade in protected whales links Japan with the US and South Korea. *Biology Letters, 6*(5), 647-650. doi:10.1098/rsbl.2010.0239

Baker, J. D. (2007). Post-weaning migration of northern fur seal *Callorhinus ursinus* pups from the Pribilof Islands, Alaska. *Marine Ecology Progress Series, 341*, 243-255. doi:10.3354/meps341243

Baker, J. D. and Donohue, M. J. (2000). Otogeny of swimming and diving in northern fur seal (*Callorhinus ursinus*) pups. *Canadian Journal of Zoology, 78*(1), 100-109.

Balcomb, K. C. (1989). Baird's beaked whale *Berardius bairdii* Stejneger, 1883: Arnoux's beaked whale *Berardius arnuxii* Duvernoy, 1851. In S. H. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals* (Vol. 4: River Dolphins and the Larger Toothed Whales, pp. 261-288). Academic Press.

Baldwin, R. M., Gallagher, M. and Van Waerebeek, K. (1999). A review of cetaceans from waters off the Arabian Peninsula. In M. Fisher, S. A. Ghazanfur and J. A. Soalton (Eds.), *The Natural History of Oman: A Festschrift for Michael Gallagher* (pp. 161-189). Backhuys Publishers.

Ballance, L. T. and Pitman, R. L. (1998). Cetaceans of the western tropical Indian Ocean: Distribution, relative abundance, and comparisons with cetacean communities of two other tropical ecosystems. *Marine Mammal Science, 14*(3), 429-459.

Barendse, J., Best, P. B., Thornton, M., Pomilla, C., Carvalho, I. and Rosenbaum, H. C. (2010). Migration redefined? Seasonality, movements and group composition of humpback whales Megaptera novaeangliae off the west coast of South Africa. *African Journal of Marine Science, 32*(1), 1-22. doi:10.2989/18142321003714203

Barlow, J. (1994). Abundance of large whales in California coastal waters: A comparison of ship surveys in 1979/80 and in 1991. *Report of the International Whaling Commision, 44*, 399-406.

Barlow, J. (1995). The abundance of cetaceans in California waters. Part I: Ship surveys in summer and fall of 1991. *Fishery Bulletin, 93*, 1-14.

Barlow, J. (1999). Trackline detection probability for long-diving whales. In G. W. Garner, S. C. Amstrup, J. L. Laake, B. F. J. Manly, L. L. McDonald and D. G. Robertson (Eds.), *Marine mammal survey and assessment methods* (pp. 209-221). Rotterdam, Netherlands: A.A. Balkema.

Barlow, J. (2006). Cetacean abundance in Hawaiian waters estimated from a summer/fall survey in 2002. *Marine Mammal Science, 22*(2), 446-464. doi: 10.1111/j.1748-7692.2006.00032.x

Barlow, J., Calambokidis, J., Falcone, E. A., Baker, C. S., Burdin, A. M., Clapham, P. J., et al. (2011). Humpback whale abundance in the North Pacific estimated by photographic capture-recapture with bias correction from simulation studies. *Marine Mammal Science, 27*(4), 793-818. doi:10.1111/j.1748-7692.2010.00444.x

Barlow, J., Ferguson, M. C., Perrin, W. F., Ballance, L., Gerrodette, T., Joyce, G., et al. (2006). Abundance and densities of beaked and bottlenose whales (family Ziphiidae). *Journal of Cetacean Research and Management, 7*(3), 263-270.

Barlow, J. and Taylor, B. L. (2001). *Estimates of Large Whale Abundance off California, Oregon, Washington, and Baja California based on 1993 and 1996 Ship Surveys*. (Administrative Report LJ-01-03, pp. 15). La Jolla, CA: Southwest Fisheries Science Center, National Marine Fisheries Service and NOAA.

Barrett-Lennard, L. G., Ford, J. K. B. and Heise, K. A. (1996). The mixed blessing of echolocation: Differences in sonar use by fish-eating and mammal-eating killer whales. *Animal Behaviour, 51*, 553-565.

Barrett-Lennard, L. G., Matkin, C. O., Durban, J. W., Saulitis, E. L. and Ellifrit, D. (2011). Predation on gray whales and prolonged feeding on submerged carcasses by transient killer whales at Unimak Island, Alaska. *Marine Ecology Progress Series, 421*, 229-241. doi:10.3354/meps08906

Barros, N. B. and Duffield, D. (2003). Unraveling the mysteries of pygmy and dwarf sperm whales. *Strandings: Newsletter of the Southeast U.S. Marine Mammal Stranding Network, December 2003*, 1, 3, 11.

Barros, N. B., Jefferson, T. A. and Parsons, E. C. M. (2002). Food habits of finless porpoises (*Neophocaena phocaenoides*) in Hong Kong waters. *Raffles Bulletin of Zoology, 10*, 115-123.

Barros, N. B. and Myrberg, A. A. (1987). Prey detection by means of passive listening in bottlenose dolphins (Tursiops truncatus). *Journal of the Acoustical Society of America, 82*, S65.

Barros, N. B. and Wells, R. S. (1998). Prey and feeding patterns of resident bottlenose dolphins (*Tursiops truncatus*) in Sarasota Bay, Florida. *Journal of Mammalogy, 79*(3), 1045-1059.

Baumann-Pickering, S., Wiggins, S. M., Hildebrand, J. A., Roch, M. A. and Schnitzler, H. U. (2010). Discriminating features of echolocation clicks of melon-headed whales (*Peponocephala electra*), bottlenose dolphins (*Tursiops truncatus*), and Gray's spinner dolphins (*Stenella longirostris longirostris*). *Journal of the Acoustical Society of America, 128*(4), 2212-2224. doi:10.1121/1.3479549

Baumgartner, M. F. (1997). The distribution of Risso's dolphin (Grampus griseus) with respect to the physiography of the northern Gulf of Mexico. *Marine Mammal Science, 13*(4), 614-638.

Baumgartner, M. F. and Fratantoni, D. M. (2008). Diel periodicity in both sei whale vocalization rates and the vertical migration of their copepod prey observed from ocean gliders. *Limnology and Oceanography, 53*(5 part 2), 2197-2209. doi:10.4319/lo.2008.53.5_part_2.2197

Baumgartner, M. F., Lysiak, N. S. J., Schuman, C., Urban-Rich, J. and Wenzel, F. W. (2011). Diel vertical migration behavior of *Calanus finmarchicus* and its influence on right and sei whale occurrence. *Marine Ecology Progress Series, 423*, 167-184. doi:10.3354/meps08931

Baumgartner, M. F. and Mate, B. R. (2003). Summertime foraging ecology of North Atlantic right whales. *Marine Ecology Progress Series, 264*, 123-135.

Baumgartner, M. F., Mullin, K. D., May, L. N. and Leming, T. D. (2001). Cetacean habitats in the northern Gulf of Mexico. *Fishery Bulletin, 99*, 219-239.

Baumgartner, M. F., Van Parijs, S. M., Wenzel, F. W., Tremblay, C. J., Esch, H. C. and Warde, A. M. (2008). Low frequency vocalizations attributed to sei whales (*Balaenoptera borealis*). *Journal of the Acoustical Society of America, 124*(2), 1339-1339. doi:10.1121/1.2945155

Bazua-Durian, C. and Au, W. W. L. (2002). The whistles of Hawaiian spinner dolphins. *Journal of the Acoustical Society of America, 112*, 3064-3072.

Beamish, P. and Mitchell, E. (1973). Short pulse length audio frequency sounds recorded in the presence of a minke whale (Balaenoptera acutorostrata). *Deep-Sea Research and Oceanographic Abstracts, 20*, 375-386.

Bearzi, G., Pierantonio, N., Affronte, M., Holcer, D., Maio, N. and Di Sciara, G. N. (2011). Overview of sperm whale *Physeter macrocephalus* mortality events in the Adriatic Sea, 1555-2009. *Mammal Review, 41*(4), 276-293. doi:10.1111/j.1365-2907.2010.00171.x

Bearzi, G., Reeves, R. R., Remonato, E., Pierantonio, N. and Airoldi, S. (2011). Risso's dolphin *Grampus griseus* in the Mediterranean Sea. *Mammalian Biology, 76*(4), 385-400. doi:10.1016/j.mambio.2010.06.003

Bearzi, M. (2003). *Behavioral ecology of the marine mammals of Santa Monica Bay, California.* (Ph.D. dissertation). University of California at Los Angeles.

Bearzi, M. (2005). Dolphin sympatric ecology. *Marine Biology Research, 1*(3), 165-175. doi:10.1080/17451000510019132

Beatson, E. (2007). The diet of pygmy sperm whales, Kogia breviceps, stranded in New Zealand: Implications for conservation. *Reviews in Fish Biology and Fisheries, 17*, 295-303. doi: 10.1007/s11160-007-9039-9

Beier, J. C. and Wartzok, D. (1979). Mating behaviour of captive spotted seals (*Phoca largha*). *Animal Behaviour, 27*, 772-781.

Belliere, E. N., Esperon, F., Fernandez, A., Arbelo, M., Munoz, M. J. and Sanchez-Vizcaino, J. M. (2011). Phylogenetic analysis of a new cetacean morbillivirus from a short-finned pilot whale stranded in the Canary Islands. *Research in Veterinary Science, 90*(2), 324-328. doi:10.1016/j.rvsc.2010.05.038

Benoit-Bird, K. J. (2004). Prey caloric value and predator energy needs: Foraging predictions for wild spinner dolphins. *Marine Biology, 145*, 435-444.

Benoit-Bird, K. J., Au, W. W., Brainard, R. E. and Lammers, M. O. (2001). Diel horizontal migration of the Hawaiian mesopelagic boundary community observed acoustically. *Marine Ecology Progress Series, 217*, 1-14.

Benoit-Bird, K. J. and Au, W. W. L. (2003). Prey dynamics affect foraging by a pelagic predator (Stenella longirostris) over a range of spatial and temporal scales. *Behavioral Ecology and Sociobiology, 53*, 364-373. doi: 10.1007/s00265-003-0585-4

Benoit-Bird, K. J. and Au, W. W. L. (2009). Cooperative prey herding by the pelagic dolphin, *Stenella longirostris*. *Journal of the Acoustical Society of America, 125*(1), 125-137. doi:10.1121/1.2967480

Benoit-Bird, K. J., Dahood, A. D. and Wursig, B. (2009). Using active acoustics to compare lunar effects on predator-prey behavior in two marine mammal species. *Marine Ecology Progress Series, 395*, 119-135. doi:10.3354/meps07793

Berghan, J., Algie, K. D., Stockin, K. A., Wiseman, N., Constantine, R., Tezanos-Pinto, G., et al. (2008). A preliminary photo-identification study of bottlenose dolphin (*Tursiops truncatus*) in Hauraki Gulf, New Zealand. *New Zealand Journal of Marine and Freshwater Research, 42*(4), 465-472.

Berman-Kowalewski, M., Gulland, F. M. D., Wilkin, S., Calambokidis, J., Mate, B., Cordaro, J., et al. (2010). Association between blue whale (*Balaenoptera musculus*) mortality and ship strikes along the California Coast. *Aquatic Mammals, 36*(1), 59-66. doi:10.1578/am.36.1.2010.59

Bermudez, L., Van Bressem, M. F., Reyes-Jaimes, O., Sayegh, A. J. and Paniz-Mondolfi, A. E. (2009). Lobomycosis in man and lobomycosis-like disease in bottlenose dolphin, Venezuela. *Emerging Infectious Diseases, 15*(8), 1301-1303. doi:10.3201/eid1508.090347

Bernard, H. J. and Reilly, S. B. (1999). Pilot whales *Globicephala* Lesson, 1828. In S. H. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals* (Vol. 6, pp. 245-280). San Diego, CA: Academic Press.

Beron-Vera, B., Crespo, E. A., Raga, J. A. and Fernandez, M. (2007). Parasite communities of common dolphins (*Delphinus delphis*) from Patagonia: The relation with host distribution and diet and comparison with sympatric hosts. *Journal of Parasitology, 93*(5), 1056-1060. doi:10.1645/ge-1070r.1

Berta, A., Sumich, J. L. and Kovacs, K. M. (2006). *Marine Mammals: Evolutionary Biology* (2nd ed.). Burlington, MA: Elsevier.

Berzin, A. A. and Vladimirov, V. L. (1981). Changes in abundance of whalebone whales in the Pacific and Antarctic since the cessation of their exploitation. *Reports of the International Whaling Commission, 31*, 495-499.

Best, P. B. (1994). Seasonality of reproduction and the length of gestation in southern right whales *Eubalaena australis*. *Journal of Zoology, London, 232*, 175-189.

Best, P. B. (1996). Evidence of migration by Bryde's whales from the offshore population in the southeast Atlantic. *Reports of the International Whaling Commission, 46*, 315-322.

Best, P. B. (2007). *Whales and Dolphins of the Southern African Subregion* (pp. 338). Cambridge University Press.

Best, P. B. and Lockyer, C. H. (2002). Reproduction, growth and migrations of sei whales *Balaenoptera borealis* off the west coast of South Africa in th 1960s. *South African Journal of Marine Science, 24*, 111-133.

Best, P. B., Rademeyer, R. A., Burton, C., Ljungblad, D., Sekiguchi, K., Shimada, H., et al. (2003). The abundance of blue whales on the Madagascar Plateau, December 1996. *Journal of Cetacean Research and Management, 5*(3), 253-260.

Bigg, M. A. (1981). Harbour seal Phoca vitulina Linnaeus, 1758 and Phoca largha Pallas, 1811 S. H. Ridgway and R. J. Harrison (Eds.), *Handbook of Marine Mammals, Volume 2: Seals* (pp. 1-27). Academic Press.

Birkeland, C. (1977, June 12). Surrounded by whales. *Islander*, 13-15.

Bjorge, A. (2002). How persistent are marine mammal habitats in an ocean of variability?. In P. G. H. Evans and A. Raga (Eds.), *Marine Mammals: Biology and Conservation* (pp. 63-91). Kluwer Academic/Plenum Publishers.

Black, N. A. (1994). *Behavior and ecology of Pacific white-sided dolphins (Lagenorhynchus obliquidens) in Monterey Bay, California.* (Master's). San Francisco State University.

Black, N. A. (2009). Pacific white-sided dolphin *Lagenorhynchus obliquidens*. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 817-819). Academic Press.

Blois-Heulin, C., Crevel, M., Boye, M. and Lemasson, A. (2012). Visual laterality in dolphins: importance of the familiarity of stimuli. *BMC Neuroscience, 13*, 9. doi:10.1186/1471-2202-13-9

Bloodworth, B. and Marshall, C. D. (2005). Feeding kinematics of *Kogia* and *Tursiops* (Odontoceti: Cetacea): characterization of suction and ram feeding. *Journal of Experimental Biology, 208*(19), 3721-3730. doi:10.1242/jeb.01807

Bloodworth, B. and Odell, D. K. (2008). Kogia breviceps. *Mammalian Species, 819*, 1-12. doi:10.1644/819.1

Boisseau, O. (2005). Quantifying the acoustic repertoire of a population: The vocalizations of free-ranging bottlenose dolphins in Fiordland, New Zealand. *Journal of the Acoustical Society of America, 117*(4), 2318-2329. doi:10.1121/1.1861692

Bonnell, M. L., LeBoeuf, B. J., Pierson, M. O., Dettman, D. H., Farrens, G. D., Heath, C. B., et al. (1980). *Summary of Marine Mammal and Seabird Surveys of the Southern California Bight area, 1975-1978*. (Vol. 3 - Investigators' Reports, Part I - Pinnipeds of the Southern California Bight, Final Report to the Bureau of Land Management, under Contract AA550-CT7-367, pp. 535). Santa Cruz, California: University of California.

Borggaard, D., Lien, J. and Stevick, P. (1999). Assessing the effects of industrial activity on large cetaceans in Trinity Bay, Newfoundland (1992-1995). *Aquatic Mammals, 25*(3), 149-161.

Borsa, P. (2006). Marine mammal strandings in the New Caledonia region, Southwest Pacific. *Comptes Rendus Biologies, 329*(4), 277-288. doi:10.1016/j.crvi.2006.01.004

Bowen, W. D., Tully, D., Boness, D. J., Bulheier, D. M. and J., M. G. (2002). Prey-dependent foraging tactics and prey profitability in a marine mammal. *Marine Ecology Progress Series, 244*, 235-245.

Boyd, I. L., Lockyer, C. and Marsh, H. D. (1999). Reproduction in marine mammals. In J. E. R. III and S. A. Rommel (Eds.), *Biology of Marine Mammals* (pp. 218-286). Smithsonian University Press.

Boye, T. K., Simon, M. and Madsen, P. T. (2010). Habitat use of humpback whales in Godthaabsfjord, West Greenland, with implications for commercial exploitation. *Journal of the Marine Biological Association of the United Kingdom, 90*(8), 1529-1538. doi:10.1017/s0025315410000755

Bradford, A. L., Weller, D. W., Ivashchenko, Y. V., Burdin, A. M. and Brownell, R. L. (2009). Anthropogenic scarring of western gray whales (*Eschrichtius robustus*). *Marine Mammal Science, 25*(1), 161-175. doi:10.1111/j.1748-7692.2008.00253.x

Bradford, A. L., Weller, D. W., Wade, P. R., Burdin, A. M. and Brownell, R. L., Jr (2008). Population abundance and growth rate of western gray whales *Eschrichtius robustus*. *Endangered Species Research, 6*, 1-14. doi:10.3354/esr00106

Braham, H. W. (1983). Northern records of Risso's dolphins, *Grampus griseus*, in the northeast Pacific. *Canadian Field-Naturalist, 97*, 89-90.

Branch, T. A. (2007). Abundance of Antarctic blue whales south of 60°S from three complete circumpolar sets of surveys. *Journal of Cetacean Research and Management, 9*(3), 253-262.

Branch, T. A. and Butterworth, D. S. (2001). Estimates of abundance south of 60°S for cetacean species sighted frequently on the 1978/79 to 1997/98 IWC/IDCR-SOWER sighting surveys. *Journal of Cetacean Research and Management, 3*(3), 251-270.

Branch, T. A. and Mikhalev, Y. A. (2008). Regional differences in length at sexual maturity for female blue whales based on recovered Soviet whaling data. *Marine Mammal Science, 24*(3), 690-703. doi:10.1111/j.1748-7692.2008.00214.x

Branch, T. A., Mikhalev, Y. A. and Kato, H. (2009). Separating pygmy and Antarctic blue whales using long-forgotten ovarian data. *Marine Mammal Science, 25*(4), 833-854. doi:10.1111/j.1748-7692.2009.00292

Branch, T. A., Stafford, K. M., Palacios, D. M., Allison, C., Bannister, J. L., Burton, C. L. K., et al. (2007). Past and present distribution, densities and movements of blue whales Balaenoptera musculus in the Southern Hemisphere and northern Indian Ocean. *Mammal Review, 37*(2), 116-175. doi:10.1111/j.1365-2907.2007.00106

Branstetter, B., Moore, P. W., Finneran, J. J., Tormey, M. N. and Aihara, H. (2012). Directional properties of bottlenose dolphin (*Tursiops truncatus*) clicks, burst-pulse, and whistle sounds. *Journal of the Acoustical Society of America, 131*(2), 1613-1321. doi:10.1121/1.3676694

Brehmer, P., Josse, E. and Nottestad, L. (2012). Evidence that whales (*Balaenoptera borealis*) visit drifting fish aggregating devices: do their presence affect the processes underlying fish aggregation? *Marine Ecology, 33*(2), 176-182. doi:10.1111/j.1439-0485.2011.00478.x

Brown, D. H., Caldwell, D. K. and Caldwell, M. C. (1966). Observations on the behavior of wild and captive false killer whales, with notes on associated behavior of other genera of captive dolphins. *Los Angeles County Museum of Natural History, Contributions in Science, 95*, 32.

Brown, J. C., Smaragdis, P. and Nousek-McGregor, A. (2010). Automatic identification of individual killer whales. *Journal of the Acoustical Society of America, 128*(3), EL93-EL98. doi:10.1121/1.3462232

Browne, P., Conley, A. J., Spraker, T., Ream, R. R. and Lasley, B. L. (2006). Sex steroid concentrations and localization of steroidogenic enzyme expression in free-ranging female northern fur seals (*Callorhinus ursinus*). *General and Comparative Endocrinology, 147*(2), 175-183. doi:10.1016/j.ygcen.2005.12.019

Brownell Jr., R. L., Ralls, K., Baumann-Pickering, S. and Poole, M. M. (2009). Behavior of melon-headed whales, Peponocephala electra, near oceanic islands. *Marine Mammal Science, 25*(3), 639-658.

Brownell, R. L., Clapham, P. J., Miyashita, T. and Kasuya, T. (2001). Conservation status of North Pacific right whales. *Journal of Cetacean Research and Management, Special Issue 2*, 269-286.

Brownell, R. L., Jr., Anderson, P. K., Owen, R. P. and Ralls, K. (1981). The status of dugongs at Palau, an isolated island group. In H. Marsh (Ed.), *The Dugong: Proceedings of a Seminar/Workshop held at James Cook University of North Queensland, 8-13 May 1979* (pp. 18-42). Townsville, Australia.

Brownell, R. L., Jr. and Kasuya, T. (1999). Western gray whale captured off western Hokkaido, Japan [Scientific Working Document]. (SC/51/AS25, pp. 5). Grenada, WI: International Whaling Commission Scientific Committee.

Brownell, R. L., Jr., Mead, J. G., van Helden, A. L., Yamada, T. K. and Frantzis, A. (2005, April 2-7, 2005). Worldwide mass strandings of beaked whales: Retrospective review and causes. [Abstract]. Presented at the 19th Annual Conference of the European Cetacean Society and associated workshops, La Rochelle, France.

Brownell, R. L., Jr., Ralls, K., Baumann-Pickering, S. and Poole, M. M. (2009). Behavior of melon-headed whales, Peponocephala electra, near oceanic islands. *Marine Mammal Science, 25*(3), 639-658. doi: 10.1111/j.1748-7692.2009.00281.x

Brownell, R. L., Jr., Yamada, T., Mead, J. G. and van Helden, A. L. (2004). Mass strandings of Cuvier's beaked whales in Japan: U.S. Naval acoustic link? *Alaska Fishery Research Bulletin* [Scientific Program Working Document]. (SC/56/E37, pp. 10) International Whaling Commission.

Brownell, R. L., Walker, W. A. and Forney, K. A. (1999). Pacific white-sided dolphin *Lagenorhynchus obliquidens* Gill, 1865. In S. H. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals* (Vol. 6: The second book of dolphins and the porpoises, pp. 57-84). Academic Press.

Buchan, S. J., Rendell, L. E. and Hucke-Gaete, R. (2010). Preliminary recordings of blue whale (*Balaenoptera musculus*) vocalizations in the Gulf of Corcovado, northern Patagonia, Chile. *Marine Mammal Science, 26*(2), 451-459. doi:10.1111/j.1748-7692.2009.00338.x

Buckland, S. T., Cattanach, K. L. and Hobbs, R. C. (1993). Abundance estimates of Pacific white-sided dolphin, northern right whale dolphin, Dall's porpoise and northern fur seal in the North Pacific, 1987-1990. *International North Pacific Fisheries Commission Bulletin, 53*(3), 387-407.

Buden, D. W. and Haglelgam, J. (2010). Review of crocodile (Reptilia: crocodilia) and dugong (Mammalia: sirenia) Sightings in the Federated States of Micronesia. *Pacific Science, 64*(4), 577-583. doi:10.2984/64.4.577

Bull, J. C., Jepson, P. D., Ssuna, R. K., Deaville, R., Allchin, C. R., Law, R. J., et al. (2006). The relationship between polychlorinated biphenyls in blubber and levels of nematode infestations in harbour porpoises, *Phocoena phocoena*. *Parasitology, 132*, 565-573. doi:10.1017/S003118200500942X

Burger, J. (2007). A framework and methods for incorporating gender-related issues in wildlife risk assessment: Gender-related differences in metal levels and other contaminants as a case study. *Environmental Research, 104*(1), 153-162. doi:10.1016/j.envres.2006.08.001

Burns, J. J. (1970). Remarks on the distribution and natural history of pagophilic pinnipeds in the Bering and Chukchi Seas. *Journal of Mammalogy, 51*(3), 445-454.

Burns, J. J. (2002). Harbor seal and spotted seal *Phoca vitulina* and *P. largha*. In W. F. Perrin, B. Würsig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (pp. 552-560). San Diego, CA: Academic Press.

Burns, J. J. (2008). Harbor seal and spotted seal *Phoca vitulina* and *P. largha*. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals (Second Edition)* (pp. 533-542). Academic Press.

Byard, R. W., Winskog, C., Machado, A. and Boardman, W. (2012). The assessment of lethal propeller strike injuries in sea mammals. *Journal of Forensic and Legal Medicine, 19*(3), 158-161. doi:10.1016/j.jflm.2011.12.017

Byrd, B. L., Hohn, A. A., Munden, F. H., Lovewell, G. N. and Lo Piccolo, R. E. (2008). Effects of commercial fishing regulations on stranding rates of bottlenose dolphin (*Tursiops truncatus*). *Fishery Bulletin, 106*(1), 72-81.

Calambokidis, J. (2009). *Symposium on the Results of the SPLASH Humpback Whale Study: Final Report and Recommendations*. (pp. 68).

Calambokidis, J. and Barlow, J. (2004). Abundance of blue and humpback whales in the eastern North Pacific estimated by capture-recapture and line-transect methods. *Marine Mammal Science, 20*(1), 63-85.

Calambokidis, J., Barlow, J., Ford, J. K. B., Chandler, T. E. and Douglas, A. B. (2009). Insights into the population structure of blue whales in the Eastern North Pacific from recent sightings and photographic identification. *Marine Mammal Science, 25*(4), 816-832. doi: 10.1111/j.1748-7692.2009.00298.x

Calambokidis, J., Chandler, T., Falcone, E. and Douglas, A. (2004). Research on large whales off California, Oregon, and Washington in 2003 *Annual Report for 2003*. La Jolla, California. Prepared by C. Research. Prepared for Southwest Fisheries Science Center.

Calambokidis, J., Falcone, E. A., Quinn, T. J., Burdin, A. M., Clapham, P. J., Ford, J. K. B., et al. (2008). *SPLASH: Structure of populations, levels of abundance and status of humpback whales in the North Pacific* [Final report]. (pp. 57). Seattle, Washington. Prepared for U.S. Dept of Commerce Western Administrative Center.

Calambokidis, J., Schorr, G. S., Steiger, G. H., Francis, J., Bakhtiari, M., Marshal, G., et al. (2007). Insights into the underwater diving, feeding, and calling behavior of blue whales from a suction-cup-attached video-imaging tag (CRITTERCAM). *Marine Technology Society Journal, 41*(4), 19-29.

Calambokidis, J., Steiger, G. H., Straley, J. M., Herman, L. M., Cerchio, S., Salden, D. R., et al. (2001). Movements and population structure of humpback whales in the North Pacific. *Marine Mammal Science, 17*(4), 769-794.

Calambokidis, J., Steiger, G. H., Straley, J. M., Quinn II, T. J., Herman, L. M., Cerchio, S., et al. (1997). Abundance and population structure of humpback whales in the North Pacific basin [Unpublished contact report the SWFSC]. (pp. 72).

Caldwell, D. K. and Caldwell, M. C. (1972). *The World of the Bottlenosed Dolphin* (pp. 157). Philadelphia, Pennsylvania: J.B. Lippincott Company.

Caldwell, D. K. and Caldwell, M. C. (1989). Pygmy sperm whale *Kogia breviceps* (de Blainville, 1838): Dwarf sperm whale *Kogia simus* Owen, 1866. In S. H. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals* (Vol. 4, pp. 234-260). San Diego, CA: Academic Press.

Call, K. A., Ream, R. R., Johnson, D., Sterling, J. T. and Towell, R. G. (2008). Foraging route tactics and site fidelity of adult female northern fur seal (*Callorhinus ursinus*) around the Pribilof Islands. *Deep Sea Research II, 55*(16-17), 1883-1896. doi:10.1016/j.dsr2.2008.04-022

Cañadas, A. and Hammond, P. S. (2008, June). Abundance and habitat preferences of the short-beaked common dolphin *Delphinus delphis* in the southwestern Mediterranean: implications for conservation. *Endangered Species Research, 4*, 309-331. doi:10.3354/esr00073

Canadas, A., Sagarminaga, R. and Garcia-Tiscar, S. (2002). Cetacean distribution related with depth and slope in the Mediterranean waters off southern Spain. *Deep Sea Research I, 49*, 2053-2073.

Canese, S., Cardinali, A., Forunta, C. M., Giusti, M., Lauriano, G., Salvati, E., et al. (2006). The first identified winter feeding ground of fin whales (Balaenoperta physalus) in the Mediterranean Sea. *Journal of the Marine Biological Association of the United Kingdom, 86*(4), 903-907. doi:10.1017/S0025315406013853

Cantor, M., Cachuba, T., Fernandes, L. and Engel, M. H. (2010). Behavioural reactions of wintering humpback whales (*Megaptera novaeangliae*) to biopsy sampling in the western South Atlantic. *Journal of the Marine Biological Association of the United Kingdom, 90*(8), 1701-1711. doi:10.1017/s0025315409991561

Cardona-Maldonado, M. A. and Mignucci-Giannoni, A. A. (1999). Pygmy and dwarf sperm whales in Puerto Rico and the Virgin Islands, with a review of *Kogia* in the Caribbean. *Caribbean Journal of Science, 35*(1-2), 29-37.

Caro, T., Beeman, K., Stankowich, T. and Whitehead, H. (2011). The functional significance of colouration in cetaceans. *Evolutionary Ecology, 25*(6), 1231-1245. doi:10.1007/s10682-011-9479-5

Carretta, J., V., and Enriquez, L. (2007). *Marine Mammal and Sea Turtle Bycatch in the California/Oregon Thresher Shark and Swordfish Drift Gillnet Fishery in 2006*. (Southwest Fisheries Science Center Administrative Report LJ-07-06, pp. 9). La Jolla, CA: National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. Available from http://swfsc.noaa.gov/uploadedFiles/Divisions/PRD/Programs/Coastal_Marine_Mammal/Carretta_Enriquez_2006_DGN_Preliminary_Mortality_LJ-07-06.pdf

Carretta, J. V., Forney, K. A., Lowry, M. S., Barlow, J., Baker, J., Johnston, D., et al. (2010). *U.S. Pacific Marine Mammal Stock Assessments: 2009*. (NOAA-TM-NMFS-SWFSC-453, pp. 336). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center.

Carretta, J. V., Forney, K. A., Muto, M. M., Barlow, J., Baker, J., Hanson, B., et al. (2005a). Blue Whale (*Balaenoptera musculus*): Western North Pacific Stock. In *U.S. Pacific Marine Mammal Stock Assessments: 2004*. (NOAA-TM-NMFS-SWFSC-375, pp. 259-264). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/po2004whbl-wn.pdf

Carretta, J. V., Forney, K. A., Muto, M. M., Barlow, J., Baker, J., Hanson, B., et al. (2005b). *U.S. Pacific Marine Mammal Stock Assessments: 2004*. (NOAA-TM-NMFS-SWFSC-375, pp. 316).

Carretta, J. V., Forney, K. A., Muto, M. M., Barlow, J., Baker, J. and Lowry, M. (2004). *Draft U.S. Pacific Marine Mammal Stock Assessments: 2004*. (NOAA Technical Memorandum NMFS-SWFSC:1-158) NOAA National Marine Fisheries Service, Southwest Fisheries Science Center.

Carretta, J. V., Forney, K. A., Oleson, E. M., Martien, K., Muto, M. M., Lowry, M. S., et al. (2011a). Blainville's Beaked Whale (*Mesoplodon densirostris*): Hawaiian Stock. In *U.S. Pacific Marine Mammal Stock Assessments: 2010*. (NOAA-TM-NMFS-SWFSC-476, pp. 261-264). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/po2010whbv-hi.pdf

Carretta, J. V., Forney, K. A., Oleson, E. M., Martien, K., Muto, M. M., Lowry, M. S., et al. (2011b). Bryde's Whale (*Balaenoptera edeni*): Hawaiian Stock. In *U.S. Pacific Marine Mammal Stock Assessments:*

2010. (NOAA-TM-NMFS-SWFSC-476, pp. 288-290). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/po2010whbr-hi.pdf

Carretta, J. V., Forney, K. A., Oleson, E. M., Martien, K., Muto, M. M., Lowry, M. S., et al. (2011c). Common Bottlenose Dolphin (*Tursiops truncatus truncatus*): Hawaiian Islands Stock Complex-Kauai/Niihau, Oahu, 4-island, Hawaii Island, Hawaii Pelagic. In *U.S. Pacific Marine Mammal Stock Assessments: 2010*. (pp. 209-216). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/po2010dobn-hi.pdf

Carretta, J. V., Forney, K. A., Oleson, E. M., Martien, K., Muto, M. M., Lowry, M. S., et al. (2011d). Cuvier's Beaked Whale (*Ziphius cavirostris*): Hawaiian Stock. In *U.S. Pacific Marine Mammal Stock Assessments: 2010*. (NOAA-TM-NMFS-SWFSC-476, pp. 265-267). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/po2010whcb-hi.pdf

Carretta, J. V., Forney, K. A., Oleson, E. M., Martien, K., Muto, M. M., Lowry, M. S., et al. (2011e). Dwarf Sperm Whale (*Kogia sima*): Hawaiian Stock. In *U.S. Pacific Marine Mammal Stock Assessments: 2010*. (NOAA-TM-NMFS-SWFSC-476, pp. 274-276). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/po2010whds-hi.pdf

Carretta, J. V., Forney, K. A., Oleson, E. M., Martien, K., Muto, M. M., Lowry, M. S., et al. (2011f). False Killer Whale (*Pseudorca crassidens*): Pacific Islands Region Stock Complex - Hawaii Insular, Hawaii Pelagic, and Palmyra Atoll Stocks. In *U.S. Pacific Marine Mammal Stock Assessments: 2010*. (NOAA-TM-NMFS-SWFSC-476, pp. 241-248). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/po2010whfk-isl.pdf

Carretta, J. V., Forney, K. A., Oleson, E. M., Martien, K., Muto, M. M., Lowry, M. S., et al. (2011g). Fin Whale (*Balaenoptera physalus physalus*): Hawaiian Stock. In *U.S. Pacific Marine Mammal Stock Assessments: 2010*. (NOAA-TM-NMFS-SWFSC-476, pp. 285-287). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/po2010whfi-hi.pdf

Carretta, J. V., Forney, K. A., Oleson, E. M., Martien, K., Muto, M. M., Lowry, M. S., et al. (2011h). Fraser's Dolphin (*Lagenodelphis hosei*): Hawaiian Stock. In *U.S. Pacific Marine Mammal Stock Assessments: 2010*. (NOAA-TM-NMFS-SWFSC-476, pp. 233-234). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/po2010dofr-hi.pdf

Carretta, J. V., Forney, K. A., Oleson, E. M., Martien, K., Muto, M. M., Lowry, M. S., et al. (2011i). Killer Whale (Orcinus orca): Hawaiian Stock. In *U.S. Pacific Marine Mammal Stock Assessments: 2010*. (NOAA-TM-NMFS-SWFSC-476, pp. 253-255). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/po2010whki-hi.pdf

Carretta, J. V., Forney, K. A., Oleson, E. M., Martien, K., Muto, M. M., Lowry, M. S., et al. (2011j). Long-Beaked Common Dolphin (*Delphinus capensis capensis*): California Stock. In *U.S. Pacific Marine Mammal Stock Assessments: 2010*. (NOAA-TM-NMFS-SWFSC-476, pp. 116-120). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/po2010docl-ca.pdf

Carretta, J. V., Forney, K. A., Oleson, E. M., Martien, K., Muto, M. M., Lowry, M. S., et al. (2011k). Melon-Headed Whale (*Peponocephala electra*): Hawaiian Stock. In *U.S. Pacific Marine Mammal Stock Assessments: 2010*. (NOAA-TM-NMFS-SWFSC-476, pp. 235-237). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/po2010whmh-hi.pdf

Carretta, J. V., Forney, K. A., Oleson, E. M., Martien, K., Muto, M. M., Lowry, M. S., et al. (2011l). Minke Whale (*Balaenoptera acutorostrata scammoni*): Hawaiian Stock. In *U.S. Pacific Marine Mammal Stock Assessments: 2010*. (NOAA-TM-NMFS-SWFSC-476, pp. 294-296). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/po2010whmi-hi.pdf

Carretta, J. V., Forney, K. A., Oleson, E. M., Martien, K., Muto, M. M., Lowry, M. S., et al. (2011m). Pantropical Spotted Dolphin (*Stenella attenuata attenuata*): Hawaiian Stock. In *U.S. Pacific Marine Mammal Stock Assessments: 2010*. (NOAA-TM-NMFS-SWFSC-476, pp. 217-221). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/po2010dops-hi.pdf

Carretta, J. V., Forney, K. A., Oleson, E. M., Martien, K., Muto, M. M., Lowry, M. S., et al. (2011n). Pygmy Killer Whale (*Feresa attenuata*): Hawaiian Stock. In *U.S. Pacific Marine Mammal Stock Assessments: 2010*. (NOAA-TM-NMFS-SWFSC-476, pp. 238-240). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/po2010whpk-hi.pdf

Carretta, J. V., Forney, K. A., Oleson, E. M., Martien, K., Muto, M. M., Lowry, M. S., et al. (2011o). Risso's Dolphin (*Grampus griseus*): Hawaiian Stock. In *U.S. Pacific Marine Mammal Stock Assessments: 2010*. (NOAA-TM-NMFS-SWFSC-476, pp. 205-208). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/po2010dori-hi.pdf

Carretta, J. V., Forney, K. A., Oleson, E. M., Martien, K., Muto, M. M., Lowry, M. S., et al. (2011p). Sei Whale (*Balaenoptera borealis borealis*): Hawaiian Stock. In *U.S. Pacific Marine Mammal Stock Assessments: 2010*. (NOAA-TM-NMFS-SWFSC-476, pp. 291-293). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/po2010whse-hi.pdf

Carretta, J. V., Forney, K. A., Oleson, E. M., Martien, K., Muto, M. M., Lowry, M. S., et al. (2011q). Short-beaked Common Dolphin (*Delphinus delphis delphis*): California/Oregon/Washington Stock. In *U.S. Pacific Marine Mammal Stock Assessments: 2010*. (NOAA-TM-NMFS-SWFSC-476, pp. 109-115). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration,

National Marine Fisheries Service, Southwest Fisheries Science Center. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/po2010docs-cow.pdf

Carretta, J. V., Forney, K. A., Oleson, E. M., Martien, K., Muto, M. M., Lowry, M. S., et al. (2011r). Sperm Whale (*Physeter macrocephalus*): Hawaiian Stock. In *U.S. Pacific Marine Mammal Stock Assessments: 2010*. (NOAA-TM-NMFS-SWFSC-476, pp. 277-280). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/po2010whsp-hi.pdf

Carretta, J. V., Forney, K. A., Oleson, E. M., Martien, K., Muto, M. M., Lowry, M. S., et al. (2011s). Striped Dolphin (*Stenella coeruleoalba*): Hawaiian Stock. In *U.S. Pacific Marine Mammal Stock Assessments: 2010*. (NOAA-TM-NMFS-SWFSC-476, pp. 229-232). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center. Available from http://www.nmfs.noaa.gov/pr/pdfs/sars/po2010dost-hi.pdf

Carretta, J. V., Forney, K. A., Oleson, E. M., Martien, K., Muto, M. M., Lowry, M. S., et al. (2012). *Draft U.S. Pacific Marine Mammal Stock Assessments: 2011*. (NOAA-TM-NMFS-SWFSC-XXX, pp. 60). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center.

Cartwright, R. and Sullivan, M. (2009). Associations with multiple male groups increase the energy expenditure of humpback whale (*Megaptera novaeangliae*) female and calf pairs on the breeding grounds. *Behaviour, 146*, 1573-1600. doi:10.1163/156853909x458377

Carvalho, V. L., Bevilaqua, C. M. L., Iniguez, A. M., Mathews-Cascon, H., Ribeiro, F. B., Pessoa, L. M. B., et al. (2010). Metazoan parasites of cetaceans off the northeastern coast of Brazil. *Veterinary Parasitology, 173*(1-2), 116-122. doi:10.1016/j.vetpar.2010.06.023

Cascadia Research (2008, Last updated 16 December 2008). *An update on our December 2008 Hawai'i field work*. [Web page] Cascadia Research,. Retrieved from http://www.cascadiaresearch.org/robin/December2008.htm, 18 August 2010.

Cascadia Research (2009, Last updated 7 May 2009). *An update on our April/May 2009 Hawai'i field work*. [Web page] Cascadia Research. Retrieved from http://www.cascadiaresearch.org/robin/AprMay2009.htm, 18 August 2010.

Cascadia Research (2010, Last updated 2 April 2010). *Hawai'i's false killer whales*. [Web page] Cascadia Research. Retrieved from http://www.cascadiaresearch.org/hawaii/falsekillerwhale.htm, 19 August 2010.

Cassoff, R. M., Moore, K. M., McLellan, W. A., Barco, S. G., Rotstein, D. S. and Moore, M. J. (2011). Lethal entanglement in baleen whales. *Diseases of Aquatic Organisms, 96*(3), 175-185. doi:10.3354/dao02385

Castellote, M., Clark, C. and Lammers, M. O. (2012). Acoustic and behavioral changes by fin whales (*Balaenoptera physalus*) in response to shipping and airgun noise. *Biological Conservation, 147*, 115-122. Retrieved from http://www.sciencedirect.com/science/article/pii/S0006320711004848

Cetacean and Turtle Assessment Program (1982). A Characterization of Marine Mammals and Turtles in the Mid- and North Atlantic Areas of the U.S. Outer Continental Shelf. [Final report]. 540.

Charif, R. A., Mellinger, D. K., Dunsmore, K. J., Fristrup, K. M. and Clark, C. W. (2002). Estimated source levels of fin whale (Balaenoptera physalus) vocalizations: Adjustments for surface interference. *Marine Mammal Science, 18*(1), 81-98.

Cheal, A. J. and Gales, N. J. (1992). Growth, sexual maturity and food intake of Australian Indian Ocean bottlenose dolphins, Tursiops truncatus, in captivity. *Australian Journal of Zoololgy, 40*, 215-223.

Chen, I., Watson, A. and Chou, L. S. (2011). Insights from life history traits of Risso's dolphins (*Grampus griseus*) in Taiwanese waters: Shorter body length characterizes northwest Pacific population. *Marine Mammal Science, 27*(2), E43-E64. doi:10.1111/j.1748-7692.2010.00429.x

Chilvers, B. L. and Corkeron, P. J. (2002). Association patterns of bottlenose dolphins (Tursiops aduncus) off Point Lookout, Queensland, Australia. *Canadian Journal of Zoology, 80*, 973-979.

Chilvers, B. L., Corkeron, P. J. and Puotinen, M. L. (2003). Influence of trawling on the behaviour and spatial distribution of Indo-Pacific bottlenose dolphins (Tursiops aduncus) in Moreton Bay, Australia. *Canadian Journal of Zoology, 81*, 1947-1955.

Chilvers, B. L., Delean, S., Gales, N. J., Holley, D. K., Lawler, I. R., Marsh, H., et al. (2004). Diving behaviour of dugongs, Dugong dugon. *Journal of Experimental Marine Biology and Ecology, 304*, 203-224.

Chilvers, B. L., Lawler, I. R., Macknight, F., Marsh, H., Noad, M. and Paterson, R. (2005). Moreton Bay, Queensland, Australia: an example of the co-existence of significant marine mammal populations and large-scale coastal development. *Biological Conservation, 122*(4), 559-571. doi:10.1016/j.biocon.2004.08.013

Choi, M., Moon, H. B., An, Y. R., Choi, S. G. and Choi, H. G. (2011). Accumulation of butyltin compounds in cetaceans from Korean coastal waters. *Marine Pollution Bulletin, 62*(5), 1120-1123. doi:10.1016/j.marpolbul.2011.03.013

Clapham, P. J. (1996). The social and reproductive biology of humpback whales: An ecological perspective. *Mammal Review, 26*, 27-49.

Clapham, P. J. (2000). The humpback whale: seasonal feeding and breeding in a baleen whale. In J. Mann, R. C. Connor, P. L. Tyack and H. Whitehead (Eds.), *Cetacean Societies: Field Studies of Dolphins and Whales* (pp. 173-196). University of Chicago Press.

Clapham, P. J., Berggren, P., Childerhouse, S., Friday, N. A., Kasuya, T., Kell, L., et al. (2003). Whaling as science. *BioScience, 53*(3), 210-212.

Clapham, P. J., Good, C., Quinn, S. E., Reeves, R. R., Scarff, J. E. and Brownell, R. L., Jr. (2004). Distribution of North Pacific right whales (*Eubalaena japonica*) as shown by 19th and 20th century whaling catch and sighting records. *Journal of Cetacean Research and Management, 6*(1), 1-6.

Clapham, P. J. and Mattila, D. K. (1990). Humpback whale songs as indicators of migration routes. *Marine Mammal Science, 6*(2), 155-160.

Clapham, P. J. and Mead, J. G. (1999). Megaptera novaeangliae. *Mammalian Species, 604*, 1-9.

Clark, C. W. and Clapham, P. J. (2004). Acoustic monitoring on a humpback whale (*Megaptera novaeangliae*) feeding ground shows continual singing into late spring. *Proceedings of the Royal Society B: Biological Sciences, 271*, 1051-1057. doi: 10.1098/rspb.2004.2699

Clark, C. W., Ellison, W. T., Southall, B. L., Hatch, L., Van Parijs, S. M., Frankel, A., et al. (2009). Acoustic masking in marine ecosystems: intuitions, analysis, and implication. *Marine Ecology Progress Series, 395*, 201-222. doi:10.3354/meps08402

Clarke, M. R. (1996). Cephalopods as prey. III. Cetaceans. *Philosophical Transactions of the Royal Society of London, 351*, 1053-1065.

Coakes, A., Gowans, S., Simard, P., Giard, J., Vashro, C. and Sears, R. (2005). Photographic identification of fin whales (Balaenoptera physalus) off the Atlantic coast of Nova Scotia, Canada. *Marine Mammal Science, 21*(2), 323-327.

Cockcroft, V. G. and Ross, G. J. B. (1990). Age, growth, and reproduction of bottlenose dolphins Tursiops truncatus from the east coast of southern Africa. *Fishery Bulletin, 88*, 289-302.

Colitz, C. M. H., Renner, M. S., Manire, C. A., Doescher, B., Schmitt, T. L., Osborn, S. D., et al. (2010). Characterization of progressive keratitis in Otariids. *Veterinary Ophthalmology, 13*(Supplement 1), 47-53.

Connor, R. C., Heithaus, M. R. and Barre, L. M. (2001). Complex social structure, alliance stability and mating access in a bottlenose dolphin 'super-alliance'. *Proceedings of the Royal Society of London, 268B*, 263-267.

Connor, R. C. and Smolker, R. A. (1996). "Pop" goes the dolphin: a vocalization male bottlenose dolphins make during consortships. *Behaviour, 133*, 643-662.

Connor, R. C., Wells, R. S., Mann, J. and Read, A. J. (2000). The bottlenose dolphin: social relationships in a fission-fusion society. In J. Mann, R. C. Connor, P. L. Tyack and H. Whitehead (Eds.), *Cetacean societies: field studies of dolphins and whales* (pp. 91-126). Chicago, IL: University of Chicago Press.

Corkeron, P. J. (1990). Aspects of the behavioral ecology of inshore dolphins Tursiops truncatus and Sousa chinensis in Moreton Bay, Australia S. Leatherwood and R. R. Reeves (Eds.), *The bottlenose dolphin* (pp. 285-293). Academic Press.

Corkeron, P. J., Bryden, M. M. and Hedstrom, K. E. (1990). Feeding by bottlenose dolphins in association with trawling operations in Moreton Bay, Australia S. Leatherwood and R. R. Reeves (Eds.), *The bottlenose dolphin* (pp. 329-336). Academic Press.

Corkeron, P. J. and Van Parijs, S. M. (2001). Vocalizations of eastern Australian Risso's dolphins, Grampus griseus. *Canadian Journal of Zoology, 79*, 160-164.

Cox T. M., Ragen T. J., Read A. J., Vos, E., Baird, R. W., Balcomb, K., et al. (2006). Understanding the impacts of anthropogenic sound on beaked whales. *Journal for Cetacean Research and Management, 7*(3), 177-187. Retrieved from http://cascadiaresearch.org/robin/coxetal2006.pdf

Coyle, K. O., Bluhm, B., Konar, B., Blanchard, A. and Highsmith, R. C. (2007). Amphipod prey of gray whales in the northern Bering Sea: Comparison of biomass and distribution between the 1980s and 2002-2003. *Deep Sea Research II, 54*(23-26), 2906-2918. doi:10.1016/j.dsr2.2007.08.026

Craig, A. S. and Herman, L. M. (2000). Habitat preferences of female humpback whales Megaptera novaeangliae in the Hawaiian Islands are associated with reproductive status. *Marine Ecology Progress Series, 193*, 209-216.

Crane, N. L. and Lashkari, K. (1996). Sound production of gray whales, *Eschrichtius robustus*, along their migration route: A new approach to signal analysis. *Journal of the Acoustical Society of America, 100*(3), 1878-1886.

Cranford, T. W., Krysl, P. and Hildebrand, J. A. (2008). Acoustic pathways revealed: Simulated sound transmission and reception in Cuvier's beaked whale (*Ziphius cavirostris*). *Bioinspiration & Biomimetics, 3*(1), 1-10. doi:10.1088/1748-3182/3/1/016001

Cranford, T. W., McKenna, M. F., Soldevilla, M. S., Wiggins, S. M., Goldbogen, J. A., Shadwick, R. E., et al. (2008). Anatomic geometry of sound transmission and reception in Cuvier's beaked whale (*Ziphius cavirostris*). *The Anatomical Record, 291*(4), 353-378. doi:10.1002/ar.20652

Croll, D. A., Acevedo-Gutierrez, A., Tershy, B. R. and Urban R., J. (2001). The diving behavior of blue and fin whales: Is dive duration shorter than expected based on oxygen stores? *Comparative Biochemistry and Physiology Part A, 129*, 797-809.

Croll, D. A., B.R. Tershy, A. Acevedo, and P. Levin. (1999). Marine vertebrates and low frequency sound [Technical report]. Santa Cruz, California: University of California. Prepared by Institute of Marine Sciences. Prepared for U.S. Navy.

Croll, D. A., Clark, C. W., Acevedo, A., Tershy, B., Flores, S., Gedamke, J., et al. (2002). Only male fin whales sing loud songs. *Nature, 417*, 809.

Croll, D. A., Clark, C. W., Calambokidis, J., Ellison, W. T. and Tershy, B. R. (2001). Effect of anthropogenic low-frequency noise on the foraging ecology of Balaenoptera whales. *Animal Conservation, 4*(PT1), 13-27.

Cullon, D. L., Yunker, M. B., Alleyne, C., Dangerfield, N. J., O'Neill, S., Whiticar, M. J., et al. (2009). Persistent organic pollutants in chinook salmon (*Oncorhynchus tshawytscha*): Implications for resident killer whales of British Columbia and adjacent waters. *Environmental Toxicology and Chemistry, 28*(1), 148-161. doi:10.1897/08-125.1

Cummings, W. C. (1985). Bryde's whale *Balaenoptera edeni* Anderson, 1878. In S. H. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals* (Vol. 3, pp. 137-154). San Diego, CA: Academic Press.

Cummings, W. C. and Fish, J. F. (1971). *A Synopsis of Marine Animal Underwater Sounds in Eight Geographic Areas*. (pp. 101). San Diego, CA: Naval Undersea Research and Development Center.

Cummings, W. C., Thompson, P. O. and Cook, R. (1968). Underwater sounds of migrating gray whales, Eschrichtius glaucus (Cope). *Journal of the Acoustical Society of America, 44*(5), 1278-1281.

Currey, R. J. C., Dawson, S. M., Schneider, K., Lusseau, D., Boisseau, O. J., Haase, P. A., et al. (2011). Inferring causal factors for a declining population of bottlenose dolphins via temporal symmetry capture-recapture modeling. *Marine Mammal Science, 27*(3), 554-566. doi:10.1111/j.1748-7692.2010.00417.x

Curry, B. E. and Smith, J. (1997). Phylogeographic structure of the bottlenose dolphin (*Tursiops truncatus*): Stock identification and implications for management. In A. E. Dizon, S. J. Chivers and W. F. Perrin (Eds.), *Molecular Genetics of Marine Mammals* (pp. 227-247). Lawrence, KS: Society for Marine Mammalogy.

D'Vincent, C. G., Nilson, R. M. and Hanna, R. E. (1985). Vocalization and coordinated feeding behavior of the humpback whale in southeastern Alaska. *Scientific Reports of the the Whales Research Institute, 36*, 41-47.

Dahlheim, M. E., Fisher, H. D. and Schempp, J. D. (1984). Sound production by the gray whale and ambient noise levels in Laguna San Ignacio, Baja California Sur, Mexico M. L. Jones, S. L. Swartz and S. Leatherwood (Eds.), *The gray whale Eschrichtius robustus* (pp. 511-541). San Diego, California: Academic Press.

Dahlheim, M. E. and Heyning, J. E. (1999). Killer whale *Orcinus orca* (Linnaeus, 1758). In S. H. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals* (Vol. 6, pp. 281-322). San Diego, CA: Academic Press.

Dahlheim, M. E. and Ljungblad, D. K. (1990). Preliminary hearing study on gray whales (*Eschrichtius robustus*) in the field J. Thomas and R. Kastelein (Eds.), *Sensory abilities of cetaceans: Laboratory and field evidence* (pp. 335-346). New York, New York and London, England: Plenum Press.

Dahlheim, M. E., Schulman-Janiger, A., Black, N., Ternullo, R., Ellifrit, D. and Balcomb, K. C. (2008). Eastern temperate North Pacific offshore killer whales (*Orcinus orca*): Occurrence, movements, and insights into feeding ecology. *Marine Mammal Science, 24*(3), 719-729. doi: 10.1111/j.1748-7692.2008.00206.x

Dahlheim, M. E. and White, P. A. (2010). Ecological aspects of transient killer whales *Orcinus orca* as predators in southeastern Alaska. *Wildlife Biology, 16*(3), 308-322. doi:10.2981/09-075

Dahlheim, M. E., White, P. A. and Waite, J. M. (2009). Cetaceans of southeast Alaska: Distribution and seasonal occurrence. *Journal of Biogeography, 36*, 410-426.

Dalebout, M. L., Mead, J. G., Baker, C. S., Baker, A. N. and van Helden, A. L. (2002). A new species of beaked whale *Mesoplodon perrini* sp. n. (Cetacea: Ziphiidae) discovered through phylogenetic analyses of mitochondrial DNA sequences. *Marine Mammal Science, 18*(3), 577-608.

Dalebout, M. L., Ross, G. J. B., Baker, C. S., Anderson, R. C., Best, P. B., Cockcroft, V. G., et al. (2003). Appearance, distribution and genetic distinctiveness of Longman's beaked whale, *Indopacetus pacificus*. *Marine Mammal Science, 19*(3), 421-461.

Dalton, R. (2008). Whales are on the rise. *Nature, 453*(7194), 433. doi:10.1038/453433a

Darling, J. D. and Bérubé, M. (2001). Interactions of singing humpback whales with other males. *Marine Mammal Science, 17*(3), 570-584.

Darling, J. D., Jones, M. E. and Nicklin, C. P. (2006). Humpback whale songs: Do they organize males during the breeding season? *Behaviour, 143*(9), 1051-1101.

Darling, J. D. and Mori, K. (1993). Recent observations of humpback whales (*Megaptera novaeangliae*) in Japanese waters off Ogasawara and Okinawa. *Canadian Journal of Zoology, 71*, 325-333.

Davis, P. Z. R. (2004). Current status of knowledge of dugongs in Palau: A review and project summary report *The Nature Conservancy Pacific Islands Countries Report*. (pp. 44).

Davis, R. W., Evans, W. E. and Wursig, B. (2000). *Cetaceans, Sea Turtles and Seabirds in the Northern Gulf of Mexico: Distribution, Abundance and Habitat Associations. Volume II: Technical report*. (USGS/BRD/CR-1999-0006; OCS Study MMS 2000-03, pp. 346). New Orleans, LA: US Department of the Interior, Geological Survey, Biological Resources Division, and Minerals Management Service, Gulf of Mexico OCS Region. Prepared by Texas A&M University at Galveston and the National Marine Fisheries Service.

Davis, R. W. and Fargion, G. S. (1996). *Distribution and abundance of cetaceans in the north-central and western Gulf of Mexico, Final Report. Volume II: Technical Report*. (OCS Study MMS 96-0027, pp. 357). New Orleans, LA: Mineral Management Service.

Davis, R. W., Fargion, G. S., May, N., Leming, T. D., Baumgartner, M., Evans, W. E., et al. (1998). Physical habitat of cetaceans along the continental slope in the north-central and western Gulf of Mexico. *Marine Mammal Science, 14*(3), 490-507.

Davis, R. W., Jaquet, N., Gendron, D., Markaida, U., Bazzino, G. and Gilly, W. (2007). Diving behavior of sperm whales in relation to behavior of a major prey species, the jumbo squid, in the Gulf of California, Mexico. *Marine Ecology Progress Series, 333*, 291-302.

Dawson, S., Barlow, J. and Ljungblad, D. (1998). Sounds recorded from Baird's beaked whale, *Berardius bairdii*. *Marine Mammal Science, 14*(2), 335-344.

de Guevara, P. L., Lavaniegos, B. E. and Heckel, G. (2008). Fin whales (*Balaenoptera physalus*) foraging on daytime surface swarms of the euphausiid *Nyctiphanes simplex* in Ballenas Channel, Gulf of California, Mexico. *Journal of Mammalogy, 89*(3), 559-566. doi:10.1644/07/mamm-a-067r2.1

De Iongh, H. H., Kiswara, W., Kustiawan, W. and Loth, P. E. (2007). A review of research on the interactions between dugongs (*Dugong dugon* Muller 1776) and intertidal seagrass beds in Indonesia. *Hydrobiologia, 591*, 73-83. doi:10.1007/s10750-007-0785-4

de la Riva, G. T., Johnson, C. K., Gulland, F. M. D., Langlois, G. W., Heyning, J. E., Rowles, T. K., et al. (2009). Association of an unusual marine mammal mortality event with *Pseudo-nitzschia* spp. blooms along the Southern California Coastline. *Journal of Wildlife Diseases, 45*(1), 109-121.

Deakos, M. H., Branstetter, B. K., Mazzuca, L., Fertl, D. and Mobley, J. R. (2010). Two unusual interactions between a bottlenose dolphin (*Tursiops truncatus*) and a humpback whale (*Megaptera novaeangliae*) in Hawaiian Waters. *Aquatic Mammals, 36*(2), 121-128. doi:10.1578/am.36.2.2010.121

Deecke, V. B., Barrett-Lennard, L. G., Spong, P. and Ford, J. K. B. (2010). The structure of stereotyped calls reflects kinship and social affiliation in resident killer whales (*Orcinus orca*). *Naturwissenschaften, 97*(5), 513-518. doi:10.1007/s00114-010-0657-z

Deecke, V. B., Ford, J. K. B. and Slater, P. J. B. (2005). The vocal behaviour of mammal-eating killer whales: Communicating with costly calls. *Animal Behaviour, 69*, 395-405.

Defran, R. H. and Weller, D. W. (1999). Occurrence, distribution, site fidelity, and school size of bottlenose dolphins (Tursiops truncatus) off San Diego, California. *Marine Mammal Science, 15*(2), 366-380.

Dehn, L. A., Follmann, E. H., Thomas, D. L., Sheffield, G. G., Rosa, C., Duffy, L. K., et al. (2006). Trophic relationships in an Arctic food web and implications for trace metal transfer. *Science of the Total Environment, 362*(1-3), 103-123. doi:10.1016/j.scitotenv.2005.11.012

DeLong, R. L. (1982). *Population biology of northern fur seals at San Miguel Island, California.* (Doctoral dissertation). UC Berkeley.

DeLong, R. L., Orr, A. J., Jenkinson, R. S. and Lyons, E. T. (2009). Treatment of northern fur seal (*Callorhinus ursinus*) pups with ivermectin reduces hookworm-induced mortality. *Marine Mammal Science, 25*(4), 944-948. doi:10.1111/j.1748-7692.2008.00274.x

Di Guardo, G., Proietto, U., Di Francesco, C. E., Marsilio, F., Zaccaroni, A., Scaravelli, D., et al. (2010). Cerebral toxoplasmosis in striped dolphins (*Stenella coeruleoalba*) stranded along the Ligurian Sea coast of Italy. *Veterinary Pathology Online, 47*(2), 245-253.

Di Iorio, L. and Clark, C. W. (2010). Exposure to seismic survey alters blue whale acoustic communication. *Biology Letters, 6*(3), 51-54. doi:10.1098/rsbl.2009.0967

Dickerson, B. R., Ream, R. R., Vignieri, S. N. and Bentzen, P. (2010). Population structure as revealed by mtDNA and microsatellites in Northern fur seals, *Callorhinus ursinus*, throughout their range. *PLoS ONE, 5*(5), e10671. doi:10.1371/journal.pone.0010671

Dietz, R., Teilmann, J., Jørgensen, M.-P. H. and Jensen, M. V. (2002). *Satellite tracking of humpback whales in West Greenland*. (NERI Technical Report 411, pp. 40). Roskilde, Denmark: Denmark Ministry of the Environment, National Environmental Research Institute.

DiGiovanni, R. A., Jr., Durham, K. F., Wocial, J. N., Pisciotta, R. P., Hanusch, R., Chaillet, A. M., et al. (2005). *Rehabilitation and post release monitoring of a male Risso's dolphin (Grampus griseus) released in New York waters.* [Abstract]. Presented at the Sixteenth Biennial Conference on the Biology of Marine Mammals, San Diego, CA.

Dizon, A. E., Perrin, W. F. and Akin, P. A. (1994). Stocks of dolphins (*Stenella spp*. and *Delphinus delphis*) in the eastern tropical Pacific: A phylogeographic classification [Technical Report]. (NMFS 119, pp. 20) NOAA.

Dolar, M. L. L. (2008). Fraser's dolphin *Lagenodelphis hosei*. In W. F. Perrin, B. Würsig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (pp. 485-487). San Diego, CA: Academic Press.

Dolar, M. L. L., Walker, W. A., Kooyman, G. L. and Perrin, W. F. (2003). Comparative feeding ecology of spinner dolphins (*Stenella longirostris*) and Fraser's Dolphins (*Lagenodelphis hosei*)in the Sulu Sea. *Marine Mammal Science, 19*(1), 1-19.

Dolphin, W. F. (1987a). Dive behavior and estimated energy expenditure of foraging humpback whales in southeast Alaska. *Canadian Journal of Zoology, 65*, 354-362.

Dolphin, W. F. (1987b). Ventilation and dive patterns of humpback whales, *Megaptera novaeangliae*, on their Alaskan feeding grounds. *Canadian Journal of Zoology, 65*, 83-90.

Domning, D. P. and Beatty, B. L. (2007). Use of tusks in feeding by dugongid sirenians: Observations and tests of hypotheses. *The Anatomical Record, 290*(6), 523-538. doi:10.1002/ar.20540

Donahue, M. A. and Perryman, W. L. (2008). Pygmy killer whale *Feresa attenuata*. In W. F. Perrin, B. Würsig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 938-939). San Diego, CA: Academic Press.

Donaldson, T. J. (1983). Further investigations of the whales *Peponocephala electra* and *Globicephala macrorhynchus* reported from Guam. *Micronesica, 19*(1-2), 173-181.

Doniol-Valcroze, T., Berteaux, D., Larouche, P. and Sears, R. (2007). Influence of thermal fronts on habitat selection by four rorqual whale species in the Gulf of St. Lawrence. *Marine Ecology Progress Series, 335*, 207-216.

Donovan, G. P. (1991). A review of IWC stock boundaries. *Reports of the International Whaling Commission, Special Issue 13*, 39-68.

Dorsey, E. M. (1983). Exclusive adjoining ranges in individually identified minke whales (*Balaenoptera acutorostrata*) in Washington State. *Canadian Journal of Zoology, 61*, 174-181.

Dorsey, E. M., Stern, S. J., Hoelzel, A. R. and Jacobsen, J. (1990). Minke whales (*Balaenoptera acutorostrata*) from the west coast of North America: Individual recognition and small-scale site fidelity. *Reports of the International Whaling Commission* (Special Issue 12), 357-368.

Doucette, G. J., Cembella, A. D., Martin, J. L., Michaud, J., Cole, T. V. N. and Rolland, R. M. (2006). Paralytic shellfish poisoning (PSP) toxins in North Atlantic right whales *Eubalaena glacialis* and their zooplankton prey in the Bay of Fundy, Canada. *Marine Ecology Progress Series, 306*, 303-313.

Douglas, A. B., Calambokidis, J., Raverty, S., Jeffries, S. J., Lambourn, D. M. and Norman, S. A. (2008). Incidence of ship strikes of large whales in Washington State. *Journal of the Marine Biological Association of the United Kingdom, 88*(6), 1121-1132. doi:10.1017/s0025315408000295

Dubey, J. P., Fair, P. A., Bossart, G. D., Hill, D., Fayer, R., Sreekumar, C., et al. (2005). A comparison of several serologic tests to detect antibodies to *Toxoplasma gondii* in naturally exposed bottlenose dolphins (*Tursiops truncatus*). *Journal of Parasitology, 91*(5), 1074-1081. doi:10.1645/ge-582r.1

Dubey, J. P., Fair, P. A., Sundar, N., Velmurugan, G., Kwok, O. C. H., McFee, W. E., et al. (2008). Isolation of *Toxoplasma gondii* from bottlenose dolphins (*Tursiops truncatus*). *Journal of Parasitology, 94*(4), 821-823. doi:10.1645/ge-1444.1

Dugong Network Okinawa. (2001). For the protection of dugongs offshore Okinawa (Material II). (pp. 49). Okinawa, Japan: University of Okinawa.

Dunlop, R. A., Cato, D. H. and Noad, M. J. (2008). Non-song acoustic communication in migrating humpback whales (*Megaptera novaeangliae*). *Marine Mammal Science, 24*(3), 613-629. doi:10.1111/j.1748-7692.2008.00208.x

Dunlop, R. A., Cato, D. H. and Noad, M. J. (2010). Your attention please: increasing ambient noise levels elicits a change in communication behaviour in humpback whales (*Megaptera novaeangliae*). *Proceedings of the Royal Society B-Biological Sciences, 277*(1693), 2521-2529. doi:10.1098/rspb.2009.2319

Dunn, R. A. and Hernandez, O. (2009). Tracking blue whales in the eastern tropical Pacific with an ocean-bottom seismometer and hydrophone array. *Journal of the Acoustical Society of America, 126*(3), 1084-1094. doi:10.1121/1.3158929

Dunphy-Daly, M. M., Heithaus, M. R. and Claridge, D. E. (2008). Temporal variation in dwarf sperm whale (Kogia sima) habitat use and group size off Great Abaco Island, Bahamas. *Marine Mammal Science, 24*(1), 171-182. doi:10.1111/j.1748-7692.2007.00183

Durban, J., Ellifrit, D., Dahlheim, M., Waite, J., Matkin, C., Barrett-Lennard, L., et al. (2010). Photographic mark-recapture analysis of clustered mammal-eating killer whales around the Aleutian Islands and Gulf of Alaska. *Marine Biology, 157*(7), 1591-1604. doi:10.1007/s00227-010-1432-6

Edds-Walton, P. L. (1997). Acoustic communication signals of mysticete whales. *Bioacoustics, 8*, 47-60.

Edwards, E. F. (2006). Duration of unassisted swimming activity for spotted dolphin (*Stenella attenuata*) calves: implications for mother-calf separation during tuna purse-seine sets. *Fishery Bulletin, 104*(1), 125-135.

Eldredge, L. G. (1991). Annotated checklist of the marine mammals of Micronesia. *Micronesica, 24*(2), 217-230.

Eldredge, L. G. (2003). The marine reptiles and mammals of Guam. *Micronesica, 35-36*, 653-660.

Elfes, C. T., VanBlaricom, G. R., Boyd, D., Calambokidis, J., Clapham, P. J., Pearce, R. W., et al. (2010). Geographic variation of persistent organic pollutant levels in humpback whale (*Megaptera novaeangliae*) feeding areas of the North Pacific and North Atlantic. *Environmental Toxicology and Chemistry, 29*(4), 824-834. doi:10.1002/etc.110

Elwen, S. H. and Leeney, R. H. (2011). Interaction between leatherback turtles and killer whales in Namibian waters, including possible predation. *South African Journal of Marine Science, 41*(2), 205-209. doi:10.3957/056.041.0207

Endo, T., Hisamichi, Y., Kimura, O., Haraguchi, K. and Baker, C. S. (2008). Contamination levels of mercury and cadmium in melon-headed whales (*Peponocephala electra*) from a mass stranding on the Japanese coast. *Science of the Total Environment, 401*(1-3), 73-80. doi:10.1016/j.scitotenv.2008.04.006

Endo, T., Hotta, Y., Hisamichi, Y., Kimura, O., Sato, R., Haraguchi, K., et al. (2012). Stable isotope ratios and mercury levels in red meat products from baleen whales sold in Japanese markets. *Ecotoxicology and Environmental Safety, 79*, 35-41. doi:10.1016/j.ecoenv.2012.01.020

Endo, T., Kimura, O., Hisamichi, Y., Minoshima, Y. and Haraguchi, K. (2007). Age-dependent accumulation of heavy metals in a pod of killer whales (*Orcinus orca*) stranded in the northern area of Japan. *Chemosphere, 67*(1), 51-59. doi:10.1016/j.chemosphere.2006.09.086

Endo, T., Kimura, O., Hisamichi, Y., Minoshima, Y., Haraguchi, K., Kakumoto, C., et al. (2006). Distribution of total mercury, methyl mercury and selenium in pod of killer whales (*Orcinus Orca*) stranded in the northern area of Japan: Comparison of mature females with calves. *Environmental Pollution, 144*(1), 145-150. doi:10.1016/j.envpol.2005.12.035

Endo, T., Yong-Un, M., Baker, C. S., Funahashi, N., Layery, S., Dalebout, M. L., et al. (2007). Contamination level of mercury in red meat products from cetaceans available from South Korea markets. *Marine Pollution Bulletin, 54*(6), 669-677. doi:10.1016/j.marpolbul.2007.01.028

Ersts, P. J. and Rosenbaum, H. C. (2003). Habitat preference reflects social organization of humpback whales (Megaptera novaeangliae) on a wintering ground. *Journal of Zoology, London, 260*, 337-345.

Esch, H. C., Sayigh, L. S., Blum, J. E. and Wells, R. S. (2009). Whistles as potential indicators of stress in bottlenose dolphins (*Tursiops truncatus*). *Journal of Mammalogy, 90*(3), 638-650. doi:10.1644/08-mamm-a-069r.1

Estep, J. S., Baumgartner, R. E., Townsend, F., Pabst, D. A., McLellan, W. A., Friedlaender, A., et al. (2005). Malignant seminoma with metastasis, sertoli cell tumor, and pheochromocytoma in a spotted dolphin (*Stenella frontalis*) and malignant seminoma with metastasis in a bottlenose dolphin (*Tursiops truncatus*). *Veterinary Pathology, 42*(3), 357-359. doi:10.1354/vp.42-3-357

Estes, J. A., Doak, D. F., Springer, A. M. and Williams, T. M. (2009). Causes and consequences of marine mammal population declines in southwest Alaska: a food-web perspective. *Philosophical Transactions of the Royal Society B-Biological Sciences, 364*(1524), 1647-1658. doi:10.1098/rstb.2008.0231

Etnier, M. A. (2007). Defining and identifying sustainable harvests of resources: Archaeological examples of pinniped harvests in the eastern North Pacific. *Journal for Nature Conservation, 15*(3), 196-207. doi:10.1016/j.jnc.2007.04.003

Etnoyer, P., Canny, D., Mate, B. R., Morgan, L. E., Ortega-Ortiz, J. G. and Nichols, W. J. (2006). Sea-surface temperature gradients across blue whale and sea turtle foraging trajectories off the Baja California Peninsula, Mexico. *Deep Sea Research II, 53*(3-4), 340-358. doi:10.1016/j.dsr2.2006.01.010

Evans, J. J., Pasnik, D. J., Klesius, P. H. and Al-Ablani, S. (2006). First report of *Streptococcus agalactiae* and *Lactococcus garvieae* from a wild bottlenose dolphin (*Tursiops truncatus*). *Journal of Wildlife Diseases, 42*(3), 561-569.

Evans, W. E. (1971). Orientation behavior of delphinids: Radio telemetric studies. *Annals of the New York Academy of Sciences, 188*, 142-160.

Evans, W. E. (1982). Distribution and differentiation of stocks of *Delphinus delphis* Linnaeus in the northeastern Pacific. In Anon. (Ed.), *Mammals in the Seas, No.5, Volume 4: Small Cetaceans, Seals, Sirenians, and Otters* (pp. 45-66). Rome, Italy: FAO.

Evans, W. E. (1994). Common dolphin, white-bellied porpoise--*Delphinus delphis* Linnaeus, 1758. In S. H. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals. Volume 5: The First Book of Dolphins* (pp. 191-224). New York: Academic Press.

Fahner, M., Thomas, J., Ramirez, K. and Boehm, J. (2004). Acoustic properties of echolocation signals by captive Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) J. A. Thomas, C. F. Moss and M. Vater (Eds.), *Echolocation in bats and dolphins* (pp. 53-59). Chicago, Illinois: University of Chicago Press.

Fair, P. A., Adams, J., Mitchum, G., Hulsey, T. C., Reif, J. S., Houde, M., et al. (2010). Contaminant blubber burdens in Atlantic bottlenose dolphins (*Tursiops truncatus*) from two southeastern US estuarine areas: Concentrations and patterns of PCBs, pesticides, PBDEs, PFCs, and PAHs. *Science of the Total Environment, 408*, 1577-1597. doi:10.1016/j.scitotenv.2009.12.021

Falcone, E. A., Schorr, G. S., Douglas, A. B., Calambokidis, J., Henderson, E., McKenna, M. F., et al. (2009). Sighting characteristics and photo-identification of Cuvier's beaked whales (*Ziphius cavirostris*) near San Clemente Island, California: A key area for beaked whales and the military? *Marine Biology, 156*, 2631-2640.

Fauquier, D. A., Kinsel, M. J., Dailey, M. D., Sutton, G. E., Stolen, M. K., Wells, R. S., et al. (2009). Prevalence and pathology of lungworm infection in bottlenose dolphins *Tursiops truncatus* from southwest Florida. *Diseases Of Aquatic Organisms, 88*, 85-90. doi: 10.3354/dao02095

Fayer, R., Fair, P. A., Bossart, G. D. and Santin, M. (2008). Examination of naturally exposed bottlenose dolphins (*Tursiops truncatus*) for Microsporidia, *Cryptosporidium*, and *Giardia*. *Journal of Parasitology, 94*(1), 143-147. doi:10.1645/ge-1262.1

Felix, F., Bearson, B. and Falconi, J. (2006). Epizoic barnacles removed from the skin of a humpback whale after a period of intense surface activity. *Marine Mammal Science, 22*(4), 979-984. doi:10.1111/j.1748-7692.2006.00058.x

Ferguson, M. C. (2005). *Cetacean Population Density in the Eastern Pacific Ocean: Analyzing Patterns With Predictive Spatial Models.* (Ph.D.). University of California, San Diego.

Ferguson, M. C., Barlow, J., Feidler, P., Reilly, S. B. and Gerrodette, T. (2006). Spatial models of delphinid (family Delphinidae) encouter rate and group size in the eastern Pacific Ocean. *Ecological Modelling, 193*, 645-662.

Ferguson, M. C., Barlow, J., Gerrodette, T. and Fiedler, P. (2001, 28 November-3 December 2001). Meso-scale patterns in the density and distribution of ziphiid whales in the eastern Pacific Ocean. [Abstract]. Presented at the Fourteenth Biennial Conference on the Biology of Marine Mammals, Vancouver, British Columbia.

Ferguson, M. C., Barlow, J., Reilly, S. B. and Gerrodette, T. (2006). Predicting Cuvier's (*Ziphius cavirostris*) and *Mesoplodon* beaked whale population density from habitat characteristics in the eastern tropical Pacific Ocean. *Journal of Cetacean Research and Management, 7*(3), 287-299.

Fernandez-Contreras, M. M., Cardona, L., Lockyer, C. H. and Aguilar, A. (2010). Incidental bycatch of short-beaked common dolphins (*Delphinus delphis*) by pairtrawlers off northwestern Spain. *ICES Journal of Marine Science, 67*(8), 1732-1738. doi:10.1093/icesjms/fsq077

Ferrero, R. C., Hobbs, R. C. and VanBlaricom, G. R. (2002). Indications of habitat use patterns among small cetaceans in the central North Pacific based on fisheries observer data. *Journal of Cetacean Research and Management, 4*(4), 311-321.

Ferrero, R. C. and Walker, W. A. (1993). Growth and reproduction of the northern right whale dolphin, *Lissodelphis borealis*, in the offshore waters of the North Pacific Ocean. *Canadian Journal of Zoology, 71*, 2335-2344.

Ferrero, R. C. and Walker, W. A. (1996). Age, growth, and reproductive patterns of the Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) taken in high seas drift nets in the central North Pacific Ocean. *Canadian Journal of Zoology, 74*, 1673-1687.

Ferrero, R. C. and Walker, W. A. (1999). Age, growth, and reproductive patterns of Dall's porpoise (*Phocoenoides dalli*) in the central North Pacific Ocean. *Marine Mammal Science, 15*(2), 273-313.

Fertl, D., Acevedo-Gutiérrez, A. and Darby, F. L. (1996). A report of killer whales (*Orcinus orca*) feeding on a carcharhinid shark in Costa Rica. *Marine Mammal Science, 12*(4), 606-611.

Fertl, D., Jefferson, T. A., Moreno, I. B., Zerbini, A. N. and Mullin, K. D. (2003). Distribution of the Clymene dolphin Stenella clymene. *Mammal Review, 33*, 253-271.

Filatova, O. A., Fedutin, I. D., Burdin, A. M. and Hoyt, E. (2011). Responses of Kamchatkan fish-eating killer whales to playbacks of conspecific calls. *Marine Mammal Science, 27*(2), E26-E42. doi:10.1111/j.1748-7692.2010.00433.x

Filatova, O. A., Fedutin, I. D., Nagaylik, M. M., Burdin, A. M. and Hoyt, E. (2009). Usage of monophonic and biphonic calls by free-ranging resident killer whales (*Orcinus orca*) in Kamchatka, Russian Far East. *Acta Ethologica, 12*(1), 37-44. doi:10.1007/s10211-009-0056-7

Finneran, J. J. (2008). Modified variance ratio for objective detection of transient evoked potentials in bottlenose dolphins (*Tursiops truncatus*). *Journal of the Acoustical Society of America, 124*(6), 4069-4082. doi:10.1121/1.2996320

Finneran, J. J., Houser, D. S., Blasko, D., Hicks, C., Hudson, J. and Osborn, M. (2008). Estimating bottlenose dolphin (*Tursiops truncatus*) hearing thresholds from single and multiple simultaneous auditory evoked potentials. *Journal of the Acoustical Society of America, 123*(1), 542-551. doi:10.1121/1.2812595

Finneran, J. J. and Schlundt, C. E. (2010). Frequency-dependent and longitudinal changes in noise-induced hearing loss in a bottlenose dolphin (*Tursiops truncatus*) (L). *Journal of the Acoustical Society of America, 128*(2), 567-570. doi:10.1121/1.3458814

Fire, S. E., Flewelling, L. J., Wang, Z., Naar, J., Henry, M. S., Pierce, R. H., et al. (2008). Florida red tide and brevetoxins: Association and exposure in live resident bottlenose dolphins (*Tursiops truncatus*) in the eastern Gulf of Mexico, U.S.A. *Marine Mammal Science, 24*(4), 831-844. doi: 10.1111/j.1748-7692.2008.00221.x

Fire, S. E., Wang, Z. H., Berman, M., Langlois, G. W., Morton, S. L., Sekula-Wood, E., et al. (2010). Trophic transfer of the harmful algal toxin domoic acid as a cause of death in a minke whale (*Balaenoptera acutorostrata*) stranding in Southern California. *Aquatic Mammals, 36*(4), 342-350. doi:10.1578/am.36.4.2010.342

Fish, F. E., Nicastro, A. J. and Weihs, D. (2006). Dynamics of the aerial maneuvers of spinner dolphins. *Journal of Experimental Biology, 209*(4), 590-598. doi:10.1242/jeb.02034

Fish, J. F. and Turl, C. W. (1976). *Acoustic Source Levels of Four Species of Small Whales*. San Diego, CA: Naval Undersea Center, Hawaii Laboratory.

Fitch, J. E. and Brownell, R. L. (1968). Fish otoliths in cetacean stomachs and their importance in interpreting feeding habits. *Journal of the Fisheries Research Board of Canada, 25*, 2561-2574.

Foote, A. D., Griffin, R. M., Howitt, D., Larsson, L., Miller, P. J. O. and Hoelzel, A. R. (2006). Killer whales are capable of vocal learning. *Biology Letters, 2*(4), 509-512. doi:10.1098/rsbl.2006.0525

Foote, A. D. and Nystuen, J. A. (2008). Variation in call pitch among killer whale ecotypes. *Journal of the Acoustical Society of America, 123*(3), 1747-1752. doi:10.1121/1.2836752

Foote, A. D., Osborne, R. W. and Hoelzel, A. R. (2008). Temporal and contextual patterns of killer whale (*Orcinus orca*) call type production. *Ethology, 114*(6), 599-606. doi:10.1111/j.1439-0310.2008.01496.x

Forcada, J. (2008). Distribution. In W. F. Perrin, B. Würsig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (pp. 316-321). San Diego, CA: Academic Press.

Ford, J. K. B. (2005). First records of long-beaked Common Dolphins, *Delphinus capensis*, in Canadian waters. *Canadian Field-Naturalist, 119*(1), 110-113.

Ford, J. K. B. (2008). Killer whale *Orcinus orca*. In W. F. Perrin, B. Würsig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 650-657). San Diego, CA: Academic Press.

Ford, J. K. B. and Ellis, G. M. (1999). *Transients: Mammal-Hunting Killer Whales of British Columbia, Washington, and Southeastern Alaska* (pp. 96). Vancouver, BC, and Seattle, WA: UBC Press and University of Washington Press.

Ford, J. K. B., Ellis, G. M., Matkin, D. R., Balcomb, K. C., Briggs, D. and Morton, A. B. (2005). Killer whale attacks on minke whales: Prey capture and antipredator tactics. *Marine Mammal Science, 21*(4), 603-618.

Ford, J. K. B., Ellis, G. M., Olesiuk, P. F. and Balcomb, K. C. (2010). Linking killer whale survival and prey abundance: food limitation in the oceans' apex predator? *Biology Letters, 6*(1), 139-142. doi:10.1098/rsbl.2009.0468

Ford, J. K. B. and Reeves, R. R. (2008). Fight or flight: antipredator strategies of baleen whales. *Mammal Review, 38*(1), 50-86. doi:10.1111/j.1365-2907.2008.00118.x

Forney, K. A. (1994). *Recent Information on the Status of Odontocetes in Californian Waters* [Technical Memorandum]. (NMFS-SWFSC-202, pp. 87) NOAA.

Forney, K. A. and Barlow, J. (1998). Seasonal patterns in the abundance and distribution of California cetaceans, 1991-1992. *Marine Mammal Science, 14*(3), 460-489.

Forney, K. A., Barlow, J. and Carretta, J. V. (1995). The abundance of cetaceans in California waters. Part II: Aerial surveys in winter and spring of 1991 and 1992. *Fishery Bulletin, 93*, 15-26.

Forney, K. A. and Wade, P. R. (2006). Worldwide distribution and abundance of killer whales. In J. A. Estes, D. P. DeMaster, D. F. Doak, T. M. Williams and R. L. Brownell (Eds.), *Whales, Whaling, and Ocean Ecosystems* (pp. 145-162). Berkeley: University of California Press.

Fossi, M. C., Urban, J., Casini, S., Maltese, S., Spinsanti, G., Panti, C., et al. (2010). A multi-trial diagnostic tool in fin whale (*Balaenoptera physalus*) skin biopsies of the Pelagos Sanctuary (Mediterranean Sea) and the Gulf of California (Mexico). *Marine Environmental Research, 69*, S17-S20. doi:10.1016/j.marenvres.2009.10.006

Foster, E., Franks, D., Morrell, L., Balcomb, K., Parsons, K., van Ginneken, A., et al. (2012). Social network correlates of food avialability in an endangered population of killer whales, *Orcinus orca*. *Animal Behaviour, 83*, 731-736. doi:10.1016/j.anbehav.2011.12.021

Frankel, A. S. and Yin, S. (2010). A description of sounds recorded from melon-headed whales (*Peponocephala electra*) off Hawai'i. *Journal of the Acoustical Society of America, 127*(5), 3248-3255. doi:10.1121/1.3365259

Frantzis, A. and Alexiadou, P. (2008). Male sperm whale (*Physeter macrocephalus*) coda production and coda-type usage depend on the presence of conspecifics and the behavioural context. *Canadian Journal of Zoology, 86*, 62-75. doi: 10.1139/Z07-114

Frantzis, A., Goold, J. C., Skarsoulis, E. K., Taroudakis, M. I. and Kandia, V. (2002). Clicks from Cuvier's beaked whales, *Ziphius cavirostris* (L). *Journal of the Acoustical Society of America, 112*(1), 34-37.

Frantzis, A. and Herzing, D. L. (2002). Mixed-species associations of striped dolphins (Stenella coeruleoalba), short-beaked common dolphins (Delphinus delphis), and Risso's dolphins (Grampus griseus) in the Gulf of Corinth (Greece, Mediterranean Sea). *Aquatic Mammals, 28*(2), 188-197.

Friedlaender, A. S., Johnston, D. W., Fraser, W. R., Burns, J., Halpin, P. N. and Costa, D. P. (2011). Ecological niche modeling of sympatric krill predators around Marguerite Bay, Western Antarctic Peninsula. *Deep Sea Research II, 58*(13-16), 1729-1740. doi:10.1016/j.dsr2.2010.11.018

Friedlaender, A. S., Lawson, G. L. and Halpin, P. N. (2009). Evidence of resource partitioning between humpback and minke whales around the western Antarctic peninsula. *Marine Mammal Science, 25*(2), 402-415.

Fripp, D. and Tyack, P. (2008). Postpartum whistle production in bottlenose dolphins. *Marine Mammal Science, 24*(3), 479-502. doi:10.1111/j.1748-7692.2008.00195.x

Fulling, G. L., Mullin, K. D. and Hubard, C. W. (2003). Abundance and distribution of cetaceans in outer continental shelf waters of the U.S. Gulf of Mexico. *Fishery Bulletin, 101*, 923-932.

Fulling, G. L., Thorson, P. H. and Rivers, J. (2011). Distribution and abundance estimates for cetaceans in the waters off Guam and the Commonwealth of the Northern Mariana Islands. *Pacific Science, 65*(3), 321-343. doi:10.2984/65.3.321

Furuta, M. (1984). Note on a gray whale found in the Ise Bay on the Pacific coast of Japan. *Scientific Reports of the Whales Research Institute, 35*, 195-197.

Fury, C. A. and Harrison, P. L. (2011). Seasonal variation and tidal influences on estuarine use by bottlenose dolphins (*Tursiops aduncus*). *Estuarine Coastal and Shelf Science, 93*(4), 389-395. doi:10.1016/j.ecss.2011.05.003

Gabriele, C. M., Straley, J. M. and Neilson, J. L. (2007). Age at first calving of female humpback whales in southeastern Alaska. *Marine Mammal Science, 23*(1), 226-239. doi:10.1111/j.1748-7692.2006.00100.x

Gallo-Reynoso, J. P. and Figueroa-Carranza, A. L. (1995). Occurrence of bottlenose whales in the waters of Isla Guadalupe, Mexico. *Marine Mammal Science, 11*(4), 573-575.

Gambell, R. (1985). Sei whale *Balaenoptera borealis* Lesson, 1828. In S. H. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals* (Vol. 3, pp. 155-170). San Diego, CA: Academic Press.

Gannier, A. (2000). Distribution of cetaceans off the Society Islands (French Polynesia) as obtained from dedicated surveys. *Aquatic Mammals, 26*(2), 111-126.

Gannier, A. (2002). Cetaceans of the Marquesas Islands (French Polynesia): distribution and relative abundance as obtained from a small boat dedicated survey. *Aquatic Mammals, 28*(2), 198-210.

Gannier, A. (2009). Comparison of odontocete populations of the Marquesas and Society Islands (French Polynesia). *Journal of the Marine Biological Association of the United Kingdom, 89*(5), 931-941. doi:10.1017/s0025315408002713

Gannier, A. and Praca, E. (2007). SST fronts and the summer sperm whale distribution in the north-west Mediterranean Sea. *Journal of the Marine Biological Association of the United Kingdom, 87*, 187-193.

Gannier, A. and West, K. L. (2005). Distribution of the rough-toothed dolphin (Steno bredanensis) around the Windward Islands, (French Polynesia). *Pacific Science, 59*, 17-24.

Gannon, D. P., Craddock, J. E. and Read, A. J. (1998). *Food habits of beaked whales (*Mesoplodon bidens *and* Ziphius cavirostris*) from the northeastern U.S.* Presented at the The World Marine Mammal Science Conference, Monaco.

Garrigue, C., Patenaude, N. and Marsh, H. (2008). Red List of threatened species. *Marine Mammal Science, 24*(1), 81-90. doi:10.1111/j.1748-7692.2007.00173.x

Gedamke, J., Costa, D. P. and Dunstan, A. (2001). Localization and visual verification of a complex minke whale vocalization. *Journal of the Acoustical Society of America, 109*, 3038-3047.

Gende, S. M., Hendrix, A. N., Harris, K. R., Eichenlaub, B., Nielsen, J. and Pyare, S. (2011). A Bayesian approach for understanding the role of ship speed in whale-ship encounters. *Ecological Applications, 21*(6), 2232-2240. doi:10.1890/10-1965.1

Gentry, R. l. (1998). Behavior and ecology of the northern fur seal (pp. 392). Princeton, New Jersey: Princeton University Press.

Gentry, R. L. (2009). Northern fur seal Callorhinus ursinus. In. *Encyclopedia of Marine Mammals*, 788-791.

Gero, S., Engelhaupt, D., Rendell, L. and Whitehead, H. (2009). Who Cares? Between-group variation in alloparental caregiving in sperm whales. *Behavioral Ecology, 20*(4), 838-843. doi:10.1093/beheco/arp068

Gibbs, S. E., Harcourt, R. G. and Kemper, C. M. (2011). Niche differentiation of bottlenose dolphin species in South Australia revealed by stable isotopes and stomach contents. *Wildlife Research, 38*(4), 261-270. doi:10.1071/wr10108

Gnone, G., Caresano, F., Cosmai, T. and Gnone, E. (2008). The orientation of cutaneous ridges influences the appearance of longitudinal stripes on the skin surface of bottlenose dolphins (*Tursiops truncatus*). *Marine Mammal Science, 24*(3), 711-718. doi:10.1111/j.1748-7692.2008.00204.x

Goldbogen, J. A., Calambokidis, J., Croll, D. A., Harvey, J. T., Newton, K. M., Oleson, E. M., et al. (2008). Foraging behavior of humpback whales: Kinematic and respiratory patterns suggest a high cost for a lunge. *The Journal of Experimental Biology, 211*, 3712-3719.

Goldbogen, J. A., Calambokidis, J., Shadwick, R. E., Oleson, E. M., McDonald, M. A. and Hildebrand, J. A. (2006). Kinematics of foraging dives and lunge-feeding in fin whales. *Journal of Experimental Biology, 209*, 1231-1244.

Goldbogen, J. A., Potvin, J. and Shadwick, R. E. (2010). Skull and buccal cavity allometry increase mass-specific engulfment capacity in fin whales. *Proceedings of the Royal Society B-Biological Sciences, 277*(1683), 861-868. doi:10.1098/rspb.2009.1680

Goldbogen, J. A., Pyenson, N. D. and Shadwick, R. E. (2007). Big gulps require high drag for fin whale lunge feeding. *Marine Ecology Progress Series, 349*, 289-301. doi:10.3354/meps07066

Gomercic, M. D., Galov, A., Gomercic, T., Skrtic, D., Curkovic, S., Lucic, H., et al. (2009). Bottlenose dolphin (*Tursiops truncatus*) depredation resulting in larynx strangulation with gill-net parts. *Marine Mammal Science, 25*(2), 392-401. doi:10.1111/j.1748-7692.2008.00259.x

Gonzalez-Barrientos, R., Morales, J. A., Hernandez-Mora, G., Barquero-Calvo, E., Guzman-Verri, C., Chaves-Olarte, E., et al. (2010). Pathology of striped dolphins (*Stenella coeruleoalba*) infected with *Brucella ceti*. *Journal of Comparative Pathology, 142*(4), 347-352. doi:10.1016/j.jcpa.2009.10.017

Goold, J. C. (2000). A diel pattern in vocal activity of short-beaked common dolphins, *Delphinus delphis*. *Marine Mammal Science, 16*(1), 240-244.

Goold, J. C. and Jefferson, T. A. (2002). Acoustic signals from free-ranging finless porpoises (*Neophocaena phocaenoides*) in the waters around Hong Kong. *Raffles Bulletin of Zoology*(Supplement 10), 131-139.

Gotz, T., Verfuss, U. K. and Schnitzler, H. U. (2006). 'Eavesdropping' in wild rough-toothed dolphins (*Steno bredanensis*)? *Biology Letters, 2*(1), 5-7. doi:10.1098/rsbl.2005.0407

Government of Japan. (2002). Research plan for cetacean studies in the western North Pacific under special permit (JARPN II) [Scientific program working document]. (SC/54/02, pp. 2). Cambridge, United Kingdom: International Whaling Commission (IWC).

Graham, M. A. and Noonan, M. (2010). Call types and acoustic features associated with aggressive chase in the killer whale (*Orcinus orca*). *Aquatic Mammals, 36*(1), 9-18. doi:10.1578/am.36.1.2010.9

Green, G. A., Brueggeman, J. J., Grotefendt, R. A., Bowlby, C. E., Bonnell, M. L. and Balcomb, K. C., III. (1992). *Cetacean distribution and abundance off Oregon and Washington, 1989-1990*. (pp. 100). Los Angeles, CA: Minerals Management Service.

Gregr, E. J. (2011). Insights into North Pacific right whale Eubalaena japonica habitat from historic whaling records. *Endangered Species Research, 15*(3), 223-239. doi:10.3354/esr00381

Gregr, E. J. and Coyle, K. O. (2009). The biogeography of the North Pacific right whale (*Eubalaena japonica*). *Progress in Oceanography, 80*, 188-198. doi: 10.1016/j.pocean.2008.12.004

Gregr, E. J. and Trites, A. W. (2001). Predictions of critical habitat for five whale species in the waters of coastal British Columbia. *Canadian Journal of Fisheries and Aquatic Sciences, 58*, 1265-1285. doi:10.1139/cjfas-58-7-1265

Griffin, R. B. and Griffin, N. J. (2004). Temporal variation in Atlantic spotted dolphin (*Stenella frontalis*) and bottlenose dolphin (*Tursiops truncatus*) densities on the west Florida continental shelf. *Aquatic Mammals, 30*(3), 380-390.

Guimaraes, P. R., de Menezes, M. A., Baird, R. W., Lusseau, D., Guimaraes, P. and dos Reis, S. F. (2007). Vulnerability of a killer whale social network to disease outbreaks. *Physical Review E, 76*(4), 042901. doi:10.1103/PhysRevE.76.042901

Hale, P. T., Barreto, A. S. and Ross, G. J. B. (2000). Comparative morphology and distribution of the *aduncus* and *truncatus* forms of bottlenose dolphin *Tursiops* in the Indian and western Pacific oceans. *Aquatic Mammals, 26*(2), 101-110.

Hamazaki, T. (2002). Spatiotemporal prediction models of cetacean habitats in the mid-western North Atlantic Ocean (from Cape Hatteras, North Carolina, U.S.A. to Nova Scotia, Canada). *Marine Mammal Science, 18*(4), 920-939.

Hamer, D. J., Childerhouse, S. J. and Gales, N. J. (2010). *Mitigating operational interactions between odontocetes and the longline fishing industry: A preliminary global review of the problem and of potential solutions* [Draft]. (SC/62/BC6, pp. 30). Tasmania, Australia: International Whaling Commission. Available from http://www.iwcoffice.org/_documents/sci_com/SC62docs/SC-62-BC6.pdf

Hamer, D. J., Ward, T. M. and McGarvey, R. (2008). Measurement, management and mitigation of operational interactions between the South Australian Sardine Fishery and short-beaked common dolphins (Delphinus delphis). *Biological Conservation, 141*(11), 2865-2878. doi:10.1016/j.biocon.2008.08.024

Hamilton, P. K., Marx, M. K. and Kraus, S. D. (1995). Weaning in North Atlantic right whales. *Marine Mammal Science, 11*(3), 386-390.

Hammill, M. O. and Smith, T. G. (1991). The role of predation in the ecology of the ringed seal in Barrow Strait, Northwest Territories, Canada. *Marine Mammal Science, 7*(2), 123-135.

Han, J. B., Sun, F. Y., Gao, X. G., He, C. B., Wang, P. L., Ma, Z. Q., et al. (2010). Low microsatellite variation in spotted seal (Phoca largha) shows a decrease in population size in the Liaodong Gulf colony. *Annales Zoologici Fennici, 47*(1), 15-27.

Handel, S., Todd, S. K. and Zoidis, A. M. (2009). Rhythmic structure in humpback whale (*Megaptera novaeangliae*) songs: Preliminary implications for song production and perception. *Journal of the Acoustical Society of America, 125*, EL225-?

Handley, C. O. (1966). A synopsis of the genus *Kogia* (pygmy sperm whales). In K. S. Norris (Ed.), *Whales, Dolphins, and Porpoises* (pp. 62-69). University of California Press.

Hanks, E. M., Hooten, M. B., Johnson, D. S. and Sterling, J. T. (2011). Velocity-based movement modeling for individual and population level inference. *PLoS ONE, 6*(8), e22795. doi:10.1371/journal.pone.0022795

Hanson, M. B. and Baird, R. W. (1998). Dall's porpoise reactions to tagging attempts using a remotely-deployed suction-cup tag. *Marine Technology Society Journal, 32*, 18-23.

Haraguchi, K., Hisamichi, Y. and Endo, T. (2009). Accumulation and mother-to-calf transfer of anthropogenic and natural organohalogens in killer whales (*Orcinus orca*) stranded on the Pacific coast of Japan. *Science of the Total Environment, 407*(8), 2853-2859. doi:10.1016/j.scitotenv.2009.01.003

Harino, H., Ohji, M., Wattayakorn, G., Adulyanukosol, K., Arai, T. and Miyazaki, N. (2007a). Accumulation of organotin compounds in tissues and organs of stranded whales along the coasts of Thailand. *Archives of Environmental Contamination and Toxicology, 53*(1), 119-125. doi:10.1007/s00244-006-0128-x

Harino, H., Ohji, M., Wattayakorn, G., Adulyanukosol, K., Arai, T. and Miyazaki, N. (2007b). Concentrations of organotin compounds in tissues and organs of dugongs from Thai coastal waters. *Archives of Environmental Contamination and Toxicology, 53*(3), 495-502. doi:10.1007/s00244-006-0254-5

Harms, C., Lovewell, G. N. and Rotstein, D. (2008). Presumed hyperglycemic cataracts in a live-stranded minke whale (*Balaenoptera acutorostrata*) calf. *Marine Mammal Science, 24*(2), 388-397. doi:10.1111/j.1748-7692.2007.00182.x

Hart, K., Kannan, K., Isobe, T., Takahashi, S., Yamada, T. K., Miyazaki, N., et al. (2008). Time trends and transplacental transfer of perfluorinated compounds in melon-headed whales stranded along the Japanese coast in 1982, 2001/2002, and 2006. *Environmental Science & Technology, 42*(19), 7132-7137. doi:10.1021/es801224v

Hauser, N., Zerbini, A. N., Geyer, Y., Heide-Jorgensen, M. P. and Clapham, P. (2010). Movements of satellite-monitored humpback whales, *Megaptera novaeangliae*, from the Cook Islands. *Marine Mammal Science, 26*(3), 679-685. doi:10.1111/j.1748-7692.2009.00363.x

Hawkins, E. R. and Gartside, D. F. (2010). Whistle emissions of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) differ with group composition and surface behaviors. *Journal of the Acoustical Society of America, 127*(4), 2652-2663. doi:10.1121/1.3308465

Hayano, A., Amano, M. and Miyazaki, N. (2003). Phylogeography and population structure of the Dall's porpoise, *Phocoenoides dalli*, in Japanese waters revealed by mitochondrial DNA. *Genes & Genetic Systems, 78*, 81-91.

Hayano, A., Yoshioka, M., Tanaka, M. and Amano, M. (2004). Population differentiation in the Pacific white-sided dolphin *Lagenorhynchus obliquidens* inferred from mitochondrial DNA and microsatellite analyses. *Zoological Science, 21*, 989-999.

Haynes, D., Carter, S., Gaus, C., Muller, J. and Dennison, W. (2005). Organochlorine and heavy metal concentrations in blubber and liver tissue collected from Queensland (Australia) dugong (*Dugong dugon*). *Marine Pollution Bulletin, 51*(1-4), 361-369. doi:10.1016/j.marpolbul.2004.10.020

Hazen, E. L., Friedlaender, A. S., Thompson, M. A., Ware, C. R., Weinrich, M. T., Halpin, P. N., et al. (2009). Fine-scale prey aggregations and foraging ecology of humpback whales Megaptera novaeangliae. *Marine Ecology Progress Series, 395*, 75-89. doi:10.3354/meps08108

HDR. (2011). *Guam Marine Species Monitoring Survey: Vessel-based Monitoring Surveys. Winter 2011*. (pp. 15). Prepared for U.S. Navy NAVFAC Pacific.

HDR. (2012). *Guam and Saipan Marine Species Monitoring: Winter-Spring Survey 15-29 March*. Prepared for U.S. Pacific Fleet and submitted to Naval Facilities Engineering Command (NAVFAC) Pacific, Pearl Harbor, Hawaii, under Contract No. N62470-10-D-3011 Task Order 17, issued to HDR, Inc. 15 November 2012.

Heimlich-Boran, J. R. (1993). *Social organisation of the short-finned pilot whale, Globicephala macrorhynchus, with reference to the comparative social ecology of delphinids.* (Doctoral dissertation). Cambridge University.

Heise, K. (1997). Life history and population parameters of Pacific white-sided dolphins (*Lagenorhynchus obliquidens*). *Reports of the International Whaling Commission, 47*, 817-826.

Heithaus, M. R. and Dill, L. M. (2002). Food availability and tiger shark predation risk influence bottlenose dolphin habitat use. *Ecology, 83*(2), 480-491.

Heithaus, M. R. and Dill, L. M. (2008). Feeding strategies and tactics. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 1100-1103). Academic Press.

Helweg, D. A., Frankel, A. S., Mobley, J. R. and Herman, L. M. (1992). Humpback whale song: our current understanding. In J. Thomas, R. Kastelein and A. Supin (Eds.), *Marine Mammal Sensory Systems* (pp. 459-484). New York, NY: Plenum Press.

Herman, D. P., Matkin, C. O., Ylitalo, G. M., Durban, J. W., Hanson, M. B., Dahlheim, M. E., et al. (2008). Assessing age distributions of killer whale *Orcinus orca* populations from the composition of endogenous fatty acids in their outer blubber layers. *Marine Ecology Progress Series, 372*, 289-302. doi:10.3354/meps07709

Herman, E. Y. K., Herman, L. M., Pack, A. A., Marshall, G., Shepard, C. M. and Bakhtiari, M. (2007). When whales collide: CRITTERCAM offers insight into the competitive behavior of humpback whales on their Hawaiian wintering grounds. *Marine Technology Society Journal, 41*(4), 35-43.

Herman, M. L. (2012). Body and self in dolphins. *Consciousness and cognition, 21*, 526-545. doi:10.101G/j.concog.2011.10.005

Hernandez-Mora, G., Gonzalez-Barrientos, R., Morales, J. A., Chaves-Olarte, E., Guzman-Verri, C., Baquero-Calvo, E., et al. (2008). Neurobrucellosis in stranded dolphins, Costa Rica. *Emerging Infectious Diseases, 14*(9), 1430-1433. doi:10.3201/eid1409.071056

Hersh, S. L. and Duffield, D. A. (1990). Distinction between northwest Atlantic offshore and coastal bottlenose dolphins based on hemoglobin profile and morphometry. In S. Leatherwood and R. R. Reeves (Eds.), *The Bottlenose Dolphin* (pp. 129-139). San Diego, CA: Academic Press.

Heyning, J. E. (1984). Functional morphology involved in intraspecific fighting of the beaked whale *Mesoplodon carlhubbsi*. *Canadian Journal of Zoology, 62*, 1645-1654.

Heyning, J. E. (1989). Cuvier's beaked whale *Ziphius cavirostris* G. Cuvier, 1823. In S. H. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals* (Vol. 4, pp. 289-308). San Diego, CA: Academic Press.

Heyning, J. E. and Mead, J. G. (1996). Suction feeding in beaked whales: Morphological and observational evidence. *Los Angeles County Museum Contributions in Science, 464*, 1-12.

Heyning, J. E. and Mead, J. G. (2008). Cuvier's beaked whale *Ziphius cavirostris*. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 294-295). Academic Press.

Heyning, J. E. and Perrin, W. F. (1994). Evidence for two species of common dolphins (Genus *Delphinus*) from the eastern north Pacific. *Contributions in Science, 442*, 1-35.

Hickmott, L. S. (2005). *Diving behaviour and foraging behaviour and foraging ecology of Blainville's and Cuvier's beaked whales in the Northern Bahamas.* (Master's thesis). University of St. Andrews, Scotland, U.K.

Higdon, J. W. and Ferguson, S. H. (2009). Loss of Arctic sea ice causing punctuated change in sightings of killer whales (Orcinus orca) over the past century. *Ecological Applications, 19*, 1365-1375.

Hildebrand, J. A. (2005). Impacts of anthropogenic sound J. E. Reynolds (Ed.), *Marine Mammal Research: Conservation beyond Crisis* (pp. 101-124). The John Hopkins University Press.

Hill, M., Ligon, A., Deakos, M., Ü, A., Milette-Winfree, A. and Oleson, E. (2013). *Cetacean Surveys of Guam and CNMI Waters: May – July, 2012*

Hill, M., Ligon, A., Deakos, M., Ü, A., Norris, E. and Oleson, E. (2011). *Cetacean Surveys of Guam and CNMI Waters: August – September, 2011*.

Hiraguchi, T., Yamada, T. K., Ishikawa, H. and Hiruda, H. (2001). Marine mammal stranding data collected by the Sea of Japan cetology. [Abstracts]. Presented at the Fourteenth Biennial Conference on the Biology of Marine Mammals.

Hirotsu, R., Yanagisawa, M., Ura, T., Sakata, M., Sugimatsu, H., Kojima, J., et al. (2010). Localization of sperm whales in a group using clicks received at two separated short baseline arrays. *Journal of the Acoustical Society of America, 127*(1), 133-147. doi:10.1121/1.3268593

Hodgson, A. J. and Marsh, H. (2007). Response of dugongs to boat traffic: The risk of disturbance and displacement. *Journal of Experimental Marine Biology and Ecology, 340*(1), 50-61. doi:10.1016/j.jembe.2006.08.006

Hoelzel, A. R. (Ed.). (2002). *Marine Mammal Biology: An Evolutionary Approach* (pp. 448). Malden, MA: Blackwell Publishing.

Hoelzel, A. R., Dorsey, E. M. and Stern, J. (1989). The foraging specializations of individual minke whales. *Animal Behaviour, 38*, 786-794.

Hoelzel, A. R., Hey, J., Dahlheim, M. E., Nicholson, C., Burkanov, V. and Black, N. (2007). Evolution of population structure in a highly social top predator, the killer whale *Molecular Biology and Evolution, 24*(6), 1407-1415. doi:10.1093/molbev/msm063

Hoelzel, A. R., Potter, C. W. and Best, P. B. (1998). Genetic differentiation between parapatric 'nearshore' and 'offshore' populations of the bottlenose dolphin. *Proceedings of the Royal Society B: Biological Sciences, 265*, 1177-1183.

Hokkaido Government (2006). Report on Conservation and Management of Seals, Hokkaido Government, Sapporo (In Japanese).

Holt, M. M., Noren, D. P., Veirs, V., Emmons, C. K. and Veirs, S. (2009). Speaking up: Killer whales (*Orcinus orca*) increase their call amplitude in response to vessel noise. *Journal of the Acoustical Society of America, 125*(1), EL27-EL32. doi:10.1121/1.3040028

Honma, Y., Ushiki, T., Takeda, M., Naito, E., Dewa, K. and Yamanouchi, H. (1999). Identification by histological and microsatellite analyses of a stranded beaked whale as that struck previously by a jetfoil operating in the Sea of Japan. *Fisheries Science, 65*(4), 574-552.

Hooker, S. K. and Baird, R. W. (2001). Diving and ranging behaviour of odontocetes: A methodological review and critique. *Mammal Review, 31*(1), 81-105.

Hooker, S. K., Baird, R. W. and Fahlman, A. (2009). Could beaked whales get the bends? Effects of diving behaviour and physiology on modelled gas echange for three species: Ziphius cavirostris, Mesoplodon densirostris and Hyperoodon ampullatus. *Respiratory Physiology and Neurobiology, 167*, 235-246.

Horwood, J. (1987). *The Sei Whale: Population Biology, Ecology, and Management* (pp. 375). New York, NY: Croom Helm.

Horwood, J. (1990). *Biology and Exploitation of the Minke Whale* (pp. 238). Boca Raton, FL: CRC Press.

Horwood, J. (2009). Sei whale *Balaenoptera borealis*. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 1001-1003). San Diego, CA: Academic Press.

Houck, W. J. and Jefferson, T. A. (1999). Dall's porpoise *Phocoenoides dalli* (True, 1885). In S. H. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals* (Vol. 6: The Second Book of Dolphins and the Porpoises, pp. 443-472). Academic Press.

Houser, D. S., Gomez-Rubio, A. and Finneran, J. J. (2008). Evoked potential audiometry of 13 Pacific bottlenose dolphins (*Tursiops truncatus gilli*). *Marine Mammal Science, 24*(1), 28-41. doi:10.1111/j.1748-7692.2007.00148.x

Houser, D. S., Helweg, D. A. and Moore, P. W. B. (2001). A bandpass filter-bank model of auditory sensitivity in the humpback whale. *Aquatic Mammals, 27*(2), 82-91.

Houston, J. (1990). Status of Hubb's beaked whale, *Mesoplodon carlhubbsi*, in Canada. *Canadian Field-Naturalist, 104*, 121-124.

Hoyt, E. (1993). *Kujira Watching. Whales and Dolphins: Alive and Being Watched Japanese-Style*. Bath, U.K.: Whale & Dolphin Conservation Society.

Hueffer, K., Lieske, C. L., McGilvary, L. M., Hare, R. F., Miller, D. L. and O'Hara, T. M. (2011). *Streptococcus phocae* isolated from a spotted seal (*Phoca largha*) with pyometra in Alaska. *Journal of Zoo and Wildlife Medicine, 42*(1), 108-112. doi:10.1638/2010-0064.1

Hui, C. A. (1979). Undersea topography and distribution of dolphins of the genus Delphinus in the southern California Bight. *Journal of Mammalogy, 60*, 521-527.

Hui, C. A. (1985). Undersea topography and the comparative distribution of two pelagic cetaceans. *Fishery Bulletin, 83*, 472-475.

Hung, C. L. H., Xu, Y., Lam, J. C. W., Jefferson, T. A., Hung, S. K., Yeung, L. W. Y., et al. (2006). An assessment of the risks associated with polychlorinated biphenyls found in the stomach contents of stranded Indo-Pacific Humpback Dolphins (*Sousa chinensis*) and Finless Porpoises (*Neophocaena phocaenoides*) from Hong Kong waters. *Chemosphere, 63*(5), 845-852. doi:10.1016/j.chemosphere.2005.07.059

Hurd, I. (2012). Almost saving whales: The ambiguity of success at the International Whaling Commission. *Ethics & International Affairs, 26*(1), 1-10. doi:10.1017/S0892679412000081

Ichikawa, K., Akamatsu, T., Shinke, T., Adulyanukosol, K. and Arai, N. (2011). Callback response of dugongs to conspecific chirp playbacks. *Journal of the Acoustical Society of America, 129*(6), 3623-3629. doi:10.1121/1.3586791

Ichikawa, K., Arai, N., Akamatsu, T., Shinke, T., Hara, T. and Adulyanukosol, K. (2003, 11-13 December 2003). Acoustical analyses on the calls of dugong. Presented at the 4th SEASTAR2000 Workshop, Bangkok, Thailand.

Ichikawa, K., Tsutsumi, C., Arai, N., Akamatsu, T., Shinke, T., Hara, T., et al. (2006). Dugong (*Dugong dugon*) vocalization patterns recorded by automatic underwater sound monitoring systems. *Journal of the Acoustical Society of America, 119*, 3726-3733.

Ilangakoon, A. D. and Tun, T. (2007). Rediscovering the Dugong (*Dugong dugon*) in myanmar and capacity building for research and conservation. *The Raffles Bulletin of Zoology, 55*(1), 195-199.

International Union for Conservation of Nature (2009). *Red List of Threatened Species. Version 2009.2*. [Database] International Union for Conservation of Nature and Natural Resources. Retrieved from http://www.iucnredlist.org/apps/redlist/search, 10 March 2010.

International Union for Conservation of Nature and Natural Resources (2012a). *The IUCN Red List of Threatened Species. Version 2012.2*. Retrieved from http://www.iucnredlist.org, 24 January 2013.

International Union for Conservation of Nature and Natural Resources (2012b). IUCN Red List Status. [Web page]. Retrieved from http://www.iucnredlist.org/initiatives/mammals/analysis/red-list-status, 25 May 2012.

International Whaling Comission (2012, Last updated 24 January 2012). Catches Taken: Under Scientific Permit. [Web page]. Retrieved from http://www.iwcoffice.org/conservation/table_permit.htm

Ionita, M., Varela, M. G., Lyons, E. T., Spraker, T. R. and Tolliver, S. C. (2008). Hookworms (*Uncinaria lucasi*) and acanthocephalans (*Corynosoma* spp. and *Bolbosoma* spp.) found in dead northern fur seals (*Callorhinus ursinus*) on St. Paul Island, Alaska in 2007. *Parasitology Research, 103*(5), 1025-1029. doi:10.1007/s00436-008-1087-0

Isobe, T., Ochi, Y., Ramu, K., Yamamoto, T., Tajima, Y., Yamada, T. K., et al. (2009). Organohalogen contaminants in striped dolphins (*Stenella coeruleoalba*) from Japan: Present contamination status, body distribution and temporal trends (1978-2003). *Marine Pollution Bulletin, 58*(3), 396-401. doi:10.1016/j.marpolbul.2008.10.008

Isobe, T., Oshihoi, T., Hamada, H., Nakayama, K., Yamada, T. K., Tajima, Y., et al. (2011). Contamination status of POPs and BFRs and relationship with parasitic infection in finless porpoises (*Neophocaena phocaenoides*) from Seto Inland Sea and Omura Bay, Japan. *Marine Pollution Bulletin, 63*(5-12), 564-571. doi:10.1016/j.marpolbul.2011.01.014

Ivashchenko, Y. V., Clapman, P. J. and Brownell, R. L. J. (2011). Soviet illegal whaling: The devil and the details. *Marine Fisheries Review, 73*(3), 1-19.

Ivashin, M. V. and Rovnin, A. A. (1967). Some results of the Soviet whale marking in the waters of the North Pacific. *Norsk Hvalfangst-Tidende, 56*(6), 123-135.

Iwasaki, T., Kai, Y., Tanakura, H. and Kato, H. (2001, 28 November - 3 December). Satellite tracking of two bottlenose dolphins driven to Taiji, Japan. [Abstract]. Presented at the Fourteenth Biennial Conference on the Biology of Marine Mammals, Vancouver, BC.

Iwashita, M., Inque, M. and Iwasaki, Y. (1963). On the distribution of Orcinus in the northern and southern Pacific equatorial waters as observed from reports on Orcinus predation. *Bulletin of the Fisheries Research Laboratory of Tokai University, 1*(1), 24-30.

IWC (2001). Report of the Standing Sub-Committee on Small Cetaceans. *Journal of Cetacean Research and Management, 3*(Supplement), 263-291.

IWC (2004). Report of the Sub-Committee on Small Cetaceans. *Journal of Cetacean Research and Management, 6*(Supplement), 315-334.

Jaaman, S. A., Lah-Anyi, Y. U. and Pierce, G. J. (2009). The magnitude and sustainability of marine mammal by-catch in fisheries in East Malaysia. *Journal of the Marine Biological Association of the United Kingdom, 89*(5), 907-920. doi:10.1017/s002531540800249x

Jaber, J. R., Perez, J., Carballo, M., Arbelo, M., de los Monteros, A. E., Herraez, P., et al. (2005). Hepatosplenic large cell Immunoblastic lymphoma in a bottlenose dolphin (*Tursiops truncatus*) with high levels of polychlorinated biphenyl congeners. *Journal of Comparative Pathology, 132*(2-3), 242-247. doi:10.1016/j.jcpa.2004.06.009

Jacobsen, J. K., Massey, L. and Gulland, F. (2010). Fatal ingestion of floating net debris by two sperm whales (*Physeter macrocephalus*). *Marine Pollution Bulletin, 60*(5), 765-767. doi:10.1016/j.marpolbul.2010.03.008

Japan Small-Type Whaling Association (2002). Japanese community-based minke whaling. Retrieved from http://homepage2.nifty.com/jstwa/, 28 July 2005.

Jaquet, N., Dawson, S. and Slooten, E. (2000). Seasonal distribution and diving behaviour of male sperm whales off Kaikoua: foraging implications. *Canadian Journal of Zoology, 78*, 407-419.

Jaquet, N. and Gendron, D. (2009). The social organization of sperm whales in the Gulf of California and comparisons with other populations. *Journal of the Marine Biological Association of the United Kingdom, 89*(5), 975-983. doi:10.1017/s0025315409001507

Jefferson, T. A. (1988). *Phocoenoides dalli*. *Mammalian Species, 319*, 7.

Jefferson, T. A. (1989). Calving seasonality of Dall's porpoise in the eastern North Pacific. *Marine Mammal Science, 5*, 196-200.

Jefferson, T. A. (1990). Sexual dimorphism and development of external features in Dall's porpoise *Phocoenoides dalli*. *Fishery Bulletin, 88*, 119-132.

Jefferson, T. A. (1991). Observations on the distribution and behavior of Dall's porpoise (*Phocoenoides dalli*) in Monterey Bay, California. *Aquatic Mammals, 17*(1), 12-19.

Jefferson, T. A. (2009a). Dall's porpoise *Phocoenoides dalli*. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 296-298). Academic Press.

Jefferson, T. A. (2009b). Rough-toothed dolphin *Steno bredanensis*. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals (Second Edition)* (pp. 990-992). Academic Press.

Jefferson, T. A. and Barros, N. B. (1997). Peponocephala electra. *Mammalian Species, 553*, 1-6.

Jefferson, T. A., Fertl, D., Bolanos Jiminez, J. and Zerbini, A. N. (2009). Distribution of common dolphins (*Delphinus spp.*) in the western Atlantic Ocean: A critical re-examination. *Marine Biology, 156*, 1109-1124.

Jefferson, T. A., Fertl, D., Michael, M. and Fagin, T. D. (2006). An unusual encounter with a mixed school of melon-headed whales *(Peponocephala electra)* and rough-toothed dolphins *(Steno bredanensis)* at Rota, Northern Mariana Islands. *Micronesica, 38*(2), 239-244.

Jefferson, T. A. and Hung, S. K. (2004). *Neophocaena phocaenoides*. *Mammalian Species, 746*, 1-12.

Jefferson, T. A. and Leatherwood, S. (1994). *Lagenodelphis hosei*. *Mammalian Species, 470*, 1-5.

Jefferson, T. A., Leatherwood, S. and Webber, M. A. (1993a). FAO species identification guide. Marine mammals of the world. Rome, Italy: Food and Agriculture Organization of the United Nations.

Jefferson, T. A., Leatherwood, S. and Webber, M. A. (1993b). Marine mammals of the world: FAO species identification guide. Rome, Italy: Food and Agriculture Organization of the United Nations.

Jefferson, T. A. and Lynn, S. K. (1994). Marine mammal sightings in the Gulf of Mexico and Caribbean Sea, summer 1991. *Caribbean Journal of Science, 30*, 83-89.

Jefferson, T. A. and Newcomer, M. W. (1993). *Lissodelphis borealis*. *Mammalian Species, 425*, 1-6.

Jefferson, T. A., Pitman, R. L., Leatherwood, S. and Dolar, M. L. L. (1997). Developmental and sexual variation in the external appearance of Fraser's dolphins (*Lagenodelphis hosei*). *Aquatic Mammals, 23*(3), 145-153.

Jefferson, T. A., Robertson, K. M. and Wang, J. Y. (2002). Growth and reproduction of the finless porpoise in southern China. *Raffles Bulletin of Zoology*(Supplement 10), 105-113.

Jefferson, T. A. and Van Waerebeek, K. (2002). The taxonomic status of the nominal dolphin species *Delphinus tropicalis* van Bree, 1971. *Marine Mammal Science, 18*(4), 787-818.

Jefferson, T. A., Webber, M. A. and Pitman, R. L. (2008). *Marine Mammals of the World: A Comprehensive Guide to their Identification* (pp. 573). London, UK: Elsevier.

Jensen, F. H., Beedholm, K., Wahlberg, M., Bejder, L. and Madsen, P. T. (2012). Estimated communication range and energetic cost of bottlenose dolphin whistles in a tropical habitat. *The Journal of the Acoustical Society of America, 131*(1), 582-592. doi:10.1121/1.3662067

Jensen, F. H., Bejder, L., Wahlberg, M., Aguilar Soto, N., Johnson, M. and Madsen, P. T. (2009). Vessel noise effects on delphinid communication. *Marine Ecology Progress Series, 395*, 161–175. doi:10.3354/meps08204

Jensen, F. H., Perez, J. M., Johnson, M., Soto, N. A. and Madsen, P. T. (2011). Calling under pressure: short-finned pilot whales make social calls during deep foraging dives. *Proceedings of the Royal Society B: Biological Sciences, 278*(1721), 3017-3025. doi:10.1098/rspb.2010.2604

Johnson, A., Salvador, G., Kenney, J., Robbins, J., Landry, S. and Clapham, P. (2005). Fishing gear involved in entanglements of right and humpback whales. *Marine Mammal Science, 21*(4), 635-645. doi:10.1111/j.1748-7692.2005.tb01256.x

Johnson, G., Frantzis, A., Johnson, C., Alexiadou, V., Ridgway, S. and Madsen, P. T. (2010). Evidence that sperm whale (*Physeter macrocephalus*) calves suckle through their mouth. *Marine Mammal Science, 26*(4), 990-996. doi:10.1111/j.1748-7692.2010.00385.x

Johnson, M., Hickmott, L. S., Aguilar Soto, N. and Madsen, P. T. (2008). Echolocation behavior adapted to prey in foraging Blainville's beaked whale (*Mesoplodon densirostris*). *Proceeding of the Royal Society of Biology, 275*, 133-139.

Johnson, M., Madsen, P. T., Zimmer, W. M. X., Aguilar de Soto, N. and Tyack, P. L. (2004). Beaked whales echolocate on prey. *Proceedings of the Royal Society of London, 271 (Supplement B)*, S383-S386.

Johnson, M. and Tyack, P. (2004). *Measuring the Behavior and Response to Sound of Beaked Whales using Recording Tags*. (Award Number: OCE-0427577). Washington, DC: National Oceanographic Partnership Program. Prepared by Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.

Johnson, S. R., Richardson, W. J., Yazvenko, S. B., Blokhin, S. A., Gailey, G., Jenkerson, M. R., et al. (2007). A western gray whale mitigation and monitoring program for a 3-D seismic survey, Sakhalin Island, Russia. *Environmental Monitoring and Assessment, 134*(1-3), 1-19. doi:10.1007/s10661-007-9813-0

Johnson, W. R., Torralba, M., Fair, P. A., Bossart, G. D., Nelson, K. E. and Morris, P. J. (2009). Novel diversity of bacterial communities associated with bottlenose dolphin upper respiratory tracts. *Environmental Microbiology Reports, 1*(6), 555-562. doi:10.1111/j.1758-2229.2009.00080.x

Johnston, D. W., Thorne, L. H. and Read, A. J. (2005). Fin whales *Balaenoptera physalus* and minke whales *Balaenoptera acutorostrata* exploit a tidally driven island wake ecosystem in the Bay of Fundy. *Marine Ecology Progress Series, 305*, 287-295.

Johnstone, R. A. and Cant, M. A. (2010). The evolution of menopause in cetaceans and humans: the role of demography. *Proceedings of the Royal Society B-Biological Sciences, 277*(1701), 3765-3771. doi:10.1098/rspb.2010.0988

Jones, B. A., Stanton, T. K., Lavery, A. C., Johnson, M. P., Madsen, P. T. and Tyack, P. L. (2008). Classification of broadband echoes from prey of a foraging Blainville's beaked whale. *Journal of the Acoustical Society of America, 123*(3), 1753-1762. doi:10.1121/1.2828210

Jones, M. L. and Swartz, S. L. (2009). Gray whale *Eschrichtius robustus*. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 503-511). Academic Press.

Josephson, B. (2006). *USA Progress Report on Cetacean Research, May 2006 to April 2007, with Statistical Data for the Calendar Year 2004*. (SC/59/ProgRepUSA, pp. 40). Woods Hole, MA: Natioal Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center. Available from http://iwcoffice.org/_documents/sci_com/2007progreports/SC-59-ProgRepUSA.pdf

Kajimura, K. (1984). *Opportunistic Feeding of the Northern Fur Seal,* Callorhinus ursinus*, in the Eastern North Pacific Ocean and Eastern Bering Sea*. (NOAA Technical Report NMFS SSRF-779, pp. 49). Washington, DC: U.S. Department of Commerce, National Oceanic and Atmospheric Administration and National Marine Fisheries Service.

Kajiwara, N., Kamikawa, S., Amano, M., Hayano, A., Yamada, T. K., Miyazaki, N., et al. (2008). Polybrominated diphenyl ethers (PBDEs) and organochlorines in melon-headed whales, *Peponocephala electra*, mass stranded along the Japanese coasts: Maternal transfer and temporal trend. *Environmental Pollution, 156*(1), 106-114. doi:10.1016/j.envpol.2007.12.034

Kajiwara, N., Kunisue, T., Kamikawa, S., Ochi, Y., Yano, S. and Tanabe, S. (2006). Organohalogen and organotin compounds in killer whales mass-stranded in the Shiretoko Peninsula, Hokkaido, Japan. *Marine Pollution Bulletin, 52*(9), 1066-1076. doi:10.1016/j.marpolbul.2006.01.011

Kakuda, T., Tajima, Y., Arai, K., Kogi, K., Hishii, T. and Yamada, T. K. (2002). On the resident "bottlenose dolphins" from Mikura water. *Memoirs of the National Science Museum, Tokyo, 38*, 255-272.

Kami, H. T. and Hosmer, A. J. (1982). Recent beachings of whales on Guam. *Micronesica, 18*, 133-135.

Kami, H. T. and Lujan, R. J. (1976). Records of the dwarf sperm whale *Kogia simus* Owen from Guam. *Micronesica, 12*(2), 327-332.

Kamminga, C., Kataoka, T. and Engelsma, F. J. (1986). Investigations on cetacean sonar VII: Underwater sounds of *Neophocaena phocaenoides* of the Japanese coastal population. *Aquatic Mammals, 12*(2), 52-60.

Kanda, N., Goto, M., Kat, H., McPhee, M. V. and Pastene, L. A. (2007). Population genetic structure of Bryde's whales (Balaenoptera brydei) at the inter-oceanic and trans-equatorial levels. *Conservative Genetics, 8*(4), 853-864. doi:10.1007/s10592-006-9232-8

Kane, E. A. and Marshall, C. D. (2009). Comparative feeding kinematics and performance of odontocetes: belugas, Pacific white-sided dolphins and long-finned pilot whales. *Journal of Experimental Biology, 212*(24), 3939-3950. doi:10.1242/jeb.034686

Kane, E. A., Olson, P. A., Gerrodette, T. and Fiedler, P. C. (2008). Prevalence of the commensal barnacle *Xenobalanus globicipitis* on cetacean species in the eastern tropical Pacific Ocean, and a review of global occurrence. *Fishery Bulletin, 106*(4), 395-404.

Kasai, H., Saito, H., Yoshimori, A. and Taguchi, S. (1997). Variability in timing and magnitude of spring bloom in the Oyashio region, the western subarctic Pacific off Hokkaido, Japan. *Fisheries Oceanography, 6*(2), 118-129.

Kasamatsu, F., Matsuoka, K. and Hakamada, T. (2000). Interspecific relationships in density among the whale community in the Antarctic. *Polar Biology, 23*(7), 466-473.

Kaschner, K., Tittensor, D. P., Ready, J., Gerrodette, T. and Worm, B. (2011). Current and future patterns of global marine mammal biodiversity. *PLoS ONE, 6*(5), e19653. doi:10.1371/journal.pone.0019653

Kastak, D. and Schusterman, R. J. (1998). Low-frequency amphibious hearing in pinnipeds: Methods, measurements, noise, and ecology. *Journal of the Acoustical Society of America, 103*(4), 2216-2228.

Kastak, D. a. R. J. S. (1998). Low-frequency amphibious hearing in pinnipeds: Methods, measurements, noise, and ecology. *Journal of the Acoustical Society of America, 103*, 2216-2228.

Kastelein, R. A., Hagedoom, M., Au, W. W. L. and de Haan, D. (2003). Audiogram of a striped dolphin (Stenella coeruleoalba). *Journal of the Acoustical Society of America, 113*, 1130-1137.

Kasuya, T. (1971). Consideration of distribution and migration of toothed whales off the Pacific coast of Japan based upon aerial sighting record. *Scientific Reports of the Whales Research Institute, 23*, 37-60.

Kasuya, T. (1978). The life history of Dall's porpoise with special reference to the stock off the Pacific coast of Japan. *Scientific Reports of the Whales Research Institute, 30*, 1-63.

Kasuya, T. (1986). Distribution and behavior of Baird's beaked whales off the Pacific coast of Japan. *Scientific Reports of the Whales Research Institute, 37*, 61-83.

Kasuya, T. (1999a). Dugongs in Okinawa. *SIRENEWS, 31*, 10-11.

Kasuya, T. (1999b). Examination of the reliability of catch statistics in the Japanese coastal sperm whale fishery. *Journal of Cetacean Research and Management, 1*(1), 109-122.

Kasuya, T. (1999c). Finless porpoise *Neophocaena phocaenoides* (G. Cuvier, 1829). In S. H. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals. Volume 6: The second book of dolphins and the porpoises* (pp. 411-442). San Diego: Academic Press.

Kasuya, T. (2009). Giant beaked whales *Berardius bairdii* and *B. arnuxii*. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 498-500). Amsterdam: Academic Press.

Kasuya, T., Brownell, R. L. and Balcomb, K. C. (1997). Life history of Baird's beaked whales off the Pacific coast of Japan. *Reports of the International Whaling Commission, 47*, 969-980.

Kasuya, T. and Brownell, R. L., Jr. (2001). Conservation status and the future prospects of dugongs in Japanese water. [Submitted Manuscript]. *Marine Mammal Science*, 8.

Kasuya, T., Izumisawa, Y., Komyo, Y., Ishino, Y. and Maejima, Y. (1997). Life history parameters of bottlenose dolphins off Japan. *IBI Reports, 7*, 71-107.

Kasuya, T. and Marsh, H. (1984). Life history and reproductive biology of the short-finned pilot whale, *Globicephala macrorhynchus*, off the coast of Japan. *Reports of the International Whaling Commission*(Special Issue 6), 259-310.

Kasuya, T. and Miyashita, T. (1988). Distribution of sperm whale stocks in the North Pacific. *Scientific Reports of the Whales Research Institute, 39*, 31-75.

Kasuya, T. and Miyashita, T. (1997). Distribution of Baird's beaked whales off Japan. *Reports of the International Whaling Commission, 47*, 963-968.

Kasuya, T., Miyashita, T. and Kasamatsu, F. (1988). Segregation of two forms of short-finned pilot whales off the Pacific coast of Japan. *Scientific Reports of the Whales Research Institute, 39*, 77-90.

Kasuya, T. and Nishiwaki, M. (1971). First record of *Mesoplodon densirostris* from Formosa. *Scientific Reports of the Whales Research Institute, 23*, 129-137.

Kasuya, T. and Ohsumi, S. (1984). Further analysis of the Baird's beaked whale stock in the western North Pacific. *Reports of the International Whaling Commission, 34*, 587-595.

Kasuya, T. and Shirakihara, K. (2005). *Abundance of Japanese Finless Porpoise Populations*. (Scientific Committee Paper SM/WP4, pp. 2). Cambridge, UK: International Whaling Commission.

Kasuya, T. and Tai, S. (1993). Life history of short-finned pilot whale stocks off Japan and a description of the fishery. *Reports of the International Whaling Commission*(Special Issue 14), 439-473.

Kasuya, T., Tobayama, T. and Matsui, S. (1984). Review of the live-capture of small cetaceans in Japan. *Reports of the International Whaling Commission, 34*, 597-602.

Kasuya, T., Yamamoto, Y. and Iwatsuki, T. (2002). Abundance decline in the finless porpoise population in the Inland Sea of Japan. *Raffles Bulletin of Zoology*(Supplement 10), 57-65.

Kato, H. (1982). Food habits of largha seal pups in the pack ice area. *Scientific Reports of the Whales Research Institute, 34*, 123-136.

Kato, H. and Kasuya, T. (2002). Some analyses on the modern whaling catch history of the western North Pacific stock of gray whales (*Eschrichtius robustus*), with special reference to the Ulsan whaling ground. *Journal of Cetacean Research and Management, 4*(3), 277-282.

Kato, H. and Miyashita, T. (2004). *Japan Progress Report on Cetacean Research, April 2003 to April 2004*. (SC/56/ProgRep. Japan) National Research Institute of Far Seas Fisheries.

Kato, H. and Perrin, W. F. (2008). Bryde's whales *Balaenoptera edeni/brydei*. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 158-163). San Diego, CA: Academic Press.

Kato, H., Shinohara, E., Kishiro, T. and Noji, S. (1996). Distribution of Bryde's whales off Kochi, Southwest Japan, from the 1994/95 sighting survey. *Reports of the International Whaling Commission, 46*, 429-436.

Katona, S., Baxter, B., Brazier, O., Kraus, S., Perkins, J. and Whitehead, H. (1979). Identification of humpback whales by fluke photographs. In H. E. Winn and B. L. Olla (Eds.), *Behavior of Marine Animals: Current Perspectives in Research* (Vol. 3: Cetaceans, pp. 33-44). New York, NY: Plenum Press.

Katsumata, E., Ohishi, K. and Maruyama, T. (2004). Rehabilitation of a rescued pygmy sperm whale stranded on the Pacific coast of Japan. *IEEE Journal*, 488-491. doi: 10.1109/OCEANS.2004.1402964

Keck, N., Kwiatek, O., Dhermain, F., Dupraz, F., Boulet, H., Danes, C., et al. (2010). Resurgence of *Morbillivirus* infection in Mediterranean dolphins off the French coast. *Veterinary Record, 166*, 654-655. doi: 10.1136/vr.b4837

Kellar, N. M., Trego, M. L., Marks, C. I., Chivers, S. J., Danil, K. and Archer, F. I. (2009). Blubber testosterone: A potential marker of male reproductive status in short-beaked common dolphins. *Marine Mammal Science, 25*(3), 507-522. doi:10.1111/j.1748-7692.2009.00291.x

Kemp, N. J. (1996). Habitat loss and degradation. In M. P. Simmonds and J. D. Hutchinson (Eds.), *The Conservation of Whales and Dolphins* (pp. 476). New York, NY: John Wiley & Sons.

Kemper, C. M. (2004). Osteological variation and taxonomic affinities of bottlenose dolphins, *Tursiops* spp., from South Australia. *Australian Journal of Zoology, 52*, 29-48.

Kenney, R. D. (1990). Bottlenose dolphins off the northeastern United States. In S. Leatherwood and R. R. Reeves (Eds.), *The Bottlenose Dolphin* (pp. 369-386). San Diego, CA: Academic Press.

Kenney, R. D. (2008). North Atlantic, north Pacific, and southern right whales (Eubalaena glacialis, E. japonica, and E. australis). In *Encyclopedia of Marine Mammals*, 962-972.

Kenney, R. D. and Winn, H. E. (1987). Cetacean biomass densities near submarine canyons compared to adjacent shelf/slope areas. *Continental Shelf Research, 7*, 107-114.

Ketten, D. R. (1992a). The cetacean ear: form, frequency, and evolution J. Thomas, R. Kastelein and A. Supin (Eds.), *Marine mammal sensory systems* (pp. 53-76). Plenum Press.

Ketten, D. R. (1992b). The marine mammal ear: specializations for aquatic audition and echolocation. In D. B. Webster, R. R. Fay and A. N. Popper (Eds.), *The Evolutionary Biology of Hearing* (pp. 717-750). Berlin, Germany: Springer-Verlag.

Ketten, D. R. (1997). Structure and function in whale ears. *Bioacoustics, 8*, 103-135.

Ketten, D. R. (1998). *Marine Mammal Auditory Systems: A Summary of Audiometric and Anatomical Data and its Implications for Underwater Acoustic Impacts*. (NOAA Technical Memorandum NMFS-SWFSC-256, pp. 74). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center.

Kishiro, T. (1996). Movements of marked Bryde's whales in the western North Pacific. *Reports of the International Whaling Commission, 46*, 421-428.

Kishiro, T. (2001, 28 November-3 December). External morphology of Risso's dolphin off the Pacific coast of Japan. [Abstract]. Presented at the Fourteenth Biennial Conference on the Biology of Marine Mammals, Vancouver, BC.

Kishiro, T. and Kasuya, T. (1993). Review of Japanese dolphin drive fisheries and their status. *Reports of the International Whaling Commission, 43*, 439-452.

Kiszka, J., Simon-Bouhet, B., Gastebois, C., Pusineri, C. and Ridoux, V. (2012). Habitat partitioning and fine scale population structure among insular bottlenose dolphins (*Tursiops aduncus*) in a tropical lagoon. *Journal of Experimental Marine Biology and Ecology, 416–417*, 176-184. doi:10.1016/j.jembe.2012.03.001

Kiyota, M., Insley, S. J. and Lance, S. L. (2008). Effectiveness of territorial polygyny and alternative mating strategies in northern fur seals, *Callorhinus ursinus*. *Behavioral Ecology and Sociobiology, 62*(5), 739-746. doi:10.1007/s00265-007-0499-7

Kiyota, M. and Okamura, H. (2005). Harassment, abduction, and mortality of pups by nonterritorial male northern fur seals. *Journal of Mammalogy, 86*(6), 1227-1236. doi:10.1644/04-mamm-a-031r2.1

Kiyota, M., Tomita, N. and Baba, N. (2009). Latitudinal variation in birth dates of northern fur seals (Callorhinus ursinus) in captivity. *Mammal Study, 34*(4), 231-235. doi:10.3106/041.034.0409

Kjeld, M., Olafsson, O., Vikingsson, G. A. and Sigurjonsson, J. (2006). Sex hormones and reproductive status of the North Atlantic fin whales (Balaenoptera physalus) during the feeding season. *Aquatic Mammals, 32*(1), 75-84. doi:10.1578/AM.32.1.2006.75

Kloepper, L. N., Nachtigall, P. E., Quintos, C. T. and Vlachos, S. (2012). Single-lobed frequency-dependent beam shape in an ecolocating false killer whale (*Pseudorca crassidens*). *Journal of the Acoustical Society of America, 131*(1), 577-851. doi:10.1121/1.3664076

Kniest, E., Burns, D. and Harrison, P. (2010). Fluke matcher: A computer-aided matching system for humpback whale (*Megaptera novaeangliae*) flukes. *Marine Mammal Science, 26*(3), 744-756. doi:10.1111/j.1748-7692.2009.00368.x

Kogi, K., Hishii, T., Imamura, A., Iwatani, T. and Dudzinski, K. M. (2004). Demographic parameters of Indo-Pacific bottlenose dolphins (Tursiops aduncus) around Mikura Island, Japan. *Marine Mammal Science, 20*(3), 510-526.

Kopelman, A. H. and Sadove, S. S. (1995). Ventilatory rate differences between surface-feeding and non-surface-feeding fin whales (Balaenoptera physalus) in the waters off eastern Long Island, New York, U.S.A., 1981-1987. *Marine Mammal Science, 11*, 200-208.

Kot, B. W., Ramp, C. and Sears, R. (2009). Decreased feeding ability of a minke whale (*Balaenoptera acutorostrata*) with entanglement-like injuries. *Marine Mammal Science, 25*(3), 706-713. doi:10.1111/j.1748-7692.2009.00285.x

Kot, B. W., Sears, R., Anis, A., Nowacek, D. P., Gedamke, J. and Marshall, C. D. (2012). Behavioral responses of minke whales (*Balaenoptera acutorostrata*) to experimental fishing gear in a coastal environment. *Journal of Experimental Marine Biology and Ecology, 413*(0), 13-20. doi:10.1016/j.jembe.2011.11.018

Krahn, M. M., Ford, M. J., Perrin, W. F., Wade, P. R., Angliss, R. P., Hanson, M. B., et al. (2004). *2004 Status Review of Southern Resident Killer Whales (Orcinus orca) under the Endangered Species Act*. (NOAA Technical Memorandum NMFS-NWFSC-62, pp. 73). Seattle, WA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center.

Krahn, M. M., Hanson, M. B., Schorr, G. S., Emmons, C. K., Burrows, D. G., Bolton, J. L., et al. (2009). Effects of age, sex and reproductive status on persistent organic pollutant concentrations in "Southern Resident" killer whales. *Marine Pollution Bulletin, 58*(10), 1522-1529. doi:10.1016/j.marpolbul.2009.05.014

Kruse, S., Caldwell, D. K. and Caldwell, M. C. (1999). Risso's dolphin *Grampus griseus* (G. Cuvier, 1812). In S. H. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals* (Vol. 6, pp. 183-212). San Diego, CA: Academic Press.

Krützen, M., Sherwin, W. B., Connor, R. C., Barre, L. M., Van de Casteele, T., Mann, J., et al. (2003). Contrasting relatedness patterns in bottlenose dolphins (*Tursiops* sp.) with different alliance strategies. *Proceedings of the Royal Society of London B, 270*, 497-502. doi: 10.1098/rspb.2002.2229

Kuhn, C. E. (2011). The influence of subsurface thermal structure on the diving behavior of northern fur seals (*Callorhinus ursinus*) during the breeding season. *Marine Biology, 158*(3), 649-663. doi:10.1007/s00227-010-1589-z

Kuker, K. J., Thomson, J. A. and Tscherter, U. (2005). Novel surface feeding tactics of minke whales, Balaenoptera acutorostrata, in the Saguenay-St. Lawrence National Marine Park. *Canadian Field-Naturalist, 119*(2), 214-218.

Kunisue, T., Sakiyama, T., Yamada, T. K., Takahashi, S. and Tanabe, S. (2007). Occurrence of hydroxylated polychlorinated biphenyls in the brain of cetaceans stranded along the Japanese coast. *Marine Pollution Bulletin, 54*(7), 963-973. doi:10.1016/j.marpolbul.2007.02.017

Kunisue, T. and Tanabe, S. (2009). Hydroxylated polychlorinated biphenyls (OH-PCBs) in the blood of mammals and birds from Japan: Lower chlorinated OH-PCBs and profiles. *Chemosphere, 74*(7), 950-961. doi:10.1016/j.chemosphere.2008.10.038

Kuzin, A. E. (2010). The intrapopulation structure of the northern fur seal (*Callorhinus ursinus* L.) on Tyuleniy Island during the post-depression years (1993-2009). *Russian Journal of Marine Biology, 36*(7), 507-517. doi:10.1134/s1063074010070047

Kwan, D., Marsh, H. and Delean, S. (2006). Factors influencing the sustainability of customary dugong hunting by a remote indigenous community. *Environmental Conservation, 33*(2), 164-171. doi:10.1017/s0376892906002992

Lafortuna, C. L., Jahada, M., Azzellino, A., Saibene, F. and Colombini, A. (2003). Locomotor behaviours and respiratory pattern of the Mediterranean fin whale (*Balaenoptera physalus*). *European Journal of Applied Physiology, 90*, 387-395. doi: 10.1007/s00421-003-0887-2

Lagerquist, B. A., Mate, B. R., Ortega-Ortiz, J. G., Winsor, M. and Urbán-Ramirez, J. (2008). Migratory movements and surfacing rates of humpback whales (*Megaptera novaeangliae*) satellite tagged at Socorro Island, Mexico. *Marine Mammal Science, 24*(4), 815-830. doi:10.1111/j.1748-7692.2008.00217.x

Lahaye, V., Bustamante, P., Dabin, W., Churlaud, C. and Caurant, F. (2007). Trace element levels in foetus-mother pairs of short-beaked common dolphins (*Delphinus delphis*) stranded along the French coasts. *Environment International, 33*(8), 1021-1028. doi:10.1016/j.envint.2007.05.008

Laidre, K. L., Heide-Jorgensen, M. P. and Orr, J. R. (2006). Reactions of Narwhals, *Monodon monoceros*, to Killer Whale, *Orcinus orca*, attacks in the Eastern Canadian Arctic. *Canadian Field-Naturalist, 120*(4), 457-465.

Laidre, K. L., Stirling, I., Lowry, L. F., Wiig, O., Heide-Jorgensen, M. P. and Ferguson, S. H. (2008). Quantifying the sensitivity of Arctic marine mammals to climate-induced habitat change. *Ecological Applications, 18*(2 Supplement), S97-S125.

Laist, D. W., Knowlton, A. R., Mead, J., Collet, A. and Podesta, M. (2001). Collisions between ships and whales. *Marine Mammal Science, 17*(1), 35-75.

Laist, D. W. and Reynolds, J. E. (2005). Influence of power plants and other warm-water refuges on Florida manatees. *Marine Mammal Science, 21*(4), 739-764.

Lambert, E., MacLeod, C. D., Hall, K., Brereton, T., Dunn, T. E., Wall, D., et al. (2011). Quantifying likely cetacean range shifts in response to global climatic change: implications for conservation strategies in a changing world. *Endangered Species Research, 15*(3), 205-222. doi:10.3354/esr00376

Lammers, M. O., Au, W. W. L. and Herzing, D. L. (2003). The broadband social acoustic signaling behavior of spinner and spotted dolphins. *Journal of the Acoustical Society of America, 114*, 1629-1639.

Lanyon, J. M. (2003). Distribution and abundance of dugongs in Moreton Bay, Queensland Australia. *Wildlife Research, 30*, 397-409.

Lanyon, J. M. and Sanson, G. D. (2006). Degenerate dentition of the dugong (*Dugong dugon*), or why a grazer does not need teeth: morphology, occlusion and wear of mouthparts. *Journal of Zoology, 268*(2), 133-152. doi:10.1111/j.1469-7998.2005.00004.x

Larese, J. P. and Chivers, S. J. (2009). Growth and reproduction of female eastern and whitebelly spinner dolphins incidentally killed in the eastern tropical Pacific tuna purse-seine fishery. *Canadian Journal of Zoology, 87*(6), 537-552. doi:10.1139/z09-038

Lavery, S., Dalebout, M. L., Funahashi, N., Yong-Woon, M. and Baker, C. S. (2003, 14-19 December). Genetic evidence for multiple stocks of minke whales threatened by hunting and bycatch in coastal waters of Japan and Korea. [Abstract]. Presented at the Fifteenth Biennial Conference on the Biology of Marine Mammals, Greensboro, NC.

Lavery, T. J., Butterfield, N., Kemper, C. M., Reid, R. J. and Sanderson, K. (2008). Metals and selenium in the liver and bone of three dolphin species from South Australia, 1988-2004. *Science of the Total Environment, 390*(1), 77-85. doi:10.1016/j.scitotenv.2007.09.016

Leatherwood, S., Dolar, M. L. L., Wood, C. J., Aragones, L. V. and Hill, C. L. (1992). Marine mammal species confirmed from Philippine waters. *Silliman Journal, 36*, 65-86.

Leatherwood, S., Hubbs, C. L. and Fisher, M. (1979). First records of Risso's dolphin (Grampus griseus) from the Gulf of California with detailed notes on a mass stranding. *Transactions of the San Diego Society of Natural History, 19*, 45-52.

Leatherwood, S., Jefferson, T. A., Norris, J. C., Stevens, W. E., Hansen, L. J. and Mullin, K. D. (1993). Occurrence and sounds of Fraser's dolphins (Lagenodelphis hosei) in the Gulf of Mexico. *Texas Journal of Science, 43*, 349-354.

Leatherwood, S., Perrin, W. F., Garvie, R. L. and LaGrange, J. C. (1973). *Observations of Sharks Attacking Porpoises (*Stenella spp. *and* Delphinus cf. D. delphis*)*. (NUC Technical Note 908, pp. 7).

Leatherwood, S., Perrin, W. F., Kirby, V. L., Hubbs, C. L. and Dahlheim, M. (1980). Distribution and movements of Risso's dolphin, *Grampus griseus*, in the eastern North Pacific. *Fishery Bulletin, 77*(4), 951-963.

Leatherwood, S., Reeves, R. R., Bowles, A. E., Stewart, B. S. and Goodrich, K. R. (1984). Distribution, seasonal movements and abundance of Pacific white-sided dolphins in the eastern North Pacific. *Scientific Reports of the Whales Research Institute, 35*, 129-157.

Leatherwood, S., Reeves, R. R., Perrin, W. F. and Evans, W. E. (1988). *Whales, Dolphins, and Porpoises of the Eastern North Pacific and Adjacent Arctic Waters: A Guide to Their Identification*. New York, NY: Dover Publications, Inc.

Leatherwood, S. and Walker, W. A. (1979). The northern right whale dolphin *Lissodelphis borealis* peale in the eastern North Pacific. In H. E. Winn and B. L. Olla (Eds.), *Behavior of Marine Animals* (Vol. 3, pp. 85-141). Plenum Press.

LeDuc, R. G., Perryman, W. L., Gilpatrick, J. W., Jr., Hyde, J., Stinchcomb, C., Carretta, J., V., et al. (2001). A note on recent surveys for right whales in the southeastern Bering Sea. *Journal of Cetacean Research and Management, 2*(Special Issue), 287-289.

Lefebrve, K. A., Robertson, A., Frame, E. R., Colegrove, K. M., Nance, S., Baugh, K. A., et al. (2010). Clinical signs and histopathology associated with domoic acid poisoning in northern fur seals (*Callorhinus ursinus*) and comparison of toxin detection methods. *Harmful Algae, 9*, 374-383. doi:10.1016/j.hal.2010.01.007

Leslie, M. S., Batibasaga, A., Weber, D. S., Olson, D. and Rosenbaum, H. C. (2005). First record of Blainville's beaked whale *Mesoplodon densirostris* in Fiji. *Pacific Conservation Biology, 11*(4), 302-304.

Lettevall, E., Richter, C., Jaquet, N., Slooten, E., Dawson, S. M., Whitehead, H., et al. (2002). Social structure and residency in aggregations of male sperm whales. *Canadian Journal of Zoology, 80*, 1189-1196. doi: 10.1139/Z02-102

Levy, A. M., Brenner, O., Scheinin, A., Morick, D., Ratner, E., Goffman, O., et al. (2009). Laryngeal snaring by ingested fishing net in a common bottlenose dolphin (*Tursiops truncatus*) off the Israeli shoreline. *Journal of Wildlife Diseases, 45*(3), 834-838.

Li, S., Wang, K., Wang, D. and Akamatsu, T. (2005). Echolocation signals of the free-ranging Yangtze finless porpoise (*Neophocaena phocaenoides asiaeorientialis*). *Journal of the Acoustical Society of America, 117*(5), 3288-3296.

Li, S. H., Nachtigall, P. E. and Breese, M. (2011). Dolphin hearing during echolocation: evoked potential responses in an Atlantic bottlenose dolphin (*Tursiops truncatus*). *Journal of Experimental Biology, 214*(12), 2027-2035. doi:10.1242/jeb.053397

Ligon, A. D. and Baird, R. W. (2001, November 28 - December 3, 2001). *Diving behaviour of false killer whales off Maui and Lana'i, Hawaii.* [Abstract]. Presented at the Fourteenth Biennial Conference on the Biology of Marine Mammals, Vacouver, British Columbia.

Ligon, A. D., Deakos, M. H. and U, A. C. (2011). *Small-Boat Cetacean Surveys off Guam and Saipan, Mariana Islands, February - March 2010*. (Order No. AB133F-10-SE-0930, pp. 33). Honolulu, HI: Pacific Island Fisheries Science Center.

Lindstrom, U. and Haug, T. (2001). Feeding strategy and prey selectivity in common minke whales (Balaenoptera acutorostrata) foraging in the southern Barents Sea during early summer. *Journal of Cetacean Research and Management, 3*(3), 239-250.

Lipsky, J. D. (2009). Right whale dolphins *Lissodelphis borealis* and *L. peronii*. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 958-962). Amsterdam: Academic Press.

Liwanag, H. E. M. (2010). Energetic costs and thermoregulation in Northern fur seal (*Callorhinus ursinus*) pups: The importance of behavioral strategies for thermal balance in furred marine mammals. *Physiological and Biochemical Zoology, 83*(6), 898-910. doi:10.1086/656426

Lodi, L. and Hetzel, B. (1999). Rough-toothed dolphin, Steno bredanensis, feeding behaviors in Ilha Grande Bay, Brazil. *Biociências, 7*(1), 29-42.

Lopez, B. D. (2011). Whistle characteristics in free-ranging bottlenose dolphins (*Tursiops truncatus*) in the Mediterranean Sea: Influence of behaviour. *Mammalian Biology, 76*(2), 180-189. doi:10.1016/j.mambio.2010.06.006

Loughlin, T. R. and Perez, M. A. (1985). Mesoplodon stejengeri. *Mammalian Species, 250*, 1-6

Lowry, L. F., Frost, K. J., Davis, R., DeMaster, D. P. and Suydam, R. S. (1998). Movements and behavior of satellite-tagged spotted seals (*Phoca largha*) in the Bering and Chukchi Seas. *Polar Biology, 19*, 221-230.

Lukoschek, V., Funahashi, N., Lavery, S., Dalebout, M. L., Cipriano, F. and Baker, C. S. (2009). High proportion of protected minke whales sold on Japanese markets is due to illegal, unreported or unregulated exploitation. *Animal Conservation, 12*(5), 385-395. doi:10.1111/j.1469-1795.2009.00302.x

Lusseau, D. (2005). Residency pattern of bottlenose dolphins *Tursiops* spp. in Milford Sound, New Zealand, is related to boat traffic. *Marine Ecology Progress Series, 295*, 265-272. doi:10.3354/meps295265

Lusseau, D., Bain, D. E., Williams, R. and Smith, J. C. (2009). Vessel traffic disrupts the foraging behavior of southern resident killer whales *Orcinus orca*. *Endangered Species Research, 6*, 211–221. doi:10.3354/esr00154

Lux, C. A., Costa, A. S. and Dizon, A. E. (1997). Mitochondrial DNA population structure of the Pacific white-sided dolphin. *Reports of the International Whaling Commission, 47*, 645-652.

Lyamin, O., Pryaslova, J., Kosenko, P. and Siegel, J. (2007). Behavioral aspects of sleep in bottlenose dolphin mothers and their calves. *Physiology & Behavior, 92*(4), 725-733. doi:10.1016/j.physbeh.2007.05.064

Lyndersen, C. and Øritsland, N. A. (1990). Surface and submerging intervals in minke whale, *Balaenoptera acutorostrata*, diving cycles. *Fauna Norvegica, Series A*(11), 35-37.

Lynn, S. K. and Reiss, D. L. (1992). Pulse sequence and whistle production by two captive beaked whales, *Mesoplodon* species. *Marine Mammal Science, 8*(3), 299-305.

Lyons, E. T. (2005). Historic importance of some aspects of research by O. Wilford Olsen on hookworms (*Uncinaria lucasi*) in northern fur seals (*Callorhinus ursinus*) and Steller sea lions (*Eumatopias jubatus*) in 1951 on St. Paul Island, Alaska. *Parasitology Research, 95*(5), 353-357. doi:10.1007/s00436-005-1309-7

Lyons, E. T., Spraker, T. R., De Long, R. L., Ionita, M., Melin, S. R., Nadler, S. A., et al. (2011). Review of research on hookworms (*Uncinaria lucasi* Stiles, 1901) in northern fur seals (*Callorhinus ursinus* Linnaeus, 1758). *Parasitology Research, 109*(2), 257-265. doi:10.1007/s00436-011-2420-6

MacLeod, C. and Claridge, D. (1999). *Habitat use in dense beaked whales, Mesoplodon densirostris.* [Abstract]. Presented at the Thirteenth Biennial Conference on the Biology of Marine Mammals, Wailea, HI.

MacLeod, C. D. (1999). A review of beaked whale acoustics, with inferences on potential interactions with military activities. *European Research on Cetaceans, 13*, 35-38.

MacLeod, C. D. (2000). Review of the distribution of *Mesoplodon* species (order Cetacea, family Ziphiidae) in the North Atlantic. *Mammal Review, 30*(1), 1-8.

MacLeod, C. D. (2005). *Niche partitioning, distribution and competition in North Atlantic beaked whales.* (Ph.D dissertation). University of Aberdeen, Aberdeen, UK.

MacLeod, C. D. (2010). The relationship between body mass and relative investment in testes mass in cetaceans: Implications for inferring interspecific variations in the extent of sperm competition. *Marine Mammal Science, 26*(2), 370-380. doi:10.1111/j.1748-7692.2009.00348.x

MacLeod, C. D. and D'Amico, A. (2006). A review of beaked whale behaviour and ecology in relation to assessing and mitigating impacts of anthropogenic noise. *Journal of Cetacean Research and Management, 7*(3), 211-222.

MacLeod, C. D., Hauser, N. and Peckham, H. (2004). Diversity, relative density and structure of the cetacean community in summer months east of Great Abaco, Bahamas. *Journal of the Marine Biological Association of the United Kingdom, 84*, 469-474.

MacLeod, C. D. and Mitchell, G. (2006). Key areas for beaked whales worldwide. *Journal of Cetacean Research and Management, 7*(3), 309-322.

MacLeod, C. D., Perrin, W. F., Pitman, R. L., Barlow, J., Ballance, L., D'Amico, A., et al. (2006). Known and inferred distributions of beaked whale species (Ziphiidae: Cetacea). *Journal of Cetacean Research and Management, 7*(3), 271-286.

MacLeod, C. D., Santos, M. B., Lopez, A. and Pierce, G. J. (2006). Relative prey size consumption in toothed whales: implications for prey selection and level of specialisation. *Marine Ecology-Progress Series, 326*, 295-307. doi:10.3354/meps326295

MacLeod, C. D., Santos, M. B. and Pierce, G. J. (2003). Review of data on diets of beaked whales: evidence of niche separation and geographic segregation. *Journal of the Marine Biological Association of the United Kingdom, 83*, 651-665.

MacLeod, K., Simmonds, M. P. and Murray, E. (2006). Abundance of fin (Balaenoptera physalus) and sei whales (B. borealis) amid oil exploration and development off northwest Scotland. *Journal of Cetacean Research and Management, 8*(3), 247-254.

Madsen, P. T., Carder, D. A., Au, W. W. L., Nachtigall, P. E., Møhl, B. and Ridgway, S. H. (2003). Sound production in neonate sperm whales (L). *Journal of the Acoustical Society of America, 113*(6), 2988-2991.

Madsen, P. T., Johnson, M., Aguilar de Soto, N., Zimmer, W. M. X. and Tyack, P. (2005). Biosonar performance of foraging beaked whales (Mesoplodon densirostris). *Journal of Experimental Biology, 208*, 181-194. doi:10.1242/jeb.01327

Madsen, P. T., Kerr, I. and Payne, R. (2004). Source parameter estimates of echolocation clicks from wild pygmy killer whales (*Fersa attenuata*) (L). *Journal of the Acoustical Society of America, 116*(4), 1909-1912. doi: 10.1121/1.1788726

Maldini, D. F., Mazzuca, L. and Atkinson, S. (2005). Odontocete stranding patterns in the main Hawaiian Islands (1937-2002): How do they compare with live animal surveys? *Pacific Science, 59*(1), 55-67.

Malme, C. I., Würsig, B., Bird, J. E. and Tyack, P. (1986). Behavioral responses of gray whales to industrial noise: Feeding observations and predictive modeling [Final Report]. (OCS Study MMS 88-0048, pp. 393-600). Anchorage, AK: Minerals Management Service, Outer Continental Shelf Environmental Assessment Program Research Unit 675.

Mann, D., Hill-Cook, M., Manire, C., Greenhow, D., Montie, E., Powell, J., et al. (2010). Hearing loss in stranded Odontocete dolphins and whales. *PLoS ONE, 5*(11), e13824. doi:10.1371/journal.pone.0013824

Marcoux, M., Whitehead, H. and Rendell, L. (2006). Coda vocalizations recorded in breeding areas are almost entirely produced by mature female sperm whales (*Physeter macrocephatus*). *Canadian Journal of Zoology, 84*(4), 609-614. doi:10.1139/z06-035

Marcoux, M., Whitehead, H. and Rendell, L. (2007). Sperm whale feeding variations by location, year, social group and clan: Evidence from stable isotopes. *Marine Ecology Progress Series, 333*, 309-314.

Marine Mammal Commission. (2002). Dugongs in Okinawa (*Dugong dugon*). In *Species of Special Concern, Annual Report to Congress, 2001*. (pp. 129-130). Bethesda, MD: Marine Mammal Commission.

Marine Mammal Commission. (2003). Gray Whale (*Eschrichtius robustus*). In *Species of Special Concern, Annual Report to Congress, 2002*. (pp. 38-45). Bethesda, MD: Marine Mammal Commission.

Marini, L., Consiglio, C., Catalano, B., Valentini, T. and Villetti, G. (1996). Aerial behavior in fin whales (*Balaenoptera physalus*) in the Mediterranean Sea. *Marine Mammal Science, 12*(3), 489-495.

Marsh, H. (1995). The life history pattern of breeding, and population dynamics of the dugong T. J. O'Shea, B. B. Ackerman and H. F. Percival (Eds.), *Population biology of the Florida manatee* (Vol. Information and Technology Report 1, pp. 75-83). U.S. Department of the Interior, NBS.

Marsh, H., De'ath, G., Gribble, N. and Lane, B. (2005). Historical marine population estimates: Triggers or targets for conservation? The dugong case study. *Ecological Applications, 15*(2), 481-492. doi:10.1890/04-0673

Marsh, H. and Kwan, D. (2008). Temporal variability in the life history and reproductive biology of female dugongs in Torres Strait: The likely role of sea grass dieback. *Continental Shelf Research, 28*(16), 2152-2159. doi:10.1016/j.csr.2008.03.023

Marsh, H., Penrose, H. and Eros, C. (2003). A future for the dugong? N. Gales, M. Hindell and R. Kirkwood (Eds.), *Marine Mammals: Fisheries, Tourism and Management Issues* (pp. 383-399). CSIRO Publishing.

Marsh, H., Penrose, H., Eros, C. and Hugues, J. (2002). Dugong: Status report and action plans for countries and territories *Early Warning and Assessment Report Series* [UNEP Report]. (UNEP/DEWA/RS.02-1, pp. 155) UNEP.

Marsh, H. E. (1989). Mass Stranding of Dugongs by a Tropical Cyclone in Northern Australia. *Marine Mammal Science, 5*(1), 78-84.

Marshall, C. D., Maeda, H., Iwata, M., Furuta, M., Asano, S., Rosas, F., et al. (2003). Orofacial morphology and feeding behaviour of the dugong, Amazonian, West African and Antillean manatees (Mammalia: Sirenia): Functional morphology of the muscular-vibrissal complex. *Journal of Zoology, London, 259*, 245-260.

Marten, K. (2000). Ultrasonic analysis of pygmy sperm whale (*Kogia breviceps*) and Hubbs' beaked whale (*Mesoplodon carlhubbsi*) clicks. *Aquatic Mammals, 26*(1), 45-48.

Masaki, Y. (1976). Biological studies on the North Pacific sei whale. *Bulletin of the Far Seas Fisheries Research Laboratory, 14*, 1-104

Masaki, Y. (1977). The separation of the stock units of sei whales in the North Pacific. *Reports of the International Whaling Commission*(Special Issue 1), 71-79.

Masaki, Y. and Kato, H. (1979). The results of a survey of small cetaceans from the western equatorial Pacific, Coral Sea, Arafura Sea, Timor Sea, and Indian Ocean. *Geiken Tsushin (News of the Cetacean Research Institute), 330*, 73-82.

Mate, B. R., Gisiner, R. and Mobley, J. (1998). Local and migratory movements of Hawaiian humpback whales tracked by satellite telemetry. *Canadian Journal of Zoology, 76*, 863-868.

Matkin, C. O., Saulitis, E. L., Ellis, G. M., Olesiuk, P. and Rice, S. D. (2008, March 18). Ongoing population-level impacts on killer whales *Orcinus orca* following the 'Exxon Valdez' oil spill in Prince William Sound, Alaska. *Marine Ecology Progress Series, 356*, 269-281. doi: 10.3354/meps07273

Mattila, D. K., Guinee, L. N. and Mayo, C. A. (1987). Humpback whale songs on a North Atlantic feeding ground. *Journal of Mammalogy, 68*(4), 880-883.

Mazzuca, L., Atkinson, S., Keating, B. and Nitta, E. (1999). Cetacean mass strandings in the Hawaiian Archipelago, 1957-1998. *Aquatic Mammals, 25*(2), 105-114.

McAlpine, D. F. (2009). Pygmy and dwarf sperm whales *Kogia breviceps* and *K. sima.* In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals (Second Edition)* (pp. 936-938). Academic Press.

McDonald, M. A., Calambokidis, J., Teranishi, A. M. and Hildebrand, J. A. (2001). The acoustic calls of blue whales off California with gender data *Journal of the Acoustical Society of America, 109*, 1728-1735.

McDonald, M. A., Hildebrand, J. A., Wiggins, S. M., Thiele, D., Glasgow, D. and Moore, S. E. (2005). Sei whale sounds recorded in the Antarctic. *Journal of the Acoustical Society of America, 118*(6), 3941-3945. doi: 10.1121/1.2130944

McFee, W. E., Schwacke, J. H., Stolen, M. K., Mullin, K. D. and Schwacke, L. H. (2010). Investigation of growth phases for bottlenose dolphins using a Bayesian modeling approach. *Marine Mammal Science, 26*(1), 67-85. doi:10.1111/j.1748-7692.2009.00306.x

McSweeney, D. J., Baird, R. W. and Mahaffy, S. D. (2007). Site fidelity, associations, and movements of Cuvier's (*Ziphius cavirostris*) and Blainville's (*Mesoplodon densirostris*) beaked whales off the Island of Hawaii. *Marine Mammal Science, 23*(3), 666-687. doi: 10.1111/j.1748-7692.2007.00135.x

Mead, J. G. (1977). Records of sei and Bryde's whales from the Atlantic coast of the United States, the Gulf of Mexico, and the Caribbean. *Reports of the International Whaling Commission, Special Issue 1*, 113-116.

Mead, J. G. (1984). Survey of reproductive data for the beaked whales (Ziphiidae). *Reports of the International Whaling Commission, Special Issue 6*, 91-96.

Mead, J. G. (1989). Beaked whales of the genus *Mesoplodon.* In S. H. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals* (Vol. 4, pp. 349-430). San Diego, CA: Academic Press.

Mead, J. G. and Potter, C. W. (1995). Recognizing two populations of the bottlenose dolphin (*Tursiops truncatus*) off the Atlantic Coast of North America: Morphologic and ecologic considerations. *IBI Reports, 5*, 31-44.

Mead, J. G., Walker, W. A. and Houck, W. J. (1982). Biological observations on *Mesoplodon carlhubbsi* (Cetacea: Ziphiidae). *Smithsonian Contributions to Zoology, 344*, 1-25

Medrano-González, L., Baker, C. S., Robles-Saavedra, M. R., Murrell, J., Vázquez-Cuevas, M. J., Congdon, B. C., et al. (2001). Trans-oceanic population genetic structure of humpback whales in the North and South Pacific. *Memoirs of the Queensland Museum, 47*(2), 465-479.

Meier, S. K., Yazvenko, S. B., Blokhin, S. A., Wainwright, P., Maminov, M. K., Yakovlev, Y. M., et al. (2007). Distribution and abundance of western gray whales off northeastern Sakhalin Island, Russia, 2001-2003. *Environmental Monitoring and Assessment, 134*(1-3), 107-136. doi:10.1007/s10661-007-9811-2

Melcon, M. L., Cummins, A. J., Kerosky, S. M., Roche, L. K., Wiggins, S. M. and Hildebrand, J. A. (2012). Blue Whales Respond to Anthropogenic Noise. *PLoS ONE, 7*(2), e32681. doi:10.1371/journal.pone.0032681

Melero, M., Rubio-Guerri, C., Crespo, J. L., Arbelo, M., Vela, A. I., García-Párraga, D., et al. (2011). First case of erysipelas in a free-ranging bottlenose dolphin (*Tursiops truncatus*) stranded in the Mediterranean Sea. *Diseases Of Aquatic Organisms, 97*(2), 167-170. doi:10.3354/dao02412

Melin, S. R., Ream, R. R. and Zeppelin, T. K. (2006). *Report of the Alaska Region and Alaska Fisheries Science Center Northern Fur Seal Tagging and Census Workshop: 6-9 September 2005*. (AFSC

Processed Report 2006-15, pp. 59). Seattle, WA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center. Available from http://www.afsc.noaa.gov/Publications/ProcRpt/PR%202006-15.pdf

Mellinger, D. K., Carson, C. D. and Clark, C. W. (2000). Characteristics of minke whale (*Balaenoptera acutorostrata*) pulse trains recorded near Puerto Rico. *Marine Mammal Science, 16*(4), 739-756.

Mellinger, D. K. and Clark, C. W. (2003). Blue whale (*Balaenoptera musculus*) sounds from the North Atlantic. *Journal of the Acoustical Society of America, 114*(2), 1108-1119.

Mellinger, D. K., Nieukirk, S. L., Matsumoto, H., Heimlich, S. L., Dziak, R. P., Haxel, J., et al. (2007). Seasonal occurrence of North Atlantic right whale (*Eubalaena glacialis*) vocalizations at two sites on the Scotian Shelf. *Marine Mammal Science, 23*(4), 856-867. doi:10.1111/j.1748-7692.2007.00144.x

Mercado, E., III, Schneider, J. N., Pack, A. A. and Herman, L. M. (2010). Sound production by singing humpback whales. *Journal of the Acoustical Society of America, 127*(4), 2678-2691. doi:10.1121/1.3309453

Meynier, L., Pusineri, C., Spitz, J., Santos, M. B., Pierce, G. J. and Ridoux, V. (2008). Intraspecific dietary variation in the short-beaked common dolphin *Delphinus delphis* in the Bay of Biscay: importance of fat fish. *Marine Ecology Progress Series, 354*, 277-287. doi:10.3354/meps07246

Miclard, J., Mokhtari, K., Jouvion, G., Wyrzykowski, B., Van Canneyt, O., Wyers, M., et al. (2006). Microcystic meningioma in a dolphin (*Delphinus delphis*): Immunohistochemical and ultrastructural study. *Journal of Comparative Pathology, 135*(4), 254-258. doi:10.1016/j.jcpa.2006.08.005

Mignucci-Giannoni, A. A. (1998). Zoogeography of cetaceans off Puerto Rico and the Virgin Islands. *Caribbean Journal of Science, 34*(3-4), 173-190.

Mignucci-Giannoni, A. A., Swartz, S. L., Martinez, A., Burks, C. M. and Watkins, W. A. (2003). First records of the pantropical spotted dolphin (*Stenella attenuata*) for the Puerto Rican Bank, with a review of the species for the Caribbean. *Caribbean Journal of Science, 39*(3), 381-392.

Mignucci-Giannoni, A. A., Toyos-González, G. M., Pérez-Padilla, J., Rodríguez-López, M. A. and Overing, J. (1999). Mass stranding of pygmy killer whales (*Feresa attenuata*) in the British Virgin Islands. *Journal of the Marine Biological Association of the United Kingdom, 80*, 759-760.

Miksis-Olds, J. L., Buck, J. R., Noad, M. J., Cato, D. H. and Stokes, M. D. (2008). Information theory analysis of Australian humpback whale song. *Journal of the Acoustical Society of America, 124*(4), 2385-2393. doi:10.1121/1.2967863

Miller, E. J. (1989). *Distribution and behavior of Dall's porpoise (Phocoenoides dalli) in Puget Sound, Washington.* (Master's). University of Washington.

Miller, P. J. O., Aoki, K., Rendell, L. E. and Amano, M. (2008). Stereotypical resting behavior of the sperm whale. *Current Biology, 18*(1), R21-R23. doi:10.1016/j.cub.2007.11.003

Miller, P. J. O., Johnson, M. P., Madsen, P. T., Biassoni, N., Quero, M. and Tyack, P. L. (2009). Using at-sea experiments to study the effects of airguns on the foraging behavior of sperm whales in the Gulf of Mexico. *Deep Sea Research I, 56*(7), 1168-1181. doi:10.1016/j.dsr.2009.02.008

Miller, P. J. O., Johnson, M. P. and Tyack, P. L. (2004). Sperm whale behaviour indicates the use of echolocation click buzzes 'creaks' in prey capture. *Proceedings of the Royal Society B: Biological Sciences, 271*, 2239-2247. doi:10.1098/rspb.2004.2863

Miller, P. J. O., Shapiro, A. D. and Deecke, V. B. (2010). The diving behaviour of mammal-eating killer whales (*Orcinus orca*): variations with ecological not physiological factors. *Canadian Journal of Zoology, 88*(11), 1103-1112. doi:10.1139/z10-080

Minamikawa, S., Iwasaki, T. and Kishiro, T. (2007). Diving behaviour of a Baird's beaked whale, *Berardius bairdii*, in the slope water region of the western North Pacific: First dive records using a data logger. *Fisheries Oceanography, 16*, 573-577.

Mitchell, E. (1968). Northeast Pacific stranding distribution and seasonality of Cuvier's beaked whale *Ziphius cavirostris*. *Canadian Journal of Zoology, 46*, 265-279.

Mitchell, E. (1975). Report of the meeting on smaller cetaceans, Montreal, April 1-11, 1974. *Journal of the Fisheries Research Board of Canada, 32*(7), 889-983.

Miyashita, T. (1993a). Abundance of dolphin stocks in the western North Pacific taken by the Japanese drive fishery. *Reports of the International Whaling Commission, 43*, 417-437.

Miyashita, T. (1993b). Distribution and abundance of some dolphins taken in the North Pacific driftnet fisheries. *International North Pacific Fisheries Commission Bulletin, 53*(3), 435-450.

Miyashita, T. and Fujise, Y. (1997). Abundance estimate of the Western North Pacific Minke Whale in sub-area 9 with notes on the results of dedicated surveys. *Reports of the International Whaling Commission, 47*, 543-551.

Miyashita, T. and Hatanaka, H. (1997). A note on whaling grounds for the western North Pacific minke whale. *Reports of the International Whaling Commission, 47*, 539-542.

Miyashita, T. and Kasuya, T. (1988). Distribution and abundance of Dall's porpoise off Japan. *Scientific Reports of the Whales Research Institute, 35*, 107-128.

Miyashita, T., Kishiro, T., Higashi, N., Sato, F., Mori, K. and Kato, H. (1996). Winter distribution of cetaceans in the western North Pacific inferred from sighting cruises 1993-1995. *Reports of the International Whaling Commission, 46*, 437-442.

Miyazaki, N. (1983). Catch statistics of small cetaceans taken in Japanese waters. *Reports of the International Whaling Commission, 33*, 621-631.

Miyazaki, N. and Amano, M. (1994). Skull morphology of two forms of short-finned pilot whales off the Pacific coast of Japan. *Reports of the International Whaling Commission, 44*, 499-508.

Miyazaki, N., Fujise, Y. and Iwata, K. (1998). Biological analysis of a mass stranding of melon-headed whales (*Peponocephala electra*) at Aoshima, Japan. *Bulletin of the National Science Museum, Tokyo, 24*(1), 31-60.

Miyazaki, N., Kasuya, T. and Nishiwaki, M. (1974). Distribution and migration of two species of *Stenella* in the Pacific coast of Japan. *Scientific Reports of the Whales Research Institute, 26*, 227-243.

Miyazaki, N. and Nakayama, K. (1989). Records of cetaceans in the waters of the Amami Islands. *Memoirs of the National Science Museum, Tokyo, 22*, 235-249.

Miyazaki, N. and Perrin, W. F. (1994). Rough-toothed dolphin *Steno bredanensis* (Lesson, 1828). In S. H. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals* (Vol. 5, pp. 1-21). San Diego, CA: Academic Press.

Miyazaki, N. and Shikano, C. (1989). Two forms of *Lagenorhynchus obliquidens* in the Japanese waters. [Abstract]. Presented at the 5th International Theriological Congress, Rome, Italy.

Miyazaki, N. and Wada, S. (1978a). Fraser's dolphin, *Lagenodelphis hosei* in the western North Pacific. *Scientific Reports of the Whales Research Institute, 30*, 231-244.

Miyazaki, N. and Wada, S. (1978b). Observation of Cetacea during whale marking cruise in the western tropical Pacific, 1976. *Scientific Reports of the Whales Research Institute, 30*, 179-195.

Mizroch, S. A. and Breiwick, J. M. (1984). Variability in age at length and length at age in Antarctic Fin, Sei and Minke Whales. *Reports of the International Whaling Commission, 34*, 723-732.

Mizroch, S. A., Rice, D. W., Zwiefelhofer, D., Waite, J. and Perryman, W. L. (2005). *Distribution and Movements of Fin Whales in the North Pacific Ocean* [Draft]. (pp. 71).

Mizroch, S. A., Rice, D. W., Zwiefelhofer, D., Waite, J. M. and Perryman, W. L. (2009). Distribution and movements of fin whales in the North Pacific Ocean. *Mammal Review, 39*, 193-227. doi:10.1111/j.1365-2907.2009.00147.x

Mizroch, S. A., Tillman, M. F., Jurasz, S., Straley, J. M., von Ziegesar, O., Herman, L. M., et al. (2011). Long-term survival of humpback whales radio-tagged in Alaska from 1976 through 1978. *Marine Mammal Science, 27*(1), 217-229. doi:10.1111/j.1748-7692.2010.00391.x

Mizuno, A. W. (2002). Assessment of seasonal abundance of the spotted seal (*Phoca largha*) from incidental takes in fishing nets along the Notsuke Peninsula, Hokkaido. *Mammal Study, 27*, 135-136.

Mizuno, A. W., Suzuki, M. and Ohtaishi, N. (2001). Distribution of the spotted seal *Phoca largha* along the coast of Hokkaido, Japan. *Mammal Study, 26*(2), 109-118.

Mobley, J., J. R., Spitz, S. S., Forney, K. A., Grotefendt, R. and Forestell, P. H. (2000). Distribution and abundance of odontocete species in Hawaiian waters: Preliminary results of 1993-98 aerial surveys. (Southwest Fisheries Science Center Administrative Report LJ-00-14C, pp. 26).

Mobley, J. R. (2007). *Marine Mammal Monitoring Surveys in Support of "Valiant Shield" Training Exercises (Aug. 13-17, 2007)-- Final Report*. (pp. 12). Prepared for Commander, U.S. Pacific Fleet.

Møhl, B., Wahlberg, M., Madsen, P. T., Heerfordt, A. and Lund, A. (2003). The monopulsed nature of sperm whale clicks. *Journal of the Acoustical Society of America, 114*(2), 1143-1154.

Moon, H. B., An, Y. R., Choi, S. G., Choi, M. and Choi, H. G. (2012). Accumulation of PAHs and synthetic musk compound in minke whales (*Balanoptera acutorostrata*) and long-beaked common dolphins (*Delphinus capensis*) from Korean coastal waters. *Environmental Toxicology and Chemistry, 31*(3), 477-485. doi:10.1002/etc.1710

Moon, H. B., Kannan, K., Choi, H. G., An, Y. R., Choi, S. G., Park, J. Y., et al. (2010). Concentrations and accumulation features of PCDDs, PCDFs and dioxin-like PCBs in cetaceans from Korean coastal waters. *Chemosphere, 79*(7), 733-739. doi:10.1016/j.chemosphere.2010.02.043

Moon, H. B., Kannan, K., Choi, M., Yu, J., Choi, H. G., An, Y. R., et al. (2010). Chlorinated and brominated contaminants including PCBs and PBDEs in minke whales and common dolphins from Korean coastal waters. *Journal of Hazardous Materials, 179*(1-3), 735-741.

Moon, H. B., Kannan, K., Yun, S., An, Y. R., Choi, S. G., Park, J. Y., et al. (2010). Perfluorinated compounds in minke whales (*Balaenoptera acutorostrata*) and long-beaked common dolphins (*Delphinus capensis*) from Korean coastal waters. *Marine Pollution Bulletin, 60*(7), 1130-1135. doi:10.1016/j.marpolbul.2010.04.007

Mooney, T. A., Nachtigall, P. E. and Yuen, M. M. L. (2006). Temporal resolution of the Risso's dolphin, *Grampus griseus* auditory system. *Journal of Comparative Physiology A, 192*(4), 373-380. doi:10.1007/s00359-005-0075-4

Moore, J. C. (1972). More skull characters of the beaked whale *Indopacetus pacificus* and comparative measurements of austral relatives. *Fieldiana Zoology, 62*, 1-19.

Moore, M. J., Bogomolni, A. L., Dennison, S. E., Early, G., Garner, M. M., Hayward, B. A., et al. (2009). Gas bubbles in seals, dolphins, and porpoises entangled and drowned at depth in gillnets. *Veterinary Pathology, 46*(3), 536-547. doi:10.1354/vp.08-VP-0065-M-FL

Moore, P. W., Dankiewicz, L. A. and Houser, D. S. (2008). Beamwidth control and angular target detection in an echolocating bottlenose dolphin (*Tursiops truncatus*). *Journal of the Acoustical Society of America, 124*(5), 3324-3332. doi:10.1121/1.2980453

Moore, P. W. B. and Schusterman, R. J. (1987). Audiometric assessment of northern fur seals, *Callorhinus ursinus*. *Marine Mammal Science, 3*(1), 31-53.

Moore, S. E. and Clarke, J. T. (2002). Potential impact of offshore human activities on gray whales (*Eschrichtius robustus*). *Journal of Cetacean Research and Management, 4*(1), 19-25.

Moore, S. E., Watkins, W. A., Daher, M. A., Davies, J. R. and Dahlheim, M. E. (2002). Blue whale habitat associations in the northwest Pacific: Analysis of remotely-sensed data using a Geographic Information System. *Oceanography, 15*, 20-25.

Morato, T., Varkey, D. A., Damaso, C., Machete, M., Santos, M., Prieto, R., et al. (2008). Evidence of a seamount effect on aggregating visitors. *Marine Ecology Progress Series, 357*, 23-32. doi:10.3354/meps07269

Morejohn, G. V. and Rice, D. W. (1973). First record of Bryde's whale (Balaenoptera edeni) off California. *California Fish and Game, 59*, 313-315.

Morell, V. (2011). Killer whales earn their name. *Science, 331*(6015), 274-276. doi:10.1126/science.331.6015.274

Moreno, I. B., Zerbini, A. N., Danilewicz, D., Santos, M. O. S., Simoes-Lopes, P. C., Lailson Brito, J., et al. (2005). Distribution and habitat characteristics of dolphins of the genus *Stenella* (Cetacea: Delphinidae) in the southwest Atlantic Ocean. *Marine Ecology Progress Series, 300*, 229-240.

Moretti, D., Marques, T. A., Thomas, L., DiMarzio, N., Dilley, A., Morrissey, R., et al. (2010). A dive counting density estimation method for Blainville's beaked whale (*Mesoplodon densirostris*) using a bottom-mounted hydrophone field as applied to a Mid-Frequency Active (MFA) sonar operation. *Applied Acoustics, 71*(11), 1036-1042. doi:10.1016/j.apacoust.2010.04.011

Mori, J., Kubodera, T. and Baba, N. (2001). Squid in the diet of northern fur seals, *Callorhinus ursinus*, caught in the western and central North Pacific Ocean. *Fisheries Research, 52*, 91-97.

Mori, K. (1999, 28 November). Whale and dolphin watching and associated research programs in the Ogasawara Islands, Japan. [Presentation]. Presented at the Wild Dolphin Swim Program Workshop: A workshop held in conjunction with the 13th Biennial Conference on the Biology of Marine Mammals, Maui, HI.

Morin, P. A., Archer, F. I., Foote, A. D., Vilstrup, J., Allen, E. E., Wade, P., et al. (2010). Complete mitochondrial genome phylogeographic analysis of killer whales (*Orcinus orca*) indicates multiple species. *Genome Research, 20*(7), 908-916. doi:10.1101/gr.102954.109

Morisaka, T., Shinohara, M., Nakahara, F. and Akamatsu, T. (2005a). Effects of ambient noise on the whistles of Indo-Pacific bottlenose dolphin populations. *Journal of Mammalogy, 86*, 541-546.

Morisaka, T., Shinohara, M., Nakahara, F. and Akamatsu, T. (2005b). Geographic variation in the whistles among three Indo-Pacific bottlenose dolphin Tursiops aduncus popultions in Japan. *Fisheries Science, 71*, 568-576.

Morton, A. (2000). Occurrence, photo-identification and prey of Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) in the Broughton Archipelago, Canada 1984-1998. *Marine Mammal Science, 16*(1), 80-93.

Moura, A., Sillero, N. and Rodrigues, A. (2012). Common dolphin (*Delphinus delphis*) habitat preferences using data from two platforms of opportunity. *Acta Oecologica, 38*, 24-32. doi:10.1016/j.actao.2011.08.006

Mullin, K. D., Jefferson, T. A., Hansen, L. J. and Hoggard, W. (1994). First sightings of melon-headed whales (*Peponocephala electra*) in the Gulf of Mexico. *Marine Mammal Science, 10*(3), 342-348.

Munger, L. M., Wiggins, S. M., Moore, S. E. and Hildebrand, J. A. (2008). North Pacific right whale (*Eubalaena japonica*) seasonal and diel calling patterns from long-term acoustic recordings in the southeastern Bering Sea, 2000-2006. *Marine Mammal Science, 24*(4), 795-814. doi:10.1111/j.1748-7692.2008.00219.x

Murase, H., Tamura, T., Kiwada, H., Fujise, Y., Watanabe, H., Ohizumi, H., et al. (2007). Prey selection of common minke (*Balaenoptera acutorostrata*) and Bryde's (*Balaenoptera edeni*) whales in the western North Pacific in 2000 and 2001. *Fisheries Oceanography, 16*(2), 186-201. doi:10.1111/j.1365-2419.2006.00426.x

Murdoch, M. E., Mazzoil, M., McCulloch, S., Bechdel, S., O'Corry-Crowe, G., Bossart, G. D., et al. (2010). Lacaziosis in bottlenose dolphins *Tursiops truncatus* along the coastal Atlantic Ocean, Florida, USA. *Diseases of Aquatic Organisms, 92*(1), 69-73. doi:10.3354/dao02282

Murphy, M. A. (1995). Occurrence and group characteristics of minke whales, *Balaenoptera acutorostrata*, in Massachusetts Bay and Cape Cod Bay. *Fishery Bulletin, 93*(3), 577-585.

Murphy, S., Collet, A. and Rogan, E. (2005). Mating strategy in the male common dolphin (*Delphinus delphis*): What gonadal analysis tells us. *Journal of Mammalogy, 86*(6), 1247-1258. doi:10.1644/1545-1542(2005)86[1247:msitmc]2.0.co;2

Mussi, B., Miragliuolo, A., De Pippo, T., Gambi, M. C. and Chiota, D. (2004). The submarine canyon of Cuma (southern Tyrrhenian Sea, Italy), a cetacean key area to protect. *European Research on Cetaceans, 15*, 178-179.

Mwevura, H., Amir, O. A., Kishimba, M., Berggren, P. and Kylin, H. (2010). Organohalogen compounds in blubber of Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) and spinner dolphin (*Stenella longirostris*) from Zanzibar, Tanzania. *Environmental Pollution, 158*(6), 2200-2207. doi:10.1016/j.envpol.2010.02.027

Nachtigall, P. E. (2011). *AEP Hearing Experiments with Marine Mammals*. (Grant Number: N00014-08-1-1159, pp. 17). Honolulu, HI: University of Hawaii. Available from http://www.ncbi.nlm.nih.gov/pubmed/21697433

Nachtigall, P. E., Au, W. W. L., Pawloski, J. L. and Moore, P. W. B. (1995). Risso's dolphin (*Grampus griseus*) hearing thresholds in Kaneohe Bay, Hawaii. In R. A. Kastelein, J. A. Thomas and P. E.

Nachtigall (Eds.), *Sensory Systems of Aquatic Mammals* (pp. 49-53). Woerden, The Netherlands: De Spil Publishers.

Nachtigall, P. E., Lemonds, D. W. and Roitblat, H. L. (2000). Psychoacoustic studies of dolphin and whale hearing. In W. W. L. Au, A. N. Popper and R. R. Fay (Eds.), *Hearing by whales and dolphins* (pp. 330-363). New York, NY: Springer-Verlag.

Nachtigall, P. E., Pawloski, J. L. and Au, W. W. L. (2003). Temporary threshold shifts and recovery following noise exposure in the Atlantic bottlenosed dolphin (*Tursiops truncatus*). *Journal of the Acoustical Society of America, 113*(6), 3425-3429. doi: 10.1121/1.1570438

Nachtigall, P. E. and Supin, A. Y. (2008). A false killer whale adjusts its hearing when it echolocates. *Journal of Experimental Biology, 211*(11), 1714-1718. doi:10.1242/jeb.013862

Nachtigall, P. E., Supin, A. Y., Pawloski, J. and Au, W. W. L. (2004). Temporary threshold shifts after noise exposure in the bottlenose dolphin (*Tursiops truncatus*) measured using evoked auditory potentials. *Marine Mammal Science, 20*(4), 673-687.

Nachtigall, P. E., Yuen, M. M. L., Mooney, T. A. and Taylor, K. A. (2005). Hearing measurements from a stranded infant Risso's dolphin, *Grampus griseus*. *Journal of Experimental Biology, 208*, 4181-4188.

Naito, Y. (1976). The occurrence of the phocid seals along the coast of Japan and possible dispersal of pups. *Scientific Reports of the Whales Research Institute, 28*, 175-185.

Naito, Y. and Konno, S. (1979). The post-breeding distributions of ice-breeding harbour seal (*Phoca largha*) and ribbon seal (*Phoca fasciata*) in the southern sea of Okhotsk. *Scientific Reports of the Whales Research Institute, 31*, 105-119.

Naito, Y. and Nishiwaki, M. (1972). The growth of two species of the harbour seal in the adjacent waters of Hokkaido. *Scientific Reports of the Whales Research Institute, 24*, 127-144.

Nakagawa, E., Kobayashi, M., Suzuki, M. and Tsubota, T. (2009). Growth variation in skull morphology of Kuril harbor seals (*Phoca vitulina stejnegeri*) and spotted seals (*Phoca largha*) in Hokkaido, Japan. *Japanese Journal of Veterinary Research, 57*(3), 147-162.

Nakagawa, E., Kobayashi, M., Suzuki, M. and Tsubota, T. (2010). Genetic variation in the harbor seal (*Phoca vitulina*) and spotted seal (*Phoca largha*) around Hokkaido, Japan, based on mitochondrial cytochrome *b s*equences. *Zoological Science, 27*(3), 263-268. doi:10.2108/zsj.27.263

Nakahara, F. and Miyazaki, N. (2011). Vocal exchanges of signature whistles in bottlenose dolphins (*Tursiops truncatus*). *Journal of Ethology, 29*(2), 309-320. doi:10.1007/s10164-010-0259-4

Nakahara, F., Uchida, S., Higashi, N., Takemura, A. and Amano, M. (2003). A comparison of the vocalizations of two forms of short-finned pilot whales *Globicephala macrorhynchus* off the Pacific Coast of Japan. Presented at the 15th Biennial Conference on the Biology of Marine Mammals, Greensboro, NC.

Nakajima, M. and Nishiwaki, M. (1965). The first occurrence of a porpoise (*Electra electra*) in Japan. *Scientific Reports of the Whales Research Institute, 19*, 91-104.

Nakata, H. (2005). Occurrence of synthetic musk fragrances in marine mammals and sharks from Japanese coastal waters. *Environmental Science & Technology, 39*(10), 3430-3434. doi:10.1021/es050199l

Nakata, H., Kannan, K., Nasu, T., Cho, H. S., Sinclair, E. and Takemura, A. (2006). Perfluorinated contaminants in sediments and aquatic organisms collected from shallow water and tidal flat areas

of the Ariake Sea, Japan: Environmental fate of perfluorooctane sulfonate in aquatic ecosystems. *Environmental Science & Technology, 40*(16), 4916-4921. doi:10.1021/es0603195

Nakayama, K., Matsudaira, C., Tajima, Y., Yamada, T. K., Yoshioka, M., Isobe, T., et al. (2009). Temporal and spatial trends of organotin contamination in the livers of finless porpoises (*Neophocaena phocaenoides*) and their association with parasitic infection status. *Science of the Total Environment, 407*(24), 6173-6178. doi:10.1016/j.scitotenv.2009.08.043

National Marine Fisheries Service. (1993). *Final Conservation Plan for the Northern Fur Seal (Callorhinus ursinus)*. (pp. 80). Prepared by National Marine Mammal Laboratory/Alaska Fisheries Science Center, Seattle, Washington and Office of Protected Resources/National Marine Fisheries Service, Silver Spring, Maryland.

National Marine Fisheries Service. (2006). *Recovery Plan for The Sperm Whale (Physeter macrocephalus)* [Draft Report]. (pp. 92). Silver Spring, MD: National Marine Fisheries Service.

National Marine Fisheries Service. (2007). *Conservation Plan for the Eastern Pacific Stock of Northern Fur Seal (*Callorhinus ursinus*)*. Juneau, AK: NMFS Protected Resources Division, Alaska Region.

National Marine Fisheries Service. (2008). *Recovery Plan for Southern Resident Killer Whales (*Orcinus orca*)*. (pp. 251). Seattle, WA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Region.

National Marine Fisheries Service (2009a, 12 August). Endangered and threatened species; initiation of a status review for the humpback whale and request for information. *Federal Register, 74*(154), 40568.

National Marine Fisheries Service. (2009b). *Sperm Whale (Physeter macrocephalus): 5-Year Review: Summary and Evaluation*. (pp. 42). Silver Spring, MD: National Marine Fisheries Service Office of Protected Resources.

National Marine Fisheries Service. (2010). *Recovery Plan for the Fin Whale (*Balaenoptera physalus*)* [Final report]. (pp. 121). Silver Spring, MD: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources.

National Marine Fisheries Service (2011a, Last updated 14 October 2011). False Killer Whale. [Web page] National Oceanic and Atmospheric Administraion Fisheries, Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/falsekillerwhale.htm

National Marine Fisheries Service (2011b, Last updated 15 November 2011). Marine Mammals. [Web Page] National Oceanic and Atmospheric Administration Fisheries, Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/, 15 February 2012.

National Marine Fisheries Service (2011c, Last updated 12 December 2011). Minke Whale (*Balaenoptera acutorostrata*). [Web page] National Oceanic and Atmospheric Administration Fisheries, Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/minkewhale.htm, 19 January 2012.

National Marine Fisheries Service (2012a). Baird's Beaked Whale (*Berardius bairdii*). [Web page] National Oceanic and Atmospheric Administration Fisheries, Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/beakedwhale_bairds.htm, 19 January 2012.

National Marine Fisheries Service (2012b). Blainville's Beaked Whale (*Mesoplodon densirostris*). [Web page] National Oceanic and Atmospheric Administration Fisheries, Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/beakedwhale_blainvilles.htm, 19 January 2012.

National Marine Fisheries Service (2012c). Blue Whale (*Balaenoptera musculus*). [Web page] National Oceanic and Atmospheric Administration Fisheries, Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/bluewhale.htm, 19 January 2012.

National Marine Fisheries Service (2012d). Bryde's Whale (*Balaenoptera edeni*). [Web page] National Oceanic and Atmospheric Administration Fisheries, Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/brydeswhale.htm, 19 January 2012.

National Marine Fisheries Service (2012e). Cuvier's Beaked Whale (*Ziphius cavirostris*). [Web page] National Oceanic and Atmospheric Administration Fisheries, Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/beakedwhale_cuviers.htm, 19 January 2012.

National Marine Fisheries Service (2012f). Dall's Porpoise (*Phocoenoides dalli*). [Web page] National Oceanic and Atmospheric Administration Fisheries, Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/dallsporpoise.htm, 19 January 2012.

National Marine Fisheries Service (2012g). Humpback Whale (*Megaptera novaeangliae*). [Web page] National Oceanic and Atmospheric Administration Fisheries, Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/humpbackwhale.htm, 19 January 2012.

National Marine Fisheries Service (2012h). Long-Beaked Common Dolphin (*Delphinus capensis*). [Web page] National Oceanic and Atmospheric Administration Fisheries, Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/commondolphin_longbeake, 19 January 2012.

National Marine Fisheries Service (2012i). Melon-headed Whale (*Peponocephala electra*). [Web page] National Oceanic and Atmospheric Administration Fisheries, Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/melonheadedwhale.htm, 19 January 2012.

National Marine Fisheries Service (2012j). North Pacific Right Whale. [Web page] National Oceanic and Atmospheric Administration Fisheries, Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/rightwhale_northpacific.htm

National Marine Fisheries Service (2012k). Northern Right Whale Dolphin (*Lissodelphis borealis*). [Web page] National Oceanic and Atmospheric Administration Fisheries, Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/northernrightwhaledolphin, 19 January 2012.

National Marine Fisheries Service (2012l). Risso's Dolphin (*Grampus griseus*). [Web page] National Oceanic and Atmospheric Administration Fisheries, Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/rissosdolphin.htm, 19 January 2012.

National Marine Fisheries Service (2012m). Short-Beaked Common Dolphin (*Delphinus delphis*). [Web page] National Oceanic and Atmospheric Administration Fisheries, Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/commondolphin, 19 January 2012.

National Marine Fisheries Service (2012n). Short-Finned Pilot Whale (*Globicephala macrorhynchus*). [Web page] National Oceanic and Atmospheric Administration Fisheries, Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/pilotwhale_shortfinned.htm, 19 January 2012.

National Marine Fisheries Service (2012o). Sperm Whales (*Physeter macrocephalus*). [Web page] National Oceanic and Atmospheric Administration Fisheries, Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/spermwhale.htm, 19 January 2012.

National Marine Fisheries Service (2012p). Spotted Seal (*Phoca largha*). [Web page] National Oceanic and Atmospheric Administration Fisheries, Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/pinnipeds/spottedseal.htm, 19 January 2012.

National Marine Fisheries Service (2012q). Stejneger's Beaked Whale (*Mesoplodon stejnegeri*). [Web page] National Oceanic and Atmospheric Administration Fisheries, Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/beakedwhale_stejnegers.htm, 19 January 2012.

National Marine Fisheries Service (2012r). Striped Dolphin (*Stenella coeruleoalba*). [Web page] National Oceanic and Atmospheric Administration Fisheries, Office of Protected Resources. Retrieved from http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/stripeddolphin.htm, 19 January 2012.

National Oceanic and Atmospheric Administration. (2009). North Atlantic Right Whale Seasonal Distribution and Habitat Use [Electronic map]. (Area covered: East coast [US to Canada]). Available from http://sero.nmfs.noaa.gov/pr/marine%20mammal/rightwhales/RW%20Seasonal%20Distribution%20and%20Habitat%20Use.pdf

Natoli, A., Peddemors, V. M. and Hoelzel, A. R. (2004). Population structure and speciation in the genus *Tursiops* based on microsatellite and mitochondrial DNA analyses. *Journal of Evolutionary Biology, 17*, 363-375. doi:10.1046/j.1420-9101.2003.00672.x

Neilson, J. L., Straley, J. M., Gabriele, C. M. and Hills, S. (2009). Non-lethal entanglement of humpback whales (*Megaptera novaeangliae*) in fishing gear in northern Southeast Alaska. *Journal of Biogeography, 36*(3), 452-464. doi:10.1111/j.1365-2699.2007.01820.x

Nelson, D. and Lien, J. (1996). The status of the long-finned pilot whale, *Globicephala melas*, in Canada. *Canadian Field-Naturalist, 110*, 511-524.

Nelson, T. A., Duffus, D. A., Robertson, C. and Feyrer, L. J. (2008). Spatial-temporal patterns in intra-annual gray whale foraging: Characterizing interactions between predators and prey in Clayquot

Sound, British Columbia, Canada. *Marine Mammal Science, 24*(2), 356-370. doi:10.1111/j.1748-7692.2008.00190.x

Nemoto, T. and Kawamura, A. (1977). Characteristics of food habits and distribution of baleen whales with special reference to the abundance of North Pacific sei and Bryde's whales. *Reports of the International Whaling Commission, Special Issue 1*, 80-87.

Neumann, D. R. (2001). Seasonal movements of short-beaked common dolphins (*Delphinus delphis*) in the north-western Bay of Plenty, New Zealand: influence of sea surface temperature and El Nino/La Nina. *New Zealand Journal of Marine and Freshwater Research, 35*, 371-374. Retrieved from http://www.coastalmarineresearchgroup.com/PDFs/Neumann%20(2001)-%20Seasonal%20movement%20of%20short%20beak%20common%20in%20Bay%20of%20Plenty.pdf

Newell, C. L. and Cowles, T. J. (2006). Unusual gray whale *Eschrichtius robustus* feeding in the summer of 2005 off the central Oregon Coast. *Geophysical Research Letters, 33*, L22S11. doi:10.1029/2006GL027189

Newman, K. and Springer, A. M. (2008). Nocturnal activity by mammal-eating killer whales at a predation hot spot in the Bering Sea. *Marine Mammal Science, 24*(4), 990-999. doi:10.1111/j.1748-7692.2008.00236.x

Newsome, S. D., Etnier, M. A., Gifford-Gonzalez, D., Phillips, D. L., van Tuinen, M., Hadly, E. A., et al. (2007). The shifting baseline of northern fur seal ecology in the northeast Pacific Ocean. *Proceedings of the National Academy of Sciences of the United States of America, 104*(23), 9709-9714. doi:10.1073/pnas.0610986104

Nino-Torres, C. A., Zenteno-Savin, T., Gardner, S. C. and Urban, J. (2010). Organochlorine pesticides and polychlorinated biphenyls in fin whales (*Balaenoptera physalus*) from the Gulf of California. *Environmental Toxicology, 25*(4), 381-390. doi:10.1002/tox.20508

Ninomiya, H., Inomata, T., Shirouzu, H. and Katsumata, E. (2005). Microanatomy of the terminal air spaces of Baird's beaked whale (*Berardius bairdii*) lungs. *Journal of Veterinary Medical Science, 67*(5), 473-479. doi:10.1292/jvms.67.473

Nishiwaki, M. (1967). Distribution and migration of marine mammals in the North Pacific area. *Bulletin of the Ocean Research Institute, 1*, 1-63.

Nishiwaki, M. (1973). Status of the Japanese sea lion. In *Seals: Proceedings of a Working Meeting of Seal Specialists on Threatened and Depleted Seals of the World, Held Under the Auspices of the Survival Service Commission of IUCN* (pp. 80-81). Morges, Switzerland: The World Wildlife Fund.

Nishiwaki, M. and Handa, C. (1958). Killer whales caught in the coastal waters off Japan for recent 10 years. *Scientific Reports of the Whales Research Institute, 13*, 85-96.

Nishiwaki, M. and Kasuya, T. (1970). A Greenland right whale caught at Osaka Bay. *Scientific Reports of the Whales Research Institute, 22*, 45-62.

Nishiwaki, M., Kasuya, T., Kureha, K. and Oguro, N. (1972). Further comments on *Mesoplodon ginkgodens*. *Scientific Reports of the Whales Research Institute, 24*, 43-56.

Nishiwaki, M., Kasuya, T., Miyazaki, N., Tobayama, T. and Kataoka, T. (1979). Present distribution of the dugong in the world. *Scientific Reports of the Whales Research Institute, 31*, 133-141.

Nishiwaki, M. and Nagasaki, F. (1960). Seals of the Japanese coastal waters. *Mammalia, 24*(3), 459-467.

Nishiwaki, M. and Norris, K. S. (1966). A new genus, *Peponocephala*, for the odontocete cetacean species *Electra electra*. *Scientific Reports of the Whales Research Institute, 20*, 95-100.

Niu, F., Liu, Z., Wen, H., Xu, D. and Yang, Y. (2012). Behavioral responses of two captive bottlenose dolphins (*Tursiops truncatus*) to a continuous 50kHz tone. *Journal of the Acoustical Society of America, 131*(2), 1643-1649. doi:10.1121/1.3675945

Noad, M. J. and Cato, D. H. (2007). Swimming speeds of singing and non-singing humpback whales during migration. *Marine Mammal Science, 23*(3), 481-495. doi:10.1111/j.1748-7692.2007.02414.x

Noel, M., Barrett-Lennard, L., Guinet, C., Dangerfield, N. and Ross, P. S. (2009). Persistent organic pollutants (POPs) in killer whales (*Orcinus orca*) from the Crozet Archipelago, southern Indian Ocean. *Marine Environmental Research, 68*(4), 196-202. doi:10.1016/j.marenvres.2009.06.009

Nollens, H. H., Rivera, R., Palacios, G., Wellehan, J. F. X., Saliki, J. T., Caseltine, S. L., et al. (2009). New recognition of *Enterovirus* infections in bottlenose dolphins (*Tursiops truncatus*). *Veterinary Microbiology, 139*(1-2), 170-175. doi:10.1016/j.vetmic.2009.05.010

Nollens, H. H., Wellehan, J. F. X., Saliki, J. T., Caseltine, S. L., Jensen, E. D., Van Bonn, W., et al. (2008). Characterization of a parainfluenza virus isolated from a bottlenose dolphin (*Tursiops truncatus*). *Veterinary Microbiology, 128*(3-4), 231-242. doi:10.1016/j.vetmic.2007.10.005

Noren, S. R., Williams, T. M., Ramirez, K., Boehm, J., Glenn, M. and Cornell, L. (2012). Changes in partial pressures of respiratory gases during submerged voluntary breath hold across odontocetes: is body mass important? *Journal of Comparative Physiology B-Biochemical Systemic and Environmental Physiology, 182*(2), 299-309. doi:10.1007/s00360-011-0612-0

Norman, S. A., Bowlby, C. E., Brancato, M. S., Calambokidis, J., Duffield, D., Gearin, P. J., et al. (2004). Cetacean strandings in Oregon and Washington between 1930 and 2002. *Journal of Cetacean Research and Management, 6*(1), 87-99.

Norris, K. S. and Dohl, T. P. (1980). Behavior of the Hawaiian spinner dolphin, Stenella longirostris. *Fishery Bulletin, 77*, 821-849.

Norris, K. S., Wursig, B., Wells, R. S., Wursig, M., Brownlee, S. M., Johnson, C., et al. (1985). *The Behavior of the Hawaiian Spinner Dolphin, Stenella longirostris*. (Southwest Fisheries Center Administrative Report LJ-85-06C, pp. 213). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center.

Norris, T. F., Jacobsen, J. and Cerchio, S. (2000). *A Comparative Analysis of Humpback Whale Songs Recorded in Pelagic Waters of the Eastern North Pacific: Preliminary Findings and Implications for Discerning Migratory Routes and Assessing Breeding Stock Identity* [Final Report]. (NMFS-SWFSC-295, pp. 33) National Oceanic and Atmospheric Administration.

Norris, T. F., McDonald, M. and Barlow, J. (1999). Acoustic detections of singing humpback whales (*Megaptera novaeangliae*) in the eastern North Pacific during their northbound migration. *Journal of the Acoustical Society of America, 106*(1), 506-514.

Norris, T. F., Oswald, J., Yack, T., Ferguson, E., Hom-Weaver, C., Dunleavy, K., et al. (2011). *An Analysis of Acoustic Data from the Mariana Islands Sea Turtle and Cetacean Survey (MISTCS)*. (MSA NO. CON-005-4394-009, pp. 103). Encinitas, CA: Bio-Waves Inc. Prepared for HDR Environmental, Operations and Construction, Inc.

Northridge, S. (2008). Fishing industry, effects of. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 443-447). San Diego, CA: Academic Press.

Northrop, J., Cummings, W. C. and Thompson, P. O. (1968). 20-Hz signals observed in the central Pacific. *Journal of the Acoustical Society of America, 43*(2), 383-384.

Nøttestad, L., Fernö, A. and Axelsen, B. E. (2002). Digging in the deep: Killer whales' advanced hunting tactic. *Polar Biology, 25*, 939-941.

Nowacek, D. P. (2005). Acoustic ecology of foraging bottlenose dolphins (*Tursiops truncatus*), habitat-specific use of three sound types. *Marine Mammal Science, 21*(4), 587-602. doi:10.1111/j.1748-7692.2005.tb01253.x

Nowacek, D. P., Johnson, M. P. and Tyack, P. L. (2004). North Atlantic right whales (*Eubalaena glacialis*) ignore ships but respond to alerting stimuli. *Proceedings of the Royal Society of London B, 271*, 227-231. doi: 10.1098/rspb.2003.2570

Nymo, I. H., Tryland, M. and Godfroid, J. (2011). A review of Brucella infection in marine mammals, with special emphasis on Brucella pinnipedialis in the hooded seal (Cystophora cristata). *Veterinary Research, 42*(93), 1-13. doi:10.1186/1297-9716-42-93

Ocean Alliance. (2010). *The Voyage of the Odyssey: Executive Summary*. (pp. 34). Available from http://www.oceanalliance.org/documents/OAVoyageoftheOdyssey-ExecutiveSummary.pdf

Odell, D. K. and McClune, K. M. (1999). False killer whale -- *Pseudorca crassidens* (Owen, 1846). In S. H. Ridgway and S. R. Harrison (Eds.), *Handbook of Marine Mammals, vol. 6: The Second Book of Dolphins and the Porpoises* (Vol. 6: The second book of dolphins and the porpoises, pp. 213-244). New York: Academic Press.

Ohishi, K., Fujise, Y. and Maruyama, T. (2008). Brucella Infection *in Whales in the Western North Pacific and Antarctic: A review*. (SC/59/DW1, pp. 6). Japan: Japan Agency for Marine-Earth Science and Ecology.

Ohizumi, H., Isoda, T., Kishiro, T. and Kato, H. (2003). Feeding habits of Baird's beaked whale *Berardius bairdii*, in the western North Pacific and Sea of Okhotsk off Japan. *Fisheries Science, 69*, 11-20.

Ohizumi, H., Kuramochi, T., Amano, M. and Miyazaki, N. (2000). Prey switching of Dall's porpoise *Phocoenoides dalli* with population decline of Japanese pilchard *Sardinops melanostictus* around Hokkaido, Japan. *Marine Ecology Progress Series, 200*, 265-275.

Ohizumi, H., Matsuishi, T. and Kishino, H. (2002). Winter sightings of humpback and Bryde's whales in tropical waters of the western and central North Pacific. *Aquatic Mammals, 28*(1), 73-77.

Ohsumi, S. (1972). Catch of marine mammals, mainly of small cetaceans, by local fisheries along the coast of Japan. *Bulletin of the Far Seas Fisheries Research Laboratory, 7*, 137-166.

Ohsumi, S. (1977). Bryde's whales in the pelagic whaling ground of the North Pacific. *Reports of the International Whaling Commission, Special Issue 1*, 140-150.

Ohsumi, S. (1980). Population assessment of the sperm whale in the North Pacific. *Reports of the International Whaling Commission, Special Issue 2*, 31-42.

Ohsumi, S. and Kato, H. (2008). A bottlenose dolphin (*Tursiops truncatus*) with fin-shaped hind appendages. *Marine Mammal Science, 24*(3), 743-745. doi:10.1111/j.1748-7692.2008.00202.x

Ohsumi, S. and Masaki, Y. (1975). Japanese whale marking in the North Pacific, 1963-1972. *Bulletin of the Far Seas Fisheries Research Laboratory, 12*, 171-219.

Okamura, H., Matsuoka, K., Hakamada, T., Okazaki, M. and Miyashita, T. (2001). Spatial and temporal structure of the western North Pacific minke whale distribution inferred from JARPN sightings data. *Journal of Cetacean Research and Management, 3*(2), 193-200.

Olavarria, C., Acevedo, J., Vester, H. I., Zamorano-Abramson, J., Viddi, F. A., Gibbons, J., et al. (2010). Southernmost distribution of common bottlenose dolphins (*Tursiops truncatus*) in the Eastern South Pacific. *Aquatic Mammals, 36*(3), 288-293. doi:10.1578/am.36.3.2010.288

Olesiuk, P. F., Ellis, G. M. and Ford, J. K. B. (2005). *Life history and population dynamics of northern resident killer whales (*Orcinus orca*) in British Columbia* [Research Document]. (2005/045, pp. 75) Canadian Science Advisory Secretartiat.

Oleson, E. M., Barlow, J., Gordon, J., Rankin, S. and Hildebrand, J. A. (2003). Low frequency calls of Bryde's whales. *Marine Mammal Science, 19*(2), 406-419.

Oleson, E. M., Boggs, C. H., Forney, K. A., Hanson, B., Kobayashi, D. R., Taylor, B. L., et al. (2010). *Status Review of Hawaiian Insular False Killer Whales (*Pseudorca crassidens*) under the Endangered Species Act*. (NOAA Technical Memorandum NMFS-PIFSC-22, pp. 140 + Appendices) U.S. Department of Commerce and National Oceanic and Atmospheric Administration.

Oleson, E. M. and Hill, M. C. (2010). *2010 Report to PACFLT: Report of Cetacean Surveys in Guam, CNMI, and the High-seas*. (pp. 23) NOAA-NMFS-Pacific Islands Fisheries Science Center.

Olson, P. A. (2009). Pilot whales *Globicephala melas* and *G. macrorhynchus*. In W. F. Perrin, B. Würsig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 898-903). San Diego, CA: Academic Press.

Omata, Y., Hammond, T., Itoh, K. and Murata, K. (2005). Antibodies against *Toxoplasma gondii* in the Pacific bottlenose dolphin (*Tursiops aduncus*) from the Solomon Islands. *Journal of Parasitology, 91*(4), 965-967. doi:10.1645/ge-3457rn.1

Omura, H. (1974). Possible migration route of the gray whale on the coast of Japan. *Scientific Reports of the Whales Research Institute, 26*, 1-14.

Omura, H. (1977). Review of the occurrence of Bryde's whale in the northwest Pacific. *Reports of the International Whaling Commission*(Special Issue 1), 88-91.

Oremland, M. S., Allen, B. M., Clapham, P. J., Moore, M. J., Potter, C. and Mead, J. G. (2010). Mandibular fractures in short-finned pilot whales, *Globicephala macrorhynchus*. *Marine Mammal Science, 26*(1), 1-16. doi:10.1111/j.1748-7692.2009.00334.x

Ortega-Ortiz, J. G., Engelhaupt, D., Winsor, M., Mate, B. and Hoelzel, A. R. (2011). Kinship of long-term associates in the highly social sperm whale. *Molecular Ecology, 21*, 732-744. doi:10.1111/j.1365-294X.2011.05274.x

Ortiz, R. M., Long, B., Casper, D., Ortiz, C. L. and Williams, T. M. (2010). Biochemical and hormonal changes during acute fasting and re-feeding in bottlenose dolphins (*Tursiops truncatus*). *Marine Mammal Science, 26*(2), 409-419. doi:10.1111/j.1748-7692.2009.00309.x

Oswald, J. N., Barlow, J. and Norris, T. F. (2003). Acoustic identification of nine delphinid species in the eastern tropical Pacific Ocean. *Marine Mammal Science, 19*(1), 20-37.

Oswald, J. N., Rankin, S. and Barlow, J. (2007). First description of whistles of Pacific Fraser's dolphins *Lagenodelphis hosei*. *Bioacoustics, 16*, 99-111.

Pack, A. A., Herman, L. M., Spitz, S. S., Hakala, S., Deakos, M. H. and Herman, E. Y. K. (2009). Male humpback whales in the Hawaiian breeding grounds preferentially associate with larger females. *Animal Behaviour, 77*(3), 653-662. doi:10.1016/j.anbehav.2008.11.015

Pack, A. A., Salden, D. R., Ferrari, M. J., Glockner-Ferrari, D. A., Herman, L. M. and Stubbs, H. A. (1998). Male humpback whale dies in competitive group. *Marine Mammal Science, 14*(4), 861-872.

Palacios, D. M. (1996). On the specimen of the ginkgo-toothed beaked whale, *Mesoplodon ginkgodens*, from the Galápagos Islands. *Marine Mammal Science, 12*(3), 444-446.

Panigada, S., Notarbartolo di Sciara, G., Zanardelli, M., Airoldi, S., Borsani, J. F. and Jahoda, M. (2005). Fin whales (Balaenoptera physalus) summering in the Ligurian Sea: Distribution, encounter rate, mean group size and relation to physiographic variables. *Journal of Cetacean Research and Management, 7*, 137-145.

Panigada, S., Zanardelli, M., Canese, S. and Jahoda, M. (1999). How deep can baleen whales dive? *Marine Ecology Progress Series, 187*, 309-311.

Panigada, S., Zanardelli, M., MacKenzie, M., Donovan, C., Melin, F. and Hammond, P. S. (2008). Modelling habitat preferences for fin whales and striped dolphins in the Pelagos Sanctuary (Western Mediterranean Sea) with physiographic and remote sensing variables. *Remote Sensing of Environment, 112*(8), 3400-3412. doi:10.1016/j.rse.2007.11.017

Panin, K. I. and Panina, G. K. (1968). Fur seal ecology and migration to the Sea of Japan during winter and spring. In V. A. Arsen'ev and K. I. Panin (Eds.), *Pinnipeds of the North Pacific* (pp. 66-76). Moscow, Russia.

Paniz-Mondolfi, A. E. and Sander-Hoffmann, L. (2009). Lobomycosis in inshore and estuarine dolphins. *Emerging Infectious Diseases, 15*(4), 672-673. doi: 10.3201/eid1504.080955

Park, B. K., Park, G. J., An, Y. R., Choi, H. G., Kim, G. B. and Moon, H. B. (2010). Organohalogen contaminants in finless porpoises (*Neophocaena phocaenoides*) from Korean coastal waters: Contamination status, maternal transfer and ecotoxicological implications. *Marine Pollution Bulletin, 60*(5), 768-774. doi:10.1016/j.marpolbul.2010.03.023

Parks, S. E., Ketten, D. R., Trehey O'Malley, J. and Arruda, J. (2004). Hearing in the North Atlantic right whale: Anatomical predictions. *Journal of the Acoustical Society of America, 115*(5, Part 2), 2442.

Parks, S. E. and Tyack, P. L. (2005). Sound production by North Atlantic right whales (*Eubalaena glacialis*) in surface active groups. *Journal of the Acoustical Society of America, 117*(5), 3297-3306. doi:10.1121/1.1882946

Parsons, E. C. M., Rose, N. A. and Telecky, T. M. (2010). The trade in live Indo-Pacific bottlenose dolphins from Solomon Islands-A CITES decision implementation case study. *Marine Policy, 34*(3), 384-388. doi:10.1016/j.marpol.2009.08.008

Parsons, K. M., Balcomb, K. C., Ford, J. K. B. and Durban, J. W. (2009). The social dynamics of southern resident killer whales and conservation implications for this endangered population. *Animal Behaviour, 77*(4), 963-971. doi:10.1016/j.anbehav.2009.01.018

Paulos, R. D., Dudzinski, K. M. and Kuczaj, S. A., III (2008). The role of touch in select social interactions of Atlantic spotted dolphin (*Stenella frontalis*) and Indo-Pacific bottlenose dolphin (*Tursiops aduncus*). *Journal of Ethology, 26*(1), 153-164. doi:10.1007/s10164-007-0047-y

Payne, K., Tyack, P. and Payne, R. (1983). Progressive changes in the songs of humpback whales (*Megaptera novaengliae*): a detailed analysis of two seasons in Hawaii. In R. Payne (Ed.), *Communication and Behavior of Whales* (pp. 9-57). Westview Press (AAAS Symposium Book).

Payne, P. M. and Heinemann, D. W. (1993). The distribution of pilot whales (*Globicephala* spp.) in shelf/shelf edge and slope waters of the northeastern United States, 1978-1988. *Reports of the International Whaling Commission, Special Issue 14*, 51-68.

Payne, P. M., Heinemann, D. W. and Selzer, L. A. (1990). *A Distributional Assessment of Cetaceans in Shelf/Shelf-Edge and Adjacent Slope Waters of the Northeastern United States Based on Aerial and Shipboard Surveys, 1978-1988* [Contract report]. (pp. 108). Woods Hole, MA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center.

Payne, R. S. and McVay, S. (1971). Songs of humpback whales. *Science, 173*, 585-597.

Peddemors, V. M. (1999). Delphinids of southern Africa: a review of their distribution, status and life history. *Journal of Cetacean Research and Management, 1*(2), 157-165.

Perkins, J. S. and Miller, G. W. (1983). Mass stranding of *Steno bredanensis* in Belize. *Biotropica, 15*(3), 235-236.

Perrin, W. F. (1976). First record of the melon-headed whale, *Peponocephala electra*, in the eastern Pacific, with a summary of world distribution. *Fishery Bulletin, 74*(2), 457-458.

Perrin, W. F. (1998). *Stenella longirostris*. *Mammalian Species, 599*, 1-7.

Perrin, W. F. (2001). *Stenella attenuata*. *Mammalian Species, 683*, 1-8.

Perrin, W. F. (2008a). Common dolphins *Delphinus delphis* and *D. capensis*. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 255-259). Academic Press.

Perrin, W. F. (2008b). Pantropical spotted dolphin *Stenella attenuata*. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 819-821). Academic Press.

Perrin, W. F. (2008c). Spinner dolphin *Stenella longirostris*. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 1100-1103). Academic Press.

Perrin, W. F., Baker, C. S., Berta, A., Boness, D. J., Brownell, R. L., Jr., Dalebout, M. L., et al. (2009, Last updated *Last updated 7 December 2009 by members of the Ad Hoc Committee on Taxonomy*). *Marine Mammal Species and Subspecies*. Retrieved from http://www.marinemammalscience.org/index.php?option=com_content&view=article&id=420&Itemid=280

Perrin, W. F., Best, P. B., Dawbin, W. H., Balcomb, K. C., Gambell, R. and Ross, G. J. B. (1973). Rediscovery of Fraser's dolphin *Lagenodelphis hosei*. *Nature, 241*, 345-350.

Perrin, W. F. and Brownell, R. L. (2008). Minke whales *Balaenoptera acutorostrata* and *B. bonaerensis*. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 733-735). Academic Press.

Perrin, W. F., Dolar, M. L. L., Chan, C. M. and Chivers, S. J. (2005). Length-weight relationships in the spinner dolphin (*Stenella longirostris*). *Marine Mammal Science, 21*(4), 765-778. doi:10.1111/j.1748-7692.2005.tb01264.x

Perrin, W. F., Dolar, M. L. L. and Robineau, D. (1999). Spinner dolphins (*Stenella longirostris*) of the western Pacific and southeast Asia: Pelagic and shallow-water forms. *Marine Mammal Science, 15*(4), 1029-1053.

Perrin, W. F. and Gilpatrick, J. W., Jr. (1994). Spinner dolphin *Stenella longirostris* (Gray, 1828). In S. H. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals, Volume 5: The first book of dolphins* (Vol. 5, pp. 99-128). San Diego, CA: Academic Press.

Perrin, W. F. and Hohn, A. A. (1994). Pantropical spotted dolphin *Stenella attenuata*. In S. H. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals* (Vol. 5, pp. 71-98). San Diego, CA: Academic Press.

Perrin, W. F., Leatherwood, S. and Collet, A. (1994). Fraser's dolphin Lagenodelphis hosei Fraser, 1956 S. H. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals, Volume 5: The first book of dolphins* (pp. 225-240). San Diego, California: Academic Press.

Perrin, W. F., Wilson, C. E. and Archer, F. I., II (1994). Striped dolphin--*Stenella coeruleoalba* (Meyen, 1833). In S. H. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals* (Vol. 5: The First Book of Dolphins, pp. 129-159). San Diego, CA: Academic Press.

Perrin, W. F., Würsig, B. and Thewissen, J. G. M. (Eds.). (2008). *Encyclopedia of Marine Mammals* (2nd ed., pp. 1316). San Diego, CA: Academic Press.

Perry, C. and Thornton, A. L. (2000). *Towards Extinction: The Exploitation of Small Cetaceans in Japan*. (pp. 28). London, England: Environmental Investigation Agency.

Perry, S. L., DeMaster, D. P. and Silber, G. K. (1999). The great whales: history and status of six species listed as Endangered under the U.S. Endangered Species Act of 1973. *Marine Fisheries Review, 61*(1), 1-74.

Perryman, W. L. (2008). Melon-headed whale *Peponocephala electra*. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 719-721). Academic Press.

Perryman, W. L., Au, D. W. K., Leatherwood, S. and Jefferson, T. A. (1994). Melon-headed whale Peponocephala electra Gray, 1846 S. H. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals, Volume 5: The first book of dolphins* (pp. 363-386). Academic Press.

Perryman, W. L. and Foster, T. C. (1980). *Preliminary Report on Predation by Small Whales, Mainly the False Killer Whale,* Pseudorca crassidens*, on Dolphins (*Stenella spp*. and* Delphinus delphis*) in the Eastern Tropical Pacific* [Administrative Report]. (LJ-80-05, pp. 9). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center.

Philips, J. D., Nachtigall, P. E., Au, W. W. L., Pawloski, J. L. and Roitblat, H. L. (2003). Echolocation in the Risso's dolphin, *Grampus griseus*. *Journal of the Acoustical Society of America, 113*(1), 605-616. doi:10.1121/1.1527964

Pierce, G. J., Santos, M. B., Murphy, S., Learmonth, J. A., Zuur, A. F., Rogan, E., et al. (2008). Bioaccumulation of persistent organic pollutants in female common dolphins (*Delphinus delphis*) and harbour porpoises (*Phocoena phocoena*) from western European seas: Geographical trends, causal factors and effects on reproduction and mortality. *Environmental Pollution, 153*(2), 401-415. doi:10.1016/j.envpol.2007.08.019

Pierce, G. J., Santos, M. B., Smeenk, C., Saveliev, A. and Zuur, A. F. (2007). Historical trends in the incidence of strandings of sperm whales (*Physeter macrocephalus*) on North Sea coasts: An

association with positive temperature anomalies. *Fisheries Research, 87*(2-3), 219-228. doi:10.1016/j.fishres.2007.06.001

Pilot, M., Dahlheim, M. E. and Hoelzel, A. R. (2010). Social cohesion among kin, gene flow without dispersal and the evolution of population genetic structure in the killer whale (*Orcinus orca*). *Journal of Evolutionary Biology, 23*(1), 20-31. doi:10.1111/j.1420-9101.2009.01887.x

Piscitelli, M. A., McLellan, W. A., Rommel, S. A., Blum, J. E., Barco, S. G. and Pabst, D. A. (2010). Lung size and thoracic morphology in shallow- and deep-diving cetaceans. *Journal of Morphology, 271*(6), 654-673. doi:10.1002/jmor.10823

Pitman, R. (2008a). Indo-Pacific beaked whale *Indopacetus pacificus*. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 600-602). Academic Press.

Pitman, R. L. (2008b). Mesoplodont whales *Mesoplodon spp.* In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals (Second Edition)* (pp. 721-726). Academic Press.

Pitman, R. L., Au, D. W. K., Scott, M. D. and Cotton, J. M. (1988). *Observations of Beaked Whales (*Ziphiidae*) from the Eastern Tropical Pacific Ocean*. (SC/40/SM14) International Whaling Commission.

Pitman, R. L. and Ballance, L. T. (1992). Parkinson's petrel distribution and foraging ecology in the eastern Pacific: Aspects of an exclusive feeding relationship with dolphins. *The Condor, 94*, 825-835.

Pitman, R. L. and Ensor, P. (2003). Three forms of killer whales (Orcinus orca) in Antarctic waters. *Journal of Cetacean Research and Management, 5*(2), 131-139.

Pitman, R. L., Fearnbach, H., LeDuc, R., Gilpatrick, J. W., Jr, Ford, J. K. B. and Ballance, L. T. (2007). Killer whales preying on a blue whale calf on the Costa Rica Dome: Genetics, morphometrics, vocalisations and composition of the group. *Journal of Cetacean Research and Management, 9*(2), 151-157.

Pitman, R. L., Palacios, D. M., Brennan, P. L. R., Brennan, B. J., Balcomb, K. C., III and Miyashita, T. (1999). Sightings and possible identity of a bottlenose whale in the tropical Indo-Pacific: Indopacetus pacificus. *Marine Mammal Science, 15*(2), 531-549.

Pitman, R. L. and Stinchcomb, C. (2002). Rough-toothed dolphins (Steno bredanensis) as predators of mahimahi (Coryphaena hippurus). *Pacific Science, 56*(4), 447-450.

Pivorunas, A. (1979). The feeding mechanisms of baleen whales, *American Scientist* (Vol. 67, pp. 432-440).

Plon, S. (2004). *The status and natural history of pygmy (Kogia breviceps) and dwarf (K. sima) sperm whales off southern Africa.* (Ph.D.). Rhodes University.

Pollock, K. H., Marsh, H. D., Lawler, I. R. and Alldredge, M. W. (2006). Estimating animal abundance in heterogeneous environments: An application to aerial surveys for Dugongs. *Journal of Wildlife Management, 70*(1), 255-262. doi:10.2193/0022-541x(2006)70[255:eaaihe]2.0.co;2

Poole, M. M. (1995). *Aspects of the behavioral ecology of spinner dolphins (Stenella longirostris) in the nearshore waters of Mo'orea, French Polynesia.* (Ph.D. dissertation). University of California, Santa Cruz.

Popov, V. V. and Klishin, V. O. (1998). EEG study of hearing in the common dolphin, *Delphinus delphis*. *Aquatic Mammals, 24*(1), 13-20.

Popov, V. V., Supin, A. Y., Klishin, V. O., Tarakanov, M. B. and Pletenko, M. G. (2008). Evidence for double acoustic windows in the dolphin, *Tursiops truncatus*. *Journal of the Acoustical Society of America, 123*(1), 552-560. doi:10.1121/1.2816564

Popov, V. V., Supin, A. Y., Wang, D. and Wang, K. X. (2006). Nonconstant quality of auditory filters in the porpoises, *Phocoena phocoena* and *Neophocaena phocaenoides* (Cetacea, Phocoenidae). *Journal of the Acoustical Society of America, 119*(5), 3173-3180. doi:10.1121/1.2184290

Popov, V. V., Surpin, A. Y., Wang, D., Wang, K., Xiao, J. and Li, S. (2005). Evoked-potential audiogram of the Yangtze finless porpoise *Neophocaena phocaenoides asiaeorientalis* (L). *Journal of the Acoustical Society of America, 117*(5), 2728-2731. doi: 10.1121/1.1880712

Preen, A. (1995a). Diet of dugongs: are they omnivores? *Journal of Mammalogy, 76*, 163-171.

Preen, A. (1995b). Impacts of dugong foraging on seagrass habitats: Observational and experimental evidence for cultivation grazing. *Marine Ecology Progress Series, 124*, 201-213.

Pryor, K. and Shallenberger, I. K. (1991). Social structure in spotted dolphins (*Stenella attenuata*) in the tuna purse seine fishery in the eastern tropical Pacific. In K. Pryor and K. S. Norris (Eds.), *Dolphin societies: Discoveries and puzzles* (pp. 161-196). Berkeley, CA: University of California Press.

Quakenbush, L. T. (1988). Spotted seal--*Phoca largha.* In J. W. Lentfer (Ed.), *Selected Marine Mammals of Alaska: Species Accounts with Research and Management Recommendations* (pp. 107-124). Washington, DC: Marine Mammal Commission.

Quick, N. J. and Janik, V. M. (2008). Whistle rates of wild bottlenose dolphins (*Tursiops truncatus*): Influences of group size and behavior. *Journal of Comparative Psychology, 122*(3), 305-311. doi:10.1037/0735-7036.122.3.305

Ragen, T. J., Antonelis, G. A. and Kiyota, M. (1995). Early migration of northern fur seal pups from St. Paul Island, Alaska. *Journal of Mammalogy, 76*(4), 1137-1148.

Rajamani, L., Cahanban, A. S. and Abdul Rahman, R. (2006). Indigenous use and trade of Dugong (*Dugong dugon*) in Sabah, Malaysia. *AMBIO, 35*(5), 266-268. doi:10.1579/05-s-093.1

Ramu, K., Kajiwara, N., Lam, P. K. S., Jefferson, T. A., Zhou, K. Y. and Tanabe, S. (2006). Temporal variation and biomagnification of organohalogen compounds in finless porpoises (*Neophocaena phocaenoides*) from the South China Sea. *Environmental Pollution, 144*(2), 516-523. doi:10.1016/j.envpol.2006.01.027

Ramu, K., Kajiwara, N., Tanabe, S., Lam, P. K. S. and Jefferson, T. A. (2005). Polybrominated diphenyl ethers (PBDEs) and organochlorines in small cetaceans from Hong Kong waters: Levels, profiles and distribution. *Marine Pollution Bulletin, 51*(8-12), 669-676. doi:10.1016/j.marpolbul.2005.02.041

Randall, R. H., Tsuda, R. T., Jones, R. S., Gawel, M. J., Chase, J. A. and Rechebei, R. (1975). *Marine Biological Survey of the Cocos Barrier Reefs and Enclosed Lagoon*. (Technical Report No. 17) University of Guam Marine Laboratory. Prepared for U.S. Army Corps of Engineers under Contract No. DACW84-72-C-0015.

Rankin, S. and Barlow, J. (2005). Source of the North Pacific "boing" sound attributed to minke whales. *Journal of the Acoustical Society of America, 118*, 3346-3351.

Rankin, S., Barlow, J. and Stafford, K. M. (2006). Blue whale (*Balaenoptera musculus*) sightings and recordings South of the Aleutian Islands. *Marine Mammal Science, 22*(3), 708-713. doi:10.1111/j.1748-7692.2006.00054.x

Rankin, S., Norris, T. F., Smultea, M. A., Oedekoven, C., Zoidis, A. M., Silva, E., et al. (2007). A visual sighting and acoustic detections of minke whales, Balaenoptera acutorostrata (Cetacea: Balaenopteridae), in nearshore Hawaiian waters. *Pacific Science, 61*, 395-398.

Read, A. J. (2008). The looming crisis: Interactions between marine mammals and fisheries. *Journal of Mammalogy, 89*(3), 541-548.

Ream, R. R., Sterling, J. T. and Loughlin, T. R. (2005). Oceanographic features related to northern fur seal migratory movements. *Deep Sea Research II, 52*(5-6), 823-843. doi:10.1016/j.dsr2.2004.12.021

Reeves, R. R., Clapham, P. J., Brownwell, R. L., Jr. and Silber, G. K. (1998). *Recovery Plan for the Blue Whale (*Balaenoptera musculus*)*. (pp. 42). Silver Spring, MD: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources.

Reeves, R. R. and Kenney, R. D. (2003). Baleen whales: Right whales and allies. In G. A. Feldhamer, B. C. Thompson and J. A. Chapman (Eds.), *Wild Mammals of North America: Biology, Management, and Conservation* (2nd ed., pp. 425-463). Baltimore, MD: Johns Hopkins University Press.

Reeves, R. R., Leatherwood, S. and Baird, R. W. (2009). Evidence of a possible decline since 1989 in false killer whales (Pseudorca crassidens) around the main Hawaiian Islands. *Pacific Science, 63*, 253-261.

Reeves, R. R., Leatherwood, S., Stone, G. S. and Eldredge, L. G. (1999). *Marine Mammals in the Area Served by the South Pacific Regional Environment Programme (SPREP)* (pp. 48). New York, NY: Croom Helm.

Reeves, R. R. and Mitchell, E. (1993). Status of Baird's beaked whale, *Berardius bairdii*. *Canadian Field-Naturalist, 107*(4), 509-523.

Reeves, R. R., Perrin, W. F., Taylor, B. L., Baker, C. S. and Mesnick, S. L. (Eds.). (2004). *Report of the Workshop on Shortcomings of Cetacean Taxonomy in Relation to Needs of Conservation and Management, April 30 - May 2, 2004 La Jolla, California* [Technical Memorandum]. (NOAA-TM-NMFS-SWFSC-363, pp. 94). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center.

Reeves, R. R., Smith, B. D., Crespo, E. A. and Notarbartolo di Sciara, G., compilers (2003). 2002-2010 conservation action plan for the world's cetaceans: Dolphins, whales and porpoises (pp. 147). Gland, Switzerland: IUCN, The World Conservation Union. Retrieved from http://data.iucn.org/dbtw-wpd/edocs/2003-009.pdf.

Reeves, R. R., Smith, T. D., Webb, R. L., Robbins, J. and Clapham, P. J. (2002). Humpback and fin whaling in the Gulf of Maine from 1800 to 1918. *Marine Fisheries Review, 64*(1), 1-12.

Reeves, R. R., Stewart, B. S., Clapham, P. J. and Powell, J. A. (2002). *National Audubon Society Guide to Marine Mammals of the World* (pp. 527). New York, NY: Alfred A. Knopf.

Reidenberg, J. S. (2007). Anatomical adaptations of aquatic mammals. *The Anatomical Record, 290*(6), 507-513. doi:10.1002/ar.20541

Reidenberg, J. S. and Laitman, J. T. (2007). Blowing bubbles: An aquatic adaptation that risks protection of the respiratory tract in humpback whales (*Megaptera novaeangliae*). *The Anatomical Record, 290*(6), 569-580. doi:10.1002/ar.20537

Reijnders, P. J. H., Aguilar, A. and Borrell, A. (2008). Pollution and marine mammals. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 890-898). San Diego, CA: Academic Press.

Reilly, S. B. (1990). Seasonal changes in distribution and habitat differences among dolphins in the eastern tropical Pacific. *Marine Ecology Progress Series, 66*, 1-11.

Reilly, S. B., Bannister, J., Best, P. B., Brown, M., Brownell, R. L., Jr., Butterworth, D. S., et al. (2008). Eubalaena japonica. In *IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2*. Retrieved from http://www.iucnredlist.org/apps/redlist/details/41711/0, 11 June 2012.

Reilly, S. B., Bannister, J., Best, P. B., Brown, M., Brownwell, R. L., Jr., Butterworth, D. S., et al. (2000). Eschrichtius robustus (western subpopulation). In *IUCN 2012. IUCN Red List of Threatened Species. Version 2012.1*. [Web page]. Retrieved from http://www.iucnredlist.org/apps/redlist/details/8099/0, 20 June 2012.

Reilly, S. B., Bannister, J. L., Best, P. B., Brown, M., Brownell, R. L., Jr., Butterworth, D. S., et al. (2008). *Balaenoptera omuri*. In *IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2*. [Web page]. Retrieved from www.iucnredlist.org, 19 January 2012.

Reisinger, R. R. and Karczmarski, L. (2010). Population size estimate of Indo-Pacific bottlenose dolphins in the Algoa Bay region, South Africa. *Marine Mammal Science, 26*(1), 86-97. doi:10.1111/j.1748-7692.2009.00324.x

Rendell, L. and Whitehead, H. (2004). Do sperm whales share coda vocalizations? Insights into coda usage from acoustic size measurements. *Animal Behaviour, 67*, 865-874.

Renner, M. and Bell, K. (2008). A white killer whale in the Central Aleutians. *Arctic, 61*(1), 102-104.

Reynolds, J. E., III and Rommel, S. A. (1999). *Biology of Marine Mammals* (pp. 578). Washington, DC: Smithsonian Institution Press.

Rice, D. W. (1989). Sperm whale *Physeter macrocephalus* Linnaeus, 1758. In S. H. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals, Volume 4: River dolphins and the larger toothed whales* (Vol. 4, pp. 177-234). San Diego, CA: Academic Press.

Rice, D. W. (1998). Marine mammals of the world: systematics and distribution *Society for Marine Mammalogy Special Publication* [Special Publication]. (4, pp. 231). Lawrence, KS: Society for Marine Mammology.

Rice, D. W., Wolman, A. A., Withrow, D. E. and Fleischer, L. A. (1981). Gray whales on the winter grounds in Baja California. *Reports of the International Whaling Commission, 31*, 477-493.

Richardson, W. J. (1995). Marine mammal hearing. In W. J. Richardson, C. R. Greene, Jr., C. I. Malme and D. H. Thomson (Eds.), *Marine Mammals and Noise* (pp. 205-240). San Diego, CA: Academic Press.

Richardson, W. J., Greene, C. R., Malme, C. I. and Thomson, D. H. (1995). Marine Mammals and Noise (pp. 576). San Diego, CA: Academic Press.

Ridgway, S. H. (2000). The auditory central nervous system of dolphins. In W. W. L. Au, A. N. Popper and R. R. Fay (Eds.), *Hearing By Whales and Dolphins* (pp. 273-293). New York, NY: Springer-Verlag.

Ridgway, S. H. (2011). Neural time and movement time in choice of whistle or pulse burst responses to different auditory stimuli by dolphins. *Journal of the Acoustical Society of America, 129*(2), 1073-1080. doi:10.1121/1.3523431

Ridgway, S. H. and Carder, D. A. (2001). Assessing hearing and sound production in cetaceans not available for behavioral audiograms: Experiences with sperm, pygmy sperm, and gray whales. *Aquatic Mammals, 27*(3), 267-276.

Ridgway, S. H., Carder, D. A., Smith, R. R., Kamolnick, T., Schlundt, C. E. and Elsberry, W. R. (1997). *Behavioral Responses and Temporary Shift in Masked Hearing Threshold of Bottlenose Dolphins, Tursiops truncatus, to 1-second Tones of 141 to 201 dB re 1 µPa*. (Technical Report 1751, Revision 1). San Diego, CA: U.S. Department of Navy, Naval Command, Control and Ocean Surveillance Center, RDT&E Division.

Ridgway, S. H. and Harrison, R. J. (1986). Diving dolphins. In M. M. Bryden and R. Harrison (Eds.), *Research on Dolphins* (pp. 33-58). Oxford University Press.

Ridgway, S. H., Scronce, B. L. and Kanwisher, J. (1969). Respiration and deep diving in the bottlenose porpoise. *Science, 166*, 1651-1654.

Ringelstein, J., Pusineri, C., Hassani, S., Meynier, L., Nicolas, R. and Ridoux, V. (2006). Food and feeding ecology of the striped dolphin, *Stenella coeruleoalba*, in the oceanic waters of the north-east Atlantic. *Journal of the Marine Biological Association of the United Kingdom, 86*, 909-918.

Risch, D., Corkeron, P. J., Ellison, W. T. and Van Parijs, S. M. (2012). Changes in humpback whale song occurrence in response to an acoustic source 200 km away. *PLoS ONE, 7*(1), e29741. doi:10.1371/journal.pone.0029741

Ritter, F. (2002). Behavioural observations of rough-toothed dolphins (*Steno bredanensis*) off La Gomera, Canary Islands (1995-2000), with special reference to their interactions with humans. *Aquatic Mammals, 28*(1), 46-59.

Ritter, F. (2007). Behavioral responses of rough-toothed dolphins to a dead newborn calf. *Marine Mammal Science, 23*(2), 429-433. doi:10.1111/j.1748-7692.2007.00107.x

Rivers, J. A. (1997). Blue whale, Balaenoptera musculus, vocalizations from the waters off central California. *Marine Mammal Science, 13*(2), 186-195.

Rizzo, L. Y. and Schulte, D. (2009). A review of humpback whales' migration patterns worldwide and their consequences to gene flow. *Journal of the Marine Biological Association of the United Kingdom, 89*(5), 995-1002. doi:10.1017/s0025315409000332

Robeck, T. R. and Monfort, S. L. (2006). Characterization of male killer whale (*Orcinus orca*) maturation and reproductive seasonality. *Theriogenology, 66*, 242-250. doi:10.1016/j.theriogenology.2005.11.007

Robeck, T. R., Steinman, K. J., Greenwell, M., Ramirez, K., Van Bonn, W., Yoshioka, M., et al. (2009). Seasonality, estrous cycle characterization, estrus synchronization, semen cryopreservation, and artificial insemination in the Pacific white-sided dolphin (*Lagenorhynchus obliquidens*). *Reproduction, 138*(2), 391-405. doi:10.1530/rep-08-0528

Robertson, K. M. and Chivers, S. J. (1997). Prey occurrence in pantropical spotted dolphins, Stenella attenuata, from the eastern tropical Pacific. *Fishery Bulletin, 95*(2), 334-348.

Robertson, P. (2010). Real research or sham science? A review of Japan's scientific whaling. *Eureka, 1*(1), 43-46. Retrieved from http://ejournals.library.ualberta.ca/index.php/eureka/article/view/7630/6482

Robson, B. W., ed. (2002). *Fur Seal Investigation, 2000-2001*. (NOAA Technical Memorandum NMFS-AFSC-134, pp. 82). Seattle, WA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Fisheries Science Center.

Rock, T. (1993, 12 April). Killer whales of the tropics. *Pacific Daily News*, 19.

Rogers, A. D. (1994). The biology of seamounts. *Advances in Marine Biology, 30*, 305-350.

Romero, A., Agudo, I. A., Green, S. M. and Notarbartolo di Sciara, G. (2001). *Cetaceans of Venezuela: Their Distribution and Conservation Status NOAA Technical Report*. (NOAA Technical Report NMFS-151, pp. 60). Seattle, WA: U.S. Department of Commerce.

Rosel, P. E. and Watts, H. (2008). Hurricane impacts on bottlenose dolphins in the northern Gulf of Mexico. *Gulf of Mexico Science, 25*(1), 88-94.

Rosenbaum, H. C., Brownell, R. L., Jr., Brown, M. W., Schaeff, C., Portway, V., White, B. N., et al. (2000). World-wide genetic differentiation of *Eubalaena*: Questioning the number of right whale species. *Molecular Ecology, 9*(11), 1793-1802.

Ross, G. J. B. (1971). Shark attack on an ailing dolphin *Stenella coeruleoalba* (Meyen). *South African Journal of Science, 67*, 413-414.

Ross, G. J. B. (1979). Records of pygmy and dwarf sperm whales, genus Kogia, from southern Africa, with biological notes and some comparisons. *Annals of the Cape Provincial Museums (Natural History), 11*(14), 259-327.

Ross, G. J. B. and Leatherwood, S. (1994). Pygmy killer whale Feresa attenuata Gray, 1874 S. H. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals, Volume 5: The first book of dolphins* (pp. 387-404). Academic Press.

Rosso, M., Moulins, A. and Wurtz, M. (2008). Colour patterns and pigmentation variability on striped dolphin *Stenella coeruleoalba* in north-western Mediterranean Sea. *Journal of the Marine Biological Association of the United Kingdom, 88*(6), 1211-1219. doi:10.1017/s0025315408001641

Rotstein, D. S., West, K., Levine, G., Lockhart, S. R., Raverty, S., Morshed, M. G., et al. (2010). *Cryptococcus gattii* VGI in a Spinner Dolphin (*Stenella longirostris*) from Hawaii. *Journal of Zoo and Wildlife Medicine, 41*(1), 181-183. doi:10.1638/2009-0145.1

Rowntree, V., Darling, J., Silber, G. and Ferrari, M. (1980). Rare sighting of a right whale (*Eubalaena glacialis*) in Hawaii. *Canadian Journal of Zoology, 58*, 309-312.

Rudolph, P., Smeenk, C. and Leatherwood, S. (1997). Preliminary checklist of Cetacea in the Indonesian archipelago and adjacent waters. *Zoologische Verhandelingen, 312*, 1-48.

Rugh, D., Breiwick, J., Muto, M., Hobbs, R., Shelden, K., D'Vincent, C., et al. (2008). *Report of the 2006-2007 Census of the Eastern North Pacific Stock of Gray Whales*. (AFSC Processed Report 2008-03, pp. 157). Seattle, WA: NOAA, NMFS, Alaska Fisheries Science Center.

Saipan Tribune (2011). Necropsy found abnormalities in kidneys, intestines of beached whale. 29 August 2011 ed. [Electronic newspaper article]. Retrieved from http://www.saipantribune.com/newsstory.aspx?newsID=112203 07 July 2013.

Sakai, M., Hishii, T., Takeda, S. and Kohshima, S. (2006). Flipper rubbing behaviors in wild bottlenose dolphins (*Tursiops aduncus*). *Marine Mammal Science, 22*(4), 966-978. doi:10.1111/j.1748-7692.2006.00082.x

Salden, D. R. and Mickelsen, J. (1999). Rare sighting of a North Pacific right whale (*Eubalaena glacialis*) in Hawaii. *Pacific Science, 53*(4), 341-345.

Saliki, J. T., Cooper, E. J., Rotstein, D. S., Caseltine, S. L., Pabst, D. A., McLellan, W. A., et al. (2006). A novel gammaherpesvirus associated with genital lesions in a Blainville's beaked whale (*Mesoplodon densirostris*). *Journal of Wildlife Diseases, 42*(1), 142-148.

Salvadeo, C. J., Lluch-Belda, D., Gómez-Gallardo, A., Urbán-Ramírez, J. and MacLeod, C. D. (2010). Climate change and a poleward shift in the distribution of the Pacific white-sided dolphin in the northeastern Pacific. *Endangered Species Research, 11*, 13-19. doi:10.3354/esr00252

Samarra, F. I. P., Deecke, V. B., Vinding, K., Rasmussen, M. H., Swift, R. J. and Miller, P. J. O. (2010). Killer whales (*Orcinus orca*) produce ultrasonic whistles. *Journal of the Acoustical Society of America, 128*(5), EL205-EL210. doi:10.1121/1.3462235

Santora, J. A., Reiss, C. S., Loeb, V. J. and Veit, R. R. (2010). Spatial association between hotspots of baleen whales and demographic patterns of Antarctic krill *Euphausia superba* suggests size-dependent predation. *Marine Ecology Progress Series, 405*, 255-269. doi:10.3354/meps08513

Santos, M. B., Martin, V., Arbelo, M., Fernandez, A. and Pierce, G. J. (2007). Insights into the diet of beaked whales from the atypical mass strandings in the Canary Islands in September 2002. *Journal of the Marine Biological Association of the United Kingdom, 87*, 243-251. doi:10.1017/S0025315407054380

Sasaki, T., Nikaido, M., Wada, S., Yamada, T. K., Cao, Y., Hasegawa, M., et al. (2006). *Balaenoptera omurai* is a newly discovered baleen whale that represents an ancient evolutionary lineage. *Molecular Phylogenetics and Evolution, 41*(1), 40-52. doi:10.1016/j.ympev.2006.03.032

Saulitis, E., Matkin, C., Barrett-Lennard, L. G., Heise, K. A. and Ellis, G. (2000). Foraging strategies of sympatric killer whale (*Orcinus orca*) populations in Prince William Sound, Alaska. *Marine Mammal Science, 16*(1), 94-109.

Scarff, J. E. (1986). Historic and present distribution of the right whale (*Eubalaena glacialis*) in the eastern North Pacific south of 50°N and east of 180°W. *Report of the International Whaling Commission*(Special Issue 10), 43-64.

Scarff, J. E. (1991). Historic distribution and abundance of the right whale (Eubalaena glacialis) in the North Pacific, Bering Sea, Sea of Okhotsk and Sea of Japan from the Maury Whale Charts. *Reports of the International Whaling Commission, 41*, 467-492.

Schilling, M. R., Seipt, I., Weinrich, M. T., Frohock, S. E., Kuhlberg, A. E. and Clapham, P. J. (1992). Behavior of individually identified sei whales *Balaenoptera borealis* during an episodic influx into the southern Gulf of Maine in 1986. *Fishery Bulletin, 90*, 749-755.

Schlundt, C. E., Finneran, J. J., Carder, D. A. and Ridgway, S. H. (2000). Temporary shift in masked hearing thresholds of bottlenose dolphins, *Tursiops truncatus*, and white whales, *Delphinapterus leucas*, after exposure to intense tones. *Journal of the Acoustical Society of America, 107*(6), 3496-3508.

Schoenherr, J. R. (1991). Blue whales feeding on high concentrations of euphausiids around Monterey Submarine Canyon. *Canadian Journal of Zoology, 69*, 583-594.

Schotten, M., Au, W. W. L., Lammers, M. O. and Aubauer, R. (2004). Echolocation recordings and localization of wild spinner dolphins (*Stenella longirostris*) and pantropical spotted dolphins (S. *attenuata*) using a four-hydrophone array. In J. A. Thomas, C. F. Moss and M. Vater (Eds.), *Echolocation in bats and dolphins* (pp. 393-400). Chicago, IL: University of Chicago Press.

Schultz, K. W., Cato, D. H., Corkeron, P. J. and Bryden, M. M. (1995). Low frequency narrow-band sounds produced by bottlenose dolphins. *Marine Mammal Science, 11*, 503-509.

Schulz, J. (1980, 7 July). Beached whale found in Ipan. *Pacific Daily News, 11*(157).

Schulz, T. M., Whitehead, H., Gero, S. and Rendell, L. (2008). Overlapping and matching of codas in vocal interactions between sperm whales: insights into communication function. *Animal Behaviour, 76*, 1977-1988. doi:10.1016/j.anbehav.2008.07.032

Schwacke, L. H., Twiner, M. J., De Guise, S., Balmer, B. C., Wells, R. S., Townsend, F. I., et al. (2010). Eosinophilia and biotoxin exposure in bottlenose dolphins (*Tursiops truncatus*) from a coastal area impacted by repeated mortality events. *Environmental Research, 110*(6), 548-555. doi:10.1016/j.envres.2010.05.003

Science Daily (2007). Killer whales metabolize contaminants, yet still show record-high contamination levels. [Electronic Article]. Retrieved from http://www.sciencedaily.com/releases/2007/07/070721223714.htm, 23 March 2012.

Scott, M. D. and Chivers, S. J. (1990). Distribution and herd structure of bottlenose dolphins in the eastern tropical Pacific Ocean. In S. Leatherwood and R. R. Reeves (Eds.), *The Bottlenose Dolphin* (pp. 387-402). Academic Press.

Scott, M. D. and Chivers, S. J. (2009). Movements and diving behavior of pelagic spotted dolphins. *Marine Mammal Science, 25*, 137-160.

Scott, T. M. and Sadove, S. S. (1997). Sperm whale, *Physeter macrocephalus*, sightings in the shallow shelf waters off Long Island, New York. *Marine Mammal Science, 13*(2), 317-321.

Sears, R. and Perrin, W. F. (2008). Blue whale. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 120-124). San Diego, CA: Academic Press.

Secretariat of the Pacific Regional Environment Programme. (2011). *Lady of the Sea: Dugongs Respect and Protect. Dugong Profile for Range States in the Pacific Islands*. (pp. 27). Apia, Samoa: Austrailian Government Depatment of Sustainability, Environment, Water, Population and Communities. Available from www.sprep.org/attachments/Publications/Dugong_Profile.pdf

Sekiguchi, K., Klages, N. T. W. and Best, P. B. (1992). Comparative analysis of the diets of smaller odontocete cetaceans along the coast of southern Africa. *South African Journal of Marine Science, 12*, 843-861.

Shane, S. H. (1990). Comparison of bottlenose dolphin behavior in Texas and Florida, with a critique of methods for studying dolphin behavior. In S. Leatherwood and R. R. Reeves (Eds.), *The Bottlenose Dolphin* (pp. 541-558). San Diego, CA: Academic Press.

Shane, S. H. (1994). Occurrence and habitat use of marine mammals at Santa Catalina Island, California from 1983-91. *Bulletin of the Southern California Academy of Sciences, 93*(1), 13-29.

Shane, S. H., Wells, R. S. and Wursig, B. (1986). Ecology, behavior and social organization of the bottlenose dolphin: a review. *Marine Mammal Science, 2*(1), 34-63.

Shaughnessy, P. D. and Fay, F. H. (1977). A review of the taxonomy and nomenclature of North Pacific harbour seals. *Journal of Zoology, London, 182*, 385-419.

Shelden, K. E. W. and Clapham, P. (2006). Habitat requirements and extinction risks of eastern North Pacific right whales. (AFSC Processed Report 2006-06, pp. 52).

Shelden, K. E. W., Moore, S. E., Waite, J. M., Wade, P. R. and Rugh, D. J. (2005). Historic and current habitat use by North Pacific right whales Eubalaena japonica in the Bering Sea and Gulf of Alaska. *Mammal Review, 35*, 129-155.

Sheppard, J. K., Jones, R. E., Marsh, H. and Lawler, I. R. (2009). Effects of Tidal and Diel Cycles on Dugong Habitat Use. *Journal of Wildlife Management, 73*(1), 45-59. doi:10.2193/2007-468

Sheppard, J. K., Lawler, I. R. and Marsh, H. (2007). Seagrass as pasture for seacows: Landscape-level dugong habitat evaluation. *Estuarine Coastal and Shelf Science, 71*(1-2), 117-132. doi:10.1016/j.ecss.2006.07.006

Sheppard, J. K., Preen, A. R., Marsh, H., Lawler, I. R., Whiting, S. D. and Jones, R. E. (2006). Movement heterogeneity of dugongs, *Dugong dugon* (Muller), over large spatial scales. *Journal of Experimental Marine Biology and Ecology, 334*(1), 64-83. doi:10.1016/j.jembe.2006.01.011

Shero, M. R., Lestyk, K. C., Andrews, R. D. and Burns, J. M. (2012). Development of oxygen stores and muscle in Northern fur seals (*Callorhinus ursinus*): limits on juvenile foraging ability? *Integrative and Comparative Biology, 50*, E161.

Shirakihara, K. (2005). *Abundance and Distribution of Finless Porpoises in Japanese Waters*. (Scientific program working document SC/57/SM11, pp. 20) International Whaling Commission.

Shirakihara, K., Shirakihara, M. and Yamamoto, Y. (2007). Distribution and abundance of finless porpoise in the Inland Sea of Japan. *Marine Biology, 150*(5), 1025-1032. doi:10.1007/s00227-006-0363-8

Shirakihara, M., Seki, K., Takemura, A., Shirakihara, K., Yoshida, H. and Yamazaki, T. (2008). Food habits of finless porpoises *Neophocaena phocaenoides* in Western Kyushu, Japan. *Journal of Mammalogy, 89*(5), 1248-1256. doi:10.1644/07-mamm-a-264.1

Shirakihara, M., Shirakihara, K., Tomonaga, J. and Takatsuki, M. (2002). A resident population of Indo-Pacific bottlenose dolphins (Tursiops aduncus) in Amakusa, western Kyushu, Japan. *Marine Mammal Science, 18*(1), 30-41.

Shirakihara, M., Yoshida, H. and Shirakihara, K. (2003). Indo-Pacific bottlenose dolphins *Tursiops aduncus* in Amakusa, western Kyushu, Japan. *Fisheries Science, 69*, 654-656.

Shirakihara, M., Yoshida, H., Yokochi, H., Ogawa, H., Hosokawa, T., Higashi, N., et al. (2007). Current status and conservation needs of dugongs in southern Japan. *Marine Mammal Science, 23*(3), 694-706. doi:10.1111/j.1748-7692.2007.00123.x

Sigurjonsson, J. (1995). On the life history and autecology of North Atlantic rorquals. In A. S. Blix, L. Walloe and O. Ultang (Eds.), *Whales, Seals, Fish and Man* (pp. 425-441). Elsevier.

Silva, F. J. D. and Da Silva, J. M., Jr. (2009). Circadian and seasonal rhythms in the behavior of spinner dolphins (*Stenella longirostris*). *Marine Mammal Science, 25*(1), 176-186. doi:10.1111/j.1748-7692.2008.00238.x

Silva, M. A., Prieto, R., Magalhaes, S., Seabra, M., Santos, R. and Hammond, P. (2008). Ranging patterns of bottlenose dolphins living in oceanic waters: implications for population structure. *Marine Biology, 156*(2), 179-192. doi:10.1007/s00227-008-1075-z

Simao, S. M. and Moreira, S. C. (2005). Vocalizations of a female humpback whale in Arraial do Cabo (RJ, Brazil). *Marine Mammal Science, 21*(1), 150-153.

Simard, Y., Roy, N. and Gervaise, C. (2008). Passive acoustic detection and localization of whales: Effects of shipping noise in Saguenay-St. Lawrence Marine Park. *Journal of the Acoustical Society of America, 123*(6), 4109-4117. doi:10.1121/1.2912453

Simmonds, M. P. and Eliott, W. J. (2009). Climate change and cetaceans: Concerns and recent developments. *Journal of the Marine Biological Association of the United Kingdom, 89*(1), 203-210. doi:10.1017/S0025315408003196

Simonis, A. E., Baumann-Pickering, S., Oleson, E., Melcon, M. L., Gassmann, M., Wiggins, S. M., et al. (2012). High-frequency modulated signals of killer whales (*Orcinus orca*) in the North Pacific. *Journal of the Acoustical Society of America, 131*(4), EL295-EL301. doi:10.1121/1.3690963

Sinclair, E. H., Vlietstra, L. S., Johnson, D. S., Zeppelin, T. K., Byrd, G. V., Springer, A. M., et al. (2008). Patterns in prey use among fur seals and seabirds in the Pribilof Islands. *Deep Sea Research II, 55*(16-17), 1897-1918. doi:10.1016/j.dsr2.2008.04.031

Siniscalchi, M., Dimatteo, A. M. P., Sasso, R. and Quaranta, A. (2012). Visual lateralization in wild striped dolpins (*Stenella coeruleoalba*) in response to stumuli with different degrees of familiarity. *PLoS ONE, 7*(1), e30001. doi:10.1371/journal.pone.0030001

Sirovic, A., Hildebrand, J. A., Wiggins, S. M., McDonald, M. A., Moore, S. E. and Thiele, D. (2004). Seasonality of blue and fin whale calls and the influence of sea ice in the Western Antarctic Peninsula. *Deep Sea Research II, 51*(17-19), 2327-2344. doi:10.1016/j.dsr2.2004.08.005

Sleptsov, M. M. (1961). Distribution of cetaceans in the Sea of Japan. *Trudy Instituta Morfologii Zhivotnykh, 34*, 93-110.

Smith, B. D., Braulik, G., Strindberg, S., Mansur, R., Diyan, M. A. A. and Ahmed, B. (2009). Habitat selection of freshwater-dependent cetaceans and the potential effects of declining freshwater flows and sea-level rise in waterways of the Sundarbans mangrove forest, Bangladesh. *Aquatic Conservation: Marine and Freshwater Ecosystems, 19*, 209-225. doi: 10.1002/aqc.987

Smith, J. N., Goldizen, A. W., Dunlop, R. A. and Noad, M. J. (2008). Songs of male humpback whales, *Megaptera novaeangliae*, are involved in intersexual interactions. *Animal Behaviour, 76*, 467-477. doi:10.1016/j.anbehav.2008.02.013

Smith, J. N., Grantham, H. S., Gales, N., Double, M. C., Noad, M. J. and Paton, D. (2012). Identification of humpback whale breeding and calving habitat in the Great Barrier Reef. *Marine Ecology Progress Series, 447*, 259-272. doi:10.3354/meps09462

Smith, R. C., Dustan, P., Au, D., Baker, K. S. and Dunlap, E. A. (1986). Distribution of cetaceans and sea-surface chlorophyll concentrations in the California Current. *Marine Biology, 91*, 385-402.

Smith, S. D. and Whitehead, H. (1999). Distribution of dolphins in Galapagos waters. *Marine Mammal Science, 15*(2), 550-555.

Smith, T. D. (2003). A three-breeding-group migratory hypothesis for common minke whales in the western North Pacific. *Journal of Cetacean Research and Management, 5*(Supplement), 483-486.

Smolker, R., Richards, A., Connor, R., Mann, J. and Berggren, P. (1997). Sponge carrying by dolphins (Delphinidae, *Tursiops* sp.): A foraging specialization involving tool use? *Ethology, 103*, 454-465.

Smultea, M. A. (1994). Segregation by humpback whale (*Megaptera novaeangliae*) cows with a calf in coastal habitat near the island of Hawaii. *Canadian Journal of Zoology, 72*, 805-811.

Smultea, M. A., Jefferson, T. A. and Zoidis, A. M. (2010). Rare sightings of a Bryde's whale (*Balaenoptera edeni*) and sei whales (*B. borealis*) (Cetacea: Balaenopteridae) northeast of O'ahu, Hawai'i. *Pacific Science, 64*, 449-457.

Soldevilla, M. S., Henderson, E. E., Campbell, G. S., Wiggins, S. M., Hildebrand, J. A. and Roch, M. A. (2008). Classification of Risso's and Pacific white-sided dolphins using spectral properties of echolocation clicks. *Journal of the Acoustical Society of America, 124*(1), 609-624. doi:10.1121/1.2932059

Soldevilla, M. S., Wiggins, S. M. and Hildebrand, J. A. (2010). Spatio-temporal comparison of Pacific white-sided dolphin echolocation click types. *Aquatic Biology, 9*(1), 49-62. doi:10.3354/ab00224

Song, K. J., Kim, Z. G., Zhang, C. I. and Kim, Y. H. (2010). Fishing gears involved in entanglements of minke whales (*Balaenoptera acutorostrata*) in the East Sea of Korea. *Marine Mammal Science, 26*(2), 282-295. doi:10.1111/j.1748-7692.2009.00340.x

Soto, S., Gonzalez, B., Willoughby, K., Maley, M., Olvera, A., Kennedy, S., et al. (2012). Systemic herpesvirus and morbillivirus co-infection in a striped dolphin (*Stenella coeruleoalba*). *Journal of Comparative Pathology, 146*(2–3), 269-273. doi:10.1016/j.jcpa.2011.04.002

Sousa-Lima, R. S. and Groch, K. R. (2010). Correlation between body length and fluke width in humpback whales, *Megaptera novaeangliae*. *Marine Mammal Science, 26*(4), 977-981. doi:10.1111/j.1748-7692.2010.00373.x

Southall, B. L., Bowles, A. E., Ellison, W. T., Finneran, J. J., Gentry, R. L., Greene, C. R., et al. (2007). Marine mammal noise and exposure criteria: initial scientific recommendations. *Aquatic Mammals, 33*, 411-521.

Southall, B. L., Braun, R., Gulland, F. M. D., Heard, A. D., Baird, R. W., Wilkin, S., et al. (2006). *Hawaiian Melon-headed Whale (Peponocephala electra) Mass Stranding Event of July 3-4, 2004*. (NOAA-TM-NMFS-OPR-31, pp. 73). Silver Spring, MD: National Oceanic and Atmospheric Administration and National Marine Fisheries Service.

Spitz, J., Cherel, Y., Bertin, S., Kiszka, J., Dewez, A. and Ridoux, V. (2011). Prey preferences among the community of deep-diving odontocetes from the Bay of Biscay, Northeast Atlantic. *Deep Sea Research I, 58*(3), 273-282. doi:10.1016/j.dsr.2010.12.009

Spitz, J., Mourocq, E., Leaute, J. P., Quero, J. C. and Ridoux, V. (2010). Prey selection by the common dolphin: Fulfilling high energy requirements with high quality food. *Journal of Experimental Marine Biology and Ecology, 390*(2), 73-77. doi:10.1016/j.jembe.2010.05.010

Spong, P. (2000). *New orca sighting makes news.* Canadian Marine Environment Protection Society, 1 August 2005.

Spraker, T. R. and Lander, M. E. (2010). Causes of mortality in Northern fur seals (*Callorhinus ursinus*), St. Paul Island, Pribilof Islands, Alaska, 1986-2006. *Journal of Wildlife Diseases, 46*(2), 450-473.

Springer, A. M., Piatt, J. F., Shuntov, V. P., Van Vliet, G. B., Vladimirov, V. L., Kuzin, A. E., et al. (1999). Marine birds and mammals of the Pacific Subarctic Gyres. *Progress in Oceanography, 43*, 443-487.

Stacey, P. J., Leatherwood, S. and Baird, R. W. (1994). *Pseudorca crassidens*. *Mammalian Species, 456*, 1-6.

Stafford, K. M., Bohnenstiehl, D. R., Tolstoy, M., Chapp, E., Mellinger, D. K. and Moore, S. E. (2004). Antarctic-type blue whale calls recorded at low latitudes in the Indian and eastern Pacific oceans. *Deep-Sea Research I, 51*, 1337-1346. doi:10.1016/j.dsr.2004.05.007

Stafford, K. M., Mellinger, D. K., Moore, S. E. and Fox, C. G. (2007). Seasonal variability and detection range modeling of baleen whale calls in the Gulf of Alaska, 1999-2002. *Journal of the Acoustical Society of America, 122*(6), 3378-3390. doi:10.1121/1.2799905

Stafford, K. M. and Moore, S. E. (2005). Atypical calling by a blue whale in the Gulf of Alaska (L). *Journal of the Acoustical Society of America, 117*(5), 2724-2727. doi:10.1121/1.1887005

Stafford, K. M., Nieukirk, S. L. and Fox, C. G. (2001). Geographic and seasonal variation of blue whale calls in the North Pacific. *Journal of Cetacean Research and Management, 3*(1), 65-76.

Staggs, L., Leger, J. S., Bossart, G., Townsend, F. I., Hicks, C. and Rinaldi, M. (2010). A novel case of *Fusarium oxysporum* infection in an Atlantic bottlenose dolphin (*Tursiops truncatus*). *Journal of Zoo and Wildlife Medicine, 41*(2), 287-290. doi:10.1638/2009-0037r2.1

Stamation, K. A., Croft, D. B., Shaughnessy, P. D., Waples, K. A. and Briggs, S. V. (2010). Behavioral responses of humpback whales (*Megaptera novaeangliae*) to whale-watching vessels on the southeastern coast of Australia. *Marine Mammal Science, 26*(1), 98-122. doi:10.1111/j.1748-7692.2009.00320.x

Stamper, M. A., Whitaker, B. R. and Schofield, T. D. (2006). Case study: Morbidity in a pygmy sperm whale *Kogia breviceps* due to ocean-bourne plastic. *Marine Mammal Science, 22*(3), 719-722. doi:10.1111/j.1748-7692.2006.00062.x

Steiger, G. H., Calambokidis, J., Straley, J. M., Herman, L. M., Cerchio, S., Salden, D. R., et al. (2008). Geographic variation in killer whale attacks on humpback whales in the North Pacific: implications for predation pressure. *Endangered Species Research, 4*(3), 247-256. doi:10.3354/esr00078

Stensland, E. and Berggren, P. (2007). Behavioural changes in female Indo-Pacific bottlenose dolphins in response to boat-based tourism. *Marine Ecology Progress Series, 332*, 225-234. doi:10.3354/meps332225

Sterling, J. T. and Ream, R. R. (2004). At-sea behavior of juvenile male northern fur seals (*Callorhinus ursinus*). *Canadian Journal of Zoology, 82*, 1621-1637. doi:10.1139/Z04-136

Stern, S. J. (1992). Surfacing rates and surfacing patterns of minke whales (*Balaenoptera acutorostrata*) off central California, and the probability of a whale surfacing within visual range. *Reports of the International Whaling Commission, 42*, 379-385.

Stevick, P. T., Allen, J., Clapham, P. J., Friday, N., Katona, S. K., Larsen, F., et al. (2003). North Atlantic humpback whale abundance and rate of increase four decades after protection from whaling. *Marine Ecology Progress Series, 258*, 263-273.

Stevick, P. T., McConnell, B. J. and Hammond, P. S. (2002). Patterns of movement A. R. Hoelzel (Ed.), *Marine mammal biology: An evolutionary approach* (pp. 185-216). Oxford, United Kingdom: Blackwell Science.

Stevick, P. T., Neves, M. C., Johansen, F., Engel, M. H., Allen, J., Marcondes, M. C. C., et al. (2010). A quarter of a world away: female humpback whale moves 10000 km between breeding areas. *Biology Letters* (published online October 13, 2010).

Stewart, B. S. and Leatherwood, S. (1985). Minke whale *Balaenoptera acutorostrata* Lacepede, 1804. In S. H. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals* (Vol. 3, pp. 91-136). San Diego, CA: Academic Press.

Stimpert, A. K., Wiley, D. N., Au, W. W. L., Johnson, M. P. and Arsenault, R. (2007). 'Megapclicks': acoustic click trains and buzzes produced during night-time foraging of humpback whales (*Megaptera novaeangliae*). *Biology Letters, 3*(5), 467-470. doi:10.1098/rsbl.2007.0281

Stockin, K. A., Fairbairns, R. S., Parsons, E. C. M. and Sims, D. W. (2001). Effects of diel and seasonal cycles on the dive duration of the minke whale (Balaenoptera acutorostrata). *Journal of the Marine Biological Association of the United Kingdom, 81*(1), 189-190.

Stone, G., Florez-Gonzalez, L. and Katona, S. (1990). Whale migration record. *Nature, 346*(6286), 705-705. doi:10.1038/346705a0

Stone, G. S., Katona, S. K., Mainwaring, A., Allen, J. M. and Corbett, H. D. (1992). Respiration and surfacing rates of fin whales (Balaenoptera physlaus) observed from a lighthouse tower. *Reports of the International Whaling Commission, 42*, 739-746.

Straley, J. M., Quinn, T. J., II and Gabriele, C. M. (2009). Assessment of mark-recapture models to estimate the abundance of a humpback whale feeding aggregation in Southeast Alaska. *Journal of Biogeography, 36*(3), 427-438.

Supin, A. Y., Nachtigall, P. E. and Breese, M. (2006). Source-to-sensation level ratio of transmitted biosonar pulses in an echolocating false killer whale. *Journal of the Acoustical Society of America, 120*(1), 518-526. doi:10.1121/1.2202862

Suzuki, G., Tue, N. M., van der Linden, S., Brouwer, A., van der Burg, B., van Velzen, M., et al. (2011). Identification of major dioxin-like compounds and androgen receptor antagonist in acid-treated tissue extracts of high trophic-level animals. *Environmental Science & Technology, 45*(23), 10203-10211. doi:10.1021/es2024274

Swartz, S. L., Taylor, B. L. and Rugh, D. J. (2006). Gray whale *Eschrichtius robustus* population and stock identity. *Mammal Review, 36*(1), 66-84.

Sylvestre, J.-P. (1988). Note on three dwarf sperm whales *Kogia simus* (Owen, 1866) and comments on kogiids of Japanese coasts. *Aquatic Mammals, 14*(3), 120-122.

Szabo, A. and Duffus, D. (2008). Mother-offspring association in the humpback whale, *Megaptera novaeangliae*: following behaviour in an aquatic mammal. *Animal Behaviour, 75*, 1085-1092. doi:10.1016/j.anbehav.2007.08.019

Szczepaniak, I. D., Webber, M. A. and Jefferson, T. A. (1992). First record of a *truei*-type Dall's porpoise from the eastern North Pacific. *Marine Mammal Science, 8*(4), 425-428.

Szymanski, M. D., Bain, D. E., Kiehl, K., Pennington, S., Wong, S. and Henry, K. R. (1999). Killer whale (*Orcinus orca*) hearing: Auditory brainstem response and behavioral audiograms. *Journal of the Acoustical Society of America, 106*(2), 1134-1141.

Tajima, Y., Shimada, A., Yamada, T. K. and Cowan, D. F. (2007). Amyloidosis in two Stejneger's beaked whales (*Mesoplodon stejnegeri*) stranded at the Sea of Japan. *Journal of Zoo and Wildlife Medicine, 38*(1), 108-113. doi:10.1638/05-108.1

Tanaka, S. (1987). Satellite radio tracking of bottlenose dolphins Tursiops truncatus. *Nippon Suisan Gakkaishi, 53*, 1327-1338.

Taniguchi, A. (1999). Differences in the structure of the lower trophic levels of pelagic ecosystems in the eastern and western subarctic Pacific. *Progress in Oceanography, 43*, 289-315.

Taylor, B. L., Chivers, S. J., Larese, J. and Perrin, W. F. (2007). *Generation Length and Percent Mature Estimates for IUCN Assessments of Cetaceans*. (Administrative Report LJ-07-01, pp. 24). La Jolla, CA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center.

Teloni, V., Johnson, M. P., Miller, J. O. P. and Madsen, P. T. (2008). Shallow food for deep divers: Dynamic foraging behavior of male sperm whales in a high latitude habitat. *Journal of Experimental Marine Biology and Ecology, 354*, 119-131. doi:10.1016/j.jembe.2007.10.010

Terasawa, F., Yamagami, T., Kitamura, M. and Fujimoto, A. (1997). A pygmy killer whale (*Feresa attenuata*) stranded at Sagami Bay, Japan. *Aquatic Mammals, 23*(1), 69-72.

Terhune, J. and Turnbull, S. (1995). Variation in the psychometric functions and hearing thresholds of a harbour seal. In R. A. Kastelein, J. A. Thomas and P. E. Nachtigall (Eds.), *Sensory Systems of Aquatic Mammals* (pp. 81-93). Woerden, The Netherlands: De Spil Publishers.

Tershy, B. R. (1992). Body size, diet, habitat use, and social behavior of *Balaenoptera* whales in the Gulf of California. *Journal of Mammalogy, 73*(3), 477-486.

Tezanos-Pinto, G., Baker, C. S., Russell, K., Martien, K., Baird, R. W., Hutt, A., et al. (2009). A worldwide perspective on the population structure and genetic diversity of bottlenose dolphins (*Tursiops truncatus*) in New Zealand. *Journal of Heredity, 100*(1), 11-24. doi:10.1093/jhered/esn039

The Beaked Whale Resource (2012a). Ginkgo-Toothed Whale *Mesoplodon ginkgodens*. [Web page]. Retrieved from http://www.beakedwhaleresource.com/bwginko.htm, 25 April 2012.

The Beaked Whale Resource (2012b). Hubb's Beaked Whale *Mesoplodon carlhubbsi*. [Web page]. Retrieved from http://www.beakedwhaleresource.com/bwhubbs.htm, 25 April 2012.

The Whale and Dolphin Conservation Society (2010). Hubbs' beaked whale *Mesoplodon carlhubbsi*. In *WDCS Species Guide*. [Web page]. Retrieved from http://www2.wdcs.org/species/species.php?sp=mesoplodon_carlhubbsi, 25 April 2012.

Thewissen, J. G. M. (2008). Sensory Biology: Overview. In W. F. Perrin, B. Würsig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 1003-1005). San Diego, CA: Academic Predd.

Thode, A., Mellinger, D. K., Steinessen, S., Martinez, A. and Muillin, K. (2002). Depth-dependent acoustic features of diving sperm whales (*Physeter macrocephalus*) in the Gulf of Mexico. *Journal of the Acoustical Society of America, 112*(1), 308-321. doi:10.1121/1/1482077

Thomas, J., Chun, N., Au, W. and Pugh, K. (1988). Underwater audiogram of a false killer whale (*Pseudorca crassidens*). *Journal of the Acoustical Society of America, 84*(3), 936-940.

Thomas, J. A., Pawloski, J. L. and Au, W. W. L. (1990). Masked hearing abilities in a false killer whale (Pseudorca crassidens) J. A. Thomas and R. A. Kastelein (Eds.), *Sensory abilities of cetaceans: Laboratory and field evidence* (pp. 395-404). Plenum Press.

Thomas, K., Harvey, J., Goldstein, T., Barakos, J. and Gulland, F. (2010). Movement, dive behavior, and survival of California sea lions (*Zalophus californianus*) posttreatment for domoic acid toxidosis. *Marine Mammal Science, 26*(1), 36-52. doi: 10.1111/j.1748-7692.2009.00314.x

Thomson, D. H. and Richardson, W. J. (1995). Marine mammal sounds. In W. J. Richardson, C. R. Greene, Jr., C. I. Malme and D. H. Thomson (Eds.), *Marine mammals and noise* (pp. 159-204). San Diego, CA: Academic Press.

Tobayama, T., Nishiwaki, M. and Yang, H. C. (1973). Records of the Fraser's Sarawak dolphin (*Lagenodelphis hosei*) in the western North Pacific. *Scientific Reports of the Whales Research Institute, 25*, 251-263.

Tomo, I., Kemper, C. M. and Lavery, T. J. (2010). Eighteen-year Study of South Australian dolphins shows variation in lung nematodes by season, year, age class and location. *Journal of Wildlife Diseases, 46*(2), 488-498.

Tornero, V., Borrell, A., Aguilar, A., Forcada, J. and Lockyer, C. (2006). Organochlorine contaminant and retinoid levels in blubber of common dolphins (*Delphinus delphis*) off northwestern Spain. *Environmental Pollution, 140*(2), 312-321. doi:10.1016/j.envpol.2005.07.006

Torres de la Riva, G., Johnson, C. K., Gulland, F. M. D., Langlois, G. W., Heyning, J. E., Rowles, T., et al. (2009). Association of an unusual marine mammal mortality event with *Pseudo-nitzschia* spp. blooms along the southern California coastline. *Journal of Wildlife Diseases, 45*(1), 109-121.

Torres, L. G., Read, A. J. and Halpin, P. (2008). Fine-scale habitat modeling of a top marine predator: Do prey data improve predictive capacity? *Ecological Applications, 18*(7), 1702-1717. doi:10.1890/07-1455.1

Towell, R. G., Ream, R. R. and York, A. E. (2006). Decline in northern fur seal (*Callorhinus ursinus*) pup production on the Pribilof Islands. *Marine Mammal Science, 22*(2), 486-491. doi:10.1111/j.1748-7692.2006.00026.x

Townsend, C. H. (1935). The distribution of certain whales as shown by logbook records of American whaleships. *Zoologica: Scientific contributions of the New York Zoological Society, 19*(1-2), 3-50.

Tremel, D. P., Thomas, J. A., Ramirez, K. T., Dye, G. S., Bachman, W. A., Orban, A. N., et al. (1998). Underwater hearing sensitivity of a Pacific white-sided dolphin, *Lagenorhynchus obliquidens*. *Aquatic Mammals, 24*(2), 63-69.

Trianni, M. S. and Kessler, C. C. (2002). Incidence and strandings of the spinner dolphin, *Stenella longirostris*, in Saipan Lagoon. *Micronesica, 34*(2), 249-260.

Trites, A. W. and York, A. E. (1993). Unexpected changes in reproductive rates and mean age at first birth during the decline of the pribilof northern fur seal (*Callorhinus ursinus*) *Canadian Journal of Fisheries and Aquatic Sciences, 50*, 858-864. Retrieved from http://www.marinemammal.org/pdfs/trites/Trites_York1993.pdf

Tsutsumi, C., Ichikawa, K., Arai, N., Akamatsu, T., Shinke, T., Hara, T., et al. (2006). Feeding behavior of wild dugongs monitored by a passive acoustical method. *Journal of the Acoustical Society of America, 120*(3), 1356-1360. doi:10.1121/1.2221529

Turl, C. W. (1993). Low-frequency sound detection by a bottlenose dolphin. *Journal of the Acoustical Society of America, 94*(5), 3006-3008.

Turner, P. S. (2004). Showdown at Sea: What happens when Great White sharks go fin-to-fin with Killer whales? [Web page] National Wildlife Federation. Retrieved from http://www.nwf.org/News-and-Magazines.aspx, 26 April 2012.

Twiss, J. R., Jr. and Reeves, R. R. (Eds.). (1999). *Conservation and Managment of Marine Mammals* (pp. 471). Washington, D.C.: Smithsonian Institution Press.

Tyack, P. and Whitehead, H. (1983). Male competition in large groups of wintering humpback whales. *Behavior, 83*, 132-154.

Tyack, P. L. (2009, November). Human-generated sound and marine mammals. *Physics Today*, 39-44.

Tyack, P. L., Johnson, M., Aguilar Soto, N., Sturlese, A. and Madsen, P. T. (2006). Extreme deep diving of beaked whales. *Journal of Experimental Biology, 209*, 4238-4253. doi:10.1242/jeb.02505

Tyack, P. L., Zimmer, W. M. X., Moretti, D., Southall, B. L., Claridge, D. E., Durban, J. W., et al. (2011). Beaked whales respond to simulated and actual Navy sonar. *PLoS ONE, 6*(3), e17009. doi:10.1371/journal.pone.0017009

Tynan, C. T., DeMaster, D. P. and Peterson, W. T. (2001). Endangered right whales on the southeastern Bering Sea shelf. [Article]. *Science, 294*(5548), 1894.

Tzika, A. C., D'Amico, E., Alfaro-Shigueto, J., Mangel, J. C., Van Waerebeek, K. and Milinkovitch, M. C. (2010). Molecular identification of small cetacean samples from Peruvian fish markets. *Conservation Genetics, 11*(6), 2207-2218. doi:10.1007/s10592-010-0106-8

U.S. Fish and Wildlife Service (2003, December 17). Endangered and threatened wildlife and plants; Determination of endangered status for the dugong (*Dugong dugon*) in the Republic of Palau. *Federal Register, 68*(242), 70185-70190.

U.S. Pacific Fleet/Naval Facilities Engineering Command Pacific. (2007). *Marine Mammal and Sea Turtle Survey and Density Estimates for Guam and the Commonwealth of the Northern Mariana Islands*. (Contract No. N68711-02-D-8043: Task Order No. 0036). Prepared by SRS-Parsons Joint Venture, Geo Marine, Inc, and Bio-Waves, Inc. Prepared for Naval Facilities Engineering Command Pacific.

Uchida, S. (TransPerfect Translations). (1982). Research on cetaceans in the Ryukyu Archipelago. (pp. 43). Okinawa, Japan: Okinawa Keeping Center.

Uchida, S. (1985). Research on cetaceans in the Ryukyu Archipelago: II. (Vol. 2, pp. 36). Okinawa, Japan: Management Foundation of the Ocean Expo Memorial Park.

Uchida, S. (1997). In search of humpbacks (A 1991-1995 survey of cetaceans in Japanese waters). In *Kings of the Sea: Humpback Whales: A 1991-1995 Survey of Cetaceans in Japanese Waters* (pp. 18-33). Tokai, Japan: Tokai Foundation.

United Nations Environment Programme (n.d.-a). *Dolphins and Porpoises*. [Electronic fact sheet]. Retrieved from http://www.unep.org/regionalseas/marinemammals/downloads/Dolphins&Porpoises.doc

United Nations Environment Programme (n.d.-b). Whales. [Electronic fact sheet]. Retrieved from http://www.unep.org/regionalseas/marinemammals/downloads/Whales.doc

Urick, R. J. (1983). *Principles of Underwater Sound* (3rd ed.). Los Altos, California: Peninsula Publishing.

Van Bressem, M. F. O., Van Waerebeek, K., Montes, D., Kennedy, S., Reyes, J. C., Garcia-Godos, I. A., et al. (2006). Diseases, lesions and malformations in the long-beaked common dolphin *Delphinus capensis* from the Southeast Pacific. *Diseases of Aquatic Organisms, 68*(2), 149-165. doi:10.3354/dao068149

van der Woude, S. E. (2009). Bottlenose dolphins (*Tursiops truncatus*) moan as low in frequency as baleen whales. *Journal of the Acoustical Society of America, 126*(3), 1552-1562. doi:10.1121/1.3177272

Van Waerebeek, K., Baker, A. N., Felix, F., Gedamke, J., Iñiguez, M., Sanino, G. P., et al. (2007). Vessel collisions with small cetaceans worldwide and with large whales in the southern hemisphere, an initial assessment. *Latin American Journal of Aquatic Mammals, 6*(1), 43-69.

Van Waerebeek, K., Felix, F., Haase, B., Palacios, D., Mora-Pinto, D. M. and Munoz-Hincapie, M. (1998). Inshore records of the striped dolphin, *Stenella coeruleoalba*, from the Pacific coast of South America. *Reports of the International Whaling Commission, 48*, 525-532.

Vanderlaan, A. S. M., Corbett, J. J., Green, S. L., Callahan, J. A., Wang, C., Kenney, R. D., et al. (2009). Probability and mitigation of vessel encounters with North Atlantic right whales. *Endangered Species Research, 6*(3), 273-285. doi:10.3354/esr00176

Vanderlaan, A. S. M., Hay, A. E. and Taggart, C. T. (2003). Characterization of North Atlantic right-whale (*Eubalaena glacialis*) sounds in the Bay of Fundy. *IEEE Journal of Oceanic Engineering, 28*(2), 164-173.

Venn-Watson, S., Smith, C. R. and Jensen, E. D. (2008). Primary bacterial pathogens in bottlenose dolphins *Tursiops truncatus*: needles in haystacks of commensal and environmental microbes. *Diseases of Aquatic Organisms, 79*(2), 87-93. doi:10.3354/dao01895

Viricel, A., Strand, A. E., Rosel, P. E., Ridoux, V. and Garcia, P. (2008). Insights on common dolphin (*Delphinus delphis*) social organization from genetic analysis of a mass-stranded pod. *Behavioral Ecology and Sociobiology, 63*(2), 173-185. doi:10.1007/s00265-008-0648-7

Visser, I. N. and Bonoccorso, F. J. (2003). New observations and a review of killer whale (*Orcinus orca*) sightings in Papua New Guinea waters. *Aquatic Mammals, 29*(1), 150-172.

Visser, I. N., Zaeschmar, J., Halliday, J., Abraham, A., Ball, P., Bradley, R., et al. (2010). First record of predation on false killer whales (*Pseudorca crassidens*) by killer whales (*Orcinus orca*). *Aquatic Mammals, 36*(2), 195-204. doi:10.1578/am.36.2.2010.195

Vogt, S. (2004). *Seabird, Sea Turtle and Marine Mammal Surveys on Farallon de Medinilla for the Year 2003*. (pp. 5). Honolulu, HI: Naval Facilities Engineering Command. Prepared for Commander, U.S. Naval Forces Marianas, Environmental, Guam.

Vogt, S. (2008). *Fiscal Years 2007-2008 Annual Report for 61755NR410 Wildlife Surveys on Military Leased Lands, Farallon de Medinilla, Commonwealth of the Northern Mariana Islands*. (pp. 16). Honolulu, Hawaii: U.S. Navy, NAVFAC Pacific.

von Benda-Beckmann, A. M., Lam, F. P. A., Moretti, D. J., Fulkerson, K., Ainslie, M. A., van Ijsselmuide, S. P., et al. (2010). Detection of Blainville's beaked whales with towed arrays. *Applied Acoustics, 71*(11), 1027-1035. doi:10.1016/j.apacoust.2010.05.015

Von Saunder, A. and Barlow, J. (1999). *A Report of the Oregon, California and Washington Line-Transect Experiment (ORCAWALE) Conducted in West Coast Waters During Summer/Fall 1996*. (NOAA Technical Memorandum NMFS-SWFSC-264, pp. 49).

von Streit, C., Ganslosser, U. and von Fersen, L. (2011). Ethogram of two captive mother-calf dyads of bottlenose dolphins (*Tursiops truncatus*): Comparison with field ethograms. *Aquatic Mammals, 37*(2), 193-197. doi:10.1578/am.37.2.2011.193

Vos, D. J., Quakenbush, L. T. and Mahoney, B. A. (2006). Documentation of sea otters and birds as prey for killer whales. *Marine Mammal Science, 22*(1), 201-205.

Vu, E. T., Risch, D., Clark, C. W., Gaylord, S., Hatch, L. T., Thompson, M. A., et al. (2012). Humpback whale song occurs extensively on feeding grounds in the western North Atlantic Ocean. *Aquatic Biology, 14*(2), 175-183. doi:10.3354/ab00390

Wada, K., Hayama, S., Nakaoka, T. and Uno, H. (1991). Interactions between Kuril seals and salmon trap net fishery in the coastal waters of southeastern Hokkaido. *Marine Mammal Science, 7*(1), 75-84.

Wada, S. (1983). Genetic structure and taxonomic status of minke whales in the coastal waters of Japan. *Reports of the International Whaling Commission, 33*, 361-363.

Wada, S. (1988). Genetic differentiation between two forms of short-finned pilot whales off the Pacific coast of Japan. *Scientific Reports of the Whales Research Institute, 39*, 91-101.

Wada, S., Oishi, M. and Yamada, T. K. (2003). A newly discovered species of living baleen whale. *Nature, 426*(6964), 278-281. doi:10.1038/nature02103

Wade, P. R., Durban, J. W., Waite, J. M., Zerbini, A. N. and Dahlheim, M. E. (2003). Surveying killer whale abundance and distribution in the Gulf of Alaska and Aleutian Islands. *NAFSC Quarterly Report, Oct-Dec 03*, 1-16.

Wade, P. R. and Gerrodette, T. (1993). Estimates of cetacean abundance and distribution in the eastern tropical Pacific. *Reports of the International Whaling Commission, 43*, 477-493.

Wade, P. R., Heide-Jorgensen, M. P., Shelden, K. E. W., Barlow, J., Carretta, J., Durban, J. W., et al. (2006). Acoustic detection and satellite-tracking leads to discovery of rare concentration of endangered North Pacific right whales. *Biology Letters, 2*, 417-419.

Wade, P. R., Kennedy, A., LeDuc, R., Barlow, J., Carretta, J., V., Shelden, K., et al. (2010). The world's smallest whale population? [online in advance of print journal]. *Biology Letters*. doi: 10.1098/rsbl.2010.0477

Wade, P. R., Ver Hoef, J. M. and DeMaster, D. P. (2009). Mammal-eating killer whales and their prey — trend data for pinnipeds and sea otters in the North Pacific Ocean do not support the sequential megafaunal collapse hypothesis. *Marine Mammal Science, 25*(3), 737-747.

Walker, W. A. and Hanson, M. B. (1999). Biological observations on Stejneger's beaked whale, *Mesoplodon stejnegeri*, from strandings on Adak Island, Alaska. *Marine Mammal Science, 15*(4), 1314-1329.

Walker, W. A., Leatherwood, S., Goodrich, K. R., Perrin, W. F. and Stroud, R. K. (1986). Geographical variation and biology of the Pacific white-sided dolphin, *Lagenorhynchus obliquidens,* in the north-eastern Pacific M. M. Bryden and R. Harrison (Eds.), *Research on dolphins* (pp. 441-465). Oxford, England: Clarendon Press.

Walker, W. A., Mead, J. G. and Brownell, R. L. (2002). Diets of Baird's beaked whales *Berardius bairdii*, in the southern Sea of Okhotsk and off the Pacific Coast of Honshu, Japan. *Marine Mammal Science, 18*, 902-919.

Wang, D. L., Shelver, W. L., Atkinson, S., Mellish, J. A. and Li, Q. X. (2010). Tissue distribution of polychlorinated biphenyls and organochlorine pesticides and potential toxicity to Alaskan Northern fur seals assessed using PCBs congener specific mode of action schemes. *Archives of Environmental Contamination and Toxicology, 58*(2), 478-488. doi:10.1007/s00244-009-9396-6

Wang, J. Y., Chou, L. S. and White, B. N. (1999). Mitochondrial DNA analysis of sympatric morphotypes of bottlenose dolphins (genus: Tursiops) in Chinese waters. *Molecular Ecology, 8*, 1603-1612.

Wang, J. Y., Chou, L. S. and White, B. N. (2000). Differences in external morphology of two sympatric species of bottlenose dolphins (genus Tursiops) in the waters of China. *Journal of Mammalogy, 81*(4), 1157-1165.

Wang, J. Y., Frasier, T. R., Yang, S. C. and White, B. N. (2008). Detecting recent speciation events: the case of the finless porpoise (genus *Neophocaena*). *Heredity, 101*(2), 145-155. doi:10.1038/hdy.2008.40

Wang, J. Y. and Yang, S. C. (2006). Unusual cetacean stranding events of Taiwan in 2004 and 2005. *Journal of Cetacean Research and Management, 8*(3), 283-292.

Wang, J. Y., Yang, S. C. and Liao, H. C. (2001). Species composition, distribution and relative abundance of cetaceans in the waters of southern Taiwan: Implications for conservation and eco-tourism. *Journal of the National Parks of Taiwan, 11*(2), 136-158.

Wang, J. Y., Yang, S. C., Wang, B. J. and Wang, L. S. (2010). Distinguishing between two species of finless porpoises (*Neophocaena phocaenoides* and *N. asiaeorientalis*) in areas of sympatry. *Mammalia, 74*(3), 305-310. doi:10.1515/mamm.2010.029

Wang, K. X., Wang, D., Akamatsu, T., Li, S. H. and Xiao, J. Q. (2005). A passive acoustic monitoring method applied to observation and group size estimation of finless porpoises. *Journal of the Acoustical Society of America, 118*(2), 1180-1185. doi:10.1121/1.1945487

Wang, M. C., Walker, W. A., Shao, K. T. and Chou, L. S. (2002). Comparative analysis of the diets of pygmy sperm whales and dwarf sperm whales in the Taiwanese waters. *Acta Zoologica Taiwanica, 13*(2), 53-62.

Ward, E. J., Holmes, E. E. and Balcomb, K. C. (2009). Quantifying the effects of prey abundance on killer whale reproduction. *Journal of Applied Ecology, 46*(3), 632-640. doi:10.1111/j.1365-2664.2009.01647.x

Ware, C., Friedlaender, A. S. and Nowacek, D. P. (2011). Shallow and deep lunge feeding of humpback whales in Fjords of the West Antarctic Peninsula. *Marine Mammal Science, 27*(3), 587-605. doi:10.1111/j.1748-7692.2010.00427.x

Waring, G. T., Hamazaki, T., Sheehan, D., Wood, G. and Baker, S. (2001). Characterization of beaked whale (Ziphiidae) and sperm whale (*Physeter macrocephalus*) summer habitat in shelf-edge and deeper waters off the northeast U.S. *Marine Mammal Science, 17*(4), 703-717.

Waring, G. T., Josephson, E., Maze-Foley, K. and Rosel, P. E. (2009a). *U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments 2008*. (NOAA Technical Memorandum NMFS-NE-210, pp. 429). Woods Hole, MA.

Waring, G. T., Josephson, E., Maze-Foley, K. and Rosel, P. E. (Eds.). (2009b). *U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments 2009*. (NOAA Technical Memorandum NMFS NE 213, pp. 528). Woods Hole, MA. Available from http://www.nefsc.noaa.gov/nefsc/publications/tm/tm213/index.html

Wartzok, D. (2009). Marine mammals and ocean noise. In J. H. Steele, K. K. Turekian and S. A. Thorpe (Eds.), *Encyclopedia of Ocean Sciences* (2nd ed., Vol. 3, pp. 628-634). Boston, MA: Academic Press.

Wartzok, D. and Ketten, D. R. (1999). Marine mammal sensory systems. In J. E. Reynolds III and S. A. Rommel (Eds.), *Biology of Marine Mammals* (pp. 117-175): Smithsonian University Press.

Watanabe, H., Okazaki, M., Tamura, T., Konishi, K., Inagake, D., Bando, T., et al. (2012). Habitat and prey selection of common minke, sei, and Bryde's whales in mesoscale during summer in the subarctic and transition regions of the western North Pacific. *Fisheries Science, 78*, 557-567. doi:10.1007/s12562-012-0480-x

Watkins, W. A., Daher, M. A., DiMarzio, N. A., Samuels, A., Wartzok, D., Fristrup, K. M., et al. (2002). Sperm whale dives tracked by radio tag telemetry. *Marine Mammal Science, 18*(1), 55-68.

Watkins, W. A., Daher, M. A., Fristrup, K. M., Howald, T. J. and Notarbartolo di Sciara, G. (1993). Sperm whales tagged with transponders and tracked underwater by sonar. *Marine Mammal Science, 9*, 55-67.

Watkins, W. A., Daher, M. A., Fritsrup, K. M. and Notarbartolo di Sciara, G. (1994). Fishing and acoustic behavior of Fraser's dolphin (*Lagenodelphis hosei*) near Dominica, southeast Caribbean. *Caribbean Journal of Science, 30*, 76-82.

Watkins, W. A., Daher, M. A., Reppucci, G. M., George, J. E., Martin, D. L., DiMarzio, N. A., et al. (2000). Seasonality and distribution of whale calls in the North Pacific. *Oceanography, 13*(1), 62-67.

Watkins, W. A., Daher, M. A., Samuels, A. and Gannon, D. P. (1997). Observations of *Peponocephala electra*, the melon-headed whale, in the southeastern Caribbean. *Caribbean Journal of Science, 33*(1-2), 34-40.

Watkins, W. A. and Schevill, W. E. (1977). Sperm whale codas. *Journal of the Acoustical Society of America, 62*(6), 1485-1490.

Watkins, W. A., Tyack, P. and Moore, K. E. (1987). The 20-Hz signals of finback whales (Balaenoptera physalus). *Journal of the Acoustical Society of America, 82*(6), 1901-1912.

Watson, A., Kuo, T. F., Yang, W. C., Yao, C. J. and Chou, L. S. (2008). Distinctive osteology of distal flipper bones of tropical bottlenose whales, *Indopacetus pacificus*, from Taiwan: Mother and calf, calf with polyclactyly. *Marine Mammal Science, 24*(2), 398-410. doi:10.1111/j.1748-7692.2007.00178.x

Watwood, S. L., Owen, E. C. G., Tyack, P. L. and Wells, R. S. (2005). Signature whistle use by temporarily restrained and free-swimming bottlenose dolphins, *Tursiops truncatus*. *Animal Behaviour, 69*, 1373-1386. doi:10.1016/j.anbehav.2004.08.019

Wearmouth, V. J. and Sims, D. W. (2008). Sexual segregation in marine fish, reptiles, birds and mammals: Behaviour patterns, mechanisms and conservation implications. In D. W. Sims (Ed.), *Advances in Marine Biology* (Vol. 54, pp. 107-170). doi:10.1016/s0065-2881(08)00002-3

Wei, Z., Wang, D., Kuang, X., Wang, K., Wang, X., Xiao, J., et al. (2002). Observations on behavior and ecology of the Yangtze finelss porpoise (*Neophocaena phocaenoides asiaeorientalis*) group at Tian-E-Zhou Oxbow of the Yangtze River. *The Raffles Bulletin of Zoology, Supplement No. 10*, 97-103.

Weilgart, L. and Whitehead, H. (1997). Group-specific dialects and geographical variation in coda repertoire in South Pacific sperm whales. *Behavioral Ecology and Sociobiology, 40*, 277-285.

Weir, C. R. (2008). Short-finned pilot whales (Globicephala macrorhynchus) respond to an airgun ramp-up procedure off Gabon. *Aquatic Mammals, 34*(3), 349-354. doi: 10.1578/AM.34.3.2008.349

Weir, C. R., Debrah, J., Ofori-Danson, P. K., Pierpoint, C. and Van Waerebeek, K. (2008). Records of Fraser's dolphin *Lagenodelphis hosei* Fraser 1956 from the Gulf of Guinea and Angola. *African Journal of Marine Science, 30*(2), 241-246. doi:10.2989/ajms.2008.30.2.4.554

Weiss, B. M., Symonds, H., Spong, P. and Ladich, F. (2011). Call sharing across vocal clans of killer whales: Evidence for vocal imitation? *Marine Mammal Science, 27*(2), E1-E13. doi:10.1111/j.1748-7692.2010.00397.x

Weller, D. W. (2008). Predation on marine mammals. In W. F. Perrin, B. Würsig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 923-931). San Diego, CA: Academic Press.

Weller, D. W., Reeve, S. H., Burdin, A. M., Würsig, B. and Brownell, R. L., Jr. (2002). A note on the spatial distribution of western gray whales (*Eschrichtius robustus*) off Sakhalin Island, Russia in 1998. *Journal of Cetacean Research and Management, 4*(1), 13-17.

Weller, D. W., Würsig, B., Bradford, A. L., Burdin, A. M., Blokhin, S. A., Minakuchi, H., et al. (1999). Gray whales (*Eschrichtius robustus*) off Sakhalin Island, Russia: Seasonal and annual patterns of occurrence. *Marine Mammal Science, 15*(4), 1208-1227.

Weller, D. W., Wursig, B., Whitehead, H., Norris, J. C., Lynn, S. K., Davis, R. W., et al. (1996). Observations of an interaction between sperm whales and short-finned pilot whales in the Gulf of Mexico. *Marine Mammal Science, 12*(4), 588-593.

Wells, R. S. (2000). Reproduction in wild bottlenose dolphins: Overview of patterns observed during a long-term study. In D. Duffield and T. Robeck (Eds.), *Bottlenose Dolphin Reproduction Workshop Report* (pp. 57-74). AZA Marine Mammal Taxon Advisory Group.

Wells, R. S. (2008). Tagging and tracking of rough-toothed dolphins (Steno bredanensis) from the March 2005 mass stranding in the Florida Keys. (NOAA Technical Memorandum NMFS-SEFSC-574, pp. 50). Miami, FL: United States Department of Commerce, National Oceanic and Atmospheric Administration, and National Marine Fisheries Service.

Wells, R. S., Irvine, A. B. and Scott, M. D. (1980). The social ecology of inshore odontocetes. In L. M. Herman (Ed.), *Cetacean Behavior: Mechanisms and Functions* (pp. 263-318). John Wiley and Sons.

Wells, R. S., Manire, C. A., Byrd, L., Smith, D. R., Gannon, J. G., Fauqiuer, D., et al. (2009). Movements and dive patterns of a rehabilitated Risso's dolphin, Grampus griseus, in the Gulf of Mexico and Atlantic Ocean. *Marine Mammal Science, 25*(2), 420-429.

Wells, R. S., Rhinehart, H. L., Cunningham, P., Whaley, J., Baran, M., Koberna, C., et al. (1999). Long distance offshore movements of bottlenose dolphins. *Marine Mammal Science, 15*(4), 1098-1114.

Wells, R. S. and Scott, M. D. (1999). Bottlenose dolphin *Tursiops truncatus* (Montagu, 1821). In S. H. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals, Volume 6: The Second Book of Dolphins and the Porpoises* (pp. 137-182). San Diego, CA: Academic Press.

Wells, R. S. and Scott, M. D. (2008). Common bottlenose dolphin *Tursiops truncatus*. In W. F. Perrin, W. B. and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 249-255). Academic Press.

Wells, R. S., Scott, M. D. and Irvine, A. B. (1987). The social structure of free-ranging bottlenose dolphins. In H. H. Genoways (Ed.), *Current Mammalogy* (Vol. 1, pp. 247-305). New York, NY: Plenum Press.

Wenninger, P. (2010). *FY 2010 Annual Report: Wildlife Surveys on Millitary Leased Lands, Farallon de Medinilla CNMI*. (pp. 7) U.S. Navy, Naval Base Guam Public Works Department.

Werner, T., Kraus, S., Read, A. and Zollett, E. (2006). Fishing techniques to reduce the bycatch of threatened marine animals. *Marine Technology Society Journal, 40*(3), 50-68.

Werth, A. J. (2006a). Mandibular and dental variation and the evolution of suction feeding in Odontoceti. *Journal of Mammalogy, 87*(3), 579-588.

Werth, A. J. (2006b). Odontocete suction feeding: Experimental analysis of water flow and head shape. *Journal of Morphology, 267*, 1415-1428.

West, K. L., Mead, J. G. and White, W. (2012). *Steno bredanensis* (Cetacea: Delphinidae). *Mammalian Species, 43*(1), 177-189. doi:10.1644/886.1

West, K. L., Walker, W. A., Baird, R. W., White, W., Levine, G., Brown, E., et al. (2009). Diet of pygmy sperm whales (*Kogia breviceps*) in the Hawiian Archipelago. *Marine Mammal Science, 25*(4), 931-943. doi:10.1111/j.1748-7692.2009.00295

Whitehead, H. (1985). Why whales leap. *Scientific American, 252*(3), 84-93.

Whitehead, H. (2003). *Sperm Whales: Social Evolution in the Ocean* (pp. 431). University of Chicago Press.

Whitehead, H. (2008). Sperm whale *Physeter macrocephalus*. In W. F. Perrin, B. Wursig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 1091-1097). Academic Press.

Whitehead, H., Coakes, A., Jaquet, N. and Lusseau, S. (2008). Movements of sperm whales in the tropical Pacific. *Marine Ecology Progress Series, 361*, 291-300.

Whitehead, H. and Weilgart, L. (1991). Patterns of visually observable behaviour and vocalizations in groups of female sperm whales. *Behaviour, 118*, 276-296.

Whiting, S. D. (1999). Use of the remote Sahul Banks, northwestern Australia, by dugongs, including breeding females. *Marine Mammal Science, 15*(2), 609-615.

Whiting, S. D. (2002a). Dive times for foraging dugongs in the Northern Territory. *Australian Mammalogy, 24*, 167-168.

Whiting, S. D. (2002b). Rocky reefs provide foraging habitat for dugongs in the Darwin region of northern Australia. *Australian Mammalogy, 24*, 147-150.

Wieland, M., Jones, A. and Renn, S. C. P. (2010). Changing durations of southern resident killer whale (*Orcinus orca*) discrete calls between two periods spanning 28 years. *Marine Mammal Science, 26*(1), 195-201. doi:10.1111/j.1748-7692.2009.00351.x

Wiggins, S. M., McDonald, M. A., Munger, L. M., Moore, S. E. and Hildebrand, J. A. (2004). Waveguide propagation allows range estimates for North Pacific right whales in the Bering Sea. *Canadian Acoustics, 32*(2), 146-154.

Williams, R., Hedley, S. L., Branch, T. A., Bravington, M. V., Zerbini, A. N. and Findlay, K. P. (2011). Chilean blue whales as a case study to illustrate methods to estimate abundance and evaluate conservation status of rare species. *Conservation Biology, 25*(3), 526-535. doi:10.1111/j.1523-1739.2011.01656.x

Williams, R., Krkosek, M., Ashe, E., Branch, T. A., Clark, S., Hammond, P. S., et al. (2011). Competing conservation objectives for predators and prey: Estimating killer whale prey requirements for chinook salmon. *PLoS ONE, 6*(11), e26738. doi:10.1371/journal.pone.0026738

Williams, R. and Lusseau, D. (2006). A killer whale social network is vulnerable to targeted removals. *Biology Letters, 2*(4), 497-500. doi:10.1098/rsbl.2006.0510

Williams, R. and Noren, D. P. (2009). Swimming speed, respiration rate, and estimated cost of transport in adult killer whales. *Marine Mammal Science, 25*(2), 327-350. doi:10.1111/j.1748-7692.2008.00255.x

Williams, R. and Thomas, L. (2007). Distribution and abundance of marine mamals in the coastal waters of British Columbia, Canada. *Journal of Cetacean Research and Management, 9*(1), 15-28.

Willis, P. M. and Baird, R. W. (1998). Status of the dwarf sperm whale, *Kogia simus*, with special reference to Canada. *The Canadian Field-Naturalist, 112*(1), 114-125.

Willis, P. M. and Dill, L. M. (2007). Mate guarding in male Dall's porpoises (*Phocoenoides dalli*). *Ethology, 113*(6), 587-597. doi:10.1111/j.1439-0310.2007.01347.x

Wilson, C. E., Perrin, W. F., Gilpatrick, J. W., Jr. and Leatherwood, S. (1987). *Summary of Worldwide Locality Records of the Striped Dolphin,* Stenella coeruleoalba. (NOAA Technical Memorandum NMFS-SWFC-90, pp. 65). La Jolla, CA: U. S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Center.

Winn, H. E. and Perkins, P. J. (1976). Distribution and sounds of the minke whale, with a review of mysticete sounds. *Cetology, 19*, 1-12.

Wirsing, A. J., Heithaus, M. R. and Dill, L. M. (2007a). Can measures of prey availability improve our ability to predict the abundance of large marine predators? *Oecologia, 153*(3), 563-568. doi:10.1007/s00442-007-0769-0

Wirsing, A. J., Heithaus, M. R. and Dill, L. M. (2007b). Can you dig it? Use of excavation, a risky foraging tactic, by dugongs is sensitive to predation danger. *Animal Behaviour, 74*, 1085-1091. doi:10.1016/j.anbehav.2007.02.009

Wirsing, A. J., Heithaus, M. R. and Dill, L. M. (2007c). Fear factor: do dugongs (*Dugong dugon*) trade food for safety from tiger sharks (*Galeocerdo cuvier*)? *Oecologia, 153*(4), 1031-1040. doi:10.1007/s00442-007-0802-3

Wirsing, A. J., Heithaus, M. R. and Dill, L. M. (2007d). Living on the edge: dugongs prefer to forage in microhabitats that allow escape from rather than avoidance of predators. *Animal Behaviour, 74*, 93-101. doi:10.1016/j.anbehav.2006.11.016

Wise, J. P., Payne, R., Wise, S. S., LaCerte, C., Wise, J., Gianios, C., et al. (2009). A global assessment of chromium pollution using sperm whales (*Physeter macrocephalus*) as an indicator species. *Chemosphere, 75*(11), 1461-1467. doi:10.1016/j.chemosphere.2009.02.044

Witteveen, B. H., Foy, R. J., Wynne, K. M. and Tremblay, Y. (2008). Investigation of foraging habits and prey selection by humpback whales (*Megaptera novaeangliae*) using acoustic tags and concurrent fish surveys. *Marine Mammal Science, 24*(3), 516-534.

Witteveen, B. H., Worthy, G. A. J. and Roth, J. D. (2009). Tracing migratory movements of breeding North Pacific humpback whales using stable isotope analysis. *Marine Ecology Progress Series, 393*, 173-183. doi:10.3354/meps08231

Wolanski, E., Richmond, R. H., Davis, G., Deleersnijder, E. and Leben, R. R. (2003). Eddies around Guam, an island in the Mariana Islands group. *Continental Shelf Research, 23*, 991-1003. doi:10.1016/S0278-4343(03)00087-6

Wolf, N. and Mangel, M. (2007). Strategy, compromise, and cheating in predator-prey games. *Evolutionary Ecology Research, 9*(8), 1293-1304.

Wolski, L. F., Anderson, R. C., Bowles, A. E. and Yochem, P. K. (2003). Measuring hearing in the harbor seal (*Phoca vitulina*): Comparison of behavioral and auditory brainstem response techniques. *Journal of the Acoustical Society of America, 113*(1), 629-637. doi: 10.1121/1.1527961

Won, C. and Yoo, B. (2004). Abundance, seasonal haul-out patterns and conservation of spotted seals *Phoca largha* along the coast of Bak-ryoung Island, South Korea. *Oryx, 38*(1), 109-112. doi:10.1017/S0030605304000171

Woodward, B. L. and Winn, J. P. (2006). Apparent lateralized behavior in gray whales feeding off the central British Columbia coast. *Marine Mammal Science, 22*(1), 64-73.

Woodward, B. L., Winn, J. P. and Fish, F. E. (2006). Morphological specializations of baleen whales associated with hydrodynamic performance and ecological niche. *Journal of Morphology, 267*, 1284-1294. doi:10.1002/jmor.10474

Wunschmann, A., Armien, A., Harris, N. B., Brown-Elliott, B. A., Wallace, R. J., Rasmussen, J., et al. (2008). Disseminated panniculitis in a bottlenose dolphin (*Tursiops truncatus*) due to *Mycobacterium chelonae* infection. *Journal of Zoo and Wildlife Medicine, 39*(3), 412-420. doi:10.1638/2007-0135.1

Wursig, B. and Jefferson, T. A. (1990). Methods of photo-identification for small cetaceans. *Reports of the International Whaling Commission, Special Issue 12*, 43-52.

Wursig, B., Jefferson, T. A. and Schmidly, D. J. (2000). The Marine Mammals of the Gulf of Mexico (pp. 232). Texas A&M University Press.

Wursig, B., Lynn, S. K., Jefferson, T. A. and Mullin, K. D. (1998). Behaviour of cetaceans in the northern Gulf of Mexico relative to survey ships and aircraft. *Aquatic Mammals, 24*(1), 41-50.

Würsig, B. and Richardson, W. J. (2008). Noise, effects of. In W. F. Perrin, B. Würsig and J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals* (2nd ed., pp. 765-773). San Diego, CA: Academic Press.

Yamada, T. (1998). Stejneger's beaked whale, *Mesoplodon stejnegeri*, True 1885. In Japan Fisheries Agency (Ed.), *Redbook Data on Aquatic Flora and Fauna, Part III. Aquatic Mammals* (pp. 53-59). Japan Fisheries Resource Conservation Association.

Yamada, T. (2001, 28 November-3 December). Beaked whales of the seas around Japan. Presented at the Summary of the Workshop on the Biology and Conservation of Beaked Whales, Vancouver, BC.

Yamada, T. K. (1997). Strandings of cetacea to the coasts of the Sea of Japan - with special reference to *Mesoplodon stejnegeri*. *IBI Reports, 7*, 9-20.

Yamada, T. K. (2002). *On an Unidentified Beaked Whale Found Stranded in Kagoshima* [Electronic Version]. (pp. 5) National Science Museum, Tokyo, Kagoshima City Aquarium and University of Auckland (New Zealand). Available from http://svrsh1.kahaku.go.jp/sendai/indexE.html

Yamada, T. K., Ozturk, A. A., Morota, A., Ito, H. and Sakiyama, K. (1998). A washed-up humpback whale skull and its implication on the migratory route. *Memoirs of the National Science Museum, Tokyo, 30*, 139-146.

Yamada, T. K. and Yamada, A. (1999, 28 November - 3 December). Mesoplodon stejnegeri of the seas around Japan. [Abstract]. *Thirteenth Biennial Conference on the Biology of Marine Mammals*, 205.

Yamaguchi, M., Acebes, J. M. and Miyamura, Y. (2002, 22-23 July). The breeding ground distribution of the humpback whales (*Megaptera novaeangliae*) in the western North Pacific and their trans-movements among the Ogasawara Islands, the Ryukyu Islands and the Babuyan Islands, Philippines. [Abstract]. Presented at the SEAMAM II: Second International Conference on the Marine Mammals of Southeast Asia, 22-23 July 2002, Dumaguete, Philippines.

Yamamoto, S., Ito, H. and Komaba, M. (2001, 28 November- 3 December). Two rare cases of the live strandings of two species of beaked whales (*Mesoplodon carlhubbsi Ziphiidae* and *Mesoplodon densirostris*) at the east coast of Japan. Presented at the Summary of the Workshop on the Biology and Conservation of Beaked Whales, Vancouver, BC.

Yamamuro, M., Aketa, K. and Uchida, S. (2004). Carbon and nitrogen stable isotope ratios of the tissues and gut contents of a dugong from the temperate coast of Japan. *Mammal Study, 29*, 179-183.

Yamazaki, T., Oda, S. I. and Shirakihara, M. (2008). Stomach contents of an Indo-Pacific bottlenose dolphin stranded in Amakusa, western Kyushu, Japan. *Fisheries Science, 74*(5), 1195-1197. doi:10.1111/j.1444-2906.2008.01640.x

Yang, G., Guo, L., Bruford, M. W., Wei, F. W. and Zhou, K. Y. (2008). Mitochondrial phylogeography and population history of finless porpoises in Sino-Japanese waters. *Biological Journal of the Linnean Society, 95*(1), 193-204. doi:10.1111/j.1095-8312.2008.0932.x

Yang, G. A., Ji, G. Q., Ren, W. H., Zhou, K. Y. and Wei, F. W. (2005). Pattern of genetic variation of bottlenose dolphins in Chinese waters. *The Raffles Bulletin of Zoology, 53*(1), 157-164.

Yang, W. C., Pang, V. F., Jeng, C. R., Chou, L. S. and Chueh, L. L. (2006). Morbilliviral infection in a pygmy sperm whale (*Kogia breviceps*) from Taiwanese waters. *Veterinary Microbiology, 116*(1-3), 69-76. doi:10.1016/j.vetmic.2006.03.014

Ylitalo, G. M., Baird, R. W., Yanagida, G. K., Webster, D. L., Chivers, S. J., Bolton, J. L., et al. (2009). High levels of persistent organic pollutants measured in blubber of island-associated false killer whales (*Pseudorca crassidens*) around the main Hawaiian Islands. *Marine Pollution Bulletin, 58*(12), 1922-1952. doi:10.1016/j.marpolbul.2009.08.029

Ylitalo, G. M., Stein, J. E., Hom, T., Johnson, L. L., Tilbury, K. L., Hall, A. J., et al. (2005). The role of organochlorines in cancer-associated mortality in California sea lions (Zalophus *californianus*). *Marine Pollution Bulletin, 50*(1), 30-39. doi:10.1016/j.marpolbul.2004.08.005

Yonezaki, S., Kiyota, M., Koido, T. and Takemura, A. (2005). Effects of squid beak size on the route of egestion in northern fur seals (*Callorhinus Ursinus*): Results from captive feeding trials. *Marine Mammal Science, 21*(3), 567-574. doi:10.1111/j.1748-7692.2005.tb01250.x

Yordy, J. E., Mollenhauer, M. A. M., Wilson, R. M., Wells, R. S., Hohn, A., Sweeney, J., et al. (2010). Complex contaminant exposure in cetaceans: A comparative e-screen analysis of bottlenose dolphin blubber and mixtures of four persistent organic pollutants. *Environmental Toxicology and Chemistry, 29*(10), 2143-2153. doi:10.1002/etc.279

Yoshida, H. (2002). Population structure of finless porpoises (*Neophocaena phocaenoides*) in coastal waters of Japan. *Raffles Bulletin of Zoology, Supplement No. 10*, 35-42.

Yoshida, H., Higashi, N., Ono, H. and Uchida, S. (2010). Finless porpoise (*Neophocaena phocaenoides*) discovered at Okinawa Island, Japan, with the source population inferred from mitochondrial DNA. *Aquatic Mammals, 36*(3), 278-283. doi:10.1578/am.36.3.2010.278

Yoshida, H. and Kato, H. (1999). Phylogenetic relationships of Bryde's whales in the western North Pacific and adjacent waters inferred from mitochondrial DNA sequences. *Marine Mammal Science, 15*(4), 1269-1286.

Yoshida, H., Shirakihara, K., Kishino, H. and Shirakihara, M. (1997). A population size estimate of the finless porpoise, *Neophocaena phocaenoides*, from aerial sighting surveys in Ariake Sound and Tachibana Bay, Japan. *Researches on Population Ecology, 39*(2), 239-247. doi:10.1007/bf02765270

Yoshida, M. and Trono, R. B. (2004). Dugong conservation network in Asia and Pacific. Presented at the Knowledge Marketplace Reports. The Third IUCN World Conservation Congress.

Yoshioka, M., Kanda, M., Takahashi, I., Kashiwagi, M. and Mori, K. (1999, 28 November - 3 December). Photo-identification study of sperm whales in the Kumano Sea off the Pacific Coast of central Japan. [Abstract]. Presented at the Thirteenth Biennial Conference on the Biology of Marine Mammals, Wailea, HI.

Young, B. G., Higdon, J. W. and Ferguson, S. H. (2011). Killer whale (*Orcinus orca*) photo-identification in the eastern Canadian Arctic. *Polar Research, 30*, 7203. doi:10.3402/polar.v30i0.7203

Yu, H.-y., H.-K. Mok, R.-C. Wei, and L.-S. Chou (2003, 14-19 December 2003). Vocalizations of a rehabilitated rough-toothed dolphin, Steno bredanensis. Presented at the Fifteenth Biennial Conference on the Biology of Marine Mammals, Greensboro, North Carolina.

Yuen, M. M. L., Nachtigall, P. E., Breese, M. and Supin, A. Y. (2005). Behavioral and auditory evoked potential audiograms of a false killer whale (*Pseudorca crassidens*). *Journal of the Acoustical Society of America, 118*(4), 2688-2695.

Yuen, M. M. L., Nachtigall, P. E., Breese, M. and Vlachos, S. A. (2007). The perception of complex tones by a false killer whale (*Pseudorca crassidens*). *Journal of the Acoustical Society of America, 121*(3), 1768-1774. doi:10.1121/1.2436640

Zagzebski, K. A., Gulland, F. M. D., Haulena, M., Lander, M. E., Greig, D. J., Gage, L. J., et al. (2006). Twenty-five years of rehabilitation of odontocetes stranded in central and northern California, 1977 to 2002. *Aquatic Mammals, 32*(3), 334-345. doi:10.1578/AM.32.3.2006.334

Zerbini, A. N. and de Oliveira Santos, M. C. (1997). First record of the pygmy killer whale *Feresa attenuata* (Gray, 1874) for the Brazilian coast. *Aquatic Mammals, 23*(2), 105-109.

Zerbini, A. N., Waite, J. M., Laake, J. L. and Wade, P. R. (2006). Abundance, trends and distribution of baleen whales off Western Alaska and the central Aleutian Islands. *Deep-Sea Research, 53*, 1772-1790.

Zhang, C. I., Song, K. J. and Na, J. H. (2010). Estimation of mortality coefficients and survivorship curves for minke whales (*Balaenoptera acutorostrata*) in Korean waters. *Animal Cells and Systems, 14*(4), 291-296. doi:10.1080/19768354.2010.525807

Zhao, X. J., Barlow, J., Taylor, B. L., Pitman, R. L., Wang, K. X., Wei, Z., et al. (2008). Abundance and conservation status of the Yangtze finless porpoise in the Yangtze River, China. *Biological Conservation, 141*(12), 3006-3018. doi:10.1016/j.biocon.2008.09.005

Zhou, K. (1991). Marine mammal studies in China. *IBI Reports, 2*, 11-33.

Zhou, K., Qian Weijuan and Li Yuemin (1982). Pseudorca crassidens (Owen) from the coastal waters of China. *Investigations on Cetacea, 13*, 263-269.

Zimmer, W. M., Harwood, J., Tyack, P. L., Johnson, M. P. and Madsen, P. T. (2008). Passive acoustic detection of deep-diving beaked whales. *Journal of the Acoustical Society of America, 124*, 2823-2832.

Zimmer, W. M. X., Tyack, P. L., Johnson, M. P. and Madsen, P. T. (2005). Three-dimensional beam pattern of regular sperm whale clicks confirms bent-horn hypothesis. *Journal of the Acoustical Society of America, 117*(3), 1473–1485.

Zoidis, A. M., Smultea, M. A., Frankel, A. S., Hopkins, J. L., Day, A. and McFarland, A. S. (2008). Vocalizations produced by humpback whale (*Megaptera novaeangliae*) calves recorded in Hawaii. *Journal of the Acoustical Society of America, 123*(3), 1737-1746. doi:10.1121/1.2836750

This Page Intentionally Left Blank